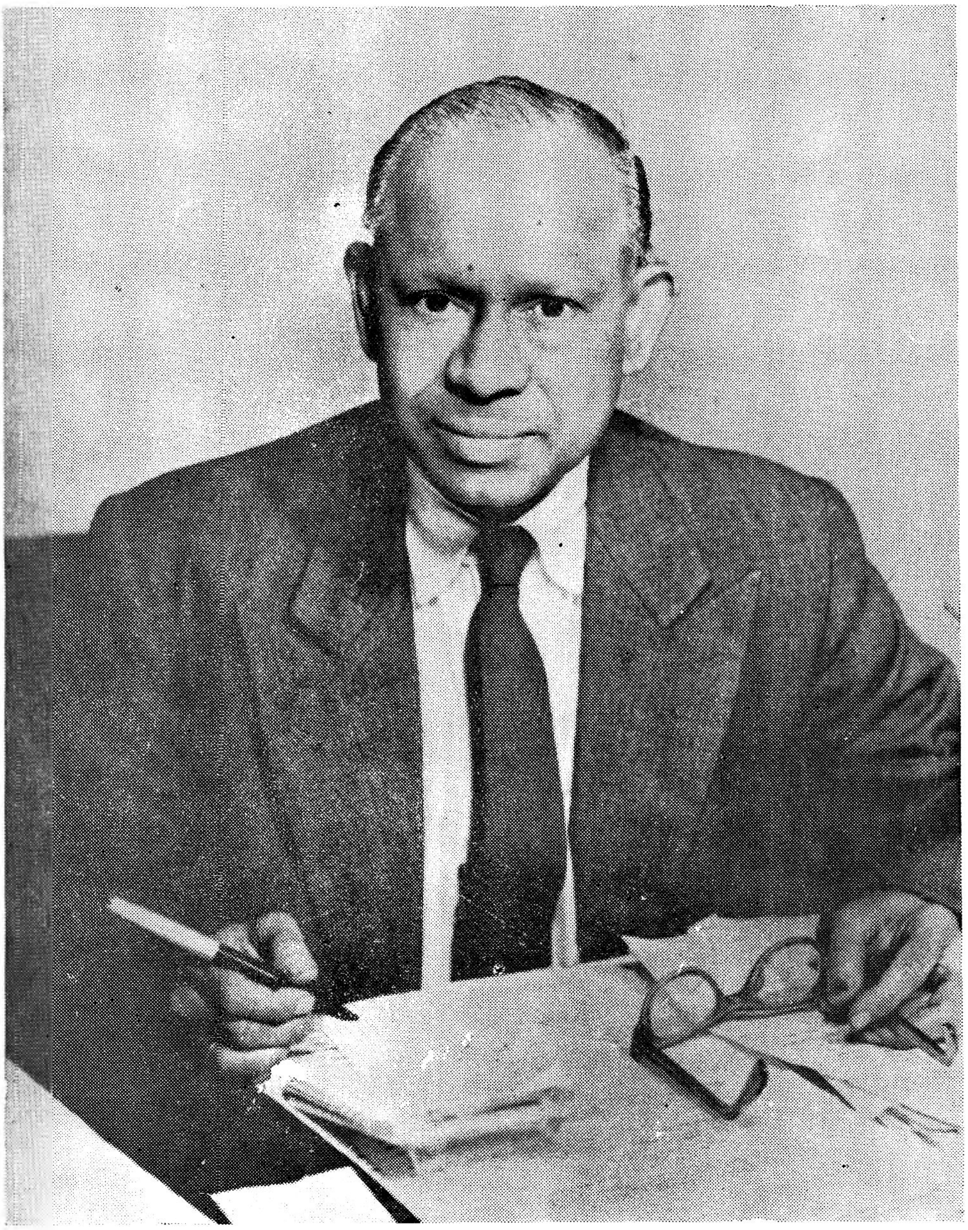

1902 — 1979

Foreword

This special volume is dedicated to the memory of Prof. V. Subrahmanyan, the founder Director of Central Food Technological Research Institute, Mysore and earlier the Professor of Biochemistry for long years at the Indian Institute of Science, Bangalore.

With vision and wisdom, drive and dynamism, energy and enthusiasm, he helped to convert a 'Maharaja's palace' into a 'modern temple' and build a trans-disciplinary scientific team covering Biochemistry, Applied Nutrition, Microbiology, Storage and Preservation, Quality Control, Fruit and Vegetable Technology, Meat and Fish Technology, Food Engineering, Infestation Control, Food Processing and Packaging, Information, Statistics and Extension Service. His was a fertile and fermenting mind that contributed along with his capable team to several new approaches, processes and products in these various fields. He also helped in instituting a training programme for food scientists and technologists and this has become an important continuing activity at CFTRI.

Food science was not a profession but a life's passion to Subrahmanyan. Even after retirement, he continued his scientific pursuits in different capacities as Consultant to FAO; advisor to the Food Ministry and later as the Head of Paddy Processing Research Centre at Tiruvarur in his home district. He travelled widely and always talked about his latest researches till his sudden demise on 30th January 1979.

This volume presents special articles written by Prof. V. Subrahmanyan's colleagues and students and encompasses all the important fields which he initiated and helped to grow, portraying the progress of Food Science and Technology in the past three decades and corresponding growth of CFTRI.

The Association of Food Scientists and Technologists of which Prof. V. Subrahmanyan was the founder President has done well to bring out this special commemoration volume to honour the memory of this Doyen of Food Research in India.

(Y. NAYUDAMMA)
Distinguished Scientist
CLRI, Madras
Former Director-General
CSIR, New Delhi.

The Publication Committee thanks the following members of "Prof. V. Subrahmanyan Commemoration Issue" Committee for organising the manuscripts

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Prof. V. Subrahmanyan Commemoration Issue

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Dr Vaidyanatha Subrahmanyan — A Pioneering Food Scientist

M. V. L. Rao
(*Scientist Rtd*)
Central Food Technological Research Institute, Mysore, India

"The old order changeth yielding place to new,
And God fulfills Himself in many ways,

. . . . .

I have lived my life and that which I have done
May He in Himself make pure!"

—Morte D'Arthur by Tennyson.

These last words of the legendary King Arthur would undoubtedly serve to reflect adequately the feelings of Dr Subrahmanyan during the latter days of his life before he passed away on January 30, 1979, after a brief intestinal ailment. His was a life of many remarkable achievements and of fulfilment in large measure. He was steeped in unresting scientific activities for over five decades and until almost the last day of his life. His death has left a void in the Indian science scene which would be difficult to fill for years to come.

Brilliant Career

Born on September 16, 1902, in Sirkazhi, a hamlet in the Tanjore District of Tamil Nadu (then the Madras Presidency) young Subrahmanyan had his education in the local schools and then graduated from the St Joseph's College at Tiruchi in 1922 with a first class in the B.A. degree examination and a first rank in chemistry for the entire University of Madras. He then joined the Department of Biochemistry at the Indian Institute of Science, (IISc), Bangalore, the only centre for post-graduate research in that subject in the country at that time. Dr G. J. Fowler, then Professor and Head of the Department, initiated him into research with some investigations on acetone fermentation. Soon his interests extended into soil science. In 1925 he secured a loan scholarship from the J. N. Tata Endowment for higher studies and proceeded to England to work at the Agricultural Research Station at Rothamstead on problems related to water-logged soils and nutrition of the rice plant under the inspiring guidance of Sir John Russel. These studies earned for him the D.Sc. degree of the University of London in 1927. On his return home he was first appointed as lecturer in the Department of Biochemistry at the Indian Institute of Science and later in 1929 as the Professor and Head of the Department, a chair he filled for nearly two decades with distinction and many notable scientific contributions.

In 1948 he was assigned as the Planning Officer for the Central Food Technological Research Institute under the Council of Scientific and Industrial Research (India). Later this Institute was located in Mysore and when it was inaugurated in 1950, Dr Subrahmanyan was chosen as its first Director. He rendered yeoman service to the Institute for thirteen years and retired in 1963.

With the irrepressible innate urge for activity, he refused to rest on his laurels after retirement and immediately took up the onerous assignment of organising a Food Technology Laboratory at the National Institute of Science and Technology in Manila, Philippines, as an expert consultant of the Food and Agricultural Organization of the United Nations. After successfully completing this mission he returned to India in 1966.

For three years thereafter he was an Emeritus Scientist of the CSIR and functioned as adviser on subsidiary foods and nutrition in the Ministry of Food, Government of India. Then he took another challenging task of building up a research laboratory for handling the problems of the post harvest technology of paddy at Tiruvarur in the heart of the rice-growing region in Tamilnadu in South India. He was Project Head of this laboratory from its inception in 1969 until his last days.

Researches in Soil Science and Environmental Beneficiation

Soil science was his first love in the early researches in the Department of Biochemistry at the IISc. Beginning with a small nucleus of research associates he soon built up a prominent school of research in soil science. The influence of manurial and cultural conditions as also of trace nutrients on soil structure, plant growth and crop yields provided the themes. A noteworthy off-shoot of these studies was the discovery of the marked catalytic effect of manganese on plant growth and crop yields, which later the Russians appear to have exploited to great advantage for increasing food production.

Another important line of investigation related to the chemurgic treatment of sanitary wastes from towns. An aerobic process (known as the Activated Sludge Process) for the conversion of sewage into an inoffensive and innocuous effluent on the one hand and on the other a sludge of organic nutrients which could serve as manure for various types of crops was developed and adopted by some of the major municipal corporations in the country. The important role played by protozoa in the clarification process was also elucidated. The treated effluent was demonstrated to be a suitable medium for pisci-culture. In more recent times the utilization of sewage for algal culture for food protein production has received considerable attention.

An anaerobic process for fermentation of vegetable garbage and night-soil in deep pits for producing useful compost was also developed. It was suitable for adoption in villages as well as in towns and cities and found nationwide application.

A Classic Piece of Basic Research

For a period of two years between 1938 and 1940 the IISc deputed Dr Subrahmanyan to England to refurbish and up-date his knowledge and experience in advanced biochemistry. During the sojourn he made short visits to several research institutions, but spent the major part of the time at the Biochemical Laboratory, Cambridge, where he collaborated with Dr D. E. Green, then a reputed enzymologist, and his associates in a very important research programme concerning the role of Vitamin B_1 (thiamine) in carbohydrate metabolism which demonstrated that thiamine pyrophosphate was an essential co-factor of carboxylase, the enzyme that decarboxylates pyruvic acid, which is a crucial step in the metabolism of carbohydrates in living cells. This was a classic discovery that opened up a new vista in biochemistry bearing on the coenzymatic function of vitamins and is now cited in all standard text books on biochemistry and metabolism.

Research During the War Years

The Second World War was in full swing by the time Dr Subrahmanyan returned to India around the middle of 1940. He initiated some new lines of work in the Biochemistry Department, such as on the chemical nature of rennin, the milk-clotting enzyme of calf stomach mucosa, insulin, carbohydrate metabolism and related aspects. However, the exigencies of the war and the consequent tilt in the policies of the IISc, which was committed to help in the war efforts of the government, towards increasing priority for application oriented research programmes weaned him away more and more into applied research with immediate bearing on indigenous production of biochemicals which were difficult to import either for civilian or defence requirements. He reset his sights and sails to suit the ambient changes, took to applied work energetically and enthusiastically. The production of certain important glandular products immediately required by the Defence Forces, like pituitrin and rennet for making junkets and cheese was organised and supplies of requisite quality and quantity delivered on time, as the know-how for the concerned processes was readily available. Conditions for the production of some others like desiccated thyroids, adrenals, etc, enzyme preparations such as pancreatin, pepsin and trypsin, and food colours like the butter and cheese colour from annato seeds, were standardized in due course. In some cases new and original procedures were developed after the necessary research and spadework. Such products included insulin (by an adsorption procedure), calcium gluconate (by electrolytic oxidation) and even penicillin at the early stage when it was not yet commercially available. Some of the processes developed were later on taken over by the appropriate industry.

These projects not only provided a fund of practical experience in applied research but also monetary benefits to the institution and to the research workers in terms of shared royalties or technical fees. The contributions made by the Department to help the war efforts were particularly appreciated by the Defence Authorities and well commended by the then Government of India.

All this hectic applied research activity was in addition to the regular basic research programmes sponsored by the Institute, the long term schemes on crop production, fats and oils and vitamin A sponsored by the Indian Council of Agricultural Research (ICAR), short-term projects under the Indian Council of Medical Research (ICMR), the Council of Sicentific and Industrial Research (CSIR) and a few others of an *ad hoc* character sponsored by the industry. The Department became virtually a bee-hive of activity day in and day out, with the maximum number of research projects and research workers among all the Departments of the Institute during the later years of the war and for several years afterwards. Dr Subrahmanyan shared the maximum burden of these projects.

Evolving into a Food Scientist

As a practically-minded biochemist, Dr Subrahmanyan, was well aware of the food and nutrition problems of the country almost from the beginning of his research career particularly because of his research interests in soil science and crop production. He and his associates had done some important work on the loss of thiamine (Vitamin B_1) during the milling of rice and also on parboiling as a means of rectifying the undesirable cooking qualities (lump formation and poor digestibility) of freshly harvested rice.

He had been much impressed by the classical experiments of Robert McCarison in the Nutrition Research Laboratories in Coonoor (now the National Institute of Nutrition, Hyderabad), which demonstrated that deficiency of protein was a common denominator in many of the practical Indian dietaries, particularly the poor rice diet consumed by the majority of the people in South India. Dr Subrahmanyan himself hailed from an area where such a diet was consumed by the majority with the inevitable consequences: stunted growth and proneness to infections and other diseases in the young and lack of stamina, low physical and mental efficiency and poor health in the elderely which is further accentuated in pregnant and nursing women. The picture of children in the poorer sections, just scaly skin and bone and a bloated abdomen had become permanently etched on his mind from his younger days and he had then vowed to do something to relieve these distressing conditions with the application of scientific knowledge. Some of the sorrowful happenings during the war years reminded him again and again of this important basic problem.

The cataclysmic Bengal Famine of 1943 jolted the people and the Government out of any further complacency with regard to the food situation *vis-a-vis* the population growth. Thoughts on food and population exercised the minds of all thinking men. Demographers prophesied an on-coming disastrous population crisis unless stringent population control measures were adopted. Agricultural scientists adovcated maximizing food production by bringing all available cultivable land under the plough and impounding the available waters of all big rivers through extensive irrigation dam projects. Some food and nutrition scientists suggested exploring new and novel sources of food-algae, bacteria, etc. and others the known sources like leaves and grass and little known sources like some exotic grains and seeds. The economists and socio-economists favoured improvement in the purchasing power of the poor common masses.

On the basis of all these suggestions an integrated approach had to be evolved and the Government was seized with such plans-a mammoth task in a vast country like India with the fast burgeoning population. Dr Subrahmanyan, who devoted much serious thought to such matters, strongly felt that concomitant with these plans there should be an energetic drive to conserve all available food resources by preventing losses through infestation, the common harvesting and processing procedures and even cooking methods and utilizing by-products of food processing now going to waste. He visualized a vital role for food science and technology in these areas from both long and short range points of view.

Beginnings of Food Research

These thoughts simmering in his mind moulded into proper research projects and he quickly got into action.

He first turned to the basic problem of finding a good source of protein to augment the dietary protein supply to children and other vulnerable groups who habitually subsist on poor protein diets such as the poor rice diet. On the basis of reports that the Chinese use 'milk type' preparations from soyabean for feeding children and even adults, he thought of giving a trial to such a preparation in the first instance. Under a project sponsored by the ICMR he and his research associates developed a feasible method of obtaining an easily digestible, protein rich milk-like emulsion from soyabean and demonstrated by animal experiments and institution feeding programmes that the 'Soy milk' thus produced was as nutritious as Cow's milk for feeding infants and children and would be a good supplement to the protein-poor Indian dietaries such as the poor rice diet.

Fully convinced that there was enormous potential in the plentifully available oilseed cakes for exploitation as rich sources of food protein for tackling the widespread problem of protein malnutrition, the theme was extended to groundnut, coconut, sesame and cottonseed. These investigations established that by proper processing, nutritious and acceptable products could be turned out of oilseeds available in the country and they would be sources of good protein supplements to our dietaries.

Another important research project carried out at this time related to the nutritional evaluation of vanaspati (hydrogenated groundnut oil) as part of an exhaustive and critical programme under the auspices of the CSIR put through simultaneously in different laboratories. The results ultimately rehabilitated the hydrogenated oils in their proper place as good sources of food fat and set at rest the misgivings raised by faulty experiments earlier regarding their safety for human consumption. It was once and for all established that hydrogenated products obtained in a controlled manner are as good as the original oils nutritionally and supplemented with Vitamins A and D are on a par with ghee.

Other research programmes having a bearing on nutrition, particularly protein nutrition, were the studies on dietary protein and liver function and clinical and biochemical studies on infantile hepatic cirrhosis, a project sponsored by the Indian Council of Medical Research.

Thus, Dr. Subrahmanyan was drawn slowly and steadily but more intimately into researches on a variety of food problems. With a view to helping him more effectively to cope with the work he had a lecturer in Food Technology appointed, who along with a small band of enthusiastic workers later constituted the Food Technology Section that was formed as a separate viable unit of the Department of Biochemistry.

After the Bengal Famine and with the complete occupation of Burma by the Japanese, the theatre of war moved close to India. The Government (then under the British) introduced food rationing and control of prices and distribution of essential commodities. Food and population problems loomed large in the thoughts of the people and the Government. Plans and projects for hydro-electric and irrigation dams for impounding water on a gigantic scale were in the offing. With the formation of a National Government in 1946, the Government of India created a Department of Food with a Technical Adviser. Whe along with some other scientists as a delegation visited the western as well as the Far Eastern countries to study the status of food science and technology in these countries. The delegation recommended the setting up of a Central Institute for Food Technology. The Government assigned this task to the CSIR which included the proposal for establishing a Central Food Technological Research Institute in its larger blue-print for national laboratories. When Dr S. S. Bhatnagar, then Director-General of the CSIR, was looking for a suitable dynamic planning officer for such an Institute the choice naturally fell on Dr Subrahmanyan because of his research interests and activities in the area of nutrition and food technology and reputation as an able administrator and organiser.

Building-up the CFTRI

Working with his characteristic zeal, driving energy and sense of expedition he completed the plans for the Institute in a very short period and through an unexpected turn of events combined with his extreme circumspection and tactful negotiatory skills he made the lucky strike of obtaining the palatial "Cheluvamba Mansions" (formerly the palace of one of the princesses of the Mysore Royal Family) in Mysore city as a munificent gift from the Government of Mysore to the Government of India for housing the Central Food Technological Research Institute. The gift included the surrounding 130 acres of free land which appeared sufficient for all foreseeable purposes of expansion in the following 20-30 years or more. The building was formally handed over to the late Prime Minister Jawaharlal Nehru in December 1948 as a gift to the Nation.

With the location and general plans of the Institute settled within six months after his taking over as Planning officer, Dr Subrahmanyan hastened to the work of fitting out two laboratory rooms, the library, the stores and the animal house. The research assistants on the schemes under his charge, sponsored by the ICMR and CSIR, now transferred over to the new Institute from the IISc., Bangalore, and a few new appointees formed the task force for this purpose. This work was completed in the next six months and by mid-1949 research on projects was resumed. A new project for the preparation of rice-like grains by processing an admixture of tapioca flour and groundnut cake flour started. This group constituted the incipient Biochemistry and Nutrition Division of the Institute.

The Fruit Research Station at Delhi was merged with the Institute and formed the Fruit and Vegetable Technology Division. The work of fitting up the laboratories proceeded rapidly apace with the necessary alterations for adapting the living and other rooms of the palace to the purpose of working laboratories. By the middle of 1950 most of the laboratory rooms had been fitted up and with the recruitment of the staff in July-August that year many of the planned divisions had started functioning. The Institute was prepared for a formal inauguration which actually came about in 1950. By that time, the following divisions had been formed and functioning: Biochemistry and Nutrition, Microbiology, Storage and Preservation, Food Processing, Food Engineering, Quality Control, Fruit and Vegetable Technology and Information and Statiscs. Subsequently, a Division of Packaging Technology was added and in later years Nutrition was separated to form a new Division of Nutrition and Dietetics and also a Division of Meat and Fish Technology came into being. However, there were no hard and fast lines of demarcation between the divisions and they all functioned in a cooperative and coordinated manner under the beneficient guidance of the Director. With his zest for work he got them all to draw up comprehensive programmes and start working vigorously. Some work was already in progress before the inauguration and significant results had been obtained. This was pursued to logical conclusion and other programmes taken on hand. Publication of research papers, started even before the formal opening of the Institute, was kept up in a steadily swelling stream over the years.

Projecting the Image of the Institute

Dr Subrahmanyan was a firm believer in the value of publications and collection and dissemination of information in regard to the developments in science and technology. Therefore he assigned the Information and Statistics Division with the task of keeping up a liaision between the Institute and other institutions, the industry, the Government and the people. To fulfill this important function he got the Division to publish the Bulletin of the CFTRI every month, which contained advance contributions from the scientists about their research findings, abstracts of papers published in national and international journals which had a bearing on the research programmes of the Institute and advances in the field of food science and technology and other general information. This later was transformed into *Food Science*, which became the forerunner of the *Journal of Food Science and Technology* currently published by the Association of Food Scientists and Technologists (India). Also, the information wing of the Institute organised periodic seminars, symposia, workshops and like activities on subjects of mutual interest to the Institute and the Industry. It also participated in exhibitions arranged by the Government, Industry or other scientific and academic institutions where the work of the Institute, the processes and products developed were displayed and properly explained. Such exhibitions and demonstrations were also arranged at the Institute now and then. These activities helped to build a good image of the Institute in the public eye and in the industrial and technical circles. It made its name in the international scientific circles through numerous publications in important international and national journals.

He also took advantage of the Colombo Plan and the Technical Cooperation Mission and other agencies for getting valuable scientific and technological instruments and equipment, specialised training for the staff of the institute in the advanced countries and the technical advice and assistance of specialised experts from these countries. These visits also helped in building up international affiliations for the Institute which further greatly strengthened the reputation it had already built through its scientific and technical contributions. The Regional Seminar on Food Technology in the Far-East organized under the auspices of the Food & Agricultural Organization of the UN in 1959 was a very important outcome of such affiliations. Apart from providing an opportunity for mutual exchange of the plans and developmental programmes by the representatives of the various countries of the region, the Seminar decided to have a Training Centre for Food Technology located in this region. The follow-up action thereon by Dr Subrahmanyan, who was a Co-Director of the Seminar, paved the way for organizing this centre at the CFTRI, later.

Thus, starting from the bare building and 5-6 research assistants on temporary sponsored projects, in the course of 13-14 years, i.e. when he retired from the service of the CFTRI in 1963, he had built up a megalith of a multi-disciplinary institution and by virtue of its scientific and technological contributions raised it to the status of a premier research institution in South-East Asia and an international reference centre for Food science and Technology. It had a staff strength of 250 scientists of all cadres and an equal number in para-scientific and administrative services. It had doubled in size with the addition of two large buildings on either side of the central mansion, one for housing some of the expanded divisions and the other for locating the pilot plants, workshops and the engineering wings. The construction of two more was in the offing. Also six Experiment Stations functioning under the Institute had been started at Bombay, Nagpur, Lucknow Kodur, Simla and Trichur and fisheries substation at Mangalore to deal with the problems of the regions around.

Development of Supplementary Protein Foods and Baby Foods

Although it would be true indeed to say that a good many of the research projects and developmental schemes at the CFTRI during Dr Subrahmanyan's regime as Director either stemmed from his original ideas or suggestions or progressed and came to fruition through his stimulating encouragement, only the few major developments in which he was directly and intimately involved could be mentioned here.

The work on 'Soya bean Milk' and on 'Groundnut Milk' which was completed at the initial stage of formation of the CFTRI touched off some other novel ideas with regard to the processing of oilseed cakes into food products. They were now thought of as good sources for the protein enrichment of tuber starches. Preparation of rice-like grains (synthetic rice!) from judicious blends of extracted groundnut flour and tapioca flour was standardized. The protein content of such simulated grains could be controlled and they could be fortified with vitamins. Such nutritionally enriched products were produced on a large-scale and their consumer acceptability established by trials on large population groups in the State of Kerala and other states in South India. Such preparations were found to be efficacious in the clinical treatment of cases of protein malnutrition (Kwashiorkor) in therapeutic trials in hospitals. Macaroni type of products could also be made out of such blends.

He visualised and successfully developed a novel integrated process for extracting the oil, protein and carbohydrate from groundnuts in one continuous wet-rendering process. The process comprises emulsification of the oil and protein in the whole kernel at a suitable pH, separation of the oil by centrifugation, and then precipitating the protein from the centrifugate by isoelectric precipitation. The residue contains the carbohydrate with some protein. The process has the merit of yielding protein preparations with unimpaired functional properties and a good quality oil. Processes for the preparation of protein isolate from solvent extracted groundnut cake were also standardized and its suitability for use in a variety of food formulations has been demonstrated.

An off-shoot of this line of thinking was the development of the Indian Multi-purpose Food which is a judicious mixture of extracted groundnut flour and Bengal gram flour which can be used for the preparation of either sweet or savoury dishes. Its nutritional quality was assessed and the beneficial effects of its inclusion as a dietary supplement demonstrated by trials on 3000 school-children in Madras who received it in their mid-day meals. It has been introduced in the mid-day feeding programmes in many other schools.

A corollary to these developments was the production of edible quality groundnut flour by solvent extraction. A 10-ton plant for the purpose was first established in Madras by UNICEF. Several other plants have come up in other parts of the country.

Another major research venture that has borne results acclaimed as a remarkable technological achievement was the development of baby food based on buffalo (caribou) milk earlier considered unsuitable for the purpose because of the tough nature of the curd which is not easily digested in the infant stomach. By suitable alterations in composition and proper processing conditions this difficulty was overcome and the feasibility of producing an acceptable baby food from buffalo milk was demonstrated. The process was taken over by the Kaira District Milk Producers' Co-operative Union in Anand, Gujarat, for commercial production. The product (under the brand name: Amul Baby Food) has achieved great popularity all over the country in the last decade and more. This development led to the establishment of the Baby Food Industry in India which has now a turnover of 500 million rupees, and the import of baby food has been banned resulting in a similar saving in foreign exchange. In sequel, this led later to the development of weaning foods.

The impressive work on protein foods carried out at the Institute elicited unreserved appreciation abroad as a result of which the National Institute of Health, USA, came forward to assist the further expansion of the research and technological programmes relating to protein foods with a grant-in-aid of over 3 million rupees per year under the PL 480 funds. This programme which was initiated at the time of Dr Subrahmanyan's superannuation continued for almost another 10 years.

Transferring Food Technology to the Philippines

Soon after his retirement from the CFTRI in 1963, he was seconded as an Expert Consultant of the FAO to help in establishing a food technology laboratory in the National Institute for Science and Technology at Manila. In the two years of his assignment, he not only set up the laboratory but also guided some practically important research projects on the preservation and processing of the coconut and 'copra' (desiccated coconut) products of great economic value to that country. By the use of simple chemical sprays he was able to work out procedures for the preservation of coconut and to produce infection-free copra from it by the ordinary drying procedures. The local commercial organizations hailed this as a big break-through as it helped to save millions of dollars-worth of the main agricultural produce of the islands from going to waste and which could be exported or processed. Procedures were also worked out for producing deoiled coconut and protein isolates therefrom which could be utilized for the relief of protein malnutrition.

He received awards of appreciation for this very valuable work from the commercial organizations and federations in the Philippines as also from the Philippine Nutrition Association, Philippine Association of Food Technologists and the National Institute for Science and Technology.

Organizing the Paddy Processing Research Centre

For two and odd years after returning from the Philippines, Dr Subrahmanyan was Adviser on Subsidiary Foods in the Department of Food of the Government of India. To his temperament, always itching for active work, the occupation appeared sedentary and he was looking for venues of more active involvement. Therefore when he met the President of the Thanjavur Cooperative Marketing Federation, he suggested that the Modern Rice Mill Complex at Tiruvarur could be strengthened greatly by adding a Research and Development Laboratory, a Rice Bran Oil Plant and a Coconut Processing plant. The president was very much attracted by these suggestions and took steps to implement them. The ultimate result was the establishment of the Paddy Processing Research Centre at Tiruvarur in 1969 which went through several stages of development and teething troubles in the formative years during which the advice and assitance of an experienced food scientist and technologist of the stature of Dr Subrahmanyan was vital. The centre has the joint support of the Government of India (Food Department), the Food Corporation of

India, the Tamilnadu Government and the National Cooperative Development Corporation.

As in the other ventures, he brought his rich experience, enthusiasm and zest for work to bear on his associates in the centre and in the course of about a decade raised it also to the status of an international centre of reference in respect of the post-harvest technology of paddy. Its major contributions are: (*i*) development of new methods of producing parboiled rice (pressure parboiling); (*ii*) elimination of putrefactive changes and improvement of yield by simple chemical treatment of the steep water used for parboiling; (*iii*) adaptation of equipment for production of oil rich bran; (*iv*) preservation of wet season paddy; and (*v*) utilization of deoiled rice germ and polishings as human food.

Investigations have been carried out on several related aspects and also on the processing of coconut and copra in continuation of the work done in the Philippines.

Affiliations, Awards and Distinctions

As an eminent Professor of the Department of Biochemistry at the IISc. he had many academic and professional affiliations. He was the founder-member of the Indian Academy of Sciences and President of the Society of Biological Chemists for many years. Also, he was Fellow of the Royal Institute of Chemistry and Fellow of the National Institute of Sciences of India. He was also a member of the Current Science Association and of its Editorial Committee. He was Founder-President of the Association of Food Technologists (now Association of Food Scientists and Technologists).

He was the President of the Chemistry Section of the Indian Science Congress in 1960 and a Vice-President of the First International Congress of Food Science and Technology, London, in 1962.

He was a member of the advisory committees of the ICAR, the Nutrition Advisory Committee of the ICMR and the Chemical Research Committee of the CSIR for many years and for some years a member of the Board of Scientific and Industrial Research. More recently, he was Chairman, National Committee for international collaboration with International Organizations for Biochemistry, Food Sciences and Technology and Nutrition Sciences and Chairman of the ICAR Scientific Panel for Post-harvest Technology and a consultant for the Central Food Technological Research Institute.

He was the recipient of many national and international awards and distinctions:

1. Research Medal of the Royal Agricultural Society of England for his work on water-logged soils and nutrition of the rice plant.
2. Rafi Ahmad Kidwai Award (1960) for outstanding contributions to Dairy Science (development of baby food).
3. Rafi Ahmad Kidwai Award (1961) for outstanding contribution to Horticulture (preservation of fruits and vegetables by spraying fungicide/hormone impregnated wax).
4. 'Padma Shri' (1960) awarded by the Government of India.
5. K. G. Naik Medal (1964) of the Baroda University for distinguished contributions to Biochemistry.
6. Sen Medal (1960) of the Institution of Chemists, India for distinguished contribution to chemical technology.
7. Babcock-Hart Award of the Institute of Food Technologists, USA (1962) for outstanding contribution to Food Technology resulting in the betterment of human health through nutrition.
8. First Friesland Award (1965) of the Netherlands Association for the Advancement of Dairy Science, for outstanding contributions on the role of milk and milk products in tropical nutrition.
9. Biresh Chandra Guha Memorial Lecturer (1969) of the National Institute of Sicences of India.

Publications

He was prolific in his scientific publications. He has authored over 600 research papers in different national and international journals and holds 30 patents. He is co-author of a monograph on "Proteins in Foods" and another on "Milks of Vegetable Origin", both published by the Indian Council of Medical Research. He placed high premium on publications and always advised his younger colleagues to publish as much of their work as possible.

Professional and Personal Attributes

As a professor he was the very image of a kindly, sympathetic and understanding elder who was helpful under all situations. He always put his students and juniors at ease by a winning smile, nice words and a pat on the back when some good work had been done. He was always free and frank in his discussions, never put on the airs of an all-knowing oracle and encouraged juniors to express themselves without fear or hesitation.

Either as a Professor or as a research director he never believed in any spoon-fed guidance. On the contrary, he put forward his basic idea or objective or problem more like an intellectual challenge for his associates to examine and resolve. This was a fine technique to draw the best out of the juniors and even the senior colleagues.

He shunned the 'ivory tower' and was down-to-earth in his ideas and suggestions. He had a peculiar penchant for the practical.

He was a believer in 'serendipity'—chance coming to the prepared mind. He had the uncanny perspicacity to recognise such an opportunity well-ahead and orient his approach to take full advantage of it. He had the ability 'to read the writing on the wall'.

Essentially a man of action, he preferred emperical experimentation, trying out a number of possible alternative procedures and choosing the best, to long deliberation and elaborate planning. He believed in pegging away at problems until the right solutions were found.

He was endowed with a prodigious capacity for work. At times he was a veritable fiend for work and a dynamo of energy which was amazing in a man who was physically not very robust and also rather frail in health. He loved to be always working and also liked to see others around him working. Dedicated hard work, pertinacity and the ability to recognise and take quick advantage of the opportunity made for his successes in life.

Failures did not frighten him. Indeed he regarded them as essential stepping stones to final success in scientific work. He used to say that only the causes for failures have to be carefully analyzed and the course of further action guided accordingly. So also, worrying about scientific problems and work, he felt, was essential. His advice to his associates and colleagues was: 'worry yourself and worry others until the thing is done'.

As an administrator he was accessible and affable to one and all of his junoirs and subordinates. He had the tact to deal with men and matters of all type. He was firm and just but also forgiving to human faults.

He had no societal affiliations; he just had no time for them amidst his busy schedule of scienfic work and engagements all day. But he was a generous host and highly sociable. His students and colleagues, friends and many of the visiting scientists from abroad and inside the country will cherish happy memories of the sumptuous dinners and the pleasant evenings they enjoyed with him and his family.

Summing-up

Dr Subrahmanyan was a distinguished professor, an eminent scientist of international stature and an able and efficient administrator. He has made lasting contributions in the fields of soil science and food science and technology and through them to the progress and prosperity of the country. He helped to establish the Baby Foods Industry in India. He has shown the way for combating protein malnutriton through exploiting the plentifully available oilseed cakes to make nutritious foods. He has also made significant advances in the processing of paddy and also of coconut. He will be remembered for ever as the founding-father of the Central Food Technological Research Institute, Mysore, the Paddy Processing Research Centre, Tiruvarur (Tamilnadu) and the Food Technology Laboratory, Manila (the Philippines). Through his scientific endeavours he laid the foundations for the development in India of Food Science and Technology as a multi-disciplinary branch of science in its own right.

To Dr Subrahmanyan work was the breath and stuff of life. He liked to end each day like Long Fellow's Village Blacksmith:

> "*Something attempted, something done,*
> *Has earned a good night's rest*"

He attempted and did many things in his lifetime before Death laid him to eternal rest. The vast circle of his students, colleagues, friends and admirers the world over share with the surviving members of his family the sad bereavement and pray: **May his soul rest in peace.**

Building A National Food Security System

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At the "Donyi—Polo" temple at Along in Arunachal Pradesh, there is a portrait of a woman who is believed to have been the first person to have cultivated rice. The early domestication of plants over 10,000 years ago started two significant developments. First, various forms of energy (collectively termed "cultural energy") were introduced to enable green plants to give stable and higher yields. Secondly, from the millions of species of world flora and fauna, only a few plants and animals were chosen for domestication. There are now only about 30 plant species whose individual world production exceeds 10 million tonnes per year and 6 animal species whose production in the form of meat exceeds 1 million tonnes per year. Such dependence on a few species has increased the vulnerability of food production systems to weather aberrations and pest epidemics. Compounding this problem of dependence is the fact that at present less than 10 countries in the world have surplus food grains for the export market. In recent years steps have been initiated to develop global and national food security systems. I would like to discuss briefly some aspects of a national food security system further. Some of the major components of an effective national food security system are: (*a*) ecological security, (*b*) technological security, (*c*) building up food reserves, (*d*) social security, and (*e*) nutrition education and finding agricultural remedies for nutritional maladies. Each will now be considered further.

Ecological Security

If the ecological infra-structure necessary for sustained agricultural advance is not preserved and strengthened, desertification processes will damage both agriculture and aqua-culture. Nothing should be done which will cause unfavourable changes in the macro and micro-environment. **To achieve this, there is need for a national movement in every country to promote economic ecology.** Unlike strictly conservation ecology, this is intended to maximise the economic benefits from a given ecological milieu and to minimise the risks and hazards characteristic of that environment. Guidelines for achieving ecological security along with agricultural progress will have to be drawn up by an inter-disciplinary team of scientists for each block.

Forest trees in particular require urgent attention. It has been predicted that within the next 25 to 30 years most of the humid tropical forest as we know it will be transformed into unproductive wasteland[1]. If this prediction is allowed to come true, it will be a disaster of the highest magnitude since according to the estimates of Earl[2] the total energy available in the unused annual increment of the world's tropical forests is equal to nearly half of the world's energy consumption from all sources in 1970. This gives an idea of some of the vast, untapped and renewable energy reserves latent in the tropical forests of the globe. A Nigerian report shows that the potential average production of crops like maize, cassava, yam and certain woods is three to ten times that now obtained in farmers' fields. This gives a glimpse of the size of the untapped production reservoir existing in current land management systems in the humid tropics.

There is frequent reference to adverse changes in the micro-environment as a result of indiscriminate felling of vegetation. Since actual instrumental observations of climate are relatively short, we must harness other sources of information about past climates and the likely impact of human activities on climate. Tree-rings are now recognised as one of the best sources of climate proxy information.[3] Variations in the width of annual rings reflect the infulence of climatic factors that limit the biological processes governing ring formation within a tree. I would hence suggest that our universities should develop a group of research scholars who work on different aspects of ecological security, including a Laboratory of Tree-Ring research.

Technological Security

Technology development should be tailored to specific ecological, economic and social conditions, and should not possess built-in seeds of social discrimination. The major aim of technology in countries with very little scope for bringing additional land under cultivation should be to increase continuously the economic yield per hectare of land or water surface without detriment to the long term production potential of soil and water. Also, productivity improvement has to be brought about without increasing heavily the consumption of non-renewable forms of energy. Improvement in yield should not also be at the cost of stability of production. Where floods and drought could make for weather-induced instability in yield, alternative cropping strategies and crop life-saving techniques should be developed to suit different weather models. Post-harvest technology should receive as much attention as production technology so that both farmer and consumer derive full benefit from the products marketed.

Breeders should adopt a "cafeteria approach" in the selection of genotypes of crops and farm animals for different farming systems. Production agronomists also should adopt such an approach in developing technologies suited for farmers with varying input-mobilising capacity. Meteorologists should measure the impact of different weather parameters on the entire system and not just on components of it, if their data are to be of use in designing more efficient systems. "Farming System Meteorology" will involve much greater attention to the micro-environment in crop canopies and to the matching of sequential use of land with weather conditions that are conducive to the optimum performance of the crops and animals farmed either together or consecutively.

I would like to refer to some aspects of technological security which merit the urgent attention of botanists and plant breeders.

(*a*) *Improving the yield potential of pulse crops:* The yields of various pulse crops grown in India and elsewhere in the world are generally poorer than those of cereals under comparable conditions. The yield of a crop is essentially determined by the amount of dry matter produced per unit area and the fraction utilized in grain production. In most pulse crops, dry matter production varies from 4 tonnes to 10 tonnes per hectare depending upon the species. This is in contrast to cereals such as wheat and rice where dry matter usually exceeds 14 tonnes per hectare. Therefore, one of the major problems in pulse crops is the improvement of dry matter production. Furthermore, pulses accumulate at least twice the amount of nitrogen in grains as do cereals. Therefore, the availability of nitrogen becomes a limiting factor in realising the grain yield potential despite the fact that these crops have a large 'sink'. Accordingly, nitrogen fixation through the symbiotic system needs to be maintained at an efficient level throughout the growth cycle, to meet the demands of nitrogen harvested as grains.

In pulse crops, the pattern of branching and flowering appears to have a profound effect on fruit and seed development. Crops such as soybean and broad bean which give a comparatively high yield are characterised by the production of a large number of fruits on the main axis and primary branches. Selection in these crops has possibly led to the isolation of culture which do not require light for flower opening and fruit set. Most of the genotypes of the pulse crops grown in India at present do not possess such a character. Consequently most of the lower branches become non-productive thereby reducing harvest index and grain yield.

Pulses are generally grown in our country as mixed crops and have usually had a secondary importance. Even now, most pulses are grown as dryland crops and are likely to experience moisture stress at some stages in their life history. The basis of adaptability to such conditions is not clear. The problem here is not only of water availability alone but in mixed cropping, of competition for water between different crops. The characteristics of crassulacean acid metabolism (CAM) have recently been reported in *Cicer arietinum* and more such studies are needed in all pulse crops.

A detailed analysis is required of carbon and nitrogen assimilation in relation to water availability and reproductive behaviour, which means close collaboration among plant breeders, physiologists, microbiologists, agronomists and soil scientists.

The major approaches to improvement in yield of pulses should include the following:

1. Collection and evaluation of *Phaseolus* (Asiatic) species indigenous to the Indian sub-continent and development of a centre for research on the genus *Phaseolus*.
2. Organisation of expeditions by Indian scientists to collect germplasm of *Cicer*, *Lens*, *Pisum* and related species from the East European, Middle East and Ethiopian regions.
3. Efforts to improve dry matter production in pure and mixed cultures at low water availability.
4. Nitrogen fixation through the symbiotic system and its response to various constraints; physiology of nodule development and senescence in relation to the host plant; a detailed survey of the soil-microflora and the survival of the introduced inoculum.
5. Contribution of the residual nitrogen or nitrogen-like response of various pulses to the subsequent crops; assessment of allelopathic or complementary effects.
6. Assessment of various agronomic practices, including mixed cropping, in the control of insect pests in different agro-climates.

7. Development of varieties with ability to respond to water and fertilizer application, so that pulse crops can be introduced in all irrigated farming systems.

In addition to research on grain legumes, there is need for more work on fodder legumes, particularly for the entire Himalayan range.

(*b*) *Incorporation of genes for relative insensitivity for photo-period and temperature:* The abundance of sunshine and favourable temperatures throughout the year makes multiple cropping possible in the tropics and sub-tropics, provided there are arrangements for irrigation. For developing crop varieties suitable for multiple cropping, it is necessary to breed relatively photo and thermo-insensitive strains. Alternate selection in segregating populations in two diverse environments, as was done by N. E. Borlaug for wheat in Mexico, is a useful procedure for isolating genotypes insensitive to photo period. Such "period-fixed" strains are very useful in standardising multiple cropping procedures. The sequence; rice (mid May to mid September), potato (mid September to early December) and wheat (mid December to mid April) is now quite common in parts of Punjab. Hence in breeding programmes designed to tailor varieties to suit specific multiple cropping sequences, selection will have to be done more on the basis of per day yield rather than absolute yield.

(*c*) *Facing the unfavourable consequences of increased intensity of cropping:* Intensive cropping rotations will require adequate efforts in soil fertility maintenance and Crop management, if productivity is to be maintained at high level on a sustained basis. In addition to selection under diverse environments, segregating populations should be grown at suitable "hot spot" locations for major pests and diseases. The spectrum of pest and diseases varies with the management practices and genotypes adopted in a particular farming system. For example, in rice the dense crop canopy advocated for the dwarf strains has led to the emergence of the brown plant hopper as the most important pest which feeds at the base of the plant. Breeding for brown plant hopper resistance has also become complicated due to the occurrence of several biotypes. Changes in the micro-environment of the plant may produce concurrent changes in the triple alliance of weeds, pests and pathogens. *Phlaris minor*, for example, has become a serious pest in fields with semi-dwarf varieties of wheat. Hence, plant protection research will have to be accorded high priority. Also, by growing in sequence crops which do not have the same pests in common, the pest cycle can be interrupted.

Countries in the tropics and sub-tropics face more serious pest problems since there are crops and vegetation all through the year to serve as alternate hosts to many pests. Also, temperature, sunlight and moisture conditions promote continuous multiplication of pests without interruption, unlike in temperate areas where the severe winter is a restraining factor. Five to ten times as many diseases occur in tropical regions for any crop over the same crop grown in temperate regions. Thus considerable research and developmental attention will be needed to insulate crops from severe devastation by pests. For developing reliable disease-forecasting procedures, the integration of meteorological data with field survey data is essential. Such an approach could lead to other beneficial results. For example, healthy seed potato is now being produced in the plains of North India as a result of the finding that during certain months of the year, aphids which serve as vectors of several virus diseases are absent.

(*d*) *Breeding for effective utilization of sunlight, throughout the year:* Sugarcane, being a C-4 plant, has a very efficient photo-synthetic system. Many tropical sugarcane varieties take 14 to 18 months from planting to harvest, which means that sugar factories remain idle for considerable periods. A breeding programme initiated at the Sugarcane Breeding Institute, Coimbatore for selection of early ripening canes has led to cultures that yield in about 8 months and give good sugar recovery. The production system with such early reipening canes can be made even more efficient with the help of chemical ripeners. Such strains make it possible either to take 3 crops (1 main and two ratoon) of sugarcane in 2 years, or to promote rice-sugarcane (with sugarcane planting in early autumn) and wheat-sugarcane (with sugarcane planting in late spring) rotations. By properly distributing the areas under spring and autumn planting the sugarcane crushing period can be considerably extended. In trials carried out at the Sugarcane Breeding Station, Coimbatore, one variety recorded in 1977 about 19 per cent sucrose with 88 per cent purity in 240 days. During 1978 also, trials with short-duration varieties gave over 18 per cent sucrose in juice at 7 months, whereas the mid-season variety (Co.6304) used as control recorded only 12.5 per cent sucrose at that time.

(*e*) *Drought and flood escaping varieties:* Early seedling vigour, rapid development of a deep root system and early maturity are characteristics which can confer considerable resilience in relation to performance under adverse rainfall conditions in drought-prone areas. This has been demonstrated for sorghum. Another example of achieving yield stability in unirrigated and uncertain rainfall regions is provided by the breeding strategy adopted in castor (*Ricinus communis*). About 60 per cent of the total area of 1 million hectares under this crop in India occurs in the Telengana region of Andhra Pradesh. In this area, rains may fail once in 3 years from September onwards. The traditional varieties used to be sown with the onset of rains in June and harvested fully by the next March. This long duration of nearly 270 days became an important factor in linking the destiny of the crop with the behaviour of the monsoon. A variety named *Aruna* was developed from an earlier strain, HC.6, through irradiation with thermal neutrons. This variety matures in 120 to 140 days and hence became immediately popular with farmers. *Aruna* castor not only helped to stabilise the yield of castor but also facilitated double cropping in single crop lands in years characterised by good winter rainfall. Similar work can be done in chronically flood-prone areas, so that damage by floods to crop can be avoided or minimised.

(*f*) *Plant breeding for a labour-intensive agriculture:* Under the prevailing socio-economic conditions in our country, the agricultural technology most relevant is the one which involves labour intensive techniques. A good example of relevant plant breeding under such conditions is the introduction for commercial cultivation of F_1 hybrids in cotton (*Gossypium hirsutum*), in which hybrid seeds are produced by a process of hand emasculation and pollination. Such production of hybrid seeds in a hectare of cotton field provides employment for about 100 women for 80 days. In 1977–78 over 20,000 quintals of seed were thus produced in 2344 hectares of land.

(*g*) *Special problems in the design of multi-level cropping systems:* In the tropics, several perennial trees like coconut and cacao are grown together in garden lands. For example, the planting density pattern of plams and rubber offers considerable opportunity for growing crops under and between trees to develop a multistoreyed cropping pattern. The choice of components of such a cropping pattern must be based on an understanding of light, water and nutrient requirements of different crops. Data are rather scanty on the transmission of light at different heights in plantation crops, but in most instances it falls below 25 k lux. The crops under the plantations would hence be exposed to conditions less conducive to transpiration. Recent studies have indicated that cacao, coffee and tea do respond to 30 to 35 k lux light intensity and that the response is further increased by fertilizer application. On the other hand pineapple, ginger, arrow-root etc. get saturated at light intensities lower than 30 k lux. In addition, the products of the latter crops are essentially acidic and carbohydrate which require much less continuous removal of nitrogenous compounds. Consequently the nitrogen requirement of these crops would be relatively less.

Water availability strongly influences the productivity of coconut palms as well as rubber. The effects of water deficit in coconut are manifested at least one year in the form of reduced fruit set and net yield, whereas in rubber the latex flow is affected. Hence, there has to be a detailed understanding of the root systems of the crops grown with coconut or rubber, so that there is optimum utilisation of water at different depths in the soil profile. Also, the crops grown in a 3 dimensional canopy should not have non-overlapping pest sensitivity.

Building up Food Reserves and Preventing Quantitative and Qualitative Damage to Food Grains

The major strength of the agricultural scene in our country today is the availability of large food reserves with Government. Much of the food produced is stored in rural areas for the consumption of the families of farmers. In order to minimise losses during storage and to ensure that the consumer gets food of good nutritive quality, several areas of research need strengthening.

(*a*) *Resistance to insects in stored grain:* Studies on the screening of wheat grain against two major stored grain pests at the Division of Entomology, Indian Agricultural Research Institute, New Delhi have established the existence of wide varietal variability to infestation by the rice weevil, *Sitophilus oryzae* and the lesser grain borer, *Rhyzopertha dominica.* Since 1965, over two thousand varieties/lines have been tested and varieties resistant to each of the two pests have been identified. Six varieties found resistant to both the pests are: NP 733, NP 780, NP 781 NP 875, HD 1593, (Kalyansona) and HD 4501. In detailed studies on the population dynamics of the two pests, the intrinsic rate of increase of the two species on Kalyansona was found lowest among the seven varieties studied. Further, *S. oryzae* reared on Kalyansona for 10 generations laid relatively fewer eggs than those reared on several other varieties. Testing of the varieties with cultures conditioned on these five varieties was seen to alter somewhat the varietal rating for resistance thus showing the importance of maintaining insect cultures on a susceptible variety and of standardising techniques for varietal screening and evaluation.

Studies conducted elsewhere in India have also confirmed the resistance of Kalyansona to the rice weevil and the lesser grain borer. In addition it has been reported that it was also resistant to another important pest, namely the Khapra beetle, *Trogoderma granarium.*

Inheritance of resistance to the rice weevil was studied at IARI in reciprocal F_1, F_2 and T_3 combinations of Kalyansona (resistant) and Hira (susceptible). It was found that the weevil resistance is (*a*) genetically controlled and heritable, (*b*) polygenic in nature, (*c*) controlled mainly by additive type of gene effects, (*d*) probably segregation transgressive, (*e*) independent of maternal effects, and (*f*) highly heritable.

Varietal resistance to pest infestation has also been studied in the barley grain. Among the various varieties tested, Notch-1 and RS 6 have been shown to be relatively resistant to the rice weevil and the lesser grain borer respectively. Notch-1 was, however, found to be susceptible to the grain moth, *Sitotroga cerealella* to which Dolma was the most resistant variety amongst those tested.

Studies at the IARI have established the importance of developing pest resistant varieties with a view to curtailing grain losses caused by insect pests in storage, and have shown the possibility of incorporating such pest resistance in wheat grain. Similar studies are needed in all economic plants.

(*b*) *Research for minimising the risk of undesirable factors in food grains:* Three of these may be further considered.

(*i*) *Naturally-occurring plant toxins: Lathyrus sativus* is a hardy pulse crop with about 28 per cent protein of fairly good quality. Currently we produce about one million tonnes of this pulse, mainly in Bihar, Madhya Pradesh and U. P. Excessive consumption of this pulse as a staple for long periods leads to the crippling paralysis termed lathyrism. The disease affects the poorest of the poor, the landless agricultural labourer. Research at the National Institute of Nutrition at Hyderabad has led to the identification of amino acid beta—(N)-oxalyl amino alanine as the neurotoxin responsible for causation of the disease. Analysis of different genotypes of this legume enabled identification of low-toxin varieties of this pulse, and research at IARI has led to lathyrus varieties like P 4, P 10 and P 17 with a toxin content as low as 0.2 per cent, which is one tenth of that of varieties grown in areas where the disease is highly endemic.

(*ii*) *Liver disease due to Crotalaria/Heliotropium Species:* In parts of Sarguja district of Madhya Pradesh, tribals were found to be affected by a liver disease, later identified as veno-occlusive disease (V.O.D.) by Dr Tandon and his colleagues of the All India Institute of Medical Sciences. Research during 1975–77 by scientists from National Institute of Nutrition, Hyderabad and the All India Institute of Medical Sciences, New Delhi helped to identify the aetiological factor as hepatotoxic alkaloids of the pyrrozolidine type occurring in a weed of the leguminosae family, *Crotalaria neuabund.* The seeds of this weed contaminate the staple millet "gondli" (*Panicum miliare*) consumed by the triabls. Measures of control such as the eradication of the weed at farm level and seiving operation to eliminate the weed at home level, have been suggested and given effect to through agricultural and health extension workers.

A similar liver disease was reported from parts of Afghanistan in 1975–76. Research by scientists from Afghanistan and the AIIMS (Delhi) has led to the identification of the causative agent as seeds of the weed, *Heliotropium species*, contaminating the wheat staple used for consumption.

(*iii*) *Toxins arising from fungal contamination:* Such post-harvest measures as adequate drying and good storage conditions are still defective at the average farmer's level. These unsatisfactory conditions and unprecedented rains and floods damage food crops, and lead also to an increase in fungal contamination of several commodities such as groundnuts, maize, rice, bajra, sorghum, fodder, etc. Aflatoxin contamination from toxigenic strains of *Aspergillus flavus* has been reported in groundnut and maize. This restricts the export potential of HPS groundnuts and of deoiled cake and also poses a health hazard in terms of liver damage, since deoiled groundnut meal is used as an ingredient of Balahar for nutritional rehabilitation of malnourished children. Aflatoxin contamination in maize was reported to be the cause of liver disease in tribals in western India in 1974. Considerable research is in progress to identify varieties of groundnuts and maize that are resistant to aflatoxin contamination.

Contamination of sorghum with *Fusarium* species of fungi has been reported but its health hazard to man is still not known. However, *Fusarium* contamination of fodder (paddy straw) in parts of Haryana has been associated with "Degnala disease" in cattle. Several high-yielding hybrids of *bajra* are reported to be susceptible to ergot contamination. Research at the National Institute of Nutrition, Hyderabad has identified the toxic alkaloids as those of the agroclavine group as different from the ergotamine group seen in wheat and rye. Consumption of ergot-infested bajra has been reported to cause symptoms of nausea, and prolonged sleepiness in man and animals (camels) in the Sikar district of Rajasthan. Downy mildew and ergot infestation result in appreciable economic loss to the primary producer. Research is needed to identify resistant varieties of *bajra.* Another aspect which needs systematic study is the problem of "black tip" in the Phalgun variety of rice grown in parts of the Godavari district of Andhra Pradesh, which affects its marketability.

Social Security

An essential component of national food security programmes should be appropriate measures of social security. This would help to provide all the citizens of the country with their minimum needs of food on the one hand, and the producers of food a remunerative return for their labour on the other. Several developing countries like India have now a large grain reserve. However, many people still go to bed hungry largely due to inadequate purchasing power. Inability to purchase food is frequently due to lack of opportunities for employment. The nutrition problem will therefore have to be dealt with both by increasing production and by providing increasing opportunities for gainful employment. The Government of India, for example, has launched a "Food for Work" Programme involving the distribution of substantial quantities of wheat and rice as payment to workers who are employed in productive works like soil and water conservation, afforestation, provision of drinking water supply, etc. Another project introduced in some parts of India (like Maharashtra) is the Employment Guarantee Scheme which will help to provide everyone who is in need of a job with an opportunity to work.

Social security is as important for farmers as for consumers. Farming is a risky activity and the farmer will never know until the harvested produce has been safely sold what the final return for his labour and investment will be. There is a need for an integrated input-output pricing policy which will be remunerative to the farmer and reasonable to the consumer. Japan, for example, could stimulate production of rice very rapidly through a favourable input-output price ratio between fertiliser and grain. The cost of one kg of nitrogen was just 0.76 that of one kg of paddy, against a ratio of 3:1 in India, and 1.6 to 3.0 in most countries. Every country will have to give serious attention to this problem of maintaining an appropriate balance between input and output prices, keeping in view the twin objective of stimulating production and promoting consumption. The cost of production must be reduced through the development of varieties and techniques which will help raise productivity without a coincident increase in the consumption of mineral fertilizers and pesticides. All areas of research relating to symbiotic and non-symbiotic nitrogen fixation, phosphorus solubilisation and the development of multi-spectral pesticides of plant origin will have to receive greater attention.

Nutrition Education and Finding Agricultural Remedies for Nutritional Maladies

There may be enough food and enough purchasing power but some sections of the population may still suffer from a variety of nutritional deficiencies. Among the important dieseases arising from nutritional deficiencies, mention may be made of marasmus and kwashiorkor arising from protein-energy malnutrition, nutritional anaemias, night blindness, xerophthalmia keratomalacia, and goitre. Some of less important deficiency diseases are rickets and osteomalacia, scurvy, pellagra and beri-beri. All these diseases can be corrected through proper diet. Simple, low-cost solutions can be found to many of these nutritional problems through appropriate local production and extension efforts. Diseases like goitre can be avoided through supply of iodized salt. Blindness induced by vitamin A deficiency can be prevented both by oral administration of vitamin A and by the widespread cultivation and consumption of carrot, spinach, amaranth, sweet potato (yellow) pumpkin (yellow), mango, papaya, *phalsa*, tomato, etc. The ICAR has suggested that during 1979, which has been designated by the United Nations as the "Year of Child", all our educational institutions should launch a movement for the establishment of Nutrition Gardens, wherever possible. With the intorudction of block-level planning, a malady-remedy analysis can be made block by block. Relevant horticulture and other steps like home mushroom gardening can make a great contribution to improving nutrition.

In addition the Nutrition Garden movement, the local population must be educated to the value of adopting a diversified cropping system. Studies at Himachal Pradesh University and elsewhere have revealed the value of *Chenopodium album* as a source of food and forage. Less-known legumes such as *Indigofera glandulosa*, *Psophocarpus tetragonolobus* (winged bean) and *Kali tur* (local variety of soybean) offer considerable promise for improving the nutritional status of low income groups. We need more research in such under-utilised plants.

Conclusion

Thus, through integrated efforts in ecology, technology, food storage and distribution, nutrition education and social security we can develop a strong National Food Security System which can help to insulate our people from the threat of hunger.

Good progress has been made in improving the yield potential of crops as well as ensuring their security from the ravages caused by the unholy triple alliance of pests, pathogens and weeds. There has been improvement in the nutritive quality, consumer acceptance and suitability for processing and storage of various economic plants. Nevertheless, it must be admitted that we have not been able to introduce any new crop plant into cultivation. The only man-made cereal, triticale, is yet to become important commercially. The scope for domesticating and improving some under-utilised plants will have to be seriously examined in coming years, since as mentioned earlier, many plants are known to have a great capacity for the production of bio-mass as well as useful natural products, e.g. *Chenopodium* sp. as food material and guayule (*Parthenium argentatum*) for rubber production.

Recent advances in genetic engineering provide hope for enlarging the gene-pool available to plant breeders by designing new and more hardy plant types. In the immediate future, however, we will have to depend largely on the techniques often referred to as 'conventional' which still provide sure and speedy methods of achieving the desired objective. Therefore, while working and waiting for new break-throughs, we should intensify our current efforts in improving the productivity of both terrestrial and aquatic farming systems based on already tested techniques. Calculations by Buringh and co-workers in the Netherlands indicate an absolute maximum global production potential of nearly 50,000 million tonnes per year in grain equivalents of a standard cereal crop. This is 40 times the present average global production in recent years of about 1300 million tonnes. The vast untapped global production reservoir is the most optimistic feature of the world food scene. Since the tropics and sub-tropics are blessed with abundant sunlight, they have the greatest opportunity for achieving a substantial step-up in current production levels.

It has been stated that hybrid maize in the United States not only helped to increase maize production in that country but also initiated a chain reaction in the improvement of farming as a whole. Farmers who saw the benefit of fertiliser application and improved management practices in hybrid maize started applying improved methods of cultivation to all other crops as well. A recent example of the potential fall-out from progress in one crop to the entire farming system is seen in the Punjab. Here, the modern phase of agricultural transformation started with the release of the dwarf, fertiliser-responsive varieties of wheat in 1966. Soon farmers, who got high yields in wheat, took also to new technology in rice, potato and other crops, thereby making the areas of wheat revolution also the centres of rice revolution.

Where vision is limited, action equally is circumscribed. It is hence the duty of scientists to enlarge the vision of all connected with development through appropriate demonstrations and on-farm testing programmes.

In our country, agriculture should not merely help to provide more and better quality food but also become an important instrument of economic growth, particularly of income and employment generation. Hence, the need to stress strategies which can help to withdraw some of the labour population from the routine operations of farming through a properly planned programme of diversification of land, water and labour use. The potential of tropical agriculture for diversified land use and for harvest of solar energy is illustrated by a Chinese saying that a plot of land can appear brown, black and green on the same day. "Brown" represents a crop which is about to be harvested, "black" the empty soil after the removal of the crop and "green" the seedlings transplanted that same day.

It is often stated that we are now in an age of technology and computors. Modern technological advances are indeed remarkable and reaching the moon is no longer science fiction. It, however, remains a fact that millions of people on this spaceship earth (a term used by Buckminster Fuller to denote the finite resources of the earth) do not yet have their minimum needs including food and safe drinking water. Our aim, therefore, should be to canalise all the techniques and tools offered by modern science and technology to grow two blades of grass where only one grew before. Because of rapid population expansion, we have also to run twice as fast to remain where we are. Hence, an age of humanism, where the highest priority is accorded to assuring the minimum needs to every human being needs to be super-imposed over the age of science and technology if there is to be a happy world. Agriculture has been definied as applied ecology and is the most important source of renewable wealth. For making worthwhile contributions we should remain in close and intimate contact with both the plant and the environment. The famous wheat breeder and great humanist Dr Norman E. Borlaug is fond of saying: "Plants speak to men but like ladies of great culture, they only whisper; hence, those who remain far away from the plants in their rooms may think that plants are deaf and dumb; remain close to them and they will reveal their secrets to you". If we follow the advice implied in this statement, we can soon make the problem of hunger in our country a problem of the past. Wherever there is space there should be green plants, thus helping to capture as much sunlight as possible. This will be the real green revolution. This will be the only tribute we can pay to plants that have the unique virtue, which we humans normally do not possess, of "unilateral love". Lord Budha referred to this aspect of a plant's *dharma* when he said:

The forest is a peculiar organism of unlimited kindness and benevolence that makes no demands for its sustenance and extends generously the products of its life activity; it affords protection to all beings, offering shade even to the axeman who destroys it.

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Food Science and Technology Development in India: Concepts and Contributions of Dr V. Subrahmanyan

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The development of food science and technology in India is synonymous with the vision and efforts of Dr V. Subrahmanyan which had begun to shape even before the dawn of independence. In the wake of the Second World War, the Government of India realised that supply of wholesome and nutritious foods to the population would assume crucial role in the destiny of this nation. Widespread famine conditions in 1946, and threats of periodic droughts forced priority planning and financial investments for raising food production levels to meet the additional needs of the growing population.

Even before independence, the centrally administered Indian Agricultural Research Institute had begun to function with a band of specialists who had generated basic data on the physico-chemical behaviour of soils, regional crop husbandry, breeding of rice and wheat, dryland agriculture and basic entomology of plants with economic importance.

Efforts however, had not yet commenced for the conservation of food produce and indigenous industry development appropriate to the changing needs of the country. The Council of Scientific and Industrial Research and the Food Industries Panel of the Government of India had recommended the establishment of a food technological research institute to help in the conservation of food materials and development of food industries. Close search for indigenous talent needed for planning, initiation and development of this premier institution led to the choice of Dr V. Subrahmanyan, the then Professor of Biochemistry at Indian Institute of Science, Bangalore.

The Central Food Technological Research Institute (CFTRI) was formally opened on 21 October 1950 by Sri Hon'ble C. Rajagopalachari, the then Home Minister of the Government of India.

The activities of the institute began with the following major objectives:

(1) to bridge the gap in food shortage of the country;
(2) to solve problems of industries;
(3) to work towards ensuring adequate supplies of wholesome nutritious products prepared from indigenous food materials; and
(4) to minimise food imports.

ORGANISATIONAL STRUCTURE

R & D Disciplines and Experiment Stations

The institute consists of the main laboratory complex at Mysore and its 6 Experiment Stations located at Ludhiana, Lucknow, Nagpur, Bombay, Hyderabad and Mangalore. The institute's R & D programmes in the initial stages were mainly concentrated in the following scientific divisions built-up in stages—

(1) Storage and Preservation
(2) Food Processing
(3) Biochemistry and Applied Nutrition
(4) Dietetics
(5) Microbiology and Sanitation
(6) Food Engineering and Process Development
(7) Packaging and Containers, and
(8) Information, Statistics and Extension Services.

The current functions of planning, research, development, information, training and technology transfer are carried out under the following disciplines:

(1) Infestation Control and Pesticides
(2) Rice and Pulse Technology
(3) Flour Milling and Baking Technology
(4) Protein Technology
(5) Lipid Technology
(6) Fruit and Vegetable Technology

(7) Meat, Fish and Poultry Technology
(8) Plantation Products and Flavour Technology
(9) Microbiology, Fermentation and Sanitation
(10) Fermentation Technology
(11) Process Development and Design
(12) Analytical Quality Control
(13) Packaging Technology
(14) Engineering and Maintenance
(15) Sensory Evaluation
(16) Industrial Development and Consultancy Services
(17) Biochemistry and Applied Nutrition
(18) Training Centre
(19) National Information Centre for Food Science and Technology
(20) Planning, Monitoring and Evaluation and
(21) Experiment Stations

Experiment Stations of CFTRI were initially assigned the task of conducting varietal trials and testing the suitability of locally available food materials for processing. Subsequently their functions were reorganised to include research, development and extension activities to serve regional needs. These stations also became channels of information dissemination and feed-back for technology transfer.

MAN POWER DEVELOPMENT AND TRAINING

Although the CFTRI began to function in 1950 the immediate need was to build-up a core of scientists, technologists and engineers committed to the goal of national food conservation and indigenous industry development.

The initial staff was almost entirely drawn from the Indian Institute of Science, and the Department of Applied Chemistry of Calcutta University which had built-up research teams specialised in biochemistry. Some research workers were also drawn from the Department of Chemical Technology, Bombay. The staff of Institute of Fruit Technology, Lyallpur, who had shifted to Delhi after partition were transferred to the CFTRI to constitute the nucleus of fruit technologists. A few scientists who had received advanced training in food processing from reputed institutions of advanced countries were also recruited to initiate research and train junior workers for undertaking major R & D tasks.

The number of R & D personnel has continued to increase over the years. Thus, the total staff of CFTRI which was about 30 in 1949–50, has increased to 877 (scientific/technical staff 638) during 1978.

Scientific and technical manpower development was a major responsibility of Dr Subrahmanyan during the initial period. The first task was to start a post-graduate training programme in food technology. This effort not only furnished young talent familiar with the post harvest technology of foods but also helped in generating institutional capability for framing syllabi, pilot plant and workshop schedules, educational tours and R & D group discussions.

The FAO regional seminar held at Mysore during 1959 recommended the establishment of food technology training centres to meet the needs of developing countries. By the year 1963, the CFTRI had gained national recognition through its contributions for the development of baby food, protein foods, cereal foods, coffee and tea industries in India, besides gaining experience in the handling, storage and processing of tropical food materials. A stage had, therefore, been set for the establishment of the International Food Technology Training Centre (IFTTC) in collaboration with FAO of the United Nations, which began to function at CFTRI with the first batch of students from 1966.

The IFTTC has so far trained 317 students from most developing countries of the world under the 2 year course for the award of M.Sc. degree of Mysore University. Besides, it has also conducted 44 national and international short-term programmes between 1966–79 training a total of 938 persons from industry and, Government organisations from India and other developing countries.

The success of these programmes has resulted in the recognition of CFTRI as an associate institution of United Nations University (UNU). The programmes of UNU are specially designed to meet the food technology needs of developing countries through training of personnel at junior (Junior UNU Fellows) and management levels (Senior UNU Fellows). The UNU work initiated in 1976 has so far trained 26 scientists and technologists.

Efforts of Dr V. Subrahmanyan till 1963, and later by his successors, have succeeded in procuring priority status to the post-harvest technology of foods in national plans. Several of the agricultural universities and the Jadhavpur University have already created food technology faculties as a result of their interaction with the activities of CFTRI.

FOOD PRODUCTION AND CONSERVATION STATUS IN 1950

From the current standards, food production (table 1) during 1950 was comparatively lower[1], and the input supplies specially of pesticides and fertilisers were also very limited.

Foodgrain storage capacity was barely 0.7 million tonnes in 1950–51 without adequate expertise or facilities for infestation control.

TABLE 1. FOOD PRODUCTION IN INDIA (MILLION TONNES)

Food material	1950–51	1977–78
Food grains	52.2	125.6
Oilseeds	5.1	8.9
Milk	17.1	27.8
Meat	0.5	0.83
Eggs (million numbers)	1428.0	10,300
Fruits and vegetables	1.5	32.0
Fish	0.7	2.5

Fruit and vegetable marketing had been confined to some seasonal produce such as mangoes and citruses in urban areas located in the immediate vicinity of producing centres. Long distance transportation and extended storage were yet to gain importance since cold storage was still an infant industry, the total capacity in 1955 being about 43,000 tonnes only.

TABLE 2. PRODUCTION OF SOME PROCESSED FOOD PRODUCTS (000 TONNES)

Item	1955–56	1977–78
Biscuits	11.90	77.00 (31)
Vanaspati	280.00 (51)	670.00 (85)
Infant food	—	26.00 (10)
Meat product	0.26 (2)	5.10 (7)
Fish product	0.60 (10)	60.00 (300)
Egg powder	—	0.03 (1)
Fruit and vegetable products	23.52 (654)	65.00 (962)

Figures in brackets indicate number of units

TABLE 3. PRODUCTION OF STARCH, GLUCOSE AND SUGAR (000 TONNES)

Item	1955–56	1977–78
Starch	42 (8)	120.0 (9)
Liquid glucose	3.4 } (3)	12.5 } (7)
Dextrose	0.6	28.0
Sugar	1892.0 (147)	6500.00 (286)

Figures in brackets indicate number of units

Food processing technology was mainly traditional, i.e., hand pounding of rice in villages, grinding of wheat and millets by stone grinders or *chakkis*, milling of pulses in cottage units, and oil extraction mainly in *ghanis*. The mechanised food industry consisted of rice hullers and shellers, oil expellers, some hydrogenated fat units and starch units (tables 2 and 3).

DR SUBRAHMANYAN'S APPROACH TO RESEARCH AND INDUSTRY DEVELOPMENT

The efforts of Dr Subrahmanyan during the formative stage of CFTRI have begun to yield benefits in the development of indigenous food industries. He foresaw a long period of gestation for food industry development but continued to encourage new ideas several of which appeared to be impractical at that time but proved appropriate with passage of years.

Dr Subrahmanyan believed that free thinking and exchange of ideas among scientists as also their dedication to specified tasks were vital for food sector development. It was his firm faith that a few productive ideas could result in spectacular changes that could establish the confidence of industry and government in the capabilities of Indian food scientists and technologists. To prove his concept, the baby food based on buffalo milk by CFTRI which was considered a figment of imagination by nutrition experts of that time became a commercial reality and laid the basis for establishing the Indian baby food industry.

HIGHLIGHTS OF R & D IN FOOD SCIENCE AND TECHNOLOGY

Before assuming the stewardship of CFTRI, Dr Subrahmanyan was already a pioneer in developing the concept of vegetable proteins and had carried out studies on the utilisation of groundnut and soya bean. He had also carried out some basic and applied studies on rice and *ragi*.

Biochemistry and Microbiology

Paucity of information on the chemistry of food materials prompted basic studies in early years. Special attention can be drawn to the CFTRI contributions on: chemical composition, nutritional value and digestibility of major oilseeds, cereals, pulses, fish and vegetable oils; insect infestation effects on the nutritional value of foodgrains; dietary deficiencies arising from uncontrolled milling of cereals and nutritional status of selected Indian population groups; mutual amino acid supplementation of vegetable proteins; calcium caseinate preparation; enzyme systems in *Ragi*, *Bajra* and garlic; metabolic effects of spices and their oils; protein modification in buffalo milk; *Idli* fermentation; and aflatoxin in food materials[2–20].

Simultaneously, infrastructure facilities were created to initiate studies on fermentation to prepare novel products such as soya and groundnut flour pastes, baker's yeast, pickles and tonic wines[19].

Information generated on biochemistry and microbiology of food materials during early years provided a solid base for advanced research of later years in the area of carbohydrates, fats, proteins, amino acids and enzymes. Advances in applied microbiology have also enabled the development of processes for food enzymes, fermented beverages, baker's yeast, alcohol production from tubers and for aflatoxin elimination from oils as well as the edible flours from oil seeds[21].

Baby Food from Buffalo Milk

Soon after CFTRI began to function, Dr V. Subrahmanyan realised that technology for baby foods had to be developed in the country to prevent imports and also break the monopoly of multi-nationals to facilitate the establishment of indigenous industry. In order, therefore, to develop indigenous know-how, investigations on the processing of buffalo milk were initiated in 1955. It was soon found that curd tension and the fat of buffalo milk needed suitable modifications to suit the digestion of infants. After standardising the processing operations, roller dried as well as spray dried products were made available for nutritional evaluation. The process went into production in 1961 and paved the way for the establishment of indigenous baby food industry. The know-how for baby food based on buffalo milk has also been released to another organisation which has gone into production[18].

The commercially available milk based food contains about 22 per cent proteins on dry basis. Hence, baby food formulations containing about 11 per cent protein as in mother's milk, have also been tested and found to be suitable for infants[21].

Foodgrain Processing

Paddy: The rice milling policy of 1955 had stipulated that the degree of milling in mechanical units should be restricted to about 4 per cent. Hence, the estimation of phosphorus released by extraction of rice flour at various stages of milling was suggested as a measure of routine process control. Two other tests have been worked out in 1972; one of them consists in the treatment of whole rice grains with concentrated aqueous alkali which rapidly dissolves the endosperm leaving the bran as a separated skin; the amount of latter gives the degree of milling. The other method involves the colorimetric measurement of bran pigment extracted by alcoholic alkali[20, 21].

A series of studies were also taken up in early years and data generated on the degree of physical and nutritional losses during washing and cooking of rice; steps for minimising the losses at home level were also suggested.

Parboiling of paddy is a traditional Indian process that yields nutritionally superior, but organoleptically less acceptable rice. One of the initial successes of CFTRI was the development of a quick, controlled process for parboiling so that the resultant rice was not only nutritious but also free from the fermented unacceptable odour characteristic of traditionally processed product.

A process was also evolved for curing the fresh paddy by regulated steaming to obtain rice capable of being cooked as discrete soft grains relished by Indian consumers. Subjecting the fresh rice itself to heating in a rotating closed chamber was also found to impart the curing effect and enabled fortification with thiamine, riboflavin, nicotinic acid and calcium (as phosphate or carbonate).

The basis laid in early years has been enlarged since 1964, consistent with national policies for the progressive improvement of rice mills to replace hullers. A small unit incorporating improved features such as cleaner, paddy separater, centrifugal sheller and polisher, has been designed and released for commercial exploitation. This mill which costs about Rs. 30,000 yields 4 per cent more of head rice than huller besides furnishing husk-free bran for oil extraction[2-21].

A distinct approach has also been introduced since 1970 to evolve farm level procedures to reduce post harvest field losses and milling breakages in paddy. Evolution and testing of sun-drying procedures at field level for milling breakage reduction, including the design of a crack detector for rice grains are some of the notable features of progress in recent years[21].

Comprehensive basic studies have also been carried in recent years to understand the nature of physico-chemical changes that occur during parboiling and also the storage of paddy. It has been found that longer period of cooking required for parboiled rices is due to the diametrically opposite phenomena of gelatinisation and retrogradation of starch. Further studies to understand the cooking behaviour of different types of rices have also been completed. The rices grown in India can be classified into high amylose, medium amylose and low amylose varieties. The amylose content of rice has been known to influence the cooking quality which can be distinguished as pasty to non-pasty. The institute's work of recent years has shown that in high amylose varieties, the percentage of insoluble amylose directly affects the cooking quality. Further work is in progress to understand the cooking behaviour of medium amylose and low-amylose varieties[21].

The byproduct bran available from organised rice milling industry had attracted the attention of Dr V. Subrahmanyan even in early years. Rice bran obtained from shellers contains 15-20 per cent of oil which rapidly turns rancid due to the bran lipase activity. Hence, earlier studies were concerned with the extraction of oil by using alcohol. The need for harnessing all sources of edible oil to meet the demands of rising population and also to minimise imports, subsequently led to the design and fabrication of bran stabilisers wherein lipase activity can be destroyed by the application of wet or dry heat. It has also been found that soaking tanks used in parboiling and the conditioning units of the oil mills can be utilised for bran stabilisation. The oil that can be recovered by hexane extraction from stabilised bran even after a period of 3-4 months contains less than 10 per cent of free fatty acids permitting the economic oil refinement for edible purposes[20].

Millets and pulses: Millets constitute the major dietary staples for low income groups of population in the country. Realising that they are dryland crops likely to play a major role in coming years, Dr V. Subrahmanyan encouraged studies on the chemical composition, nutritional value, storage and product development from millets. Initiation of All India Coordinated Programmes on millets since 1966 and also the development of improved varieties by ICRISAT have focused the attention of CFTRI on the processing of millets. The institute has, therefore, generated know-how for the debranning of jowar, bajra and also ragi. A jowar debranning unit and a maize mill to dehusk, degerm and grind into semolina have also been designed and developed for installation in rural and semi-urban areas. Simultaneously, basic and applied investigations have been initiated on the processing qualities of different varieties of jowar and bajra. A dehusked malted ragi flour has been developed for use in beverages. It has also been blended with green gram flour to prepare supplementary food for infants and children which is being tested at two institutions in Mysore.

Early studies on pulses were mainly concerned with the screening of available varieties for their cooking qualities. Efforts were also made to reduce the cooking time by flaking procedures. Soon after 1964, a survey of the pulse milling practices was undertaken, and based on the data obtained, technology as well as the equipment have been developed to streamline milling procedures and reduce wastage. Four such indigenous modern mills are already in commercial operation in different parts of the country. The process know-how is being tested on different varieties of green gram, Bengal gram and horse gram and other minor pulses to reduce the milling breakages.

Oilseed Processing for Human Consumption

Paucity of animal-based foods and protein needs of the growing population had impressed the need for utilisation of oilseed cakes as a source of edible protein. The first development in this task was the production of edible groundnut flour which has subsequently been used in a series of supplementary foods, weaning food formulations, infant foods and also the pure protein isolate. The Multipurpose food (based on a blend of defatted groundnut flour and Bengal gram flour), groundnut protein isolate and the vegetable toned milk, namely, Miltone, arising from the researches encouraged by Dr Subrahmanyan are standing illustrations of his vision and efforts for the development of Indian protein food industry.

The scope of research and development of oilseed processing at CFTRI has been expanded since 1964 to cover Rape, Mustard, Sesame, Sunflower and also Cottonseed. A special class of foods called Bal-Ahar based on cereal/millet flour, edible groundnut flour and pulse flour was developed to meet the needs of feeding programmes initiated during the drought conditions of 1966. Bal-Ahar provides nearly 400 calories and about 22 per cent of protein for every 100 g. Subsequently, another class of foods called Energy Foods based on roasted cereal and pulse flours, edible groundnut flour and jaggery were formulated to furnish around 380 calories and 15 g of protein for every 100 g of the product. Since these foods found ready acceptance in the India Population Project in Chitradurga District, the Government of Karnataka has approved the setting up of five production units in different parts of the State.

Baby food formulations containing 50 per cent each of vegetable proteins and milk proteins are also undergoing trials. A coffee and tea whitener has also been developed by using the groundnut flour and proteins for use in urban sector[21]. The initial efforts under his direction has played an important role in the establishment of many industries and wide variety of composite flour composition for feeding children and to combat malnutrition.

Food Grain Storage

Food shortage was always a national threat before the wheat crop revolution following the introduction of dwarf Mexican wheats into the country. Hence, protection of foodgrains was a prominent area of R & D even during the formative stages of CFTRI.

Initial research was mainly aimed at gaining an insight into the nature and effects of insect infestation in various foodstuffs including the cereals, millets, pulses and even tubers. During the course of studies, uric acid which is an insect metabolite was found to be a major source of food pollution and hence, a colorimetric method was developed for its determination in infested grains.

Important foodgrain protection measures were also developed during early years. These consisted in the formulation of insecticidal emulsions to coat jute bag surface for preventing cross infestation, preharvest spraying of Malathion on standing millet crops to reduce post-harvest wastages, and the development of fumigation technology suitable for bulk storages. The worth of each of these developments has already been proved by application in small and urban storages. The concept of activating the mineral clays for destroying the insect pests of foodgrains is a unique contribution of Dr V. Subrahmanyan far ahead of time.

The horizon of infestation control research has been expanded since 1964 through development of: sensitive methods for pesticide residue determination in food stuffs, fumigants for farm and domestic storages, rodent control technology, and manufacturing process for Lindane from BHC. Several new fumigants such as methyl iodide, ethyl formate, and acrylonitrile are being screened to provide additional means of infestation contro[21].

Fruit, Vegetable and Tuber Technology

Heavy losses in fresh fruits, vegetables and tubers have continued to occur due to defective post-harvest practices. Developed countries employ cold storages for extended preservation of perishables, but Dr. Subrahmanyan realised that the real challenge in India was to extend their shelf life at ambient temperatures. During the period 1955-56, he felt that wax coating of fruits could be a practical means of fruit preservation. Hence, he built-up a competent cadre of fruit physiologists who later developed a series of emulsions employing sugarcane, and petroleum waxes for coating the fruit surface to extend shelf life. Identification of problems faced in long distance banana transportation which found solution in the subsequent work of CFTRI after 1964 and enabled export trade also goes to the credit of Dr. Subrahmanyan[21].

Processing possibilities of most Indian fruits were investigated in early years; these provided the basis for commercialising the know-how for pectin and fruit bars besides enabling the institute to offer consultancy services to the fruit products industry[31].

Tuber utilisation for stretching foodgrain supplies was an area dear to Dr. Subrahmanyan. A series of products such as Atta-tapioca flour blends, grain substitutes based on wheat and tapioca, and macaroni products from tapioca, were developed and produced at CFTRI fo advising Kerala State—the biggest producer of this tuber.

Meat and Fish Technology

The objective of earlier research was to gain an insight into the traditional practices of processing and storage of fish to facilitate technology development. Research efforts in this direction led to the development of processes for hygienic curing and dehydration of fish, fish protein concentrate, canned products, hydrolysates and macaroni products[19]. Scale up studies undertaken in later years led to the design and fabrication of plants for fish meal and chitosan (from prawn wastes), as also the know-how for a variety of fish-based culinary items[21].

Work on meat and eggs was taken up in detail after 1964 leading to the know-how for processed meats, commercial production of egg powder and preservation of eggs by coating with mineral oil emulsions[21].

Plantation Products

Institute's assistance and expertise were given to the Coffee and Tea Boards even from early years. The techniques which found ready application were the balloon storage of coffee and monsooning of coffee. Over the years, sophisticated techniques have been developed and commercialised for green pepper, spice oils and oleoresins and soft drink concentrates. Ready-to-use coffee products, vegetable colorants, food flavour technology and instant tea manufacture are of current interest[21].

Process Development and Packaging

A pilot plant was established soon after the CFTRI began to function for up-scaling the laboratory level processes. Initial success in the production of protein isolate, baby food, Multipurpose food, groundnut curd and tapioca macaroni provided the confidence for the design and fabrication of citrus juice extractor, mini mills for paddy, maize, sorghum and pulses, production units for Energy foods, chitosan, pectin, spice oils and oleoresin, as also the capability generation for undertaking food engineering consultancy services.

Food packaging was a priority area for R & D even in early years. Manpower and equipment facilities have been built-up in stages to provide package designs and industrial testing services to match the changing needs. Package designs for export of banana and citrus, improved containers for the transportation of fish, grapes and eggs, and the latest development, i.e., the mechanical gadget for leaf cup production at village level are some of the highlights of development of recent years[21].

Food Information and Technology Transfer

Dissemination of food technology information was an area of sustained interest to Dr. Subrahmanyan. Early years witnessed a spurt of popular publications, participation in exhibitions and demonstrations of food processing and storage techniques for creating interest in food technology developments. Two popular periodicals in food science entitled *Ahara Vignana* (Kannada) and *Khadya Vigyan* (Hindi) were started in early years.

In order to keep pace with the rapid output of scientific information a big library was built-up and capabilities generated for the collection, storage and retrieval of food technology information over the years ultimately leading to the establishment of a National Information Centre for Food Science and Technology at the institute.

Technology transfer which was a function of the scientists themselves, has now become an interdisciplinary group effort. The institute now offers a variety of services, the major ones being the feasibility and project engineering report preparation, turnkey jobs, product development and testing for industry, process demonstrations and technical advice for solution of day-to-day problems[21].

TRIBUTE TO AN OUTSTANDING SCIENTIST

The ideal tribute to this departed scientist is to continue the spirit of research and development in the area of food technology for serving the present and future needs of the country. Even after retirement in 1963 and till his death, Dr V. Subrahmanyan continued to participate and guide programmes in food technology. The improved method of drying copra without fungal damage earned for him a place of honour in the Philippines. Thereafter, he served as the specialist scientist of the Food and Nutrition Board of the Government of India and organised the Paddy Processing Centre at Tiruvarur in Tamilnadu. His contributions at this centre were the development of a pressure parboiling technique for rice and salt treatment for hastening the ripening of the standing rice crop, and methods of preservation of moist paddy without fungal damage during monsoon seasons in Tamilnadu.

His memory will reamin green at CFTRI which began as a humble institution in 1950 expanding into a centre of advanced research, development, training and technology transfer to serve the needs of India and also the developing countries of the world. His boldness in developing a baby food from buffalo milk and original concepts for the use of vegetable protein to substitute and supplement the animal products besides advanced thinking for tuber flour utilisation to stretch foodgrain supplies merit our respect.

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Three Decades of Research on the Processing and Utilization of Foodgrains

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The author had the privilege of having worked with Prof. Subrahmanyan for about 30 years first as a student at the Indian Institute of Science, Bangalore and later as a colleague at the C.F.T.R.I., Mysore. He was initiated into research in the field of cereals by the professor who himself chose to work almost exclusively on rice during the last ten years of his life. Dr Subrahmanyan identified the most important problems for research in the field of foodgrains and under his dynamic leadership a large number of major problems were identified and solutions found for many. He has also posed many fresh problems for investigation. The progress of work in various aspects of foodgrain research carried out in India over the last 30 years is reviewed here and dedicated to his memory.

Rice, Wheat, Jowar, Maize, the Minor Millets and Pulses constitute the main foodgrains of India forming nearly 85 per cent of the total food consumed by the population. Their post-harvest processing and utilisation problems are major aspect of the R & D programmes in the field of food science and technology. The major areas of research are: (*i*) primary milling for removal of husk or bran to obtain an edible grain or flour suitable for human consumption and utilisation of the byproducts of milling; (*ii*) utilisation of the milled grain or flour in the form of cooked foods, such as rice and *dhal* or baking into products like *Chapathi*, *Roti*, *Bhakri* and factors affecting their culinary properties; and (*iii*) preparation of products based on these for use as snacks. The major advances made in research and development in these areas during the last three decades in India are broadly reviewed.

1. MILLING TECHNOLOGY

Rice

The uniqueness about the use of rice consists in its consumption in the form of cooked whole grain. Retention of whole grain without breakage is a key problem in rice milling. The main cause of breakage resides in the sunchecks or cracks formed on the grain just before or during harvest or during subsequent drying[1-7]. Pre-milling technology of paddy has been intensively studied to standardise optimal conditions to prevent or minimise preformed sunchecks or stress cracks[1-9].

Harvesting, threshing and drying: Traditional methods of harvesting and field spreading (sheaving) of crop prior to threshing and later sundrying of the threshed grains as customarily followed induces suncracks leading to breakage[1-8,10] varying from 25-50 per cent. The nature of sunchecks and their contribution to the breakage at different steps of milling have been investigated[11]. The beneficial effects of harvesting 5-6 days ahead of the customary harvesting time when grain moisture is around 22-24 per cent, threshing and drying immediately which reduces milling breakage to the minimum has been clearly demonstrated[1-4,6,10,12]. This procedure will also reduce field losses due to shedding, rodents, birds, etc.[3,13].

If harvested at high moisture, paddy has necessarily to be dried immediately after threshing as otherwise wet grain is liable to heavy fungal damage. Drying of the rice grain is not simple dehydration. It has to be done in such a manner and at such a rate that would not cause stress in the grain causing checks/cracks. The principles and conditions for mechanical drying of high moisture field paddy have been standardised[14]. A large number of mechanical driers of different designs and capacities have also been set up in different parts of India particularly by the public sector undertakings although these facilities have not been fully utilised. The cost of mechanical drying is considered uneconomically high as compared to sundrying. Improvement of the customary sundrying method for obtaining minimum milling breakage by making the drying more uniform and introducing a conditioning step has been suggested[8]. This type of drying should be suitable for drying paddy during fair weather which generally applies to the *Kharif* crop in most parts of the country.

For those situations where the harvesting season coincides with the onset of the monsoon (*Kuruvai* crop of Tamilnadu and the short summer crop of

Karnataka, Andhra Pradesh, Orissa, Assam, etc) special difficulties are encountered in drying. The need for mechanical drying of such paddy has been stressed by scientists and policy makers. Although this entails high costs, there is no other sure method for eliminating the qualitative and quantitative damage to the paddy that otherwise happens. Simple small scale drying using dry contact materials like earth, sand, husk, etc. have been shown to be possible[9] but practical utilisation has not yet started.

Short time preservation of such high moisture paddy until it can be dried in fair weather has therefore been thought of and good leads in the field have been obtained by Prof. Subrahmanyan and his colleagues at Tiruvarur. The use of salt at 5 per cent level to fresh paddy withdraws moisture by exosmosis and also exerts a preservative effect[15]. Residual salt which adheres to the grain as a sticky mother liquor and which may corrode the handling and milling equipments is the limitation to its use although repeated washing with water followed by parboiling or use of earth or powdered husk for absorbing the residual salt on the grain have been suggested for reducing the salt residues[15,16]. The salt could also be sprayed on the standing crop to hasten drying of grain to facilitate early harvest[17].

The use of urea at 0.5 per cent level for preservation of the high moisture paddy was first indicated by Prof. Subrahmanyan and his team at Tiruvarur[18]. Large scale trials have indicated that the ammonia released from the urea and which actually acts as a preserving agent penetrates through the grain and imparts an yellow colour[16,18]. Further trials with this methodology are necessary to evaluate its usefulnes on a large scale. Anaerobic or inert gas packing in partially gas proof plastic bags has also been indicated to help in preservation for a few days[19].

Varietal improvement for better milling quality and reducing field losses: The development of paddy varieties which can stand late harvesting with minimum cracking and without grain shedding in the field could be ideal varieties for the Indian farmer. A systematic investigation was undertaken at the CFTRI in screening and selecting varieties that combine resistance to shedding and cracking. A paddy Crack Detector that can detect inherent field cracks in the intact paddy was first developed[20]. Certain paddy varieties which have extremely low susceptibility to cracking were identified[21]. The methodology of making intra-varietal selection for low susceptibility to cracking and for optimal shedding quality has been standardised and successfully applied to development of 3 varieties with considerably lower crack susceptibility and better milling performance as compared with the control without detriment to its agronomic potential[22].

Performance of traditional milling machinery and modernisation of rice mills: A survey of the rice milling industry has shown that there are nearly 90,000 rice mills in India out of which nearly 80,000 are small single huller mills, the rest being automatic mills containing separate sheller and polisher equipments. Based on comparative evaluation of traditional mills and a few modern rice mills imported from Japan and Germany[23], the Government of India has encouraged the indigenous manufacture of modern rice mills having rubber roller shellers under licence with foreign firms. Modern rice mills are now completely made in India. Several firms have also taken up to manufacture of rubber roller shellers. A considerable number of modern rice mills have been set up and the Government is giving all encouragement to the setting up of such mills.

As the cost of the entire range of equipments in a modern rice mill is very high and beyond the reach of many millers, stepwise modernisation of existing rice mills has been accepted and replacement of disc-shellers by rubber rollers has been encouraged and made obligatory. Similarly, replacement of hullers by more efficient small scale rice mills has also been thought of. Mini rice mills to suit this requirement have been designed by a few centres and it is expected that a large number of these mini mills will be set up in the near future.

The relative efficacy of different types of shelling equipments and influence of variety and processing treatments on milling yield and breakage have been investigated using laboratory test mill equipments[11].

Methodology for assessment of the degree of milling of milled rice has been investigated[24-26]. Wide varietal differences in chemical composition, thickness of bran, whiteness of rice, etc. have precluded the formulation of a single standard parameter which can be applied to all varieties. For control of the degree of polish at the mill level, provision of milled rice samples of specified degree of polish to serve as reference samples for comparison has been suggested.

Parboiling of rice: Research and development work on parboiling of rice during the last 20 years has been considerable. A hot soaking method of parboiling which completely eliminates the smell has been developed[27-29] and widely used commercially. In attempts to reduce the off odours developing in the rice during the cold soaking process, bleaching powder and potassium chromate have been found useful[30-31]. The latter has shown great promise as the resultant rice is completely free from smell and the yield of parboiled rice is stated to increase as a result of this process.

As drying conditions have a profound effect on milling quality of paddy, conditions for drying of the parboiled paddy both in sun and in mechanical dryers have been standardised[32-34] and many mills have been using mechanical driers for drying parboiled rice. The effects of various soaking and steaming conditions on the colour, vitamin value and milling quality of the parboiled rice have been clearly demonstrated[35, 36]. The potential of a simple hot soaking method eliminating the need for steaming has also been indicated recently[37,38]. A method of pressure parboiling of paddy which reduces the processing time and cuts down on the drying costs has also been developed and utilised commercially[39]. Rice produced by this method however has deep yellow colour and takes long time to cook. A new method of parboiling involving the hydration of the paddy by passing saturated hot air instead of soaking in liquid water has been developed[40].

Studies on the physico-chemical properties of parboiled rice and the changes during the parboiling process have also been carried out[41-43]. The differences in hydration characteristics and the longer cooking time of parboiled rice have been attributed to the process of starch retrogradation that takes place during the slow drying of the parboiled rice[44]. Presoaking of the parboiled rice in water prior to cooking has been found to reduce its cooking time.

Milling byproducts utilisation: Bran and husk are the main byproducts of rice milling obtained in yields of approximately 5 per cent and 25 percent respectively. Their utilisation has received top priority in the last ten years particularly in the context of the shortage of both edible and fuel oils in the country.

About one third of the total bran available has been mobilised and extracted by solvent to recover about 80,000 tonnes of industrial grade rice bran oil. Stabilisation of the rice bran to destroy the inherent lipase which causes fat splitting and raises the free fatty acid content of the extracted oil has received concerted attention and conditions for enzyme inactivation standardised[46]. The location and nature of the rice bran lipase have been studied[46, 47]. Bran stabilisers using electrical heat[45], steam[45, 48] flue gases[49, 50] and hot sand[51] have been suggested. Limited quantities of low FFA rice bran oil have also been produced and used for salad oil or for hydrogenation.

The husk which forms nearly a fifth of the total rice produced is currently finding major use as a source of heat for boilers, in rice mills, hotels, households, etc. Processes have been developed for making activated charcoal, husk board and silicate from the husk[52, 54]. These processes have yet to find commercial application.

Recent thrust in research on rice husk is to improve the efficiency of burning of the husk by improved design of furnace to maximise heat output in mechanical drying of paddy. The use of the white ash from these furnaces for making cement has gained momentum[55, 56].

Wheat

Wheat is unique among cereals, in having the protein 'gluten' which renders it suitable for preparation of a variety of baked products as well as traditional unleavened baked products. As a result of the green revolution, wheat production has almost trebled in the past decade and a half, from 12 million tonnes in 1964 to about 35 million tonnes in 1979. More than 80 per cent of the total wheat produced in the country is milled in indigenous mills (*chakkis*) into *atta* (whole wheat flour).

About 10 per cent is processed in over 350 commercial roller mills (total wheat milling capacity: 6 million tonnes), which constitute one of the largest organised sector of the food processing industry. The milled products mainly consist of *maida* (white flour), *soji* (semolina) and the resultant *atta*.

The capacity of most of these mills ranges from 50-250 tonnes/day with an investment of the order of 1 to 1.5 crores of rupees. Also, most of the milling equipment are imported. Manufacture of some of the machinery items have been started in India. Studies have been initiated at the CFTRI on the development of simple milling techniques using low cost indigenous machinery. Such units can have a milling capacity of even 1-2 tonnes/day and can deliver semolina and flour for different end uses, such as baked and traditional foods as well as paste goods[57].

Coarse grains

The coarse grains like sorghum, maize, bajra, ragi, etc. constitute the staple food for the poorer section of the people. They are however not popular and are considered unpalatable by those accustomed to rice or wheat. Their relatively low palatability is caused chiefly by the outer bran layers the removal of which has been shown to give processed grains or flour with enhanced consumer acceptability. Techniques of removing the outer bran from these coarse grains have been developed[58, 59]. The process essentially consists of incipient wetting of the grain with small amount of moisture ranging from 2-4 per cent and peeling out the softened bran using appropriate abrasion machinery to obtain pearled grains. This technique is also suitable for wheat. The pearled grains could be ground to flour or semolina for food uses. A pilot mill for pearling of sorghum and for producing semolina from maize grits has been indigenously developed[60, 61]. In the case of maize, degerming is essential to give adequate shelf life to the semolina. For producing a flour free from bran from ragi and other smaller grains the roller flour mill has been found suitable[62]. A semi-refined flour with a low content of bran can also be prepared by conditioning the grain with water and step-wise milling in a plate grinder or a hammer mill[63,64].

Legumes

The removal of outer bran or husk from legumes and the splitting of the same to obtain *dhal* has been practised both as a cottage scale industry and also as a commercial industry in India. *Dhal* has a shorter cooking time, has a better appearance and is suitable for wider food uses than the whole pulse. The steps in traditional practices of *dhal* milling involve a combination of wetting, drying and oil application for loosening of the husk and depend on the availability of intense sunshine for thorough drying of the grain. Several passes are required for completing the dehusking process [65,66]. The processing losses as brokens and as powder are also quite high. A completely mechanised process involving hot air conditioning of the grain to loosen the bran thoroughly and facilitating its complete and easy removal has been developed at the CFTRI[67]. The processing schedule for making *dhal* from each of the common Indian pulses has been standardised[68]. A few *dhal* mills have come into operation using this modern technology.

2. COOKING AND PROCESSING QUALITIES

Rice

Consumers in the Indian subcontinent prefer a soft well cooked flaky type rice. A pasty type rice is not favoured by consumers. Rice from freshly harvested paddy has been known to cook to a pasty product. This quality improves after natural storage for 6 months or longer. The changes during storage which contribute to the improved culinary quality have been studied[69-71]. Accelerated ageing methods based on steaming or humid heat treatment have been developed and used extensively[72-74]. The degree of heat treatment during the steaming process has been found to control the pastiness and swelling quality of the steamed or parboiled rice [75,76].

Apart from differences caused by ageing, cooking quality differences caused by variety of the rice have also been recognised by consumers. The causes of these varietal differences in cooking quality, and the influence of the physical and chemical properties contributing to the same have been very thoroughly investigated[77]. Numerous rice varieties have been studied and classified into definite recognisable types[78,79]. Test for measuring the cooking quality have also been developed[78, 80-84]. These tests would be useful to rice breeders and technologists for assessing cooking quality of new varieties being developed and studying effect of different processing conditions on cooking quality. Degree of polishing of rice has also been found to affect hydration and cooking quality[85].

Wheat

A major part of the total wheat produced in the country is milled into *atta* (wholemeal flour) for making *chapathi*, *roti*, etc. while *maida* which is processed by the roller flour mills is used in the production of different bakery products such as bread, biscuits, cakes and various Indian sweets. The *soji* processed from different types of wheats is mainly utilised in the preparation of macaroni products and several sweet and traditional savoury snack items such as *upmav*, *idli*, *kesari bhath*.

With increasing urbanisation, the consumption of processed bakery products, especially bread, is on the increase. Under the aegis of the government undertaking the Modern Bakeries Ltd., a chain of 13 mechanised production units have been started in different parts of the country.

The suitability of several varieties of aestivums as well as Durum wheats for preparation of bread, biscuits, *chapathis* and vermicelli (macaroni type product) have been extensively studied in the last two decades. Varieties suitable for bread and biscuits as well as for *chapathis* have been identified among Indian aestivums[86,87]. The Durums are generally suitable for macaroni type products although some have been found to make good bread also[88]. Some of the Durums can also be blended with soft wheats for making bread[88,89].

Studies on quality of commercially milled *maida* from Indian wheats have indicated their deficiency in diastatic activity required for good quality bread. Use of small quantities of cereal malt or potassium bromate improves the quality of bread[90]. Recipes for bread containing 14 per cent protein and biscuits containing 15-20 per cent proteins have been worked out using soya and raw groundnut flour for protein enrichment[91].

Investigations at the CFTRI and also at the Indian Grain Research Institute, Hapur, have indicated the possibilities of using 10-20 per cent of flours from maize, jowar, tapioca, potato, groundnut and soya, etc. in baked products such as bread and biscuits[92,93].

Byproducts: Laboratory studies carried out at the CFTRI on wheat germ—a potentially nutritious byproduct of the flour milling industry—have indicated that the product, when heat processed, has an improved shelf-life upto six months[94]. In view of its high quality protein (25-30 per cent) and high content of B-vitamins and tocopherols, it can be used with advantage for enriching bread as well as biscuits upto 10-20 per cent level[95,96]. Wheat germ added *atta* has been found not suitable for the preparation of bread or *chapathis* of the desired eating quality[97].

Coarse Grains

Varietal differences in sorghum with respect to suitability for making *rotis* or *bhakris* have been recognised[98-103]. Those types which give dough that have optimal adhesiveness for rolling into thin *rotis* are preferred by housewives. The correlation between the adhesiveness of the doughs and the chemical/physical properties of the grain has been studied with respect to sorghum[100]. Use of boiling water for making the dough and optimal gelatinisation by steaming have been found beneficial in getting dough with required plasticity for rolling. Characteristic differences in the suitability of maize, sorghum and bajra for making *roti*, *dosa* and vermicelli have also been studied[104]. Maize flour has been found to require much more water than other cereal flours while making of the dough. Maize *rotis* or *chapathis* therefore are more soft for consumption. The possibility of making *chapathis* from mixes of different cereal flours for obtaining optimal pliability, desired chewing quality, etc. have been indicated from this work. The chewiness of *roti* from ragi flour can be reduced by steam treatment of ragi grain[105].

Legumes

The long time needed by *dhals* to cook to a soft mash for consumption has been known for a long time and attempts have been made to reduce the cooking time. Factors responsible are stated to be divalent cations (Ca and Mg), pectin and phosphorus[106, 107] present in the *dhal*. Varietal differences in cooking quality and hydration of *tur* and green gram have been observed[106-109]. Pressure cooking[110], flaking to reduce thickness[111] and coating with alkaline salts[112] have been found beneficial in reducing the cooking time of legumes.

3. CEREAL PRODUCTS

Apart from their use as staple food in the form of cooked rice, *dhal*, *roti*, *chapathi*, etc. cereals and legumes, either singly or in combination, have been used for preparing many products which are used as breakfast or as snack foods along with coffee or tea. Studies have been carried out to simplify these processes, increase product yield, improve quality and introduce convenience.

Flakes

A process for increasing the yield of flaked rice (*poha*, beaten rice, *aval*, *avalakki*) which is a cheap convenience rice product has been evolved. This process employs heavy flaking rolls on shelled or lightly milled rice obtained from roasted paddy and improves product yield by about 3-4 per cent as compared with the customary process which employs an edge-runner for flaking[113]. The methodology for making similar flakes from non-rice cereals has been standardised. The flakes from jowar have been shown to have great commercial possibilities[113].

Convenience Mixes

Ready mix flours, which offer convenience and eliminate drudgery for the housewife for the preparation of important national dishes made out of cereals and pulses have been developed. The formulations developed in the form of instant mixes for popular dishes such as *idli*, *dosa*, *jelebi*, *vadai*, *gulab jamun*, *rasam* and *sambar* have been commercialised. Heat treatment/gelatinisation of cereal grains has been found to have beneficial effect on the crispness of the deep fat fried products prepared from them. This has been found to be particularly true for wheat.[114]

Papads

Factors affecting the quality of *papads* as influenced by the constituent raw materials, rolling properties of *papad* dough as well as the packaging of the product have been studied[115-117].

Puffed Cereals

Factors influencing the puffing quality of various cereal grains like paddy, jowar, ragi, etc. have been studied and the effect of variety and processing conditions on the puffing volume have been determined; suitable varieties with maximum puffing quality have been identified[98,118-120]. Commercial processes for puffing of legumes, paticularly Bengal gram have been popular and continuous puffing machines for the same have been developed and are in operation in the country[121].

Fermented Products

Scientific and technological studies on *idli*, a popular food preparation with a porous texture have been carried out. The microbiology of fermentation, the effect of factors like product composition, fermentation temperature and time on acidity, leavening action, etc. have been studied[122-124]. Active principles in the black gram, a basic constituent along with rice in making *idli*, which contributes to the desired texture of the final product have been shown to be a surface active protein as also a mucilaginous viscous polysaccharide which together help in retention of gases and foam stabilisation during the steaming process[125-128]. The possibility of replacing both the cereal and legume component by other legumes or cereals has been shown[127].

Sprouted Grains

Studies on sprouting of cereals and legumes have yielded valuable information on the effect of sprouting on the inherent carbohydrates and proteins, vitamins, enzymes, nutritive value, etc.[130-137]. The increase in vitamins particularly ascorbic acid is noteworthy. Elaboration of amylases and proteases improves the digestibility of the sprouted products. Conditions of malting have been standardised and taking advantage of the decrease in viscosity as a result of malting a weaning food based on germinated ragi and green gram developed[138, 139].

Reconstituted Grains

The production of paste goods from mixes of different flours with increased nutritional quality or protein to produce macaroni or noodle type product or grain shaped materials was investigated at the CFTRI, as early as the sixties. Rice shaped grains were produced from composite mixes of groundnut flour, tapioca flour, wheat flour, jowar flour, maize flour, etc[140-143]. Broken rice could also be reconstituted into full grain shapes. While the technology of production of such products has been standardised, the commercial utilisation of the process has not become a practical possibility purely because of economic considerations. However, the production of such reconstituted grains from nutritonally blended mixes may become economical if the prepared product is for special uses for making foods for diabetics, convalescents, etc. The possibility of preparing extruded foods based on blended mixes of cereals, oilseeds, etc. for use in school feeding programmes has also been investigated. Extruders have been indigenously manufactured and the extruded foods used in feeding programmes.

Conclusion

Grains constitute the staple food of all the sections of the population. They need to be processed, stored and utilised in such a manner as to minimise waste, enhance nutritional quality, provide convenience of use and improve palatability through processes/equipments that would entail minimum additional expense. The basic frame work in which the above can be attempted to meet the Indian situation and needs has been indicated through the different approaches in grain processing reviewed in the above pages. Satisfactory progress has been made in a few directions but many problems still require basic studies. Practical details and economic feasibility have to be established for certain processes. The chief limitation to application and utilisation of research results resides in the cost factor associated with any food processing operation. Only simple and less sophisticated and low cost technologies can be expected to find wide application.

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Processing, Preservation and Transport of Fruits and Vegetables

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Dr V. Subrahmanyan, who was Professor of Biochemistry at the Indian Institute of Science, Bangalore during the early forties, was a great enthusiast who was keen to develop food science and technology when it was practically unknown in the country. When I returned to India after specialising in the field of biochemistry and food technology in the United Kingdom, a small project was drawn up and a list of simple equipment was prepared for getting the necessary sanction. Unfortunately, the erstwhile Madras State, of which I was a State Scholar in the UK, could not spare me to initiate the project. This ambition became a reality in 1950, when the Indian Institute of Fruit Technology in Lyallapur and later Delhi, with which I was associated in its earlier years, was transferred to Mysore as part of the present Central Food Technological Research Institute. I am happy to contribute this present paper to the commemoration volume in his honour in which I have expressed some of my ideas regarding what has been achieved so far in the area of fruits and vegetables in the technological, developmental and extension fields, and what remains.

Canning and Bottling

Canning[1] had its origin in France during the Napoleonic wars with the pioneering work of Nicholas Appert, and has since become a large food processing industry the world over, ranking in the USA and several European with major industries like steel. Fruits, vegetables, meat, fish, dairy products, etc., are canned and made available to the people on a very large scale and at comparatively low prices. The most important constituent is the tin can made of special quality steel base plate, coated mechanically or electrolytically with tin and sometimes lacquered to minimise interior corrosion, and to prevent also the discolouration of fruit pigments such as anthocyanins. The fabrication of the tin container, with lids lined with gasket to ensure hermetic sealing is a big industry in itself and is based on the results of a great deal of fundamental as well as applied research. World tin resources, and even the fabrication of open top cans, are controlled by a few countries. The cost of the can is quite high in countries like ours, and the canned product itself becomes too costly for the average person. Most indigenous fruits and vegetables are now canned as a result of the pioneering researches that commenced as early as 1935 and have since continued[2]. Indian canned products compete favourably with similar products anywhere in the world, and consequently canned mangoes, pineapples, orange segments, guavas, orange and pineapple juices, and temperate fruits like peaches, apricots and cherries have an increasing export market[3]. This potential can be boosted with specific research work and technological development. There is scope for export of products such as tomato paste, typical Indian vegetables in canned form, and special delicacies. Research work carried out at CFTRI has made it possible to pack even such products as canned drinking water[4] for the Defence Services, and also to lay down standards and specifications for all canned and preserved products in collaboration with the Fruit Products Order of the Ministry of Food, Government of India and the Army Specifications of the Purchase Organisation of the Defence Department. A quality control division has been built up recently to ensure that preserved fruit and vegetable products produced in the country are according to the specifications and standards of quality stipulated by the FPO, ISI, ASC or the specific requirements of the country to which they are exported. Such analytical control and pre-shipment inspection has been of great help in building a good image for Indian products in the world, and is an achievement of which CFTRI can be justly proud.

However, it is still necessary to develop suitable tinplate, hot-dipped or electrolytic, lacquered or non-lacqeured from indigenous resources, since the present cost of can fabricated from imported tinplate is disproportionately high vis-a-vis the other constituents of the canned product. The research project to evaluate and improve indigenously-produced tinplate, which has been in progress at CFTRI for some years now, has already given highly promising results[5,6]. It needs to be augmented on a wide front with active collaboration with the different agencies, research as well as developmental, so that useful results could be got as early as possible. The importance of this work cannot be over-emphasised because of the economic and strategic impact.

Proposals have been mooted to replace the familiar open top sanitary can, which has long maintained its usefulness and superiority, with other type of containers[7] such as aluminium cans, glass jars, plastic containers, pouches and so on. Although small successes have been achieved here and there, as for canned beer or fruit juices, the universal tin can has still to be replaced. It is however useful to be aware of the trend of research and developmental work in this comparatively new field, and CFTRI can usefully intensify its present efforts in that direction. Efforts have also to be made to develop indigenous know-how for food lacquers and their substitutes, and for the critical gasket in the lid, which is absolutely essential to ensure the hermetic sealing of the can. More work is necessary to minimise internal as well as external rusting of the cans, especially those intended for export, since importing countries are allergic even to tiny rust spots on the outside of the cans. Collaborative work with the canning industry will be of great use in solving some of these problems.

Fruit Juices, Squashes and Cordials

Canned and bottled fruit juices, squashes and cordials are quite popular in the country. In fact, the fruit preservation industry in this country had its beginning with the production of squashes of such fruits as the orange, lemon and mango as early as 1935 adopting simple but effective means of preservation through chemical preservatives such as sulphur dioxide in the form of potassium metabisulphite, and benzoic acid in the form of sodium benzoate or its esters.

There are quite a few problems connected with the bottling of fruit squashes and cordials that require to be solved. Settling of fruit pulp and the resulting clarification of the squash[8], fading of the added food colour, uniform dispersal of the fruit pulp in the squash without settling, development of certain terpeneous off-flavours in citrus squashes during storage, development of suitable mixed fruit juices and squashes that are attractive and acceptable comminuted citrus beverages, clarified liquid fruits employing the right type of enzymic clarification, and the formulation of a fruit-based national drink to replace the synthetic and sometimes harmful drinks now current, are some of the more pressing problems in this field that call for early solution. The development of fruit juice concentrates[9] of high density from such fruits as the orange, pineapple, apple and grape could be an excellent starting point for transport in bulk and distribution after reconstitution. The possibility of developing fruit juice powders and flavour concentrates in solid form, as exemplified by sealed-in flavours, from important fruits such as citrus, apple, pineapple or grape by the application of modern dehydration technology based on vacuum shelf-drying, puff drying, freeze drying or foam-mat drying should be explored further. The earlier work at CFTRI and elsewhere on orange juice powder, mango cereal flakes, fruit-based baby foods like banatine or mangotine requires to be developed into commercial processes as there is considerable scope for such products[10].

Jams, Jellies and Marmalades

This is an important sector in the field of fruit and vegetable preservation, and on account of the simplicity of the technique it has found favour with a large section of the population both on a home and a commercial production scale. The basic knowledge as well as its application are well-known and understood. Some minor problems that face large-scale production such as mold development in the glass jam jar, or separation of liquid in the jelly (weeping), could easily be set right by *ad-hoc* studies. Mixed fruit jams now rule the day. The present attempts to obtain pectin from indigenous sources such as papaya, citrus fruits or apple wastes on an integrated basis should be worked up to their logical conclusion. It is a well-known fact that the success of the fruit and vegetable preservation industry is to a large extent dependent upon the creation of wealth from waste products which can sometimes be as high as 40-50 per cent.

Preserves, Indian Murabbas and Pickles

The Indian *murabba*[11] is an important traditionally preserved fruit or vegetable product which has great appeal to the people and it is necessary to improve further the indigenous technology for its manufacture, packaging and distribution. The old, step-wise method of preparation is time-consuming, and the steps of intermittent heating and holding over introduce undesirable changes in the final product. Further, considerable quantity of sugar is employed for the preparation of a given quantity of the preserve, leading in turn to the problem of utilization of the excess syrup. Packaging in large tin containers leads to heavy rusting and sometimes to product fermentation, both of which are undesirable from the aesthetic as well as the consumer-acceptance points of view.

In the case of apples studies have been conducted in varietal suitability, method of peeling, puncturing, chemical treatment, etc. Similar studies on cherries and other temperate fruits done at the Jammu Experiment Station have already benefited the industry in the northern region. The hot, continuous-preserve making unit[12] designed at CFTRI, has been well received by the *murabba* industry and should be further prefected. The application of vacuum concentration to *murabba* manufacture is another important field for intensive study.

Indian *murabbas* are claimed to have certain exceptional therpeutic and medicinal effects[11] in respect of blood pressure, and cholesterol-reduction. These should be substantiated by biochemical, nutritional and therapeutical studies. Indian *murabbas*, which are simple to make and keep, could develop into an important sector of the fruit and vegetable preservation industry.

Pickles[13] are cheap to make, pack and distribute, and the products are within the means of everyone. Their nutritive value has been well recognised in this country. Traditional preparation methods should be carefully restudied, and chemical and microbiological problems investigated in depth. *Murabbas* and pickles taken together constitute at present nearly half the total production of all preserved fruit and vegetable products in the country; they therefore merit more detailed study at CFTRI, and modern advances in the science and technology of food preservation need to be examined as is being done for more sophisticated products.

Traditional Indian Delicacies

Mango chutney[14] and tomato and fruit sauces are at present the more popular products in this category. Much more work is needed in regard to these and related products towards standardisation, quality control and microbiological and nutritional aspects. Recent advances in the microbiological analyses of food products based on microbial metabolites, which are rapid and fairly inexpensive, could be utilized to ensure the safety of these and other preserved fruit and vegetable products. This is especially necessary for non-acidic vegetable products and for meat and fish products, where blends are processed.

Drying and Dehydration

Sun-drying of fruits and vegetables is an ancient simple method of preservation that has been practised the world over. Dried fruits and more particularly dried vegetables like potatoes, carrots, cabbages, cauliflower and peas became important during world War II when armies had to be fed with nutritious foods in regions far removed from centres of production of the fresh materials. Because of poor reconstitution and acceptance characteristics, these dehydrated products soon lost favour with the general public. Work on the application of modern advances in the technology of dehydration, such as puff-drying, freeze drying, foam mat drying, dehydro-freezing and osmotic dehydration[15], which have given improved products from development of varieties suitable to dehydration, and better methods of packaging and storage already in progress at CFTRI and other centres in the country should be intensified to achieve quicker results.

Freezing

In advanced countries, frozen fruits and vegetables and frozen fish and meat products occupy an important place. The method has attracted attention in this country only recently, and frozen mangoes, peaches, peas and beans are available only in large cities because of the high cost of transport and retail distribution. There is much scope for developing this industry in the country if costs can be cut down. A great deal of biochemical and microbiological investigation is necessary for control of quality, microbiological safety and consumer acceptability.

Irradiation

Irradiation is among the newer methods of preservation, and is drawing world-wide attention. Some encouraging preliminary work was done at CFTRI for bananas and onions[16], but the Bhabha Atomic Research Centre at Bombay has intensified research in the field to show the utility of the technique in prolonging the keeping quality of such important foods like the banana[17], potato and foodgrains. Topics such as residual radioactivity in the food, chemical and biochemical changes in the food likely to affect adversely its nutritional quality, packaging and storage adaptability to commercial processing and economic feasibility are being actively pursued and critically examined.

Other Methods of Preservation

The earlier work done at CFTRI on "steeping preservation" of vegetables like peas using acidified brine and permissible chemical preservative, has considerable scope for adoption in the country. A variety of Indian vegetables can be preserved in steep liquor, for subsequent conversion at home into the daily curried dishes used all over the country. An extensive study of the technique must be made of chemical and biochemical changes likely to affect the quality of the product, and of microbiological aspects to ensure its absolute safety, especially because vegetables are of non-acidic nature. In fact, what has been done for frozen fish and meat has to be repeated for steep-preserved vegetables also. The technique is very simple, and the equipment needed is cheap and suitable for adoption on a very wide front even in rural areas. The average Indian home makes excellent pickles, and would not be lacking in knowledge, resources and acceptance if the techniques were to be proved absolutely safe from all points of view.

Storage and Transport of Fresh Fruits and Vegetables

Most available methods of preservation are either technologically difficult, or too costly to adopt on a large scale. Further, fresh fruits and vegetables in all their richness are any day preferred by consumers. Accordingly, only a small fraction of these valuable protective foods is processed and preserved. Because of lack of adequate packaging and transport facilities, a large percentage of the fresh material is unnecessarily lost at various stages from the harvesting to packing, handling, transport and retail distribution. There is scope for minimising such losses at every stage by adopting well established practices of handling as has been shown in several parts of the world for such important fruits and vegetables as apples, peaches, apricots, grapes, pineapples, melons, carrots, cabbages, cauliflower and others.

Establishing cold storages at critical points is an important link in the process. Conditions for the storage of different fruits and vegetables have been standardised. The work at CFTRI[18] has been useful in the cold storage and transport of important Indian fruits and vegetables such as oranges, mangoes, bananas, tomatoes, potatoes and onions. Even preliminary work in post-harvest technology has made it possible to transport apples all the way down from Kulu and Kashmir to the southern most part of the country, pineapples from the far-off interior of Assam to Calcutta, banana from the west coast to distant countries like the USSR and the Gulf region and mangoes to the UK. and Europe. There remains, however, a great deal more to be done by organisations like CFTRI and ICAR. To confirm commercial feasibility, developmental studies have to be carried out that should involve all agencies, private as well as governmental. A great deal of work is also necessary to study the development of suitable varieties; storage behaviour and packaging methods and materials; the suitability of the method of transport by road or rail over long distances with differing climatic conditions; spoilage-prevention devices such as wrapping of the fruits prior to boxing, fungicidal wax emulsion treatment of the fruit, treatment of the cut end of the banana bunch or hand to prevent fungus infection and spoilage of the fruit; handling of the fruit at various stages of transit to the market, storage at the market and retail distribution and so on.

Any weakness in the entire chain from harvesting to retail distribution is likely to affect the efficacy and profitability of the method. It is anticipated that the recent Indo-US programme of research in post-harvest fruit and vegetable technology under the auspices of the Indian Council of Agricultural Research would look into the possibility of evolving simple and cheap methods for packaging, transport, storage and distribution of important fruits and vegetables to minimise the present enormous waste in these highly valuable but seasonal and perishable commodities.

Some General Considerations

In any scheme to improve the rural economy, the importance of fruit and vegetables should not be ignored. This agro-industry could provide gainful employment to a large section of the rural people as does the dairy industry, and thereby contribute significantly to overall improvement of the rural sector. It is, however, most important that methods and techniques evolved should be simple, cheap and easy to adopt on a very large scale. This is a highly challenging situation for both the scientists and the administration in the country.

Although the fruit and vegetable growing, handling and preservation industry should logically be a rural industry situated in the growing regions, experience in this country has been otherwise. Comparatively successful food preservation factories are situated in urban areas[19] with easy access to fruits and vegetables, and with other advantages of transport, water, power and waste disposal arrangements, and above all good marketing facilities for the preserved products. On the other hand, a large number of small to medium fruit and vegetable preservation units set up in the private or cooperative sectors with good intentions and hopes in the rural growing areas have proved failures. Critical evaluation of this situation will reveal that these units were often too small to succeed in a competitive field, or were financially inadequate, or had a poor infrastructure in regard to supply of water, electricity or fuel. Often the environment was unable to attract and hold employees of talent as can an urban situation and above all management often lacked the talent and training that are absolutely essential for production and successful marketing of finished consumer products in a highly competitive field. To add to this, the container and packaging materials were unnecessarily costly, so that the finished products lay beyond the means of the average person.

The entire situation has therefore to be examined carefully, before recommendations can be framed for setting up and developing viable fruit and vegetable preservation industries in the country. *Ad-hoc*, makeshift policies and incomplete planning are unlikely to yield results. If the preservation industry is to be located in the rural growing areas, then it is necessary to pump in fairly large amounts of money in the first instance to build up the necessary infra-structure. This will have the double advantage of not only helping growth of the main industry but also of serving as an encouragement for the setting up of other ancillary and non-ancillary industries in the rural sector.

To serve as a fillip to the development of the fruit and vegetable preservation and transport industry, it is necessary to ensure that the important ancillary raw materials such as tin and glass containers, packaging materials and so on are made available at reasonable prices and in time, as in advanced countries. Further, the present burden of high duties and levies that raise the price of the finished product by more than fifty per cent, has to be lightened if the average person is to take kindly to a good preserved product. This is especially so since he is still prejudiced against a factory-preserved product, although he accepts the home-preserved product because it is cheap and within his means. The fruit and vegetable perservation industry, has to meet many obstacles and requires sympathetic encouragement and cooperation at all levels.

Despite occassional set-backs or failures, there is every hope that this industry will succeed, since it is of intrinsic value and benefit to the country. The pace is rather slow at present. It is hoped that it will be accelerated.

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Processing and Utilization of Plantation Products of India

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The important plantation products of India are coffee, tea, cocoa, arecanut, cashewnut and spices. The post-harvest technology of these products has been the subject of research in India over a number of years. With the setting up of the Central Food Technological Research Institute (CFTRI) at Mysore in 1950 under the able guidance of Dr V. Subrahmanyan, research on plantation products received great impetus. The Coffee Board, the Tea Board, the Central Arecanut & Coconut Committees, etc. sponsored research at CFTRI on these products. The Institute has provided the technological study and application for improvement of these materials and developed new processes for their utilization. New industries have been set up based on the know-how developed.

The present write-up covers the technological and analytical studies on coffee, tea, cocoa, arecanut and spices.

Processing and Utilization of Tea

India is the major producer of tea worth Rs. 800 crores. In 1977, tea earned Rs. 550 crores foreign exchange and paid Rs. 300 crores as taxes to the Government and provided employment to about one million workers.

Tea research in India was organised in the year 1900 in the form of a Scientific Department of Indian Tea Association. Presently, the Tocklai Experiment Station at Jorhat, the UPASI Experimental Station, Davershola and the CFTRI, Mysore are carrying out R & D work on this important crop.

The work at the CFTRI has been confined to chemical composition of tea viz. total ash, water soluble ash, total water extract, caffeine, tannins, and such other constituents in different Indian samples encompassing wide regional and seasonal variations[1-3]. The nutritional aspects of different samples of tea have been investigated by Guha and coworkers[4].

Studies on the chemical components contributing to quality of tea have been carried out by Roberts and his coworkers[5]. They developed the cream index values, TF and TR ratios, methods of estimation of colour and brightness of tea infusions and they were able to establish correlation between these values and the tea tasters' evaluations and thus aid to the market value of the black tea samples. A method for chemical assessment of optimum fermentation time has been developed by the Tocklai group[6].

Developmental work on processing technology and machinery: In order to combine the best of the high quality of orthodox tea with the rapid production of CTC teas, a technique of dual manufacture has been developed and standardised at Tocklai[7]. UPASI[8] has also evolved a convenient method of CTC processing to improve the briskness and cuppage of tea. This process designated as half-cut CTC method comprises a coarse CTC cutting, half fermentation followed by a fine cut and firing.

In the development of tea processing machinery, McTear at Tocklai[9] has introduced a withering tunnel process instead of normal tray withering. More recently, Tocklai group has developed a continuous withering machine which has a better leaf handling capacity and is more economical than a conventional installation.

Orthodox teas are known to be of high quality and flavour. Because of the time consuming nature of the rolling operations involved, CTC teas have come into prominence. Tocklai continuous roller[10] has been introduced where extraction of tip and production of a low percentage of tippy orthodox tea in conjunction with CTC, is made possible.

Other important innovations are the Barbora leaf conditioner[10] which distorts larger quantities of leaf in a continuous operation and Tocklai continuous fermenting machine, wherein the fermentation is done in trays, which move on a conveyor system, exposed to oxygen enriched air.

Processing of instant teas: Instant teas or soluble teas have become very popular abroad because of their easy dispensability as a cold beverage from vending machines. It also saves on the packaging and transportation costs. Tea Board, India has sponsored two pilot plant projects on instant tea at the CFTRI, Mysore and Tocklai Experimental Station, Jorhat. According to the process developed at CFTRI[11], the withered, distorted, and fermented leaf is extracted with hot water having 4 per cent solids, concentrated *in vacuo* to a solids content of more than 20 per cent followed by removal of tea cream and spray drying.

The instant tea process presently being scaled up at Tocklai[12], consists of withering, CTC distortion and fermentation followed by extraction with batch type extractors. The tea infusion at 5 per cent concentration is centrifuged and spray dried to make a cold water soluble instant tea. Although both the processes have produced good quality instant tea some aspects such as retention of original tea aroma, clarity of the infusion at low temperatures have to be studied before these processes can be commercialised.

Utilization of tea and its by-products: Utilization of tea and its byproducts are related to the chemical constituents present in it[13]. Das *et al.* have reviewed the nutritional[14]; and pharmacological[15] properties of tea. Das and coworkers also studied the antibiotic effect of tea polyphenols[16], effect of polyphenols on capillary resistance[17] and on the vitamin synthesis by intestinal microflora[18]. John and Mukundan[19] demonstrated the antiviral properties of tea and ascribed it to mixed action of tea polyphenols and caffeine. Murari *et al.*[20] found that theaflavins and thearubigins which are structural variants of bioflavonoids have pronounced bradykinin antagonism and anti-spasmogenic action against prostaglandins. Khanna *et al*[21] have isolated and identified theaalcohols A and B, α-spinasterol and dihydrospinasterol and α-spinasterol β-D-gentibioside. Wickremasinghe *et al*[22] showed that the saponin is responsible for introducing tolerance to infestation by the scolytid beetle, *Xyleborus fornicatus*. Madhusudhana Rao *et al*[23] confirmed the identity of theaalcohol A as the new plant growth regulator n-triacontanol and found instant tea waste to be a good source followed by green tea and then black tea.

The Regional Research Laboratory, Jorhat has developed a process for the extraction of caffeine from tea waste and two small scale industrial units have been established based on this process. Chakraborty and coworkers[12] have studied the extraction of tea polyphenols from tea sweepings and their use as antioxidants.

Some recent advances in the chemistry of tea polyphenols have been reviewed by Natarajan and Seshadri[24]. Natarajan *et al.*[25] have reviewed the recent progress in studies on the flavour of tea.

Coffee

Coffee is another popular beverage in India. There has been a phenomenal increase in the output of coffee in India during the past three decades. The present annual production is 1,25,000 tonnes, nearly half of which is exported, earning foreign exchange to the tune of about 2000 million rupees. In view of the great economic importance of the crop, the Coffee Board, which controls the coffee industry, has sponsored research programmes at CFTRI since 1952 on different post-harvest technological problems concerning coffee.

Storage and quality control: A number of investigations[26, 27] on the storage of green coffee beans under simulated high humidity conditions prevailing on the West Coast during the monsoon were carried out with a view to investigating the extent of moisture pick up which results in bleaching, mould growth, swelling and insect attack in varying degrees. The results formed the basis for evolving the technique of ballooning storage of coffee for preventing moisture pick up when stored on the West Coast during the monsoon. This method has proved far more economical than transporting the coffee beans from the coast to the inland centres for monsoon storage. Investigations on the effect of variations in moisture content of coffee during storage under different conditions on its quality enabled the Coffee Board to fix the permissible limits of moisture for various types/grades of coffee[28].

Exhaustive data on the chemical constituents of various grades of coffee produced in different regions have been collected, based on which standards for coffee and derived products have been formulated[29]. Studies in respect of different components of coffee like carbohydrates,[31] proteins,[32] tannins and polyphenols[33, 34] mineral constituents,[35] volatile and non-volatile constituents responsible for aroma and taste[36, 37] have also been carried out.

Roasting and brewing: Optimal roasting conditions are essential for ensuring right quality in coffee beverage in terms of aroma, strength and taste. The important changes such as loss of moisture and organic matter during roasting have been studied in detail. Roasting standards for light, medium, heavy and dark roasts in terms of roasting loss, finishing temperature, colour, breaking strength, swelling ratios, water extractives, cup quality and changes in chemical constituents like caffeine, chlorogenic acid and sugars[38, 39] have been established.

Various aspects of brewing[40] have also been studied in detail including extraction under pressure[41] and the results have been brought out in the form of a manual entitled "How to Brew Coffee in Restaurants and Coffee Houses".[42]

More recently, a method has been standardised for the production of concentrated coffee extract (containing 30-35 per cent solids) using a battery of jacketed percolators with hot water circulation[43].

Process, product development and packaging: A quick and efficient method for the preparation of monsooned coffee (a speciality item of export) under controlled conditions of temperature and humidity has been standardized. The process is being used by the industry[44]. Other products developed include carbonated coffee beverages,[45] decaffeinated coffee[46] and cardamom-coffee blends[47].

For larger packs of roast and ground coffee, gas packing under carbon dioxide or vacuum has been found to be desirable[48] while for economic and short duration storage of unit packs, high density polyethylene is effective[49].

Detection of adulteration: A simple test for detection of adulteration of coffee with date or tamarind seed powder has been evolved based on the colour reaction of the leucoanthocyanins present only in the adulterants with dilute alkali as a quantitative method for the estimation of the extent of adulteration[51].

Waste utilization: Diverse aspects of the utilization of byproducts[52] of the coffee industry like coffee (cherry) husk[53] and spent coffee grounds[54] have been investigated.

Cocoa

India has been customarily importing about 1000 tonnes of cocoa beans to meet the demand of the cocoa industry. Cocoa cultivation was introduced some 10 years ago in India as an intercrop in coconut and arecanut gardens. It is mainly grown in Karnataka and Kerala and to some extent in Tamil Nadu and Gujarat. It is estimated that at present 5000 acres are under cocoa cultivation producing about 400 tonnes[55] of coffee and this is expected to steeply increase as more and more plantations start yielding.

The technology of processing cocoa[56], for obtaining good quality fermented and dried beans is exclusively with the cocoa product manufacturing concerns. The farmers do not know more than harvesting the mature pods and supplying the beans with the pulp for further processing. Collection centres are established by these firms and the beans are fermented, dried and despatched to the factory for making cocoa products. The process of feremntation and drying of cocoa for use at the farmer's level has been standardised[57] by CFTRI which gives the farmers added value.

The technology of making cocoa products, such as cocoa powder, chocolate, cocoa beverages, is entirely dependent on the imported technical know-how and costly machinery[58]. The CFTRI has developed indigenous know-how for these products. A process for making refined cocoa mass, which is the base material for chocolate and confectionery has been worked out at CFTRI and is being released to the industry.

Spices

India is reputed for the production of major spices like pepper, cardamom, ginger, chillies and turmeric. Other spices like clove, nutmeg, cinnamon, cassia, celery, fennel, fenugreek, coriander, cumin, and saffron, are also produced to a smaller extent.

India has been traditionally exporting only spices and these were processed in the developed countries to make products like spice oils and oleoresins. No large-scale manufacture of spice oils and oleoresins were undertaken in India earlier because of lack of know-how for making products conforming to the specifications imposed by the importing countries. The CFTRI has developed the technical know-how for the manufacture of spice oils and oleoresins. The know-how has been released to those manufacturing spice extractives[59-67]. Based on CFTRI know-how many industries have started production of spice oils and oleoresins and are exporting these products. During 1977–78, 7.5 tons of spice oils valued at Rs. 30 lakhs and 132 tons of oleoresins valued at Rs. 190 lakhs have been exported from India.

Dehydrated and canned green pepper: The colour of pepper while harvest is green, but during drying, the skin constituent is enzymatically oxidized to black pigments. It is observed that if this enzyme activity is arrested, the product remains green. To achieve this the fresh green berries are given a suitable heat treatment to inactivate the enzyme, followed by a chemical treatment and finally dried by mechnical means. The fresh green aroma and colour of this dehydrated green pepper is liked in many European countries for use in preparations like meat products, and steaks. India has been for sometime past exporting green pepper in brine both in bulk and in retail packs to Europe. This is an item which offers good scope for export from India. The processes for the manufacture of dehydrated green pepper and canned green pepper have been developed at CFTRI.

Varietal differences: Distinct differences in quality and yield of oil and oleoresin have been observed in varieties of cardamom, pepper, chillies, ginger and turmeric grown in India. These investigations have helped to identify the best varieties suitable for extraction;[68] for production of white pepper, and green pepper.

Arecanut

India is the largest producer of arecanut (*Areca catechu* Linn) which is consumed both in the raw form and after processing. Ripe fresh arecanut[69] is the chewers' favourite in Assam, Kerala and Northern parts of West Bengal. *Challi* and its half-cut form *parch* are extensively used in Western and Northern parts of India.

Processed green nut *Kalipak* is most popular in Karnataka, Kerala and Tamil Nadu.

Process for preserving fresh ripe arecanut in garden fresh condition has been developed by the CFTRI[70] By this process the fruits can be preserved in fresh ripe condition for 10-12 months.

Dried ripe nuts: Fresh ripe areca fruits are dried in the sun, by spreading whole or half cut fruits in single layers for 35-40 days. CFTRI has developed a mechanical through-flow-drier[71] for making *chali* and *parcha* which reduces the drying time to 3-4 days.

Kalipak: Areca fruits of 6-7 months maturity are used for making this important category cf processed arecanut. The main processing centres are Karnataka and Kerala. The processing consists of dehusking, cutting the soft nut into different sized pieces, boiling, coating with concentrated extracts of arecanut and drying in the sun. The mechanical through-flow drier combined for economy with boiling process has been standardized for obtaining uniform high quality product under controlled conditions.

Chemical constituents: The polyphenols which are the most important constituents of arecanuts and constitute about 20 per cent of the dried nut, have been characterised[72]. A method for the estimation of arecoline in arecanut has been standardised[73]. The percentage of fat in dry ripe arecanut has been estimated to be between 9 and 15 per cent.

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Chemistry and Technology of Fats

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When I joined the Indian Institute of Science in Bangalore in June 1943 *to work with Mr B N. Banerjee in the area of fats in the Department of Biochemistry, Dr V. Subrahmanyan was its professor. In frequent evening walks he would talk freely about his dreams for the future, inspiring us fledgling scientists with how much there was to be done, the dedication required to do it, and above all the excitement of the chase.*

The field of oils and fats has always been close to Indians by reason of the wealth of raw materials all around, both familiar and still unknown. Since independence, work with a technological bias has gained at the expense of the almost totally academic studies of earlier days. Three major technological laboratories are now working on fats: the Regional Research Laboratory, Hyderabad; the Oil Technological Research Institute, Anantapur and the Harcourt Butler Technological Institute, Kanpur. Several other research institutes have some interests in the field, like the CFTRI Mysore, and Hindustan Lever Research Centre, Bombay. A few universities have strong research centres in fats: the University Department of Chemical Technology (UDCT), Bombay; the Department of Applied Chemistry (DAC), University of Calcutta; the Laxminarayana Institute of Technology (LIT) of the University of Nagpur; and the Chemistry Departments of Karnataka University, Dharwad and Aligarh Muslim University. A brief panoramic view of the work at these centres in the last three decades will be taken in this article, with special attention to approaches that were innovative or products that were novel.

Groundnut and Integrated Processing

While analytical[1,2] and processing[3] characteristics of existing and newly-introduced varieties of groundnut came out from the OTRI Anantapur, certain newer approaches were made to utilising this traditional oilseed. Both the Anantapur Institute[4,5] and the CFTRI Mysore[6] established procedures for removing red skins and thus avoiding bitterness, discolouration and early rancidification prior to conventional processing so that the protein-rich oilcake would be of edible quality. These procedures have been commercialised, notably by Modern Proteins, Kurnool. Integrated processing of oilseds by the novel route of successive extractione of oil and protein with aqueous media of increasing alkalinity was first developed for groundnuts at CFTRI,[7] and eventually put into production by the Tata Oil Mills Co Ltd., Bombay,[8] which offers an isolate with over 90 percent protein. The aflatoxin problem which surfaced in the early sixties was overcome during integrated processing by controlled hydrogen peroxide treatment,[9] but production of groundnut cake of low aflatoxin content by standard processing in an expeller or solvent plant still remains an unsolved problem.

Other Oilseed Processing

The drive for edible proteins has been extended to many oilseeds. The CFTRI integrated aqueous processing technique has particular utility for fresh coconut flesh, yielding oil, protein and a concentrated whey ("coconut honey") all of excellent quality.[10] Commercial production has been instituted in Kerala on the same principles.

Where sesame is employed, removal of the leathery skins is necessary to reduce fibre content, avoid a bitter taste and lower the level of oxalate. The process developed by the OTRI[11] involves soaking in water followed by passage between wood or stone discs, finally washing away the skins on a sieve, while CFTRI[12,13] opted for a quick alkali-soak technique, followed by abrasion between moving belts. For rape/mustard, whose protein is of exceptionally good biological quality, CFTRI has found it expedient to remove flavour compounds from the cake by extraction with polar solvents.[14,15]

Production of cottonseed edible protein has received attention at the RRLH[16] and Sundatta Foods and Fibres.[17] Both the controlled screw-expelling approach, or the use of hexane to carry away unruptured glands containing gossypol from a carefully-ground mass of dry cottonseed meats have been followed upto pilot-plant levels. All these development efforts have rarely been followed by commercialisation because of the low demand for protein-rich edible flours, caused in turn by the small market for protein-containing processed foods in India. The demand for all edible oilseed proteins is only about 12,000 tonnes annually; two-thirds of this is for making subsidised and not truly commercial foods like Balahar used in government feeding programmes,[18] for which edible groundnut and soyabean flours are available. Two production units could meet this demand.

New Oil-bearing Materials

A silver-jubilee ago, barely 5 per cent of the cottonseed in India was utilised for oil. The rest was a prized cattlefeed, which led to much resistance to the thrust to utilise cottonseeds rationally by dehulling the seed, releasing the oil in the kernels for subsequent refining and edible use, and using the cake (to which the hulls could be added back as roughage) as a high-protein feed for ruminants. The RRL Hyderabad and the OTRI Anantapur led the way[17,19] in studying many facets of relevant R and D: compositional studies on seed and oil varieties,[19c] procedures to minimise deterioration and colour fixation in the oil on seed storage,[17c, 20, 21] the need for and degree of delinting of various seed types, and the beneficiation of linters,[22, 23] the use of bar and disc hullers,[22, 19d] the refining and bleaching of colour-fixed oils,[24, 19a, 19b] studies on soapstock utilisation for acid oil manufacture and fatty acid distillation,[25] and cake upgrading.[16] Alongside, the incentives furnished by government for export of cake and for use of refined oil in vanaspati, and the issue of standard specifications for cottonseed oils and oilcakes of various grades, for bleaching materials and for cottonseed by-products like linters, have led to utilisation at present of two-thirds of the 25 lakh tonnes of cottonseed annually produced. Indeed the major constituent of vanaspati as now manufactured is not groundnut oil but cottonseed oil. A peculiarly Indian commodity is washed cottonseed oil, a partly-refined product obtained by treating the crude oil with dilute alkali in equipment used for refining crude groundnut oil.[17b]

Striking progress has been made also in exploiting new and typically Indian oil-bearing materials of forest origin. No outside technology was available and Indian technologists had to find out how to do things for themselves. Foremost in terms of volume is sal fat which was beset with problems connected with collection, quick hydrolytic and oxidative spoilage, solvent extraction, refining and bleaching of a dark green fat, utilisation of a low-protein oilcake with moreover a high level of astringent tannins, and finally conversion of the refined fat into a product with characteristics akin to cocoa butter. Contributions were made by the Hindustan Lever Research Centre,[26,27] the OTRI Anantapur,[28,29] the RRL Hyderabad,[30ab] the University Department of Chemical Technology (UDCT), Bombay[31] and by pioneer entrepreneurs. The alcoholic alkali refining technique developed at UDCT[32, 33] was applicable to the removal of obnoxious lipid associates from a number of tree seed oils such as neem, khakan, pongam and pilu, which to-day are refined and make a contribution of one lakh tonnes to the national oil kitty. Another new source is ricebran oil, now the mainstay of the Indian soap industry. Though pioneering work had been done in Japan and Burma, technologists from CFTRI Mysore[34] and OTRI Anantapur[35, 36] developed methods for the stabilisation of rice bran and for refining rice bran oil that helped industrial development in India. Studies on various aspects of processing and utilising fish oils were particularly pursued at the CFTRI Mysore and the RRL Hyderabad,[30c, 37] and their chemistry at the Central Institute of Fisheries Technology, Ernakulam.[38-41] A great deal of technological work has also been directed to a variety of other oilseeds and oil-bearing materials that may well be exploited in the future: orange seed, musk melon seed, tea seed, rice germ and so on.[42-44]

By-product Studies

Maximum utilisation of all by-products to add value to the extraction or refining operation, and avoidance of waste products, are the watch-words of modern industry. Upgrading of oilcakes to products suitable for human use represents one aspect of such a philosophy, and by-product utilisation is another. A novel and totally indigenous development was the finding that the phospholipids present in the cottonseed and the groundnut could be isolated and put to use. Both the RRL Hyderabad[30d, 45] and the OTRI Anantapur[46, 47] showed that the sludges which settle when solvent-extracted groundnut oils are stored in tanks are a rich source of lecithins that can be easily isolated and put to food use, while the latter institute also stressed the recovery of phospholipids by hydration of cottonseed oil for non-edible uses such as in printing inks. The RRL Hyderabad looked into the preparation from cottonseed soapstock of acid oils that have added value,[25] and the odour and colour problems of distillation of fatty acids from the latter.[48] However this valuable source of fatty materials seems to be still largely neglected, even for use simply as a fat source in animal feeds, and cottonseed soapstock is now largely burnt in boilers. Several woody materials associated with oilseeds have potential as activated carbons especially after pre-treatment with metal salts like zinc; coconut shells, at the hands of the RRL Hyderabad, are the only ones to have been commercially exploited.[49] Groundnut shells are mostly burnt, and cottonseed hulls are added back to the cake to provide roughage in the cattle feed.

Commercialisation

What have been the Indian contributions to processing technology? The first of course is that the entire range of common processing units, from processing of the seed, to expression or solvent-extraction of the oil, to refining, bleaching, deodorising and hydrogenating the oil is now made in the country in various sizes and designs, and in both continuous and batch systems. The next is that the economics of the oilseed industry in the country has had the consequence of miniaturisation. For example, the "classic" belief that a solvent-extraction unit of less than 50 tonnes/day was uneconomic was given the lie when units of even 5 tonnes daily capacity were constructed and put into operation. "Baby" expellers of even 0.5-tonnes capacity, and small refining kettles, are other manifestations. Among special indigenous contributions to design may be counted units for decuticling groundnuts, deskinning sesame, destoning mango kernels, dewinging sal seeds prior to decorticating them, drying coconut meats, pelletising rice bran after freeing the latter of magnetic and siliceous contaminants, and so on. Innovative approaches were made in the late fifties, because of the shortage of petroleum products, to examine the use of alcohol for solvent extraction of the oil from rice bran at the CFTRI Mysore[50] and the RRL Hyderabad,[51] and its use for solvent crystallisation of fatty acids at the latter institution.[52] These did not then make commercial headway, but may need a fresh look in the light of the petroleum oil crisis, and the need to use renewable materials of which alcohol, being starch-derived, is an example.

Indian Oils for Speciality Uses

Reference has already been made to the commercial utilization of fats unique to India like sal, mango, and neem, and their further utilisation in value-added products has been pursued at several centres. UDCT Bombay[31, 53, 54] and CFTRI Mysore[55] have been particularly active in examining how natural hard fats like sal, mango kernel, kokum and dhupa can be converted to products with the brittleness and snap that characterise cocoa butter, for use as substitutes or extenders for the latter. Considerable work on the use of other oils as soapmaking materials also stemmed from UDCT; pisa fat was shown to consist almost entirely of lauric acid, and khakhan fat had a fine range of fatty acids for soapmaking purposes[56].

Extensive studies have centred on the castor, of which India contributes a quarter to a third of the world crop. Being non-edible, about half the production of this oil is exported, to the tune of 50,000 tonnes annually, but transformation to more sophisticated products is being extensively studied at several centres. Certain products developed through Indian R and D and already in commercial production (though still in a small way) include hydrogenated castor oil, 12-hydroxystearic acid, stearins and stearin-oleins, dehydrated castor oil and DCO fatty acids carrying 50 percent diene conjugation, undecenoic acid and heptaldehyde, heptanoic acid and its anhydride, sebacic acid and 2-octanol, polyols and certain derived urethanes that can be used as coatings, elastomers, adhesives and rocket propellants, dimer and trimer acids and derived polyamides, and various fatty amines. R & D on castor oil products has largely centred on the RRL Hyderabad, the Shri Ram Institute for Industrial Research in Delhi, UDCT Bombay, the Vikram Sarabhai Space Centre in Trivandrum and various industrial in-house research centres like Jayant Industrial and Scientific Research and Bombay Oil Industries, both in Bombay. Castor oil derivatives find outlets in a variety of products like surfactants, surface coatings, plasticisers, perfumery materials, pharmaceuticals, rubber-substitutes, lubricants, and so on. The unusual structure of ricinoleic acid, with its pendant hydroxy group and one double bond, leads to a variety of possibilities unmatched by any other oil produced in commercial quantities.[57] Moreover the oil is annually renewable.

The behaviour of various oils and oil combinations on ordinary and directed interesterification has been extensively studied at the Department of Applied Chemistry (DAC) of Calcutta University[58] and at CFTRI Mysore[59] and a variety of hard or grainy products prepared, that could provide the advantages of a hard fat with a high linoleic acid content.

Basic Studies

We may now turn to the various streams of academic studies at different centres in the country. These include both university research centres, as well as R & D institutions with a technological orientation. UDCT Bombay has, besides the development work of the types already described, been active in the preparation of extremely pure mono-, di- and triglycerides and glycol esters and a study of their physical properties, besides studies on the relationships between structure and surfactant activity among related compounds of a number of types.[60, 61] DAC of Calcutta University[62,63] has looked into methods, especially the use of thin-layer chromatography, for the detection of adulteration of ghee. This is a field in which the RRL Hyderabad has also made notable contributions in the Indian context,[64, 65] while OTRI Anantapur[66] has particularly looked into colour reactions of oils with reagents like sulphuric acid and acetic acid or anhydride as a means of identification. Fatty acid compositional studies of various oils has been a hardy subject of study at most centres, and some unusual work has emanated. Work at DAC of Calcutta has thrown much light on families whose seed fats carry conjugated triene acids.[67] The Chemistry Department of Aligarh Muslim University has uncovered a number of previously unstudied oils carrying epoxy, hydroxy, cyclopropenoid and allenic functions,[68,71] and examined reactions of fatty acids.[72,74] Hindustan Lever Research Centre, Bombay[75,76] first established the presence in kusum oil of an unusual cyanolipid in which fatty acids were esterified with a hydroxy nitrile and not with glycerol. The RRL Hyderabad[77] and the Department of Chemistry, Karnataka University[78] noted the presence of 70-80 per cent of ricinoleic acid in a hiptage fat, and the Hyderabad group, based on earlier chemical analysis of the oil at the NCL, Poona, deduced that kamala seed oil contained polyacid triglycerides, the first ever to be postulated.[79]

Reactions of fatty materials have also been examined. The RRL Hyderabad has been particularly interested in hydrogenation reactions: types of isomers produced,[80a] effects of specific poisons,[80b 81] protection of ethenoid functions during epoxy ring-opening by hydrogenation,[82] or during high-pressure hydrogenolysis of fatty materials to fatty alcohols,[83] and the like. Reduction using hydrazine hydrate as a hydrogen donor has been examined for various model compounds at LIT, Nagpur,[84,85] and conjugated hydrogenation (in which the hydrogen donors are certain lower alcohols) has been explored at the DAC of Calcutta.[86] Two groups, the RRL Hyderabad and AMU Aligarh, have interested themselves in stereo studies of epoxy and epithio ring-opening and ring-closing,[72,73,87] in halogenation, hydro-halogenation, dehydro-halogenation and hypo-halogenation reaction mechanisms,[74,88] and in the introduction of hydroxy groups into such oils as castor, safflower and linseed by a variety of approaches.[89] In certain instances the interest was mainly in methodology, but in others the resulting products, such as the polyhydroxy derivatives of castor oil, have been examined for their potential as surfactant or surface-coating bases.[90] Polyglycol and polyglycerol ethers and esters have also been prepared.[91]

Theoretical insights into the mechanisms of fat formation and fatty acid assembly in glycerides,[92-94] and fat autoxidation[95] were forthcoming from work at the Indian Agricultural Research Institute, New Delhi. The hydrogenation studies at the RRL Hyderabad threw light on the reactions at the catalyst surface, which appeared to occur at two or three distinct sites.[96] Studies at the RRL Hyderabad[97] and at the UDCT Bombay[60,61] using model compounds have led to several deductions regarding the relationship of various structural features to surfactant manifestations. Among natural antioxidants, hydroxychavicol from the betel leaf was uncovered by the NCL Poona, and catechin from *katha* by the RRL Hyderabad.[98] The latter laboratory also demonstrated the antioxidant effect of squalene,[99a] the strong synergistic effect of oleic acid with phenolic antioxidants[99b] (confirming earlier reports from the IISc Bangalore) and the presence of considerable amounts in many oilseeds of carbon dioxide, which perhaps acted as a natural antioxidant.[100] CFTRI, Mysore reported that even amino acids like proline function as antioxidants for fish oil, as do various spice-bearing materials or their extracts.[101]

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Towards Better Quality Fish, Meat, Poultry and Processed Products Therefrom

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I joined the Indian Institute of Science (II Sc.), Bangalore in August 1947 to work as a Research Scholar under the inspiring guidance of Dr V. Subrahmanyan. In December 1948, along with 3-4 other colleagues from IISc. I came to Mysore with Dr V. Subrahmanyan to assist him in creating R & D facilities in Food Technology at the Cheluvamba Mansion which is now popularly known as CFTRI. Dr Subrahmanyan visualized vast potentialites for development of different areas of Food Technology of which development of fish, meat and poultry products industry in India was an important one. I consider myself fortunate to have been chosen for specialising in this field at CSIRO, Australia, in 1955–56. As a humble tribute in grateful remembrance of our founder Director I am reviewing some of the important aspects of work in this area.

Fish and Fish Products

With a coastal line of about 5,600 km India has an annual catch of fish of about 2.4 million tonnes. The potentialities of increased fish catch are unlimited and when properly handled will greatly help the fish processing industry to overcome the imbalance between the processing capacity and available raw material[1]. With the development of fisheries in Andaman and Nicobar Islands, the total catch is expected to increase by another 7,000 tonnes/year.[2]

Total exports of fish and fish products during the year made an impressive advance to Rs. 235 crores. India has also emerged as one of the leading shrimp processing and exporting countries in the world.

Fish is highly susceptible to bacterial spoilage and should be immediately iced after catch to enable its transport in good condition over long distances.[3–6] The bacterial flora of fish from tropical waters and those from relatively colder waters are different. Since bacterial flora determine the keeping quality of fish, detailed study on microbiology of tropical fish is receiving due attention[7, 8]. Shrimps contain greater amounts of free amino acids than fish and also highly active proteolytic enzymes—the cathepsins. They are therefore highly perishable and require adequate refrigeration and expeditious handling to prevent decomposition of the catch even in the early stages.[9]

Fish get contamination from wooden boxes, ice, dressing tables, etc. which usually carry heavy bacterial load if proper hygienic conditions are not adhered to[41]. Proper treatment of surfaces and equipment with disinfectants and detergents, use of potable water for washing and ice-making are necessary to reduce bacterial contamination of fish to ensure minimum bacterial load when they reach markets and processing factories. Post rigor changes in fish during ice storage indicate protein-protein interaction.[10–13] Improved types of bamboo baskets with laminated gunny bags for transportation of fish have been developed.[14] Insulated fibre board boxes, galvanized iron containers and tea-chests have been successfully used for the transportation of fish.[15–17] Standard formulae could be used to predict time of melting of ice and temperature of fish.[18]

Systematic work on field survey and laboratory investigations on icing and marketing of tropical fresh water fish show that the pattern of spoilage is altogether different from that of temperate water fish. The feasibility of prepackaging fillets in chilled or frozen condition has been worked out [19, 20]. A simple and cheap process for removal of fish odours from refrigerated wagons has been developed enabling the railway to reuse such wagons for transporting other perishable products.[21]

The freshness or spoilage could be judged from the time taken for the development of a distinct pink colour due to the reduction of 2,3,5-triphenyl tetrazolium chloride (TPTZ) to formazan. Also filter papers impregnated with 2-P-iodophenyl-3-P-nitro phenyl-5 phenyl-2H tetrazolium chloride could be used for routine quality test of fish.[22]

There is an increasing awareness for using inexpensive varieties of fish for the development of products such as fish sausages,[23] sandwich spread, breaded fish from separated meat or freezing it in blocks as a base material for various preparations.[24]

Freezing is at present confined mainly to shrimp, frog legs, cuttle fish and lobsters meant for export. The shrimp after freezing are placed in waxed cartons lined with polyethylene sheet and stored[25] at –18 to –23°C. Mackerels can be given a protective glazing to extend their shelf life during frozen storage.[26] Block of 2 kg frozen prawns can be satisfactorily thawed electrically[27].

At present canning is limited to oil-sardines,[28] tuna and mackerels in oil[29] and shrimp in brine. These delicious types of fish could also find popularity in foreign markets. Processes have been developed to decrease water to oil ratio in sardines canned in oil[30] and for canning shrimp in brine with better texture,[31] flavour and taste[32].

A technique based on thermal processing has been developed for preparing highly acceptable convenience type products from small varieties of fish without removal of bones and skin[33].

A substantial percentage of fish at present is being processed into salted and cured products because of lack of refrigeration facilities. The methods employed for curing fish are rather crude and primitive and the products are unattractive. Case-hardening, rancidity development, colour changes, mould growth, high silica content and attack by insects and mites are some of the common defects of these fish. A salt mixture has been developed to over come these defects[34]. Fish treated with this mixture and dried can be stored for 6-7 months in polyethylene lined gunny bags. Improved type Colombo cured mackerels[35] with a shelf life of about 20 weeks is obtained by using sodium chloride in the ratio of 1:5 along with *Garcinia cambogea* 4.5 per cent and sodium benzoate 0.5 per cent. Dried prawns with good shelf life have been prepared by drum drying.[36] These techniques would help in producing hygienic safe and acceptable products that can fetch better price in export markets.

A technique has been developed for freeze-drying and packing of shrimps for export markets. Freeze-dried shrimp, sealed under vacuum have a shelf-life of about six months and weigh only one fourth after freeze-drying[37].

Dehydro-irradiated shrimp and Bombay duck have shelf life of 6-12 months at ambient temperature[38, 39]. Ethylene oxide, heat treatment, γ-irradiation effectively sterilized frog legs from salmonella contamination[40, 41]. Several varieties of radurized fish (100-150K rad) transported over a long distance of 2000 km were acceptable for 20-25 days at 0-2°C[42]. Nutritional change was least when dehydro-irradiated fish are packed under vacuum or nitrogen prior to irradiation[43]. In irradiated shrimp *Bacillus* sp. predominated followed by *Micrococcus* sp. whereas in un-irradiated shrimp *Micrococcus* was dominant[44].

A process has been developed to produce good quality oil and fish meal from oil-sardines, which is a major catch on the West coast of India. A pilot plant unit which can process 300 kg per hour was set up at Mangalore for commercial scale trials[45]. The sardine oil has been used for canning of sardine-in-oil[46] and for many other industrial applications. The by-product, fish meal which is rich in protein is a valuable poultry feed. Sardine oil free from stearins and with high iodine value could be prepared by acetone solvent winterization[47].

Fish protein concentrates (FPC) of high nutritional quality have been developed from inexpensive fishes. They are light in colour, free from grittiness and flavour reversion and can be incorporated at 3-10 per cent level in a variety of dishes to supplement daily diets[48–55].

Other products prepared from inexpensive varieties of fish include blends of fish muscle and starches to make products like fish-wafers, fish-enriched macaroni, fish balls[56] and fish-biscuits. A delicious beverage is also prepared with fish hydrolysates in combination with sugar, cocoa, malt extract and vegetable fat[54]. There is an increasing awareness in developing new products for making more protein rich food available for overcoming malnutrition. Development of products, such as FPC with improved functional properties[57] from cheap surplus and abundant varieties of fish can contribute a great deal to the urgent need of combating protein malnutrition.

Prawn waste and squilla have been successfully utilised for producing chitin and chitosan[58]. These products find extensive use in pharmaceuticals, purification of water, flocculation of algal matter[59] and in printing of textiles using basic dyes. A process has been developed for the production of fish protein hydrolysate from surplus inexpensive varieties of fish to serve as a nutritional supplement[60, 61] or as a bacteriological media in the form of bactopeptones from prawn waste[62]. Protein has been separated from prawn waste and squilla with water followed by heating, filtering and drying[63].

Shark fin rays are considered a delicacy in Far Eastern countries for soup making. India has already established an export market for dried fins of shark in many overseas countries. There is, however, further scope for increasing the exports as well as to realize better price if instead of dried shark fins, rays separated from the fins are exported. This Institute has developed a simple process for obtaining a good quality shark fin rays.

Investigations on changes in flavouring constituents of fish during processing show that there is a good scope for flavour improvement by avoiding losses during ice-storage and canning[64]. Tryptic susceptibility of myofibrillar proteins is reported.[65] Presence of *Vibrio parahaemolyticus* is reported from fish and waters.[66] $C_{16:0}$ accounts for 50-55 per cent of the total saturated acids in fish. The level of arachidonic acid was fairly high in most of the fish lipids analyzed. The ratio $C_{18:1}/C_{18:2}$

is higher for marine fish than for the fresh water fish, and is fairly costant[67].

Meat and Meat Products

The present per capita consumption of meat in India is much below the level in many other countries[68]. The availability of meat could be increased by modern animal husbandry practices like propagation of suitable breeds of animals for different agro-climatic regions. The primary requirement for developing the meat trade and export is the modernization of slaughter houses to produce wholesome meat for consumption and for processing into convenience type products. Efforts made in this direction are briefly highlighted.

Bannur lambs have given higher dressed weights and better carcass yeild than other local breeds. The meat of Bannur lamb is also superior in terms of juiciness, tenderness and flavour[69,70]. Work was undertaken in collaboration with the Government of Karnataka for improving this breed. The results will be utilized at the Sheep Breeding Farm, Dhangur, to augment meat production[71]. Various cuts from carcasses with better shelf life can be packed under hygienic conditions in polyethylene-polyester film with or without inert gas[72].

Improved techniques of quick curing of ham and bacon in 2-3 days to ensure uniform colour in the product have been developed[73]. To extend the available meat supply, sausages containing 40-45 per cent mutton, binders and fillers such as vegetable proteins, and flavouring adjuncts and spices like onion, garlic, coriander and bay leaves have been developed[74,75]. Other types of comminuted products could be prepared in the form of meat loaves, hamburger, salami, etc. The products are ready-to-use after light frying or roasting and could be stored under refrigerated condition at 4-5°C for about 2 weeks and for longer periods under frozen storage. Recipes and processing conditions have been standardised for luncheon meat[76] and strained baby foods from mutton, chicken and eggs[77]. The conventional process for preparation of corned beef has been modified by using all the curing ingredients and avoiding loss of any extractives.

Incorporation of polyphosphates prevents loss of colour and juciness in AFD mutton[78]. Freeze-dried mutton with water activity a_w of 0.11 could be stored for a long period[79].

Canned curried meat products with different flavour profiles, gravy concentrates as a ready-to-eat products are some of the convenience type products processed. A modified method for estimation of drained weight for curried meat products has been worked out.[80]

A meat tenderizer based on proteolytic enzyme has been developed for tenderizing meat from aged animals and culled poultry. Processes have been developed for preparation of meat extracts, meat soup cubes and essence of chicken.

The non-utilization of by-products from salughter houses costs our country millions of rupees[81,82]. Efforts have been made to utilize blood by fractionating it into plasma and cellular proteins[83,84] which find many uses in the industry. Addition of calcium oxide is recommended for commercial scale production of blood meals[85].

Sausage casings form an important by-product of the meat industry[86,87]. A large quantity of these in the salted form are exported to Japan. A method has been worked out to remove slime[88] from the intestines and to preserve the intestines with sodium chloride and other chemicals by which the shell-life is extended for over one year in wet-salted condition. Of the various treatments tried, lactic acid with sorbate and benzoate has given promising result. Rennet from the stomach of pigs, cattle, sheep and goat can be easily extracted with 5 per cent sodium chloride containing 2.5 per cent boric acid[89].

Work on other by-products of the meat industry has been carried out at Central Drug Research Institute, Lucknow (insulin, pepsin,[90] pancreatin,[91] cholic acids, and bile salts and albumin[92,93]), Central Leather Research Institute, Madras (blood meal, sausage casings in dried form[82]); Vallabhai Patel Chest Institute, Delhi (hyaluronidase, heparin[82]).

Raw meats could be differentiated by use of rivanol-precipitated antisera or by the electrophoretic pattern of myoglobin[94]. Ageing of fresh mutton at 5°C for 72 hr and at 28°C for 6 hr resulted in tenderization[95]. Average lion eye area was less important in predicting meatiness. Goat meat contains more of arginine, leucine and isoleucine compared to sheep meat[96].

Modernization of slaughter houses in India for the production of meat under hygienic conditions is imperative[97–101]. The Training Abattoir with Danish assistance at this Institute is being used for R & D work and training of personnel associated with handling of meat. Efforts are being made to bring about improvements in the existing slaughter houses by introduction of simple indigenous equipment so thaj the animals are slaughtered under humane condition and the meat obtained is of wholesome quality free from health hazards. The keen interest shown by some of the big industrial houses in diversifying their activities for the production of meat products augurs well for this industry.

Poultry and Poultry Products

Of late, poultry production has become an important facet of agricultural development[102]. A number of hatcheries have come up on a commercial scale to meet the increased demand for broilers and eggs. Two large poultry dressing plants at Poona and Chandigarh are capable of processing thousands of broilers per day. Keeping these facts in view, R & D work has been oriented to meet the demands of indsutry.

Techniques based on dipping or spraying eggs with mineral oil containing preservatives or lime treatment or thermo-stabilization can appreciably increase their keeping quality[103-105]. Eggs stored under refrigerated condition when brought back to room temperature deteriorate faster than the control eggs. Bacteria are not involved in the thinning of albumin, the change in physical characteristic of eggs, during storage[106]. Salmonella sero-types were isolated from poultry and poultry house environments, while pathogenic staphylococci were associated with contamination of some samples of market eggs[107-109].

Egg albumin flakes made from egg white are used in off-set printing and leather industry. In the manufacturing process, the glucose in egg albumin is removed by fermentation with *Saccharomyces cerevisiae*[110]. A process has also been standardized to manufacture egg powder[111]. Based on the know-how M/s. Foods & Inns at Bombay have started manufacturing egg powder. Loss in solubility of egg powder can be prevented by storage at –15 to –18°C[112, 113].

Losses due to breakage amount to 10-30 per cent during transportation of eggs. To prevent this an egg container of 300 eggs capacity with improved cushioning has been designed[114].

Production of frozen egg yolk pulp by enzymatic treatment using pepsin has been standardised which helps in maintaining the functional properties of egg yolk during frozen storage[115].

A poultry dressing line with indigenous equipment has been assembled and the unit is capable of handling about 50-100 broilers per day[116]. Recipes have been developed for various ready-to-eat products such as canned chicken, solid packed chicken, chicken sausages and tandoori chicken to extend the utilization of chicken meat in various forms. Sandwich spreads and bread type frozen finger sticks and chicken essence[117] have been prepared from the meat of culled birds.

Smoke cured poultry can be stored for 6-7 days at ambient temperature[118]. Three methods of curing were tried; injection and dry curing, injection and pickle curing and pickle curing. Pickle cured poultry showed better shelf life because of uniform distribution of salt within the muscle. Smoke cured poultry with ethylene glycol-gelatin film could be kept at ambient temperature without much surface dehydration. The chicken meat gets tenderized to some extent when it is chilled for about 4 hr; extractability of proteins increased during this time and was higher in white muscle compared to red meat[119]. Benzpyrene content of smoke cured poultry can be brought within the permissible limits by controlled smoking.

Silk worm pupae after processing and solvent extraction can be used as a good source of protein feed for poultry. Animal protein supplements and hatchery waste can be recycled for poultry feeding. The role of nutrients in poultry rations has been reviewed in detail[120]. Feed efficiency ratio for different cross breeds of broilers has been worked out[118]. Coumesterol, a plant estrogen from lucerne meal had deleterious effect on egg production[121].

Replacement of vitamin D_3 with its metabolite, 25-hydroxy-D_3 in the diet of layers to improve the egg shell quality has been critically examined.[122] Tannins in feeds have deleterious effect on growth of birds[123]. The ovomucoid fraction decreased significantly in eggs stored at room temperature. Lysozyme content based on Haugh units and yolk index values, can be predicted for individual flocks. Use of sulphur dioxide prevents browning of the deeper layers in hard boiled eggs during canning[124]. Useful information has been collected on meat to bone ratio for sixteen genetic groups of broilers[125]. For obtaining smoothness in ice-creams, fresh egg yolk was found superior to lecithin from egg yolk[126].

Concluding it may be pointed out that our export of marine products is expanding year after year but this is based mainly on frozen prawns[127-128]. This field could be diversified by introducing a variety of novel type processed fish products from delicious varieties of fish. It is heartening to see that Marine Products Export Development Authority is making all attempts to find newer markets for our seafoods.

If the country has to make a break-through in the export of meat and meat products, concerted efforts have to be made to raise livestock of the required quality, free of diseases like foot and mouth disease in selected zones. Recent survey carried out by the Indian Institute of Foreign Trade shows that exports of meat is about Rs. 10.56 crores (1976–77) but it emphasises that there is still a large export potential for meat and meat products. All efforts are being made towards securing an adequate production and supply of meat, improving the conditions of slaughter houses and meat markets, so that marketing and utilization could be developed into an organized modern industry.

An emerging new trend in the poultry industry is the increasing popularity of raising suitable strains of chicks for eggs and meat. The cockerels that are usually destroyed in millions every year could be utilised for table purpose by raising them on cheaper feeds.

In dealing with perishable foods such as fish, meat and poultry, it is important that a high standard of personal hygiene, plant sanitation and quality control measures be maintained. The Army Standards Committee(ASC), Indian Standards Institution (IS), Export Inspection Agency (EIA) and Meat Products Order (MPO) have done well in formulating standards for the raw materials and important processed products.

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Storage and Pest Control Strategy for Preservation of Foodgrains in India

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The delicate equilibrium between food resources and population in India was recognised in the early thirties by Dr V. Subrahmanyan. He emphasised the need for preservation, processing and transport of foodgrains to minimise the losses caused by insects and other pests, and initiated investigations not only to deveolp methods for preventing food losses caused by insects, but to use damaged grains. Some of the early methods envisaged at the Indian Institute of Science were related to the use of paddy husk, heat treatment of grain, and sieve separation of the infested materials from sound grains.[1]

After taking up Directorship of the Central Food Technological Research Institute, in the early fifties he initiated investigations on fumigation, impregnation of gunny bags, and the use of pyrethrum and even trace amounts of mercury products for pest control. In 1953, animal feeding studies on fumigated and mercury-treated products were conducted to assess their safety to consumers. He assembled a small team of workers in the storage and preservation area to carry out work both on cold storage for fruit and vegetable preservation and on the protection of grains particularly for the Department of Food. Subsequently, the Storage & Preservation Division of CFTRI was split into two wings: (*i*) Fruit and Vegetable Preservation and (*ii*) Grain Storage. In due course the Grain Storage Unit developed into the Infestation Control & Pesticides Division in 1958. In the present review some of the progress made during the last thirty years in the area of foodgrain conservation is summarised.

It was during this period that Dr Subrahmanyan initiated investigations to determine the effect of insect infestation on the nutritive value of grains. A special scheme under the Indian Council of Medical Research was put into operation to evaluate the effects of insect infestations in cereals and pulses on the quality of the stored products. During these investigations estimation of the level of uric acid as a parameter of the degree of insect infestation was discovered.[2] Further, related fundamental and basic studies were initiated to examine the effects of insect infestation on the biological value, level of vitamins, protein efficiency ratio and growth of experimental rats. On the basis of these studies the permissible level of 10 mg of uric acid for one kg of grain was presecribed for acceptance by the Ministry of Health for foodgrains of edible quality meant for human consumption.

During the decade of the fifties most of the investigations were related to (*a*) the control of insect infestation in commercial stocks of merchants; (*b*) control of insect infestation in producers' stocks; (*c*) insect-proofing of gunny bags; (*d*) development of insecticides and their formulations for household pest control; (*e*) rodent control studies; (*f*) development of storage structures and ballooning techniques; and (*g*) pesticide residue analysis.[3,4] The progress since made will now be outlined.

Intensive studies have been carried out during the last three decades for developing methods, processes and techniques in preventing insect infestation, diseases and rodent attacks. The know-how for prevention of field losses has been developed by various institutions under the ICAR, Agricultural Universities and State Agricultural Departments. As a result of varying agro-economic and ecological conditions in the country, adaptive changes in pest control techniques are required for extensive application nationally. Intensive investigations have been conducted on the various aspects of preventing post-harvest losses. Some of the measures which could be applied under existing conditions in India are mentioned below.

Pre-harvest Prophylaxis

Infestations by the stored grain pests in the field are quite common, particularly *Sitophilus* on sorghum and maize, *Callosobruchus* on pulses and *Sitotroga* on paddy. These pests appear within the grain in the post-harvest period even before they are placed for storage. Pre-harvest prophylaxis on an extensive area will be able to disinfest the grain panicle or inflorescence, and exert a prophylactic or protective action during subsequent drying, harvesting and threshing.[5] The benefits derived from such pre-harvest treatments are reflected in sound grains that carry no internal infestation at the time of storage.

Insect-proofing

If the grain is already free from initial infestation, through pre-harvest prophylaxis, no fumigation process will be necessary prior to storage. The farmers could then adopt improved storage structures that have been developed by research institutes in India. Traditional packing materials like straw, jute, cotton and other fabric bags do not prevent insect entry inside the stored agricultural produce. Plastics and paper bags which were subsequently introduced also do not protect agricultural produce from insect and rodent damages. Hence, there was a need to develop insect-proof packages for storage and transportation of grains.

Processes have been developed for the insect-proofing of gunny bag and other storage structures which could be utilised by the farmers with considerable benefit. The producers' stock could be protected from insect infestation by this two-pronged attack of pre-harvest field disinfestation and subsequent use of insect-proofed containers and packages.[6] In grains where introduction of pre-harvest prophylaxis and insect-proofing of rural structures, containers and bags are not possible, spot fumigation could be done with fumigants like EDB, chloropicrin and ethyl formate. Fumigant formulations in ampoule, disc or tablet forms were developed for safe use of these substances in rural and household conditions.[7]

The field of food storage was mostly the province of the Entomologist in the early years in India. Dr V. Subrahmanyan pioneered the integration of research workers of different Disciplines such as storage technologists, food chemists, packaging experts and related specialised groups. To work on applied and field problems such as the large-scale storage and processing of coffee, or of other hygroscopic products in the coastal areas, he set up inter-disciplinary teams.[8,9] The special problem faced by the coffee industry in regard to storage was a result of the high relative humidity in the coastal areas. The curing works and the processing plants for coffee were mostly situated in the coastal towns, for ease of port. Because of climatic factors, cured coffee had to be transported to interior places for storage and transported back to the ports for export. The Coffee Board posed the problem of storage of coffee in coastal areas so that the green coffee bean would not lose colour, taste and texture. Intensive investigations were taken up by an interdisciplinary team of CFTRI and ultimately two processes were developed; one is widely known as the ballooning technique, and the other as the controlled monsooning process. Monsoon coffee suffers from heavy infestation by the coffee bean weevil, and a technique known as the Durofume process was applied. Other problems solved through intensive investigations by interdisciplinary teams have been described elsewhere.[10]

Ballooning Technique

As warehouses with temperature and humidity or others of the ideal climatizing type cannot be made easily available or even built because of high cost, a technique was developed for storage of commodities in bags even in ordinary godowns with humid and hot atmospheres. The ballooning process is a unique technique of making stacks moisture-proof and resistant against insect and rodent attacks. The balloon of flexible polyethylene structure is made over ordinary bags stacked *in situ* and results in a hermetic condition. The structure is rendered insect and rat-proof by spraying with high viscosity formulations. Cement, fertiliser, jaggery, sugar, coffee, tamarind, spices and many other hygroscopic products can be stored on a large-scale by this technique in any type of shed or godown and even under outdoor conditions.[11]

Non-toxic Grain Protectants

Dr V. Subrahmanyan offered enormous freedom to scientific workers to think and try ideas which are not mundane. Exploration was encouraged to exploit originality and creativity. A few non-toxic grain protectants have been developed at the CFTRI after considerable fundamental investigations.[12]

Activated earth, particularly kaolin, has been found to be highly insecticidal. A laboratory process was developed for its production from ordinary china clay or even from the low-grade clay deposits found in almost all parts of India. The active ingredient in the insecticidal clay is meta-hydrogen-halloysite. Electron microscopy, differential thermal analysis, X-ray diffraction, gas adsorption, oil bleaching property, bulk density and lipophilic activity were studied as means of quality control in the laboratory production of this activated earth.[13]

Feeding trials on rats with grains that had been treated with activated earths have yielded beneficial effects on the growth of rats. No acute or chronic toxicity could be observed.[14] These insecticidal clays can be mixed with raw grains or seeds to prevent insect attack. They are also found to prevent the growth of saprophytic organisms since the clays act as dehydrating agents.

Another product, also innocuous from the human and animal points of view but highly toxic to insects, is based on tricalcium phosphate.[15] This substance affects the growth of insects by acting as a metabolic poison.[16] Calcium phosphate is not required in high quantities for insect growth and metamorphosis. Histopathological studies indicated that fat, glycogen and tissue reserves are utilised at a very fast rate when calcium phosphate is present in the diet of insects. The exoskeleton of insect becomes very hard, friable and discoloured and sometimes shows nodular growth that has pathological symptoms. Autolysis of tissues, supernumerary moulting and loss of weight are conspicuous symptoms of the toxicity of tricalcium phosphate to insects. A trace of glucose and vitamins, particularly of the B-group, greatly potentiates the toxicity of tricalcium phosphate. A dosage of 0.2 per cent on grains and their products has been found to be sufficient to protect them from insect attack. Since the Indian diet, is generally deficient in calcium, enrichment of the human diet with this grain protectant formulation based on calcium phosphate, glucose and vitamins, offers great promise for application during milling of cereals and other foodgrains.

Yet another insecticidal product selective to insects and harmless to higher animals is a bacterial insecticide.[17] This organism is a strain of *Bacillus thuringiensis*, originally isolated from *Heliothis obsoleta* larva infected in a local field. A submerged culture method for sporulation and production of toxins was developed. In addition, a tray culture process was standardised for mass production of highly potent and viable spores of the organisms. Field trials through State entomologists have shown highly promising results for use on vegetable crops, oilseeds, pulses and even cereals. For controlling lepidopterous insects on paddy and other grains and grain products, the spore powder, even at concentrations as low as 1 to 10 ppm, has been found to be effective.[18]

The techniques and products mentioned above are suitable for application at rural and semi-urban levels. Integrated application of the following is required for infestation control in rural areas.

Rural Storage

(*a*) Pre-harvest prophylaxis by—
  (*i*) Spraying of malathion formulation on grains or pods
  (*ii*) Bacterial insecticides on paddy and vegetables
(*b*) Rodent control in the field
(*c*) Insect-proofing of gunny bags
(*d*) Insect-proofing of structures
(*e*) Rodent control techniques for dwellings
  (*i*) Repellent spray
  (*ii*) Baiting with attractants
  (*iii*) Fumigation of burrows with emulsion
(*f*) Spot fumigation with ethylene dibromide tablets.
(*g*) Mixing of activated kaolin with pulses and other legumes
(*h*) Nutritional grain protectant on rice, wheat, protective foods, processed cereal foods, breakfast foods, etc.

More than 70 per cent of total production is capable of protection by these techniques. Increase in foodgrain availability from existing production would be about 10-15 million tonnes if the above steps could be implemented on a national basis.

Applicability of the processes and products for disinfestation and protection of raw and processed products is catalogued in Table 1.

TABLE 1. APPLICABILITY OF PROTECTIVE CHEMICALS AND PROCESSES[18]

Problem areas	Process or product
(*a*) Warehouses	(*i*) Durofume process for disinfestation and prevention (*ii*) Ballooning technique for storage of moisture-sensitive commodities (*iii*) Rodent-proofing of storage structures
(*b*) Food processing factories	(*i*) Heat disinfestation for processed dry products (*ii*) Serial fumigation for inpackage disinfestation (*iii*) Nutritional grain protectants for inducing, immunity against insect attack (*iv*) Multiple fumigation process for mixed commodities in large warehouses. (*v*) Insect and rodent proofing of cartons and packages for dry foods and macaroni products
(*c*) Households	(*i*) Household spray emulsion and sprayer, repellent spray for house pest control (*ii*) Spot fumigant ampoule, tablets, paste and powder for rations in domestic stores (*iii*) Calcium phsophate-based grain protectants for long-term storage of foodgrains

As regards urban warehouses, the most economical and efficient processes are the Durofume Process, Ballooning Technique and Rodent-proofing of structures. These have been described elsewhere in detail.[19]

Manpower Development

Dr V. Subrahmanyan recognised that manpower development in the area of disinfestation research and application is the prime factor in any successful strategy of food conservation in the country. He emphasised true manpower development by identifying personnel with different basic backgrounds and giving them the opportunity to work with inquisitiveness, curiosity and an experimental attitude in solving problems by out-of-the-way approaches. Such a non-traditional approach to problems led to many original findings by the group of workers under his directorship.

Perhaps a major contribution of CFTRI has been in the supply of high-level manpower to the Department of Food, the Food Corporation of India, Indian Grain Storage Institute and Indian Toxicological Research Centre in the area of post-harvest food storage and pesticide safety.

The team at CFTRI expanded rapidly and has made remarkable contributions in many of the specialised areas of food conservation. The Publications range from the entomological aspects of foodgrain storage to the technological aspects of storage structures and pesticide toxicology.[20] Some of the unique contributions of the CFTRI can be catalogued as follows:

1. Tricalcium phosphate with B group vitamins as food protectant
2. Activated clay (*meta* hydrogen halloysite) as a non-toxic seed-dressing material
3. Quinine hydroclhoride as an optical attractant for rats
4. Methyl bromide and ethylene dibromide compositions as tropical fumigants, and Durofume Process for large-scale disinfestation and storage
5. Ethylene dibromide, ethyl formate and liquid fumigant formulations, known as 'minifume' for small-scale and household fumigation
6. A new process for bulk production of a single isomer of hexachlorocyclohexane from technical BHC
7. D-xylose as a sporogenic sugar for *Bacillus thuringiensis*, the biological pesticide
8. A flexible insect-proof, rodent proof and moisture-proof storage structure known as the Ballooning technique.

In addition to the development of research personnel, Dr Subrahmanyan's contribution has been quite significant in the extension and utilisation of research by giving a start to the pest control industry. With his support and guidance, many training programmes were conducted to induct specialisation and professional skill in pest control services in government warehouses, commercial godowns, food industries, etc. During the last thirty years, a highly progressive specialised industry catering to the requirements of pest control services has emerged in India, which is more advanced in this area than in any other developing country in the world.

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Food Packaging Research and Development in India

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The object of packaging of food is to protect the contents during storage, transportation and distribution against deterioration, which may be physical, chemical, or biological. Packaging of food is hence provided at the point of production, processing or at distribution centres. Though packaging forms the last link in the chain of production, storage, marketing and distribution, it still plays an important role in delivering the contents "safe" to the ultimate user. Besides, attractive functional package performs the job of a good salesman giving an image to the product.

Increase in production can make an impact on the consumer only when the food is wholesome, unadulterated and is available under hygienic conditions at an economic price. It is reported that in India about 20-25 per cent of total foodgrains and a considerable quantity of sea and processed foods either get spoiled or become sub-standard during storage and distribution[1-3]. This colossal wastage, which sometimes results in conditions of scarcity attended by higher prices for food commodities, is attributed mainly to unscientific packaging, improper handling methods and inadequate transportation facilities.

India is a country of long distances, with varying climatic conditions ranging from sub-zero to 45°C and humidity from very low to near 100 per cent. These factors i.e., varied climatic conditions impose problems in packaging of the produce. Such a situation is aggravated by diversified food habits, low purchasing power, non-availability of packaging materials of specific functional properties ate conomic price, nonavailability of suitable packaging machinery, and paucity of trained technologists in food packaging.

Food Packaging at CFTRI

Realising the importance of adequate and functional packaging of foodstuffs during distribution and marketing, a discipline devoted to research and development in food packaging was envisaged in the early stages of planning of CFTRI, by Dr V. Subrahmanyan, the then Director of the Institute. With his great zeal, foresight and persistent efforts he was able to convince the authorities concerned, the importance of 'Scientific Food Packaging' and its impact on national economy. Consequently, a survey on food packaging in the country was carried out with the assistance of FAO and subsequently two scientific officers from CFTRI were deputed for training in food packaging in different developed countries. A fulfledged discipline of "Food Packaging Technology" was started at CFTRI in 1956 which acted as a nucleus for R & D activities in food packaging in the country. Since then considerable progress has been made in the packaging technology in India. During the last few decades many new packaging materials like synthetic polymers and a variety of combinations have become available to the users and also new uses have been developed for already existing conventional packaging materials based on wood, metal, glass, paper, etc.

The per capita consumption of packaging materials which is often considered as an index of the development of the industry is very low in India. It is also estimated that the per capita consumer spending on packaging in India is less than 1 per cent, compared to 3-4 per cent in Western countries. The total value of the output of the important packaging materials in 1973–74 in India was only Rs 57 crores as against Rs 1675, 1235 and 8084 crores in Japan, U.K. and USA respectively; the corresponding per capita expenditure on packaging materials[4] was Rupees 6, 217, 280 and 460.

In this article progress in regard to significant R & D activities of CFTRI in food packaging technology and R & D and training facilities at various centres on different aspects of food packaging are briefly reviewed.

Packaging of Food and Food Products

Knowledge of sorption characteristics of food products and the permeation behaviour of the packaging material are essential in designing and development of functional packages. Studies in progress at the CFTRI on these aspects are:

Sorption characteristics: On the basis of moisture sorption behaviour, foodstuffs may be broadly classified into: (*a*) starchy foods having sigmoid sorption isotherms indicating that these foods have high water holding capacity even at low RHs; (*b*) high fatty foods whose moisture content does not increase appreciably upto 70-80 per cent RH; (*c*) proteinaceous foods whose ERH curves flatten towards the humidity axis, (*d*) high sugar/salt foods whose moisture pickup is very rapid after a particular RH; and (*e*) hygroscopic foods which equilibrate to RH of about 10-15 per cent and become soft and soggy above 35 per cent RH. Investigations on these lines[5-7] have been extremely helpful in selecting packaging materials with appropriate water vapour transmission rate and other attributes to package specific foodstuffs.

(*b*) *Permeability of packages:* The moisture loss or gain through the package during storage and distribution alters the attributes of the contents and affects their "shelf life". Investigations on permeation of moisture of model packaging systems have enabled to predict the shelf life of the contents. These studies on moisture sorption characteristics of the product and the water vapour permeation characteristics of different designs of the package under given environmental conditions[8] have enabled designing and developing unit and bulk packages for various food items without recourse to actual storage studies.

(*c*) *Design, development and evaluation of unit containers:* Foodstuffs during storage and distribution undergo certain undesirable physico-chemical changes such as loss of crispness, free flowing property, hardening, crumbling, crushing and development of rancidity, free acids, discolouration, loss of aroma and gain of extraneous flavour and microbiological deterioration, etc The extent of these changes depend not only on the physico-chemical nature of the foodstuffs but also on environmental factors

Package profile has been worked out for a variety of food products taking into consideration their packaging characteristics, different kinds of rigid or flexible packages based on glass, metal, glassine, kraft and waxed papers, varieties of flexible films like cellophane, aluminium foil laminates, metallised films and plastics and their combinations. The products for which, packaging profiles have been worked out are: dehydrated rice and thur dhal,[9] spray dried whole egg powder,[10] ready and instant mixes, ground and whole spices[11, 12] pulses,[13] cereals and cereal flours,[14] walnuts,[15] cashew nuts,[16] dehydrated milk foods and other dairy products, instant beverages, biscuits and other bakery products[17, 18] baking powder, processed products like papads,[19] vermicelli,[20] dehydrated fruits and vegetables, deep fat fried foods,[21, 22] Indian sweets, alcoholic liquors, etc. Assistance is also being rendered to the food industries by evaluating and suggesting improvement to their packages for various types of food products under different storage conditions. These studies have helped the food industry in the development and evaluation of functional and economical unit and bulk packages for both internal and export markets

Package for Fresh and Perishable Foods

R & D activities in these areas cover: (1) the evaluation of trade packages and packaging methods for fresh produce for their functional efficiency; (2) suggestions to overcome deficiencies; and (3) development of new package designs to suit the prevailing handling, transportation and distribution practices both for the internal and export trade.

In India cheap and abundantly available natural packaging materials are generally employed in fabrication of packages. Bamboo and *arhar* containers of varying sizes, shapes and stacking strengths with paddy straw or green leaves as cushioning materials[23] are used extensively. However, these packages suffer from lack of dimensional stability, poor compression strength and other defects associated with improper weaving, and faulty design. The desired attributes in bucket shaped bamboo baskets could be obtained without increasing labour or material by changing the thickness and width of the vertical structural members to an optimum size. Damage to mangoes due to drop impact could be minimised considerably by additional paddy straw cushioning as a central core in such bucket shaped bamboo baskets[24].

A new type of basket with a rectangular top and bottom for packaging mangoes and a two-compartment basket with a horizontal partitional tray for packaging of grapes has been designed. Using corrugated fibre board (CFB) boxes with suitable liners, controlled atmosphere transport containers have been developed for fresh fruits[25].

Commercial wooden packing cases used for fruits suffer physical damage due to inadequate strength, improper cushioning and faulty design to withstand the present method of rough handling and transportation. For trade use, standard designs have been worked out for containers made of wood, plywood and CFB with adequate aeration and strength. Long and short distance transportation trials, both by rail and road, have shown the usefulness of these newly designed packages for transport of grapes,[26] oranges,[27] mangoes,[28] apples,[29] pineapples,[30] etc.

The currently used telescopic corrugated fibreboard boxes for exporting bananas need stitching of flaps in orchards and are unsuitable for carrying as headloads. An improved five panel single piece collapsible corrugated fibreboard box which economises about 30 per cent of the packaging material and eliminates stapling operation at the packaging centre has been developed[31]. At the request of some organisations, CFB boxes have been designed and developed for export of oranges[32] and successfully used to send the fruit to Singapore and other places. For export of dry chillies, a compressed bulk pack similar to a bale has been designed[33].

Pre-packaging of Fresh Produce

Fruits and vegetables lose their freshness in a short period under prevailing retail marketing conditions in the country due to high rate of physiological activities like transpiration and respiration. Studies have shown that the shelf-life of these could be doubled under normal conditions of storage by prepackaging them in appropriate plastic bags with adequate ventilation. Prepackaging reduces not only the physiological changes but also mechanical damage to the produce during sale and ensures hygienic distribution. Similar findings have been noticed under cold storage conditions. Prepackaging conditions have been standardised for a number of fresh fruits and vegetables like capsicum,[34] snap beans,[35] okra,[36] brinjal,[37] orange,[38] grapes,[39] mint leaves,[40] and mushrooms[41].

Packaging of Fish

Fish being a highly perishable commodity has to reach the consumer as quickly as possible. In India consuming centres are situated inland as far as 1000 KM from the fishing centres. In South India, split bamboo baskets, while in North India, arhar baskets or deal-wood or plywood boxes with little or no insulation material, are employed for rail and road transportation of iced fish. The functional performance of these containers is very poor. In some cases for long distance transport, two piece metal insulated containers are used, which are heavy and do not withstand rough handling. A six panel metal box (which could be dismantled) insulated with polystyrene panels has been tried successfully for long and short distance transportation of fish in uninsultated rail vans and in trucks[42]. The suitability and economics of plywood box, plywood box with polyethylene lining, plywood box lined inside with polystyrene in polyethylene bag and moisture proof corrugated fibreboard box with wood-wool insulation in between the two walls have been studied for transportation of fresh and frozen fish to distant consuming markets[43, 44]. Similar studies on containers and transport systems for reducing spoilage of fish are in progress[45,46].

Design of Drip-proof Insulated Bamboo Multi-trip Containers for Transport of Fresh Fish

An insulated bamboo basket[47] consisting of two circular baskets, one placed inside the other with a common lid has been designed. The inner basket is 3-4 cm smaller in diameter, and 8 to 10 cm less in height than the outer, and is provided with a loose inner lining of polyethylene film having a few holes at the bottom. Alround the space between the two baskets is fitted a flexible insulated pad, made of coconut fibre in a water-proof jute laminate and at the bottom is a water absorbable material like saw dust or coconut pith. The container is reusable 6-8 times.

Packaging of Processed Foods in Tinplate Containers

At present, the country's entire requirement of tinplate for canning fruit and vegetable products is imported and it was about 10,000 tonnes during 1977 valued at Rs 10 crores. This would be much more if the tin plate used for canning of other products like meat, fish and dairy products is included[48]. Upto 1967, hot dipped tinplates coated with 1.25 (28 gsm) and 1.5 lb of tin (33 gsm)/base box were imported.

In 1966, indigenously manufactured Rourkela hot dipped tinplates having phosphorus content of 0.02, 0.025 and 0.03 per cent were assessed at CFTRI for their suitability for canning different fruit and vegetable products and it was found that the first two types of tinplates compare well in their performance with imported tinplate whereas the third type is suited for canning of vegetables[49].

The canning industry in the country switched over to electrolytic tinplate with 1 lb tincoating/base box by 1967, in consonance with the trend all over the world due to shortage of tin and also to effect price reduction. Investigations on indigenously manufactured Rourkela electrolytic tinplate have shown that tinplate with 1 lb/base box (22.4 gsm) having grain size structure equivalent to or larger than ASTM No. 9 and with 0.02 per cent phosphorus content compares well with imported E 100 electrolytic tinplate in its functional attributes[50]. Investigations have further revealed the possibility of E/100 replacing electrolytic tinplate with differentially coated tinplate—D 100/50 with lacquer or lithograph outside[51].

Evaluation of metal containers with different thicknesses of tin coating with and without lacquer for packaging of different products like vanaspati, edible oil, fruit products, etc., are in progress at CFTRI and other research organisations.

Research is also in progress in many different laboratories to develop and test varieties of food lacquers (R.R.L., Hyderabad, M/s. Shalimar Paints, M/s.

Asian Paints), indigenous can sealing compounds (N.C.L., Poona), development of tin free steelplate (TFS) (N.M.L., Jamshedpur, Tinplate Co., of India), plastic coated steel plates, aluminium coated steel plates etc., with a view to reducing the cost of the metal containers and also to minimise imports.

Packaging Materials and Packages Testing

Testing of materials and packages forms an important activity in packaging research. Evaluation of packages or packaging materials as a quality control measure for a specific requirement and to compare the relative merits amongst packaging materials and packages to meet specific purposes is an immediate need of the industry. Many of the institutions engaged in package evaluation have well equipped infrastructure by way of most modern equipments like scanning electron microscope, N.M.R., I.R. spectrophotometer, cycling chamber, temperature-RH control rooms and chambers, journey hazard stimulating equipment, chemical and biochemical laboratory facilities, etc. The testing services in government research laboratories are made available to the industries particularly the small scale sector. Data on the physico-chemical properties of various packaging materials have been collected and published for the benefit of the industry[50-53].

Lately, varieties of plastics, because of their versatile physico-chemical characteristics, formability etc., are appearing in the food packaging scene in different forms and shapes with attractive printing. Many of the plastics manufactured in the country are with imported know-how and the evidence of non-toxicity of these materials is based on the test carried out in foreign countries. However, these synthetic polymeric packaging materials need to be evaluated for their safety in food packaging applications for Indian foods and environmental conditions keeping in view the rather low nutritional standards of Indian people. Intensive research programmes are being carried out in this direction and already quite a few polymeric materials manufactured in the country have been evaluated for their packaging applications,[56,57] for products like milk and fruit juices.

The insect resistance properties of a variety of flexible packaging materials such as hessian combinations, plastics and aluminium foil laminates have been studied to design insect resistant unit and bulk packages for the storage and distribution of food and food products[58-60].

Transportation Studies

To assess the suitability of the present packaging methods for transportation of fresh fruits and vegetables viz. grapes,[26] oranges,[27] mangoes,[28] apples[29] pineapples[30] and fresh water and marine fish, rail and road shipment trials have been conducted. The trials were conducted in all metal and wooden wagons, structurally modified air conditioned coaches in railways, and open and closed lorries on road. The advantages of using improved design containers, adoption of wooden and cool wagons for transportation have been amply demonstrated. Adverse effects of temperature and humidity build up and carbon dioxide concentration inside the wagon on the quality of the produce have been pointed out in a number of publications. Further, improvement needed in handling and stacking methods have been suggested.

Utilisation of Agricultural Raw and Waste Materials

Agricultural and forest waste materials like dried banana leaves, areca sheath, coconut husk and pith, jute, hemp and banana fibre thread[61] and butea and bauhinia leaves, have been converted into packaging materials and packages for foods. A thermal insulation board from coconut fibre and pith,[62] fibre straps from natural fibre threads,[63] package forms like cups, shallow trays from varieties of leaves and arecanut sheath and machines to manufacture them have been developed[64].

Packaging Machinery and Testing Equipment

Considerable progress has been made in the last two decades in the manufacture of packaging machinery and testing equipment in the country. A few types of packaging machinery like pouch form-fill-seal, can manufacturing, vacuum packing, laminating, corrugated board making, corton making, heat sealing equipment etc., are available in the market. Among testing equipment burst and puncture testers, glass bottle testing equipment, vibration testers[65] etc., have been fabricated at the CFTRI and other organisations in India.

Teaching and Training Facilities

The Packaging Technology Disicipline at CFTRI provides training facilities to packaging technologists from India and other developing countries of Asia and Africa. Training in food packaging is given to the students of the Post-graduate course in food technology conducted jointly by CFTRI and the FAO. To disseminate the knowledge of food packaging, short-term courses at national and international levels are conducted for the candidates from various governmental research organisations and industries.

Packaging Research at Other Centres

CFTRI is one of the earliest institutions to promote active research and develop various aspects of food packaging technology. Other institutions in the country have also realised the importance of functional packaging of foodstuffs. Some of the studies carried out by these institutions may be briefly mentioned. At the Bhabha Atomic Research Centre, Bombay, the behaviour on packaging of irradiated food products such as fish, some of the fruits and vegetables and investigations on chemical migration & toxicity of packaging materials are being studied. The Defence Food Research Laboratory at Mysore has been mainly interested in food packaging research with reference to the special needs of defence forces. Generally, civilian food items do not find a place among the processed rations for the services because of the stringent requirements. Multipurpose ration items of the convenience type or preserved items which could be used with little preparation, must have a shelf life of at least six months. Conditions have been standardised[66] for canning typical Indian dishes like *pulao*, *chapati*, *kheer*, *idli*, *avial*, etc. Flexible packages have been developed for *chapatis* to give a shelf life of more than 6 months and for a few convenience foods like precooked dehydrated cereals and pulses, vegetables, egg powder and Indian sweets. Research is also in progress on heat sterilisation of ready-to-eat food in flexible packages, development of fungistatic wrappers for bread, design and development of unit and transport containers for different modes of transport and other allied fields[66]. The Directorate of Materials and Supplies, Kanpur has developed bulk packages for various military stores. Research investigations on various aspects of food packaging are also being carried out at NDRI, Karnal, IIT Kharagpur, Universities of Jadavpur, Bombay, Coimbatore and the Agricultural Universities of Pantnagar, Ludhiana and Bangalore.

The National Productivity Council had recommended to the Government of India the need to establish an Institute of packaging in order to boost the export trade of the country. On the basis of a plan submitted by the CFTRI, the Government of India established the Indian Institute of Packaging at Bombay in 1966 in co-operation with the packaging industry. Also, the services of the CFTRI were made available to develop the Institute.

The Indian Institute of Packaging, Bombay is one of the major institutions in the country mainly devoted to assist the industry for improving and developing packages for export and internal trade. To achieve this objective the Institute disseminates the knowledge of packaging by offering requisite training to personnel from the industry and other concerned organisations. It has carried out a survey on trade packaging methods for a number of items like ready-made dresses, spices, and so on in the foreign countries, and has developed bulk package for export of tea, fresh flowers, etc. It has established two regional centres at Calcutta and Madras to cater to the needs of the industry regarding their packaging problems, testing of packaging materials etc.

Trends in Food Packaging

The conventional containers made of wood, metal and glass are becoming scarce and expensive. Besides, each of these packaging materials suffers from disadvantages like being fragile or susceptible to microbial and other environmental degradation. Consequently, there appears to be a fast changeover to light weight flexible packaging for food products and other items. Functional flexible packaging materials, which can stand a wide range of temperatures, offer better barrier to gases and organic vapours, possess good insect resistant and other physical and chemical attributes, are continuously appearing on the food packaging scene. The other important consideration in the production of packaging materials is economising the energy which is becoming increasingly expensive. The energy required to produce flexible packages for a unit volume of foodstuff is less than for conventional ones. Further, heat sterilization, heat processing, vacuum packaging are all possible in this system and also economy of space and freight are reflected in the unit and bulk transport containers. While looking forward to new types of packaging materials, the problems of toxicity, environmental pollution, compatibility with food, performance on machines and overall economics should not be lost sight of.

Thus with a modest beginning the science of packaging technology has made significant progress over the last two decades, and is now considered as one of the most important branches of applied science in the country. Through the promotional efforts and research activities of various research and industrial establishments in India, the country's exports have shown phenomenal increase over the years and contributed considerably to the economy. Given the necessary impetus, this important branch of applied technology will be able to serve the needs of the country's economy even more effectively in the years ahead. In this effort, research in various institutions need to gear up their efforts to strengthen the foundation laid by Dr V. Subrahmanyan, the founder-Director of CFTRI.

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Meeting the Needs of Baby and Weaning Foods In India

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Breast Feeding and Nutrition

Human milk is universally regarded as ideal for the feeding of infants during the early months. Although majority of Indian babies are breast-fed during the first 6-8 months of life[1], not every baby is fortunate in having a healthy mother who could provide adequate nutrition. Thus arises the need for baby and weaning foods.

A baby has specific nutritional needs for protein, fat, carbohydrate, minerals and vitamins. Feeding with mother's milk shows certain unique metabolic features in babies, like (*a*) quick stomach-emptying time, (*b*) enhanced lysozyme activity in the stool, (*c*) remarkable increase in the number of *Lactobacillus bifidus* in the intestinal microflora, (*d*) less burdening of the kidney to low levels of minerals, and (*e*) easy digestion and absorption efficiency. The general nutritional requirements and the specific properties of mother's milk such as high levels of mucopolysaccharides, lysozyme, unsaturated fatty acids, and low levels of protein, fat and minerals are relevant in humanizing cow and buffalo milk. Nutritionally inadequate empirical formulations cannot meet the needs of babies and can cause mortality[2].

Artificial Infant Feeding

Where breast-feeding is not possible for one reason or the other products based on liquid or dried animal milk, were a logical development and formulations were experimented upon in Switzerland, Belgium, U.K., and U.S.A. After the First World War, the use of milk powder for infant feeding became widely accepted, and products of increasing sophistication were developed in the industrial countries.

Indian Efforts

India was annually importing in the sixties about 3,000 tons of infant foods, based mainly on milk,[3,4] apart from other milk foods containing malt extract, cocoa and so on. The imports were from Western countries where the dry milk used for infant feeding was derived from cow's milk, suitably modified and humanised. Attention was given to the manufacture of baby food in India, where more than half of the milk production comes from the buffalo. Buffalo' milk varies from that of the cow both in composition and in properties, showing a higher curd tension for example. Further, its major protein, casein, differs significantly from that in cows' milk. Scientists of the CFTRI under the leadership of Dr V. Subrahmanyan, standardised, (after researches extending from 1954 to 1959) a process for the manufacture of milk food for babies from buffalo milk for the first time. The baby food was fortified with adequate amounts of iron, calcium and phosphorus. The baby food was prepared in such a way that it would form a soft digestible curd in the infant stomach. The spray-dried infant food packed under nitrogen had a shelf life of 8 months at 37°C and about 16 months at 27°C. Contamination of fluid milk with copper, which occurred when the milk was drawn or kept in brass vessels, affected shelf life adversely. Roller-dried infant food packed in tins in air had a shelf life of about a year.

Process Standardisation

Whole milk powder prepared from cows' milk contains about 26 per cent protein and 26 per cent fat. Proprietary infant foods available on the market have a widely varying protein (14-27 per cent) and fat (15-27 per cent) content[5]. According to Nichols[6], the protein and fat requirements of children under tropical conditions are somewhat lower than the standards suggested for temperate climates, and it was felt that an infant food with a protein content of 20-22 per cent and fat content of 14-15 per cent may be more suited for infants in the tropics. The fat content was purposely reduced to about 14 per cent so as to facilitate easy digestion of the food by infants. The food on reconstitution with 7 times its weight of water would yield a milk having 2.5 per cent protein and about 1.8 per cent fat.

The method of preparation of the infant food has been described by Chandrasekhara *et al*[7]. Buffalo milk after sampling was skimmed to 2.5 per cent fat and pasteurized at 88.°C. Cane sugar (3-4 per centon fresh basis) was added in the form of a syrup which had been boiled for 10 min to destroy any micro-organisms present. A small quantity of phosphate buffer (pH 6.5) was added and the milk was concentrated under vacuum to about 40 per cent solids. Calculated quantity of certain vitamins was added to the condensed milk, which was dried in a spray drier. The dried product was allowed to cool and packed in cans, either under air or nitrogen. The average chemical composition of the infant food is given in Table 1.

TABLE 1. COMPOSITION OF INFANT FOOD PREPARED FROM BUFFALO MILK

Constituents	%	Vitamins added per 100 g powder	
Moisture	2.8	Vitamin A (i.u.)	1,500
Protein	21.5	Vitamin D (i.u.)	400
Fat	14.5	Vitamin B_1 (mg)	1.0
Ash	4.8	Riboflavin (mg)	0.5
Carbohydrate (by diff)	54.5	Niacinamide (mg)	5.0
Calcium	0.98	Pyridoxine (mg)	0.6
Phosphorus	0.96	Vitamin B_{12} (μg)	2.0
		Vitamin C (mg)	30.0

Pilot-scale Manufacture

(*a*) *Spray-dried infant food:* The pilot scale production of spray-dried infant food having a composition similar to that given in Table 1 was undertaken at the Kaira District Cooperative Milk Producers' Union Ltd., Anand, where a commercial model 'Niro' spray drier was available. Two trials were made using 7,940 lb and 17,500 lb of milk. The solubility of the product was found to be 99.5 per cent. The standard plate count of the powder was 20,000/g. This is much lower than the American Standard of 48,000/g for premium grade whole milk powder[8].

(*b*) *Roller-dried infant food:* It is now generally recognized that roller drying has the following advantages over spray drying; (*i*) suitability to regions of moderate milk production (10,000-20,000 lb/day); (*ii*) better keeping quality of the powder; and (*iii*) relatively low initial cost of the equipment. Considering this, a production trial of about 600 lb of infant food was carried out at the factory of M/s. Healthway Ltd., Banaras, where a commercial-model roller drier is available. The product, packed in cans in air, was found to possess a shelf life of about 12 months when stored at 37°C. The food was readily dispersible in hot water, the solubility of the product being about 92 per cent at 60°C.

Commercialisation

Amul baby food: In 1958 the Kaira District Co-operative Milk Producers' Union Ltd., Anand in Gujarat adapted the CFTRI process for the commercial production and was the first to market an Indian baby food. The production of infant milk food in this country is now of the order of about 20,000 tonnes per year. Besides the Kaira Co-operative who make the popular brands "Amul Baby Food" and "Amul Spray", other brands are "Parag" infant milk food of the Pradeshik Co-operative Dairy Federation Ltd., Lucknow U.P., "Glaxo" baby food and "Ostermilk" of the Glaxo Laboratories (I) Ltd., Aligarh[5], U.P.; "Lever Baby Food" made by the Hindustan Lever Ltd., Etah, U.P.; "Nespray" of Food Specialities Ltd., Moga, Punjab.; "Vijayspray" from the Andhra Pradesh Dairy Development Corporation Ltd., Vijayawada. Demand is continuously growing in a highly-populated country like India.

Vijayspray

The Andhra Pradesh Dairy Development Corporation have entered into technical collaboration with CFTRI for producing and marketing infant food[9]. In addition to usual constituents Vijayspray has the added advantage of containing vitamin B_{12} and folic acid. This factory has a capacity to handle two lakh litres of milk per day and to produce 2,400 tonnes of infant food annually.

Glaxo and Ostermilk

In the private sector, Glaxo Laboratories India Private Ltd., manufacture Glaxo and Ostermilk, both infant milk foods. These are products on which much scientific and technological work, along with nutritional evaluation, has been undertaken by the parent company in the U.K.[10]. They use the roller process of drying for infant foods for two main reasons:

(*a*) with the roller process, the milk is evaporated at a higher temperature than in the spray process, resulting in complete destruction of bacteria; and

(*b*) the roller process gives a soft curd, which is more easily digested by the infant.

Hindustan Lever Ltd. and some other private factories are also manufacturing baby foods on lines similar to the above.

Weaning Foods

Weaning foods are generally fed to older babies, those above 12 weeks of age. In countries like the U.K. and U.S.A., weaning foods are prepared by processing flours from wheat, oats or rye, with added iron salts, bone meal, wheat germ, dried yeast, vitamins and so on. When prepared by multinationals in India, adaptations were required. In this field also, the CFTRI has taken the lead in developing appropriate formulations, especially using oil seed proteins.

(*a*) *Farex:* Farex was developed in the U.K. as a weaning food for infants by processing suitable cereal flours, the protein content being adjusted to about 15 per cent[10]. When a beginning was mooted in Bombay to manufacture Farex in 1958, careful consideration had to be given to several factors, such as the selection of cereals, and their cleaning, milling and storage. Rye and oats could not be considered because they were not available in sufficient quantity throughout the year. Oats, with its comparatively high fat content, might present stability problems under tropical conditions. Other considerations were that the cereals must have a proper standing in infant nutrition and not too high a fibre content. In the local formulation, oats and rye were replaced by rice and barley. Though rice does not present any serious problems barley had to be carefully selected to be free from fungal contamination The replacement of a part of the wheat by maize is a possibility in times of wheat shortage.

In connection with the milling operation, it is nutritionally beneficial to retain the cereal germs in the flours. The presence of the germ decreases the life of the raw flour, but the drying cum heating stabilised the germ by destruction of lipoxidase and other enzymes and Farex made with flour containing germ is quite stable.

The bacteriological quality of the product is high, with a small bacterial count. The protein content is about 12 per cent. The fat content is less than 3 per cent and fibre less than 1 per cent. It also contains added calcium, iron and vitamin D.

(*b*) *Bal-Amul:* This is the weaning food based on cereals and milk marketed by the Amul organisation developed in collaboration with the CFTRI Mysore[11]. The development efforts behind this will now be described.

Infant Foods Based on Vegetable Protein Blends

Scientists at CFTRI have done considerable work since the early fifties in the manufacture of infant foods formulated with groundnut protein isolate, soya flour, and so on, either as such or along with milk. Although the vegetable proteins *per se* had lower nutritive value than casein[12-14]. In view of the short supply of milk at that time Chandrasekhara and co-workers[4] tried to minimise milk constituents, and showed the possibilities of producing highly nutritious and acceptable infant foods in which two-thirds of the protein was from vegetable sources and only-one-third from milk. The standardised technique adopted was to hydrolyse wheat and groundnut flour using barley malt, extract the proteins at optimum pH, homogenise, add skim milk powder, hydrogenated groundnut oil, sugar and salts, and spray dry[15]. Kurien and co-workers[16] studied the efficiency of an infant food formulation based on groundnut protein isolate in meeting the protein requirements of protein-depleted rats relative to a milk-based food. No significant differences were observed in the moisture, fat and protein content of the livers and carcasses of depleted rats repleted on either food, but the mean weight gain per gram of protein intake, as also the mean protein retention, were significantly lower for the vegetable protein group than for rats repleted on milk food. However, CFTRI reported [17-19]. in 1964 that a spray-dried infant food formulation based on groundnut isolate and soya flour possessed an overall nutritive value as good as that of a milk food of similar composition, and had a highly significant supplementary value to a low-protein diet based on maize and tapioca.

As a result of such studies, vegetable proteins, and their blends with skim milk powder, are being increasingly used in recent times as substitutes for milk and other animal foods in the treatment and prevention of protein malnutrition in children in many developing regions[20-23]. A blend of groundnut protein isolate and skim milk powder has been particularly helpful in India in initiating cure of protein malnutrition in children[24].

Chandrasekhara and co-workers[25] later developed a process in 1966 for the preparation of spray-dried infant food based on soya *dhal*, a small amount of skim milk powder and barley malt. The PER of the product was 2.7 compared to 3.0 for skim milk, and addition of DL-methionine to the product at a level of 1.1 g/16 g N could raise the PER to 3.0. This work was an improvement over that reported earlier by Subrahmanyan and co-workers[26], in which the spray-dried infant food was based on groundnut protein isolate and skim milk powder, and also of the products containing soyabean flour and groundnut protein isolate prepared in 1964 by Shurpalekar and co-workers[27].

Alternative Products, Procedures and Raw Materials

(*a*) *Extrusion:* Some of the difficulties associated with spray drying have been overcome using cooking-extrusion as described by Prasannappa and co-workers[28]. The use of blended foods based on groundnut flour and cereal flours in feeding programmes for preschool and school children is generally associated with certain disadvantages like poor storage, lack of acceptability and the problem of preparation at site prior to distribution. These could be largely overcome by extrusion cooking of blends. The water-absorption capacity of the products was increased by this process, and the products prepared were quite soft and highly acceptable. The protein efficiency ratio of the products was not in any way reduced by the process of extrusion cooking.

(*b*) *Malting:* Recently CFTRI has developed a new low-cost nutritious weaning food supplement based on locally-available cereals and legumes, adopting the malting process[29]. Preliminary trials have indicated the high acceptability, nutritional quality and digestibility of the product. This product contains malted ragi powder and malted green gram powder, the protein content being about 12 per cent. A daily supplementation of 50-75 grams of this product compensates for protein-calorie deficiency in the child.

(c) *Soya-based products:* Kapoor and Gupta[30] have formulated a food from soyabeans and cheese whey. The weaning food was fortified with vitamins, minerals and methionine and contained protein 24 per cent, fat 18 per cent, carbohydrate 48 per cent (major component, lactose) crude fibre 0.1 per cent and non-protein nitrogen 0.35 per cent, and the solubility, wettability and dispersibility were all good. The protein efficiency ratio of the food was 2.35 against 2.50 for casein.

(*d*) *Use of buttermilk:* Buttermilk and yoghurt have been claimed by a pediatrician based on 30 years of experience to be the best and healthiest food in the developing world for babies who cannot be breast-fed.

(*e*) *Humanized buffalo milk:* Ganguli[33] has reported studies on humanized buffalo milk. Buffaloes' skim milk was treated with trypsin (1.75 mg/ml) for selective proteolysis of α-casein for 30 min and pasteurized. The trypsin-digested milk was assessed for protein components. Two vegetable oils were used to increase the content of polyunsaturated fatty acids (PUFA). Calcium level was reduced by subjecting milk to electrodialysis. The carbohydrate level was increased, and the product fortified with claculated amounts of vitamins and iron. The final product containing 26 per cent total solids was spray dried.

HBM powder had the following composition: prtoein 13 per cent, fat 25 per cent, lactose 58 per cent, calcium 70 mg and moisture 3 per cent. On reconstitution at the 10 per cent level, the composition was protein 1.3 per cent, fat 2.5 per cent, lactose 5.8 per cent and calcium 0.70 per cent, which closely simulates human milk.

The results revealed that α-casein was significantly reduced to a level not detectable by polyacrylamide gel electrophoresis. The concentration of β-casein was also reduced with a concomitant increase in the fast-moving fractions. Molecular sieving of casein from HBM showed a reduction in the major peaks of higher molecular weight proteins, and an increase in the concentration of components of low molecular weight. The fat of HBM showed distinctly the presence of 18:0, 18:2 and 18:3 fatty acids. A 50 per cent reduction in the calcium level of HBM over milk was achieved.

(*f*) *Malted milk products:* Malted milk solids are being manufactured in the country under the trade name of "Horlicks" by Hindustan Milkfood Manufacturers Ltd., Nabha, Punjab, using barley, wheat flour and buffalo milk, and also by the Amul organisation under the brand name "Nutramul[34].

(*g*) *Coconut proteins:* The importance of coconut proteins in infant nutrition has been described in a report[35] that reviews the scope for utilizing coconut proteins and the present processing procedures.

Some Nutiitional Considerations

(*a*) *Use of additives in baby foods:* It is likely that the detoxicating devices, the permeability of certain tissues, and other protective mechanisms may not have developed to a point in the infant aged upto 12 weeks where they are able to cope with substances that present no problem to the adult. It is therefore prudent that foods intended for infants under 12 weeks should contain no additives at all. Such items would include infant formulae and other milk-based preparations. On the other hand, cereal-based baby foods, "strained" foods, and "junior" foods that are intended for older children may contain additives, and should be adequately labelled to ensure that they are not consumed by infants under 12 weeks[36-39]. The availability of "junior" and "strained" focds confers an advantage in that the infant may be given a diet more varied and therefore often nutritionally more satisfactory than it would otherwise receive.

(*b*) *Amino acid availability:* Roller-drying of weaning foods in the presence of malt extract was found to lower the protein efficiency ratio while processing with sugar in place of malt extract had no effect on the ratio; however, marked reductions in chemically-available lysine occurred in both instances. Plasma threonine level was found to serve as a better indicator of lysine damage in weaning foods than available lysine or plasma lysine levels[40].

Conclusion

The last two decades have seen considerable progress in the manufacture of infant and weaning foods for babies. Due to the pioneering work of Dr V. Subrahmanyan and his team at CFTRI, India is self sufficient in infant foods and can even export to neighbouring countries. Similarly, his lead has pioneered the production of low-cost weaning foods using blends of various grains, oilseeds and legumes available lccally, not only in India but in many parts of the world.

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Technology of Vegetable Protein Foods

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Dr. V. Subrahmanyan's interest and active involvement in the area of protein foods started in the early forties with his pioneering researches on soybean milk[1] *at the Department of Biocchemistry, Indian Institute of Science, Bangalore. He was one on the earliest workers to recognise the enormity of the protein problem facing mankind and to forsee the vital role of food science and technology in the efficient utilization of vegetable protein resources for human use. In one of his early publications*[2] *entitled "Some food and nutrition problems of the present and post-war period", he focussed attention on the quality and acceptability of vegetable food materials and stressed the need for an increased application of science to the processing of foodstuffs with a view to improving not only their taste and consumer appeal but also digestibility and overall food value. A number of research projects initiated by him at the IISc., Bangalore were further enlarged and intensified at the CFTRI, Mysore and have led to practical results of far-reaching significance in later years. It was my privilege to be associated with Dr Subrahmanyan during the period* 1947–63 *in the area of oilseed and legume processing. The present article deals with the progress of work on the technology of vegetable protein foods in India with special reference to the processing and utilization of oilseeds.*

Malnutrition among the poorer sections of the population in several countries is widespread and its impact on the economic and social development of the nations is all pervasive[3]. Protein-calorie malnutrition has been an important cause of infant and child mortality in many developing countries and consequently major emphasis was placed on the processing and utilization of protein-rich raw materials for child feeding. Research in this area started after World War II and nutrition scientists were deeply involved in the selection of inexpensive and new sources of protein[4].

Availability of oilseeds: The most important and abundant sources of proteins of vegetable origin available in many of the developing countries and yet untapped for human consumption are the low fat oilseed cakes such as groundnut, coconut, sesame, soybean and cottonseed[5]. India is one of the major oilseed producing countries of the world and has the largest production of groundnut and sesame. It has also substantial quantities of cottonseed, rapeseed and mustard and coconut. It is estimated that the current production of oilseeds in the country can provide as much as 1.7 million tonnes of protein which is more than what is now available through animal products such as milk, meat, eggs and fish. If used efficiently, a major portion of the oilseed protein can go to improve the diets of the people both qualitatively and quantitatively[6].

Quality of commercial oilseed cakes: Oilseeds being primary sources of edible oil are mostly processed for oil and only a small proportion of the seed is directly used as food[7]. Owing to this reason, oil milling industry, from early times, has attached importance only to the oil and paid little attention to the proper utilization of the cake. The modern technology of oil milling has also paid attention only to the efficiency of oil recovery while relegating the quality of the protein rich meal entirely subsidiary to the whole operation. The poor quality of the oil cakes and meals, coupled with the traditional attitude that these are fit only for animal feeding have largely prevented their use as human food.

New Development in the Processing of Oilcakes for Food Use

With increasing realisation of the value of oilseed meals as potential sources of edible protein, there have been many new developments in the processing technology of oilseeds[8, 9]. Considerable attention has been given to the quality of raw material and its pre-treatment with a view to ensuring the safety, sanitary quality and nutritional value of the extracted meal. There has also been a gradual shift from direct screw-pressing methods to direct solvent extraction or pre-press extraction techniques to minimise damage to quality of the meal. Special solvent systems and selective extraction procedures have been recommended for upgrading the quality and acceptability of oilseed flours as human food.

The primary step in the processing of oilseeds for the production of edible flours and protein concentrates consists in the selection of raw materials and their pre-treatment. All extraneous matter should be removed and the seed graded to obtain uniform sound material free from shrivelled, immature and infested seeds. The next essential step is dehulling of the seed to remove the seed coat as otherwise the product will have a high fibre content with the consequent lowering of protein content. In some cases, anti-nutritional substances are also present in the skin, for example, goitrogenic factors in the red cuticle (testa) of groundnut[10], and oxalates, bitter principles and colouring matter in sesame[11]. The dehulled kernel is then milled under optimal conditions to recover oil and obtain a high quality protein-rich edible grade meal.

Several of the oilseeds contain in their natural state, a variety of chemical substances which are known to exert deleterious effects and hence may be considered toxic to experimental animals and humans[12], e.g. presence of trypsin inhibitors, hemagglutinins, goitrogenic factors, saponins and anti-vitamin/mineral factors in soybean; gossypol pigments and malvalic acid in cottonseed; thioglucosides, goitrogens and erucic acid in rape seed and mustard. These constituents must be inactivated or eliminated during processing. Apart from these intrinsic anti-nutritional factors, extraneous toxicants such as mycotoxins also pose a serious threat to the extended use of oilseed flours[13]. Mold growth and aflatoxin production are most rapid in agricultural commodities such as groundnut subjected to improper drying after harvest, but this can be controlled through improved practices in harvesting, drying and storage of food crops[14]. Mechanical removal of the fungal contaminated seeds effectively helps in eliminating aflatoxin from protein concentrates. Alternate methods involving the use of solvents and chemicals can also be practised to reduce the aflatoxin levels within permissible safe limits[15].

Oilseed Processing Technology

Groundnut: The first investigations on the comparative value of commercial, feed-grade oilcakes and specially processed defatted flours from groundnut, cottonseed, sesame and coconut were conducted at the IISc. during 1945–49[16] and further development of edible-groundnut flour was continued at the CFTRI during 1950–55[17]. Pilot scale production of groundnut flour of half a tonne per day was started at the institute in 1956 and a few commercial units of 3-10 tonne capacity came into operation in the country[18]. Careful choice of raw material, its grading, decuticling and manual picking to reject fungal attacked kernels were the essential pre-processing steps in the process. Even though aflatoxin and its hazards were not known at that time, such edible groundnut flour when examined for aflatoxin was found to have only very low content and within permissible limits of the toxin.

Edible groundnut flour has been successfully used to develop a variety of protein enriched and mineral/vitamin fortified nutritious foods suitable for different groups of the population[19-21]. These include (*i*) high protein supplementary foods such as the Indian Multi-purpose Food (MPF) containing about 40 per cent protein (*ii*) bulk foods such as fortified *atta*, *Paushtik-atta*, *Mysore flour* and tapioca macaroni containing 12-14 percent protein (*iii*) weaning foods such as *Bal-Ahar*, malt food and precooked weaning foods with 19-22 per cent protein, (*iv*) speciality foods such as enriched macaroni, chewy candies and biscuits containing 15-20 per cent protein and (*v*) energy food supplements based on roasted ingredients (cereals, legumes and groundnut cake) and sweetened with jaggery or sugar containing 14-16 percent protein. Some of these products such as MPF and protein enriched biscuits are being commercially produced on a limited scale while large scale production and distribution of *Bal-Ahar* for the various nutrition feeding programmes in the country has been in progress since 1969[22]. Energy food supplement has been under regular production at the CFTRI since August 1974 on 1 tonne/day basis for the nutrition programme of the India Population Project of Karnataka Government. Five units, each with a capacity of 12 tonnes/day are now being set up in the state[23].

Groundnut protein isolate: It is recognised that isolated oilseed proteins offer immense possibilities in the development of a new class of formulated foods[24]. The high concentration of protein with the advantage in colour, flavour and functional properties makes protein isolates ideal raw materials for use in beverages, infant and children milk foods, textured protein products and certain types of speciality foods.

A large amount of work was done at the CFTRI on groundnut protein isolation during 1955–63 leading to the development of technologically viable processes[25]. A notable contribution in this area was the newer approach of 'Integrated processing of groundnut kernel' for obtaining superior quality protein, oil and other constituents such as starch and carbohydrate meal fractions in a single process[26]. Normally for protein isolation, specially processed solvent extracted oilseed meals having high nitrogen solubility serve as raw materials; and the proteins are extracted by aqueous alkaline media and isolated from the clarified protein extract by isoelectric precipitation using mineral acid. The direct use of the oilseed as raw material for protein extraction would enable isolation of protein in an undenatured state besides obtaining high quality oil. Centrifuges form the vital units for the separation of oil from the aqueous dispersion of the oilseed, similar to the use of cream separators in the dairy industry. Protein and carbohydrate fractions are also simultaneously separated by the centrifugal process. The selection of right types of centrifuges as well as optimal conditions for making the dispersions of the oilseed in the aqueous media are of utmost importance for the recovery of oil in high yield and the protein isolate substantially free from oil[27].

Concurrently with the above development, work on the processing of edible groundnut meal for protein isolate was carried on bench and pilot scale[28]. Methods for complete destruction of aflatoxins during protein siolation were worked out[29] and factors that affect the storage quality, stability and functional uses of the isolate studied[30]. A number of processed foods based on the groundnut protein isolate which could be used in a variety of ways, such as in the treatment of kwashiorkor, as concentrated protein foods for infants and children, as malted beverages and as milk foods were developed; and the isolate has also been used in ice cream mixes and *Panir* like products[31-33]. Active collaboration with an industrial firm during the process development stages facilitated setting up of a commercial production unit for the isolate at Bombay[34] during 1967.

Sesame: Among the oilseed proteins, sesame is an exceptionally rich source of sulphur amino acids, particularly methonine and can serve as a very useful supplement in protein formulations[35]. The presence of fibrous hull fraction of the seed, however, limits the wider use of sesame products since it contributes dark colour, bitterness and oxalates. Traditionally for edible uses, the seed is dehulled on home scale by water soaking and rubbing, but the method is laborious.

A lye treatment process for the easy removal of the hulls has been developed at the CFTRI and the feasibility of the method for large scale operation established.[36,37]. From the dehulled seed, an edible flour containing 50 per cent protein and a high protein fraction containing 60 per cent protein have been prepared. Alternate methods of loosening and separation of the hulls involving water soaking, partial drying and passage between wooden or stone discs have been developed at the Oil Technological Research Institute, Ananthapur[38].

Cottonseed: Cottonseed is an important agricultural commodity in India and its utilization for edible oil production has made rapid progress in the last 15 years. The major limitation in the use of cottonseed products in human foods is the presence of free gossypol pigments which are toxic and harmful to monogastric animals. Under normal conditions of screw pressing of the seed for oil recovery, part of the gossypol goes with the oil and the remaining stays with the cake, mostly bound to the protein through interaction with the amino acid lysine. Though the cake is rendered non-toxic by this binding, it reduces the nutritive quality of the protein, as the bound lysine becomes biologically unavailable. Careful control of processing conditions is necessary to obtain a product with maximum available lysine content and minimum permissible levels of free and bound gossypol. Alternate approaches for the elimination of gossypol include, use of suitable solvents and the liquid cyclone technique for separation of the heavier gossypol glands from the lighter protein-rich fraction. The Regional Research Laboratory, Hyderabad, has been engaged in the development of edible cottonseed flour and protein concentrate and has set up a pilot plant for the purpose[39, 40]. Recently, an industrial unit in Karnataka has been doing experimental production and marketing of cottonseed protein concentrate[41].

Mustard/rape seed: Mustard/rape seed has been processed for edible oil in India for a long time. Interest in the use of the seed cake for edible proteins has been witnessed in recent years since the proteins have a well balanced amino acid composition. The seed however, contains certain toxic substances, mainly different types of glucosinolates, which on hydrolysis yield isothiocyanates which are goitrogenic. The thioglucosides present are also responsible for the bitter taste of the cake. It is therefore essential to eliminate the glucosinolates during processing of the edible flour. Work on the preparation of edible mustard/rape protein concentrate has been in progress at the CFTRI since 1967[42]. The process as standardised[43] consists in dehulling the seed, optimal conditioning of the kernels to develop pungency, followed by aqueous extraction under controlled conditions to leach out the glucosinolates, drying the extracted material and recovery of the oil and edible flour by prepressing and solvent extraction method. The concentrate obtained is bland, has a protein content of 55-60 per cent with a nutritional value comparable to that of casein. The expeller pressed oil has sufficient pungency to meet consumer acceptability. Some quantity of broken kernels obtained as fines during dehulling can also be detoxified by the above aqueous extraction procedure and processed as a feed grade protein concentrate for incorporation in poultry feeds.

Coconut: Coconut is one of the most important oil bearing tree nuts and a sizable proportion of the production in India (as much as 65 per cent) is consumed as such for culinary purposes and as tender nut for coconut water. To a small extent the meat is commercially processed for the production of desiccated coconut for confectionery uses. Copra which is sun-dried coconut meat is used as the raw material for oil milling yielding a cake with about 20 per cent protein and a high fibre content of 14 per cent. During the drying process of copra which takes several days, micro-organisms invade and grow in the meat adversely affecting both oil and meal quality. Thus, the commercial coconut cake is not suited for food uses.

Methods for preventing mold attack during sun-drying of copra have been worked out[44, 45]. These involve dipping or coating the fresh meat in alkaline or acid solutions and then allowing it to dry in the sun. Coconut flour of edible grade has been prepared by this technique. An azeotropic drying-cum-oil extraction method for fresh coconut kernel using heptane as solvent has also been reported to yield good quality oil and edible flour[46]. Extensive large scale trials on the integrated processing of coconut meat have been conducted at the CFTRI[47, 48] for recovering high grade oil, soluble sugars in the form of coconut honey and a protein rich flour with about 50 per cent protein content and having a low fibre content of 0.5 per cent. The coconut honey and protein concentrate have been used along with groundnut protein isolate in the preparation of spray dried infant foods and protein foods and in roller dried cereal flakes based on rice or wheat[49].

Sunflower: A major development in the cultivation of oilseed crops in recent years is the focus on the importance of sunflower as a source of edible oil[50]. Selected commercial varieties of Russian origin have been recently introduced in India under an All India Co-ordinated Project[51]. The seed has about 45 per cent oil comparable to that of groundnut kernels but has a high proportion of hulls, about 25 per cent. In addition, the kernel has certain polyphenolic compounds such as chlorogenic, caffeic and quinic acids. Removal of hulls and elimination of the polyphenols are necessary for obtaining a superior quality edible protein concentrate from the seed. Work on these aspects was initiated recently at the CFTRI and useful results have been reported[52]. Use of an under runner emery sheller or a centrifugal sheller facilitates easy dehulling of the seed. Pre-soaking of the kernels in dilute sodium chloride solution at slightly acidic pH helps to leach out most of the polyphenols. Edible grade protein concentrate prepared from the sodium chloride treated kernels was found to have good nutritional value and this can be further enhanced by supplementing with lysine[53] or blending with legumes rich in lysine.

Soybean: Considerable interest has been shown in India since the late 30s' on the cultivation of soybean as a food crop in view of its high protein and oil content. It has about 40 per cent protein, while the common pulses have only 20-22 per cent protein. It has also nearly 20 per cent oil compared to less than 1 per cent in pulses. A collaborative research programme on the nutritional value of soybean conducted under the auspices of the Indian Research Fund Association during 1941–45[54] showed that soybean when cooked as a pulse was neither well digested nor adequately utilized by experimental animals or human subjects; and in respect of its overall supplementary value, soybean was in no way superior to the common pulses.

The main drawbacks in the use of soybean are its objectionable beany flavour, bitterness and its poor cooking quality. It contains a variety of antinutritional factors which are inactivated only under controlled conditions of heat processing. Unlike other pulses, soybean has little or no starch; it has also fair amounts of biologically unavailable carbohydrates. In a country like India where a number of pulses with excellent flavour and culinary properties are in common use, soybean is at a disadvantage due to its unpleasant flavour. Secondly, as an oilseed crop it is inferior to the conventional oilseeds such as groundnut, sesame, and mustard/rape on account of its lower oil content.

Newer developments in the processing of soybeans have been reported to overcome the flavour problem.[55] A vast amount of information is now available on the elimination of the anti-biological factors from processed soy products. With this background, renewed interest on the introduction of soybean under an All India Coordinated Research Project was iniatiated in 1967 by the Indian Council of Agricultural Research[56]. Intensive research on this crop has also been underway at the UP Agricultural University, Pantnagar[57] and the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur[58]. Considerable data on the processing and utilization aspects of soybean have been reported from the CFTRI[59–61]. These studies relate to dehulling for obtaining split soy *dhal*, inactivation of trypsin inhibitors present in the *dhal* by steaming, heat processing and screw pressing for the preparation of low-fat edible soy flour, improvement of the cooking characteristics of soy *dhal* by flaking and preparation of full-fat edible soy flour from optimally heat processed soy grits. Protein foods based on blends of soy and groundnut flours and spray-dried milk substitutes from blends of groundnut, soybean and sesame have been developed.

Vegetable Milks

Though India is a country with along tradition for consumption of milk and milk products, the per capita availability of animal milk is low, being about 115 g daily. Milk is expensive and large sections of the low-income groups do not consume any milk. Work on the preparation of inexpensive and nutritious milk-like beverages from soybean and groundnut was started at the IISc., Bangalore in 1944 and methods for obtaining products with fairly good acceptability were standardised[62]. The production of soy milk on pilot plant scale as adopted incorporated technical improvements for the removal of beany flavour such as debittering the bean with sodium bicarbonate, steam deodourisation of the milk and use of antioxidants. Despite these improvements, the product had some residual odour characteristic of soybean. Similarly groundnut milk also had the native nutty flavour to some extent. Both soy and groundnut milks when converted to curd by lactic fermentation were found to be more acceptable.

Beverages based on vegetable protein and animal milk: It was realised that the use of isolated proteins for the preparation of milk-like beverages would greatly help in overcoming the flavour problem of vegetable milks. Considering both acceptability and the nutritional aspects, it was felt that beverages based on the isolate and milk would have many advantages since studies on the nutritive value of groundnut protein isolate had indicated that supplementation of the isolate with milk solids greatly enhanced its nutritional value, specially for curing protein-calorie malnutrition in children[63].

Many of the dairies in the country produce 'toned milk' by combining reconstituted skim milk solids with fluid buffalo or cow milk in order to extend the available supplies of fluid milk during lean months when milk production is low. In such a product, vegetable toning using groundnut protein isolate in place of skim milk solids could be considered, as this would obviate the need for importing milk solids for extending milk supplies[64].

Miltone, a vegetable toned milk developed at the CFTRI contains equal proportions of milk proteins and isolated groundnut proteins[65]. Nearly 50 per cent of the total carbohydrates in the product is derived from added sucrose and the fat component is entirely from the animal milk. Miltone has 11.5 per cent total solids, 2 per cent fat, 4 per cent protein and 5.0 per cent carbohydrates and has been found to be highly acceptable for all uses, where animal milk is used.

The method of preparation of Miltone consists in isolation of groundnut protein from defatted meal, dispersion of the wet isolate in water at neutral pH, addition of buffer salts such as citrates and phosphates, liquid glucose or sugar and vitamin premix, homogenisation, blending with standardised fluid milk, re-homogenisation and pasteurization. Miltone can also be spray dried into a powder. Miltone now under regular production at the Bangalore Dairy is being used for feeding children under the Special Nutrition Programme. Some quantity of sterilized Miltone is also being marketed as a beverage. Production of Miltone at the Bangalore Dairy is being expanded and similar units have been established at Ernakulam and Hyderabad[66]. A flavoured and sterilized beverage based on groundnut protein isolate and milk solids called *Milpro* is being marketed in Bombay[67].

Extrusion Cooked Foods

Complete pre-cooking of protein-enriched food mixes into ready-to-eat type products can be accomplished by the extrusion cooking technique which is a continuous, high temperature, short time cooking process[68]. In this method, the blended flour is steam preconditioned and moistened under carefully controlled temperature at atmospheric presure. The dough is worked in an extruder assembly at an elevated temperature and pressure and finally forced through a suitable die when expansion of the product takes place due to sudden release of the pressure. Extrusion cookers were first developed for the economic gelatinisation of cereals and in recent times this technique is finding increasing application for the processing of a variety of food materials and in the large scale processing of snack foods. Food products prepared by this method are hygienic and store well. In the USA, full fat soy flours of high nutritional value, good stability and flavour profile and textured protein foods based on soy flours and protein concentrates are being produced by extrusion cooking process.

Extrusion cooked food products are being produced to a limited extent in India and the potential of large scale processing of nutritious food supplements by this method for mass feeding programmes have been considered[69]. Extrusion cookers now in use are mostly imported and are capital intensive. Development of less expensive extruders and extrusion cookers has been in progress in India and such efforts deserve encouragement. There is considerable scope for extrusion cooked products both as snack items and convenience foods, specially in the context of high fuel costs for normal cooking of foods in homes.

Promotional Work and the Task Ahead

It is recognised that large sections of the Indian population are below poverty line and protein-calorie malnutrition is most widely prevalent among preschool children and other vulnerable groups. Providing better foods and good nutrition for the under-privileged groups should be a matter of great concern not only for the Government but also every member of the scoiety. Many possibilities of developing inexpensive nutritious food supplements and processed foods have been indicated, but much more needs to be done to manufacture these products and in making them available to the population.

Protein foods are a new concept to the common people and need promotion. Soon after the International Symposium on Protein Foods and Concentrates held at the CFTRI in 1967, a workshop was organised in Bangalore on the marketing of protein foods. Based on its recommendations, the Protein Foods Association was formed in 1968 for bringing awareness of the problems of food and nutrition among the people and food industries. This organisation, now renamed as the Protein Foods and Nutrition Development Association of India (PFNDAI), has been doing valuable work to focus attention on the problems and to recommend appropriate measures for the production of nutritious foods. The Association has organised a number of workshops on important topics[70-74].

In retrospect, if one considers all the developments on protein foods in the past three decades in India, there is no doubt that there is adequate technical know-how and technological base for the processing and utilization of oilseed proteins, but concerted efforts are needed to apply the technologies for the benefit of the people. This is indeed a great challenge not only for the food scientists and technologists but for everyone concerned with the welfare of the society.

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Development of Supplementary Foods and Their Usefulness in Applied Nutrition Programmes

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I was fortunate in joining CFTRI in June 1949 *along with some other colleagues and helped Dr V. Subrahmanyan, the Director, in establishing the Division of Nutrition and Dietetics. In collaboration with Dr Subrahmanyan, studies were initiated by me on some urgent applied nutritional problems and one of these was the development of low cost supplementary foods for the prevention and treatment of protein-calorie malnutrition in pre-school children. I like to pay my respectful tribute to Dr Subrahmanyan for the great inspiration he provided to all his colleagues by his hard work, dedication to research and dynamic leadership. I also would like to express my gratitude to my collaborators who carried out these studies with great devotion and interest. In this article, I have presented a brief account of the work done at CFTRI on supplementary foods.*

The diets consumed by a majority of the vulnerable sections of the population in India and other developing countries are based mainly on cereals, roots and tubers and contain small amounts of pulses and vegetables and negligible amounts of milk and other animal foods. Consequently protein-calorie manlutrition, anaemias and diseases due to vitamin deficiencies are widely prevalent among weaned infants and pre-school children[1]. Protein rich and protective foods such as milk, eggs, meat and fish are not available in adequate amounts. Further, they are costly and beyond the reach of the low income groups. Hence studies were undertaken to develop low-cost processed protein enriched foods based on edible oilseed meals which can be prepared in large quantities as a by-product of the oil industry.

The different categories of foods developed may be broadly divided into two groups: (*i*) Protein rich foods containing about 40-45 per cent proteins based on blends of oilseed meals and legumes and fortified with essential vitamins and minerals, and (*ii*) protein enriched cereal foods (containing about 17 to 25 per cent proteins) based on blends of cereals, oilseed meals and legumes.

Protein Rich Foods

Protein rich foods based on oilseed meals and legumes: Among the oilseeds grown in India, groundnut is the most abundant. Fair amount of other oilseeds such as sesame, safflower, niger and rape and mustard seeds are also grown in different parts of India. Coconut is cultivated in large amounts in Kerala State and in fair amounts in other Southern states in India. Processes were developed in the Institute for the development of edible low fat flours from groundnut, sesame and coconut. Studies were also carried out on soybean meal as soybean is a rich source of protein and can be cultivated easily in some parts of India. Among legumes, the most abundant is Bengal gram (chick pea).

Preparation of processed protein foods: The oilseed meals and roasted chick pea flour were mixed in suitable proportions. The blends were fortified with calcium salts and vitamins A, D and riboflavin. The chemical composition of the different protein foods is given in Table 1.

Indian Multipurpose Food (*MPF*): Indian MPF is a blend (75:25) of low fat groundnut flour and Bengal gram flour (*Cicer arietinum*) fortified with vitamins A and D, riboflavin and calcium carbonate. Three formulations were developed; (i) seasoned with salt and spice mix, (ii) unseasoned, flavoured with vanillin and (iii) unseasoned with added (20 per cent) skim milk powder[2]. The food contained 41 to 42 per cent proteins. Sixty grams (2 ounces) of MPF provides about 20 g of proteins and the daily requirements of vitamins A and D, riboflavin and calcium of pre-school children. Its cost was only about one third that of skim milk powder. MPF can be added to common Indian food preparations without any essential change of food habits. The unseasoned MPF can be made into tasty porridge and consumed after sweetening with sugar.

Indian MPF, when incorporated at 12.5 per cent levels in poor cereal diets (to provide about 5 per cent extra proteins) made up the deficiencies of proteins, vitamins A and D, riboflavin and calcium in the diets and promoted excellent growth in albino rats[3].

Supplementary value to the diets of school children: Since the diets consumed by school children of low income groups are lacking in proteins, vitamins A and D, riboflavin and calcium, the effect of supplementing their diets with 60 g MPF daily for a period of 5 months on their growth and nutritional status was studied[4]. The results showed highly significant improvement in height, weight and nutritional status in the group receiving the MPF supplement as compared with the control group.

Treatment of protein-calorie malnutrition in pre-school children with MPF (formula C): Since the incidence of protein-calorie malnutrition (PCM) among pre-school children in India is high, it was considered necessary to find out the value of MPF (formula C) containing 20 per cent skim milk powder in the treatment of PCM. The studies were carried out in the local hospitals[5]. Three children (aged 2-3 years) suffering from kwashiorkor were given daily 150 g of MPF (C). The food was given in 5 doses of 20 g each, in the form of porridge sweetened with 30 g sugar. In addition, the children were given small amounts of bread and ripe banana. The daily calorie intake was about 120 Kcal per kg body weight. The treatment was continued for a period of 39 to 65 days. The results showed that oedema subsided in about 5-7days and completely disappeared after 3 weeks treatment. Dermatoses and hyper-pigmentation began to heal by about 10-15 days and were completely cured in 25 days. The serum protein levels, which were very low before treatment, steadily increased and reached normal levels at the end of treatment. The body weight steadily increased after the disappearance of oedema. The children looked quite normal before they were discharged.

Protein food based on groundnut, coconut and Bengal gram flours: Edible coconut meal contains about 20 per cent protein but it has also too much of fibre (10-12 per cent); it can be used only at 20 to 30 per cent level in supplementary foods. The proteins of coconut are of high nutritive value. A protein food containing 50 per cent groundnut flour, 25 per cent coconut flour and 25 per cent roasted Bengal gram flour and fortified with vitamin A and D, riboflavin and calcium carbonate was pre-par ed. Studies with albino rats showed that the food when incorporated at 12.5 per cent level in poor cereal diets made up the deficiencies in the diet and promoted good growth[6]. Supplementation of the diets of school children of low income groups with 60 g of the food per day per child for a period of 5 months brought about highly significant improvement in the growth rate and nutritional status[7].

Protein food based on groundnut and soy bean flours: Soy bean is a rich source of proteins of high biological value. It can be cultivated easily in North India during winter months. It was, therefore, considered of interest to prepare a protein food containing 1:1 blend of groundnut and soy bean flours and fortified with vitamins A and D, riboflavin and calcium carbonate[8]. The protein food contained about 49 per cent protein when incorporated in a poor maize-tapioca diet (containing 5 per cent proteins) at 20 per cent level so as to provide about 9.5 per cent extra proteins, it made up the deficiencies and promoted excellent growth in albino rats. A feeding experiment conducted over a period of 6 months on school children of low income group as a supplement at 40 g/child/day showed highly significant improvement in growth and nutritional status[9].

Protein food based on groundnut, sesame and Bengal gram flours: Edible sesame meal is a rich source of proteins with an exceptionally high methionine content while groundnut, Bengal gram and soy bean are deficient in sulphur amino acids. A protein food containing 2:1:2 of groundnut, sesame and Bengal gram flours and fortified with vitamins A and D, riboflavin and calcium salts was prepared[10]. The supplementary value of the food to poor cereal diets was studied by conducting experiments with albino rats and school children. The food when incorporated at 12.5 per cent level in poor cereal diets made up the deficiencies in the diets and promoted good growth of albino rats[11]. Supplementation of the diets of school children of low income groups with 50 g of the protein food per day per child for a period of 6 months made up the deficiencies of protein, calcium, vitamins A and D and riboflavin in the diet and brought about highly significant improvement in the growth and nutritional status of children[12].

Protein Enriched Cereal Foods

Protein enriched cereal foods containing about 17 to 24 per cent proteins and fortified with essential vitamins and minerals can be used as weaning foods and supplementary foods to pre-school children in develop: ing countries and can also be used as partial substitutes for the cereals in the diets. A well known example of this category of food is INCAPARINA a supplementary food based on corn and cotton seed meal developed at the INCAP, Guatemala[13]. The cereal based protein enriched foods developed at CFTRI include (*i*) balanced malt food, (*ii*) enriched macaroni products, (*iii*) nutro biscuit, and (*iv*) Blahar. A brief account of the nutritive value of these foods is given in the following section.

Balanced malt food: A low cost balanced malt food was prepared by blending cereal malt (40 per cent), low fat groundnut flour (40 per cent), Bengal gram flour (10 per cent, and skim milk powder (10 per cent). The product was fortified with vitamins A and D, riboflavin and calcium caibonate[14]. The composition or the malt food is given in Table 1. The malt food when incorporated at 10 per cent level in poor cereal diets made up the deficiencies and promoted good growth in albino rats[14]. In feeding experiments[15] extending for 9 months weaned infants (9-20 months) fed daily a supplement of 2 oz of malt food or Indian MPF (formula C) showed highly significant increases in height, weight, and haemoglobin as well as marked improvement in nutritional status as compared with a control group receiving a daily supplement of 2 oz of rice.

Enriched macaroni products: Macaroni products can be cooked and consumed in the same way as rice. Two types of enriched macaroni products- (*i*) enriched tapioca macaroni and (*ii*) enriched wheat macaroni have been prepared and their supplementary value to poor cereal diets studied with albino rats and children. The results are briefly described below:

Enriched tapioca macroni: This has been prepared in the form of rice shaped grains from a blend of groundnut flour (30 per cent), wheat flour (30 per cent) and tapioca flour (40 per cent). This product was fortified with vitamin A and D, riboflavin and calcium carbonate. It cooks readily in 5 min and the cooked product can be consumed in the same way as cooked rice. It contains about 2 to 3 times as much protein and 3 to 6 times as much B-vitamins as compared with raw milled rice. It is a rich source of calcium in which rice is deficient. Studies with albino rats showed that when fed as sole source of nutrients enriched tapioca macaroni promoted good growth in albino rats (16.4 g/week), comparing well with that obtained on stock diet[16]. When a poor rice diet was supplemented with 50 g of enriched tapioca macaroni, the diet promoted significantly higher growth in weaned infants and pre-school children as compared with the control rice diet[17] in a period of 6 months.

Enriched wheat macaroni: Enriched wheat macaroni was prepared from a blend of wheat flour (75 per cent) and groundnut flour (25 per cent). The product was fortified with vitamins A and D, riboflavin and calcium carbonate[18]. When 50 per cent of rice in the poor rice diet consumed by school children of low income groups was replaced by enriched wheat macaroni, the diet promoted significantly greater growth in children than the basal rice diet[19].

Nutro biscuits: Since biscuits, are commonly consumed by weaned infants and pre-school children, it was considered desirable to enrich biscuits by the addition of groundnut flour, vitamins and minerals. Protein enriched biscuits were prepared from a blend of 40 per cent wheat flour, 30 per cent groundnut flour, 15 per cent sugar and 15 per cent shortening. The biscuit mix was fortified with vitamins A and D, riboflavin ald calcium carbonate[20]. The biscuits (100 g) provided 16-8 per cent proteins and half the daily requirements of vitamins A

TABLE 1. CHEMICAL COMPOSITION OF DIFFERENT SUPPLEMENTARY FOODS BASED ON OILSEED MEALS (VALUES PER 100 G)

Sl. no.	Product	Protein (g)	Calcium (g)	Riboflavin (mg)	Vitamin A (i.u.)	Ref. No.
1.	Indian MPF formula A (3:1 blend of groundnut and Bengal gram flours)	41.9	0.67	3.00	3000	(2)
2.	Indian MPF formula C (3:1:1 blend of groundnut and Bengal gram flours and skim milk powder)	40.6	0.80	3.00	3000	(2)
3.	Protein food (1:1:2 blend of coconut, Bengal gram and groundnut flours)	36.5	0.88	3.00	3000	(6)
4.	Protein food (1:1 blend of groundnut and soybean flours)	49.2	0.93	3.00	3000	(8)
5.	Protein food (2:1:2 blend of groundnut, sesame and Bengal gram flours)	40.2	0.80	3.00	3000	(10)
6.	Malt food	28.2	0.80	3.00	3000	(14)
7.	Bal-Ahar	26.5	0.60	2.00	3000	(22)
8.	Nutro biscuit	16.5	0.40	2.50	3000	(20)
9.	Enriched tapioca macaroni	19.1	0.46	1.50	1500	(16)
10.	Nutro macaroni	19.5	0.44	1.50	1500	(18)

and D, riboflavin and calcium for pre-school children. When the diets of pre-school children suffering from mild protein-calorie malnutrition was supplemented daily with 100 g of nutro biscuits, the children were cured and showed improvement in their nutritional status[21] in a period of 60 days.

Bal-ahar: A low cost cereal based weaning food known as Balahar was developed at CFTRI, Mysore for use as a supplement to the diets of pre-school children of low income groups. The food consists of a blend of cereal flours (60 per cent), groundnut flour (30 per cent) and Bengal gram flour (10 per cent)[22]. The product contained about 20 to 24 per cent proteins depending on the cereal in the blend. It was also fortified with vitamins A and D, riboflavin and calcium carbonate. Balahar can be consumed in the form of a pudding (salted or sweetened) or in the from of *dosa.* Fifty grams of Balahar will provide 10 g of proteins and about half the daily requirements of vitamins A and D, riboflavin and calcium. Supplementation of the diets of school children belonging to low income groups with 50 g of Balahar daily brought about a highly significant increase in their growth rate and marked improvement in the nutritional status[23].

Ready-to-eat Food Supplements

Extrusion cooked foods: Protein enriched food supplements such as Balahar, pose some problems both in the manufacture and delivery to target groups since they have to be cooked with other ingredients into acceptable forms and served. Moreover, these being blends of raw ingredients do not store well. A new processing technique for complete precooking of foods known as extrusion cooking has been developed in recent years for processing high protein foods and supplements. This is a continuous high temperature-short time cooking method and has great potential for the large scale production of a variety of processed foods. At present the extrusion cookers are being imported from abroad and are somewhat costly. Efforts are also in progress to develop such equipment indigenously[24].

Roasted, Parched or Toasted Foods

Yet another approach to prepare ready-to-eat nutritious food mixes involves roasting, parching or toasting technique. Sand roasting and parching of cereals and millets is a traditional process and this helps in improving the aroma and acceptability of foods. Recently a nutritious food supplement known as 'Energy Food" has been developed at the CFTRI making use of roasted ingredients. Cereals such as wheat, jowar or ragi constitute the major component in the food with small proportions of legumes and oilseed flours as protein sources. The ingredients are roasted, ground and blended in the required proportions. The food contains added sugar or jaggery as sweetening agent and is also fortified with vitamins and minerals. The food contains about 15 per cent protein, provides 380-400 calories per 100 g and has been found to be highly acceptable for feeding pre-school children and even younger children.

'Energy Food' formulation based on wheat, Bengal gram, groundnut cake and jaggery has been in continuous production during the past five years and used in the Nutrition Programme of the India Population Project of the Karnataka Government. Five large scale production units, each with a capacity of 12 tonnes/day, are now being set up in the State for enlarging the scope of supplementary feeding programme to vulnerable groups of the population[25].

Conclusion

It is evident from the results of studies carried out at CFTRI, Mysore that large scale production and use of products such as Indian Multipurpose Food, balanced malt food, Balahar, and Energy Food will help considerably in making up the deficiencies in the diets of children and improving their nutritonal status. The need for the utilization of oilseed meals in the production of supplementary foods for the vulnerable sections of the population has also been stressed in the report "International action to avert the impending protein crisis" issued by the United Nations[26].

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Developments in Industrial and Food Microbiology

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"There is a real interest in science among thoughtful people and a wide spread conviction that science and the scientific method, deliberately and resolutely applied to national development, may be the saving of this country."

It is in this context that we have to recall the vision of Dr V. Subrahmanyan in developing a Discipline of Microbiology, Fermentation and Sanitation at the Central Food Technological Research Institute, Mysore. He recognised, that Microbiology was one of the basic disciplines in a Food Research Institute.

Three major lines of development were envisaged at the time of the starting of this department, namely-Industrial Microbiology, comprising of all aspects of Fermentation Technology, Food Microbiology and Sanitation and Food Toxicology. The department of Microbiology came into being even at the inception of the Institute in 1949. This brief review, however, will be confined to two aspects of microbiology—Industrial and Food Microbiology. I have dealt with the work carried out during the last 3 decades in three chronological stages namely; 1949–1959; 1959–1969 and 1969–1979.

(*a*) 1949–1959

The food industries in India had come up only during the last decade and consequential problems of microbial spoilage had only recently caught the attention of food scientists in India. Microbiaal contamination in processed foods is not only a cause of concern to the health of the consumer, but also an economic loss to the canner. Fruits due to their high acidity and sugar content are susceptible to mould and yeast attack while vegetables and meat products, which are non-acidic have largely bacterial contamination.

Sugar is the first material of importance to canning industry. That the raw material can carry contamination has been studied by Johar[1]. Pickles and preserves have formed a part of the Indian diet from ancient times. In a series of papers, Anand and Johar studied the various aspects of the problem such as fermented and unfermented pickles[2], effect of condiment[3], action of organic acids[4], and microbiology of brining[5]. Subba Rao and Johar[6] isolated the spoilage organisms from *murabbas* and reported the inhibitory effect of acetic acid, and sodium benzoate, singly and in combination. In addition to the above, a number of reviews and technical bulletins were published pertaining to recent trends in plant sanitation by Anand[7], microbiological aid to fruit and vegetable preservation industries[8], and application of microbiology in food processing[9].

There is an increasing demand in India for amylase for use in textile and food industries. The enzymes are of microbial origin and produced from cheap substrates such as wheat bran or oil seed cake residue. Lulla and Subrahmanyan[10] found that maximum enzyme production by *Bacillus subtilis* could be secured in a medium containing wheat bran and lucerne powder. Lulla and Johar[11-13] developed methods for the production of amylase by surface and submerged fermentation methods. Keeping in view the needs of the industry, the importance of developing fermentation industries in India[14], and fermentation process in food industries were reviewed[15].

Citric acid is widely used in preserved fruit industry, besides other uses in pharmaceuticals. Lewis and Johar have studied the relationship of spore size[16], influence of iron[17], and effect of methanol[18] on citric acid production.

A review by Subrahmanyan *et al*[19] was the starting point for work on yeast. Detailed studies have been made by Lewis and Dwarakanath[20] on the production of active dry baker's yeast from molasses.

Beverages, both alcoholic and non-alcoholic, have been used in the country from fairly early times. Work carried out during the period resulted in the preparation and preservation of two beverages viz. "Gingercocktail" and "Pan supari nectar". Work on the preservation of *Neera* was carried out by Subrahmanyan and Johar[21]. Ramachandra Rao and Johar[22] showed the possibilities of fortification of beverages with autolysed yeast.

A wide variety of alcoholic beverages can be produced by the fermentation of grapes, cashew apples and raisins. Preliminary studies by Johar and Anand[23] showed the possibility of producing a suitable base for 'Tonic-wine' preparation. Technology of fruit wines was studied by Johar[24] in order to assist the industry to produce alcoholic beverages based on locally available raw material.

Besides the above major areas, some work was carried out by Lulla[25] on the possibility of production of riboflavin and on the synthesis of fat from molasses by Lewis *et al.*[26].

As a flavouring, vinegar has been in use for a long time. It is produced by the successive alcoholic and acetic fermentations of sugars from various saccharine sources. A small scale vinegar generator has been developed by Johar and Anand[27]. In a detailed study, Natarajan *et al.*[28] have attempted evaluation of the quality of some vinegars produced in the country.

Subrahmanyan *et al*[29] reviewed the role of intestinal microflora in human health and nutrition. This concept led to an intensive investigation on dietary adjuncts used in India. The effect of different condiments in mango pickle was studied by Anand and Johar[30]. This was followed by studies on the effect of garlic by Subrahmanyan *et al.*[31], who clearly showed the lowering of coliforms by garlic therapy. Detailed studies[32] on garlic indicated their specific antibacterial effect on, *Aerobacter aerogenes*, *Staphylococcus aureus* and *Shigella sonnei.*

Thus the work carried out during the first decade (1949–59) clearly indicated the possibilities of producing microbial enzymes from bacteria, active dry Baker's yeast, acidulants for use in food industry and both alcoholic and non-alcoholic beverages from locally available raw materials. A possible role for food adjuncts in Indian dietary was also brought out.

(*b*) 1959–1969

In many areas of the world an important part of the diet is supplied by fermented foods. These are largely based on cereals, and pulses and a wide variety of additives in which microorganisms play an important role modifying the physical, nutritional and organoleptic properties. *Idli* is one of the very widely used fermented foods of South India. Lewis and Johar[33] studied *idli* batter and invariably found large number of cells of yeast, *Streptococci* and *Lactobacilli.* Further studies by Lewis[34] established the conditions for preparing good *idli.* Desikachar *et al*[35] studied first the changes in the batter in respect of chemical constituents such as nitrogen, reducing sugar and acidity development. They established that presoaking of blackgram (*Phaseolus mungo*) *dhal* was an important step in fermentation. By using antibiotics they showed that both bacteria and yeasts participate in the fermentation.

Radhakrishnamurthy *et al.*[36] established that blackgram flour was necessary for *idli* fermentation, which served as a major source of micro-organisms. Ananthachar and Desikachar[37] studied the nutritional value of *idli.* Even though there is no overall increase in nutritive value, yet the digestibility or ease of digestion of the *idli* was improved by fermentation.

Japan has a long history of using microorganisms to process soybeans into products with better flavour, texture and nutritive value. This traditional microbial technique was made use of to process selected Indian oil seed cakes and pulses. Ramachandra Rao[38-40], had shown the clear possibility of preparing predigested foods by selective microbial action. A welcome feature was the low salt content of these foods as against the traditional *miso* with high salt content. These studies were extended by Narayana Rao[41] who standardised the conditions for preparation of *miso*-like products from soybeans and combination of soybeans with other oil seed cakes. Sreenkatiah[42] studied enzymic hydrolysis of defatted seasame and peanut meals with various legumes and developed a protein-rich food, well balanced in amino acid composition.

Garlic is widely used in our dietary as a flavouring agent. It is also used as a therapeutic agent both in ancient and modern systems of medicine. Sreenivasa murthy *et al*[43] studied various aspects of this problem, such as preparation of an active factor in a palatable growth of yeasts and molds[44], its usefulness in the treatment of rhueumatoid arthritis[45] and acute lepromatous neuritis[46]. The preparation used in these studies was a syrup containing allin extracted from enzyme-inactivated garlic cloves. The enzyme was supplied in the form of a powder filled in gelatin capsules. After administration the enzyme is released in the stomach and acting on the precursor, gives allicin which has got antibacterial properties.

Pickling is a method of preservation of fruits and vegetables by use of salt and acid. The bulk of pickles produced in India are of the unfermented type with a large amount of salt. The raw material used are usually acidic in nature. In pickles, prepared by the traditional method the preservation is largely due to maintenance of high levels of salt and acid. Soumithri *et al.*[47] studied the levels of salt and acid needed for lime, mango and gooseberry pickles. The incidence of spoilage in brine pickles is a very common phenomenon. Subba Rao and Johar[48] reviewed the types of spoilage such as bloater formation, blackening and ropiness in brine. It was, therefore, of interest to develop a suitable preservative which could be used with traditional pickles in India. In a series of papers, Subba Rao *et al*[49-52] described a pickle preservative emulsion containing acetic acid, orange peel oil, brown mustard and turmeric powders. Extending these studies, Subba Rao[53] investigated the inhibitory effect of essential oils of orange and lemon. Orange oil was the most suitable ingredient which could control most of the gram-negative cultures, yeasts to a large extent and even moulds at slightly higher concentrations.

Systematic investigations with regard to commercial production of microbial enzymes for industrial use were initiated first at the Indian Institute of Science, Bangalore by Prof. M. Sreenivasiya. Later the work on bacterial amylases was continued at Central Food Technological Research Institute, Mysore and also independently at National Chemical Laboratory, Poona. Enzymes capable of degrading pectic substances are of great commercial importance in the fruit processing industry in India. Even though a variety of microorganisms are capable of producing pectolytic enzymes, the preferred enzymes are from fungal sources as their optimum pH corresponds to that found in fruit juices.

Sreekantiah and Johar[54] started a screening programme and selected high yeilding strains of moulds. Srikantiah *et al.*[55] studied the effect of nutritional and cultural conditions on the secretion of the enzymes and also tested the efficacy of these preparations for extraction of fruit juices[56,57]. Sreekantiah[58,59] and Richard Joseph[60] showed the application of the enzyme in extraction and clarification of banana and grape juices also in the preparation of lime juice cordial.

Cheese is an excellent source of protein, calcium, fat and vitamins. In view of the limited availability and cost of animal rennet, it was desirable to find rennet substitutes, from plant or microbial origin. Krishnaswamy and Johar[61-63], studied the utilization of vegetable rennet from *Ficus* for the manufacture of cheddar cheese. Krishnaswamy and Patel[64], prepared a cheese spread from vegetable milk based on peanut protein using enzyme from *Ficus*.

Cellulases have been used to digest the fibre in foods and for utilising cellulosic wastes. Ramamurthi and Johar[65], reported some details in respect of predigesting the fibres of coconut cake. Chandrasekaran and Shantamma[66,67] tested the hydrolytic activity of cellulase from fungi and groundnut cake. Numerous reports have appeared on the fermentative production of amino acids for use in foods as flavouring agents and also as supplements. Tauro[68] studied the production of valine by bacterial fermentation. This was followed up by work on production of lysine by fungi and glutamic acid[69,70] by bacteria.

About eighty papers have been published during the above period. Some review studies on cheddar cheese[71], food processing[72], microbiological research[73], industrial enzymes[74], Indian spices[75], and pickles[76] also appeared during this period.

(*c*) 1969–79

Spices are known to harbour bacteria, yeasts and moulds which under favourable conditions cause spoilage of foods. These spices are often used in the form of curry powder, which contains mixtures of various spices. Satyanarayana Rao *et al*[77], have reported on the microbiological examination of curry powders and spice mixtures. Since more detailed information was required, in order to suggest control measures, Krishnaswamy *et al*[78] conducted a series of investigations relating to: enumeration of micro-organisms in spices and spice mixtures, microbiological quality of spices[79], and identified coliforms, aerobic mesophilic spore formers, yeasts and molds in spices[80].

Satyanarayana Rao[81], surveyed the hygienic conditions of certain cashew processing units. Krishnaswamy *et al*[82,83] made detailed studies on the microbiological quality of cashewnut and reported that the microflora on processed cashewnut poses no health hazard.

Fungal proteolytic enzymes find wide application in food industries and have some advantages over other sources. Nagaraja Rao *et al*[84] studied the elaboration of proteolytic enzymes from fungal sources and tested their ability to degrade proteins from both animal and plant sources. Among plant, animal and microbial proteases, fungal coagulants have found greater acceptance as a substitute of rennet for cheese making. Krishnaswamy[85] studied the production of an enzyme from a *Rhizopus* which possessed high milk clotting and relatively low proteolytic acivity. Srikanta *et al*[86] succeeded in reducing the proteolytic acivity, thus obtaining a fraction with high milk clotting property.

Glucose-isomerase is one of the important commercial enzymes used in the production of high fructose syrups. Richard Joseph *et al*[87] and Krishna Nand *et al*[88] studied the conditions suitable for the production of glucose-isomerase by *S. fradiae*. Vijaya Harish and Joseph[89] attempted to improve the xylan degrading ability of the culture by inducted mutation with ultra-violet. Sreenath,[90] studied the stimulation of glucose-isomerase by hydrolyzed wheat bran fraction.

In order to demonstrate the practical application of the earlier findings, work was carried out on the enzymic hydrolysis of starch[91] and production of ethanol from rain-tree fruits[92]. Similarly, studies on vinegar were continued and in order to standardise the conditions of different methods of acetification[93] and for developing a laboratory acetator[94]. The enzymic processing of banana was carried out by Jaleel *et al.*[95], indicating its industrial feasibility.

The work on the production of amino acids by microbial techniques continued to gain interest in India. Krishna Nand *et al.*[96] obtained *Arthrobacter*, *Bacillus*, *Rhodotorula* and *Streptomyces* as potential amino acid producers. Richar Joseph[97] studied valine production by an achromogenic mutant of *M. glutamicus*. Vijaya Rao[98] worked on development of mutants, particularly using nitrosoguanidine. Richar Joseph,[99-101] in a series of papers reported the glutamic acid production and showed the possibility of employing tuber starch as raw material. Krishna Nand[102] carried out studies on isolation of autotrophic mutants of *Rhodotorula* and excretion of glutamic acid by *Arthrobacter*[103].

Narayana Rao *et al*[104] continued their studies on development of a *miso*-like food based on oil seeds and pulses and studied[105] the effect of their supplementation to rice-diet. Girija Bai *et al.*[106] studied the process for the preparation of *tempeh* (a fermented food of Japan) using soybean and groundnut.

Production of wine from Bangalore Blue grapes has attracted considerable attention in recent years. Sreekantiah and Johar[107] studied the suitability of of Bangalore Blue grapes for wine manufacture. Venkataramu *et al*[108] studied the production of red wine from Bangalore blue grapes. Patel *et al.*[109] studied the colour stability of wine by sulphites. Patel *et al.*[110] continuing their studies, reported on the changes in phenolics during storage of wine.

As India has a large and developing brewing industry,[111] it was necessary for us to initiate work in this area to help the industry. Satyanarayana Rao *et al.*[112] studied the preparation of wort from barley malt and degermed maize using microbial enzymes. Continuing their studies, Satyanarayana Rao *et al.*[113] showed that barley malt can be partially replaced by barley grain. Brewing is undergoing rapid technological changes. This aspect of the problem has been covered in two reviews by Satyanarayana Rao and Narasimham[114,115].

During the above period over a hundred papers have been published. The review articles published relate to: Proteins from micro-algae[116]; pectinase in fruit and vegetable industry[117]; fats and oils from micro-organisms[118]; and microbial processes[119].

In conclusion, I record with gratitude the inspiring guidance and support that all of us received under Dr V. Subrahmanyan's leadership. He was a pioneer and a prophet of science. It is for the younger generation of scientists, now working in the Discipline of Microbiology at C.F.T.R.I., Mysore to further Dr Subrahmanyan's vision, by dedicated and motivated work.

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Food Toxins

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Living systems whether a plant, microbe or an animal have the potential to synthesise toxic compounds that can prove inimical to other living forms. While these may be construed as a mechanism for their survival, they have posed serious problems in human and animal nutrition. Since historical times, man has evolved a code of practice spelling out what to eat and how to process it to eat. The traditional methods of cultivation, harvesting and processing so evolved are the result of age long observations and development of a methodology to provide harmless food to mankind. In recent years to meet the growing demands of the increasing population, foodgrains are being grown and harvested in different types of soils under different climatic conditions using a variety of fertilisers. Further, quite a few unconventional agricultural items are being introduced into our dietary as foods, with a pious view to cover the deficits. Although, all these approaches have helped to meet the challenge of food shortage, they have created fresh public health problems caused by (*i*) inherent toxic substances of plant food materials particularly among unconventional food items (*ii*) toxic inorganic or organic compounds picked up from the soils or the environment and retained in the grains and (*iii*) microbial growth during storage leading to the formation of toxic compounds. Although traditional processing methods can minimise the hazards of such toxic compounds, the tendency to adopt simpler methods of processing to economise on fuel consumption or to store the food in bulk to feed the expanding urban population and to keep reserves for the lean years have created certain new problems. In this context, it is pertinent to examine these problems and their solutions in depth and indicate the future course of action.

Food toxins can be examined under two broad categories namely, inherent or natural toxins and acquired toxins.

Inherent or Natural Toxins

Under this category are included those compounds that are normally synthesised and deposited in the edible portions of the plants. The earliest indication of the presence of toxic substances was in some of the inedible legumes which were believed to contain substances referred to as "toxalbumins"[1]. Early nutritionists were aware that even edible legumes could provoke deleterious reactions unless they are properly prepared. Included among such deleterious compounds are inhibitors of trypsin and amylases, haemagglutinins, goitrogenic factors, cyanogenetic glucosides, latherogens, etc. Of all these, trypsin inhibitors have been studied in great detail.

(*a*) *Trypsin inhibitor:* Osborne and Mendel[2] are generally credited with having first observed that cooking of the soybeans for several hours considerably improved its nutritive value. Reports of Bowman[3], Sohonie and Ambe[4] and Liener[5] showed that in about 24 species of legumes, improvement of the nutritive value could be observed after moist heating. With the isolation and purification of the trypsin inhibitor by Kunitz[6], the nutritionists in the early years believed that the improvement in the nutritive value caused by heating was due to the inactivation of the trypsin inhibitor. Subsequent studies however did not support this view[7]. Germinated soybeans[8] and other legumes[9] were equal in their nutritive value to the heat treated legumes although the trypsin inhibitor content increased during germination. Since the inhibitor activity of the compound was evident even on diets containing enzyme digests of the proteins, inhibition of proteolysis by the trypsin inhibitor as the cause of growth retardation was ruled out[7, 10]. Since the trypsin inhibitor is found to be antifibrinolytic or antithrombinogenic or antiproteolytic or a promoter of conversion of methionine to cystine, it is argued that trypsin inhibitor has many modes of action, manifesting ultimately in growth retardation[11].

(*b*) *Haemagglutinins:* Jaffe[12] finding that enzyme digest of casein could not overcome growth retardation effect of *Phaseolus lunatus*, concluded that the principle involved is not the trypsin inhibitor, but a substance which can agglutinate the red blood cells from various species of animals. Solgarkar and Sohonie[13] recorded a definite inhibition of growth in the case of rats fed a casein diet along with field bean haemagglutinin. Jaffe[14] is of the opinion that the action of haemagglutinins is to combine with the cells lining the intestinal wall and thus interfere with the intestinal absorption of nutrients.

It would appear logical to suspect the haemagglutinins as being responsible at least in part for the toxic manifestations observed in human subjects ingesting certain raw legumes. Solgarkar and Sohonie[13] have identified haemagglutinin A and B and demonstrated that haemagglutinin B is antitryptic but A is not. In a survey carried out by Huprikar and Sohonie[15] 14 pulses consumed in India were found to exhibit haemagglutinin activity. Liener[16] considered that 50 per cent of the growth depressing action of soybeans could be attributed to the haemagglutinin.

(c) *Amylase inhibitor:* Most beans also contain active amylase inhibitors[17], though no growth depressing action was detected by Jaffe[18]. When food intake is restricted, some antinutritional action could be expected of this compound as it has a strong *in vitro* action on pancreatic amylase.

Since in all these cases heat treatment of the material improves their nutritive value, it may be concluded that all the toxic factors are destroyed by moist heat. Soaking prior to pressure cooking in an autoclave is advisable to ensure complete destruction of the compounds. Dry heating or inadequate cooking are ineffective in destroying them.

(d) *Lathyrogens:* Lathyrism, a disease caused by lathyrogens has been frequently observed in the Mediterranean countries, India and some parts of South America. It has been attributed to the food use of legumes of the species *Lathyrus sativus*, *L. odoratus*, *L. latifolius* and *Vicia sativa*. In regions where irrigation facilities are limited, *Lathyrus* species are invariably grown. All these are known to produce non-protein toxic amino compounds. Depending on the target organ the toxic compounds of *Lathyrus* are classified into two groups namely osteolathyrogen and neurolathyrogens. The response of different species of animals to these compounds is again highly variable[19]. The active principle isolated from *Lathyrus odoratus* is identified as β-aminopropionitrile while *L. sativus* contains either L-2,4-diamino butyric acid or β-oxalyl β-diamino propionic acid. In some parts of Rajasthan and Gujarat, paralysis as well as skeletal deformities in the population have been noticed as a sequel to the consumption of pulses of *Lathyrus* species. Nagarajan[20] reviewed the methods available for eliminating these toxic compounds so that the incriminated legumes can be rendered safe for human consumption. Although, restricting the cultivation of such toxic legumes is the correct approach, some practical difficulties and some resistance among the farmers have been encountered. Dilution of the seeds by wheat or barley to reduce the effective levels of intake to 30 per cent of the total diet has been suggested. The consumers need be educated for this purpose; this is not easily achieved. Acton[21] made the important observations that feeding ducks on the seeds of *Lathyrus sativus* caused paralysis and death in their colony; but feeding pulses after steeping in water for 24 hours and draining out the water, birds thrived very well. This has been improvised to process the legume by steeping the seeds in a large volume of hot water for an hour when nearly 90 per cent of the toxin is leached out. To prevent the losses of B complex vitamins and other nutrients in this process, parboiling of the seeds is recommended where the toxic amino acid was removed in the steam condensate.

Thus, it is evident that a large number of toxic factors are inherent in food materials. But the hazards of such compounds have been at least partially eliminated by fairly simple processing. At home scale level perhaps these methods may be scrupulously followed. In bulk processing, with emphasis of fuel economy, the tendency to minimise heat processing may crop up. This has to be avoided to provide safe food to the consumer. Any modification in heat processing should be accepted only after its efficacy to destroy toxic substances is firmly established. Similarly when unconventional food items are introduced, their evaluation for safety must be made obligatory.

Acquired Toxic Factors

These factors will be discussed under two broad categories namely those that are formed by bacterial, and fungal growth, during handling and storage of food materials. Insecticidal or pesticidal residues and metal contaminants are not covered in this review.

(a) *Bacterial toxins:* Bacterial growth and associated toxin formation is a logical sequence of unhygienic handling of raw or processed foods having high moisture content. In the early days of development of food microbiology, microbial load on any food material was considered to be an index of hygienic quality as well as of the shelf-life of the product. In recent years, however, the concept has been enlarged to include the presence of toxins also as a measure of hygienic quality. Toxigenic potential of staphylococci was known as early as 1880. Pathological conditions in man and animals caused by *Clostridium perfringens* have been described in 1892. Botulism caused a mortality rate of 30 per cent in Europe between the middle of nineteenth century and the beginning of the twentieth century. Around 1870 the disease came to be known as botulism because of the frequent implication of sausages. In 1895 the organism responsible for it was isolated[22]. Subsequently the occurrence of botulism is very rare. In India, very few incidents of botulin poisoning have been reported. Of greater frequency, however, are the enterotoxins elaborated by staphylococci, *Clostridium perfringens* and *Bacillus cereus.*

(*i*) *Staphylococci intoxications:* Staphylococci are ubiquitously distributed in man's environment and are found in varying numbers in air and dust as well as in water, milk, food, faeces and sewage[23]. The primary habitat of these organisms being, nasopharynx and skin of man and animals, it is found in processed foods and milk manually handled at various stages. Staphylococci grow well in the presence of high concentrations of sodium chloride upto 10 per cent in the medium. Kamath and Sulebele[24] and Dwarakanath and Srikanta[25] have recorded heavy loads of staphylococci in some common processed foods. Among them, milk and milk products are the major carriers of staphylococci. Most species of staphylococci can produce enterotoxins under optimal conditions of growth. Under the conditions prevailing in India, staphylococcal growth leading to enterotoxin formation can be expected in milk and milk products and several non-acid foods that are manually handled for serving. At the Central Food Technological Research Institute, Mysore, growth pattern of staphylococcus on cooked rice was followed. An increase of 10^5 cells per gram was recorded during storage over a period of 24 hr at room temperature. Since storing excess cooked rice overnight at room temperature is invariably practised in many homes, it is obvious that chances exist for staphylococcal growth and toxin formation in common items of low acid foods. In the absence of a systematic reporting system in our hospitals, it is difficult to assess the degree of severity of staphylococcus food poisoning in the community. However, there are indications of its high prevalence in the country.

(*ii*) *Clostridium perfringens/Bacillus cereus:* Since these two are spore forming organisms widely distributed in nature, they are invariably and exclusively present in foods cooked under atmospheric pressure. Their load will entirely depend on the initial bacteriological quality of the material. Data collected at the Central Food Technological Research Institute, Mysore, on the growth of *Bacillus cereus* on cooked rice during storage shows a 100 fold increase in 4 hr. Similar data are not available for *Clostridium perfringens* but there are several epidemiological and laboratory studies to prove that *C. perfringens* was responsible for enteritis in the community[26-28]. Hauge[29] has published information involving *B. cereus* in cases of food poisoning. If we recognise the fact that very few houses use refrigerators to store the food and that storing the unused cooked food at room temperature for consumption the next day is common, the incidence of enterotoxins could be expected to be quite high. This could be a serious public health problem. Selection of materials of food on bacteriological quality, practising hygienic methods in handling and storage of cooked foods are the two feasible approaches to protect the consumers from the hazards of such toxins.

(*b*) *Mycotoxins:* Toxins produced by fungi are collectively termed mycotoxins and the diseases caused by them, mycotoxicoses. The omnipresence of mold spores in food, soil, air and water and the ability of of these spores to germinate and grow at moisture levels ranging from 10-18 per cent on several food materials constitute two important factors for high incidence of mycotoxins in food materials. Knowledge on the toxic hazards of moldy foods or feeds is more than a century old. Over a hundred years ago, the toxic components of ergot responsible for ergot disease were identified as alkaloids. Another dramatic disease outbreak attributed to mold contaminated cereal grains occurred in certain areas of Russia in 1942–47. The disease called alimentary toxic aleukia was caused by the consumption of millets that had overwintered in the field. Although Russian scientists published numerous papers dealing with alimentary toxic aleukia and identification of the responsible fungi, the implications of these fungi as health risks went unheeded for quite sometime. The fervent concern for the presence of mycotoxins in foods assumed an alarming stature as an important public health problem only since the discovery of aflatoxin in 1961. Table 1 lists a few common contaminating fungi isolated from food materials and the toxins they produce during growth with the nature of their toxic manifestations in man or animals.

Two important aspects that came to light after the discovery of aflatoxin emphasised new dimensions to the mycotoxin problem. In the first place, aflatoxin was shown to be a very powerful carcinogen and secondly it is synthesised by many *A. flavus* strains, distributed all the world over, having the ability to form toxins under a wide range of conditions. Today aflatoxin contamination of foods is considered to be a serious public health problem and several regulatory measures have been introduced in almost all the countries at least to minimise human exposure to this toxin.

Among various mycotoxins known, toxic effects of aflatoxin and its mode of action have been extensively studied. The morphological and biochemical lesions caused by an acute dose of aflatoxin B_1 in animals occur almost exclusively in liver cells. According to Wogan[30], the initial and critical event of its action is where aflatoxin B_1 interferes with DNA transcription causing an impaired synthesis of DNA and DNA dependent RNA. The interaction with DNA does not appear to be a direct one but rather one involving an active form of aflatoxin B_1[31]. Swenson *et al*[32]. confirming this,

TABLE 1. TOXIGENIC FUNGI IN FOODS

Culture	Toxin identified	Toxic manifestations	
		Man	Animals
Aspergillus flavus *Aspergillus parasiticus*	Aflatoxins	?	Toxic hepatitis, carcinoma
Aspergillus ochraceus *Penicillium viridicatum* *P. cyclopium*	Ochratoxins	Not reported	Nephropathy
Fusarium roseum *F. graminiarium* *F. tricintum*	Zearalenone	Not reported	Sterility caused by malfunctioning of the ovary
F. sporotrichioides *F. tricinctum* *F. roseum F. poae*	Trichothecenes T_2 toxin	No reports	Growth depression and death; haemorrhage of the mucosal surface
P. citrinum *P. viridicatum* *P. expansum*	Citrinin	?	Nephrosis
Penicillium urticae *P. claviformis* *Aspergillus clavatus*	Patulin	No reports	Oedema and haemorrhage in lungs
Claviceps purpurea *C. fusiformis*	Ergot alkaloids	Very rare	Abortion; gangrene of extremities

found the formation of a 2, 3, epoxide aflatoxin B_1 in rat and human liver microsomes. Not much is known about the mode of action of other mycotoxins but there is general agreement on the hazards posed by them and on the need for restricting their consumption by man and animals.

(*i*) *Implications of mycotoxin contaminations:* Several epidemiological studies[33-35] implicate aflatoxin in serious liver diseases of the community particularly carcinoma of the liver. One of the direct implications of mycotoxin contamination of the food is damaged health of the community which in turn inflicts a national loss. Human loss can neither be measured in terms of money nor can be made up by any other means. In farm animals productivity in terms of meat or milk yield can be seriously impaired by ingesting contaminating grains. At the individual level, chronic ailment caused by consuming mycotoxin contaminated foods needs continuous medication, thereby draining out huge sums of money shattering the economy. In addition, individual productivity will come down impairing the national output. This may ultimately hit the export markets not only due to lowered quantity but also due to poor quality since the exported edible commodities are carefully screened for the safe levels of mycotoxins. Thus the economic implications of mycotoxins to any country are too severe to be ignored.

(*ii*) *Remedial measures to minimise the hazards of mycotoxins:* The basic approach to find a solution to this problem is to drastically reduce chances for the fungus to grow on harvested and stored commodities. Keeping the moisture level below the safe limit helps in minimising fungal growth. Majumder *et al.*[36] have given the safe moisture levels for different commodities stored at different relative humidities and temperatures. Food and Agricultural Organisation of the United Nations has also given through the document No. 90, broad guidelines for storing food materials. These may help in minimising fungal growth on food materials. Where drying to safe moisture levels can be achieved in a reasonable time, temporary protection to the commodities against fungal growth can be given by using fungicidal fumigants. The practicality of such an approach and its operation are described by Majumder *et al*[36]. But such treatment should be followed by air drying either under the sun or in shade to minimise physiological activity by bringing down the moisture level and to reduce fumigant residues in the grain.

Seggregation of infected materials is another effective method widely practised to reduce the mycotoxin content in the edible grain. Handpicking or electronic color sorting help to achieve this objective. But the practicality of this approach is limited to large size grains or oilseeds.

Chemical methods of decontamination have been worked out for aflatoxin contaminated materials. Parker and Melnick[37] demonstrated that refining removes any aflatoxin that may have been present in the crude oil. Shantha and Sreenivasamurthy[38] found that washing the crude oil with 10 per cent sodium chloride solution at 80°C for 30 minutes helped in removing 85 per cent of the toxin present in the oil. In a subsequent study these authors[39] found that exposure of the oil to sunlight degraded aflatoxin almost completely. Solvent extraction of oil to remove aflatoxin has been suggested. Goldblatt and Robertson[40,41] have proposed a mixture of acetone, hexane and water for this purpose. Gardner *et al.*[42] introduced a binary system of 90 per cent acetone and 10 per cent water for reducing aflatoxin content of contaminated peanut and cottonseed meals. Use of other solvent systems based on ethanol[43] and isopropanol[44] have also been suggested. Since each of these has some limitations, they are not yet commercialised.

Detoxification of aflatoxin contaminated foods or feeds offer promising means of increasing the safety and availability of food supplies. Hypocholrite[45], hydrogen peroxide[46], ozone[47] and ammonia[48] are used for this purpose. Detoxification by the use of hydrogen peroxide is put to commercial practice in India, while among other agents, some of them are adopted to detoxify at pilot plant level.

By systematic studies on partition of aflatoxin into expeller milled cake and oil from groundnut kernel[49] and state of aflatoxin in groundnut oil[50], Basappa and Sreenivasa Murthy have found that aflatoxin in groundnut oil could be successfully removed by adsorption on fuller's earth and centrifugation or filtration. Based on these results, they have developed special filter pads, which were successfully employed for removal of 90 per cent of aflatoxin present in groundnut oil using plate and frame filter press[51].

Projections for the Future

Thus, the foregoing review shows that even natural foodstuffs are likely to carry different types of toxic compounds which may prove to be highly hazardous to human or animal health. Several approaches have already been worked out to minimise the hazards. In the context of ever changing patterns of demands and supplies, traditional practices in agriculture and commerce are giving place to newer methodologies to improve efficiency and increase production and availability of food commodities. This has been the cause of fresh problems engulfing the entire community. This calls for continued vigilance on the problems that crop up and on the application of solutions worked out in the laboratories at the field level. Hence the need for constant rapport between the field worker and the scientists.

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Toxicity Profile of Some Commonly Encountered Food Colours

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The practice of adding colours to processed foodstuffs to make them attractive goes back to very ancient times. Thus, saffron, turmeric and vegetable dyes were used by our ancestors to make their food attractive. Some of the natural colours were also believed to possess certain medicinal properties.

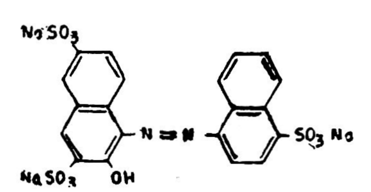
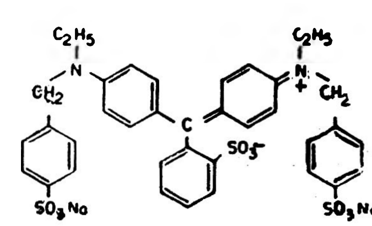
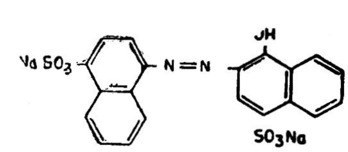
The colouring of food articles came to be adopted as an essential practice when food processing evolved into an organized industry in the beginning of this century. During processing of food, particularly vegetables and fruits their natural colour was found to be lost and artificial colouring became necessary to make them acceptable. Synthetic dyes began to attract the attention of food industry because they were considered superior to many of the vegetable dyes in tinctorial value, stability, uniformity and their availability in different shades.

Nearly 65 synthetic colours are known to be in use, the number varying from country to country, 33 in Denmark, 25 in United Kingdom, 22 in Japan and European community of Nations, 12 in the U.S.A., 10 in Canada, 5 in Chile, 3 in Soviet Union and none in Greece. The pattern of use of dyes has changed with the advancement of knowledge of their safety for human use.

SYNTHETIC FOOD COLOURS IN INDIA

In India 13 synthetic colours were allowed for use in foodstuffs under the purview of the Prevention of Food Adulteration Act 1954. Five colours were subsequently withdrawn in 1968 due to their toxic properties and three new colours were added to make the present list of eleven prescribed or permitted colours (Table 1). A number of non-permitted colours like auramine (yellow), blue VRS (blue), Congo Red, Sudan II and III (Red), malachite green (green), metanil yellow and orange II (yellow to orange) and rhodamine B (pink) are still used very commonly (Table 2) because of ready

TABLE 1. SYNTHETIC FOOD COLOURS PERMITTED IN INDIA

Amaranth	C. I. Food Red 9 (16185)	Monoazo	
Brilliant Blue	C. I. Food Blue 2 (42090)	Triaryl methane	
Carmoisine	C. I. Food Red 3 (14720)	Monoazo	

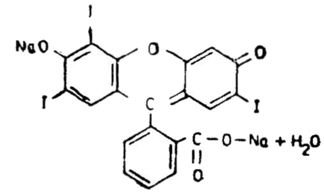
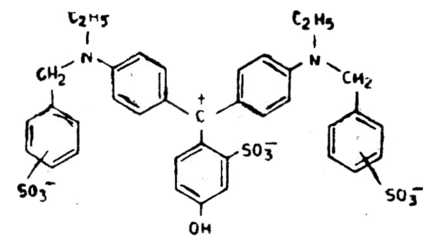
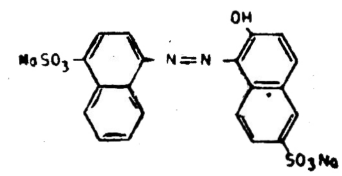
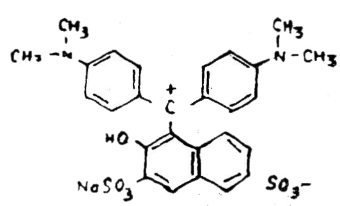
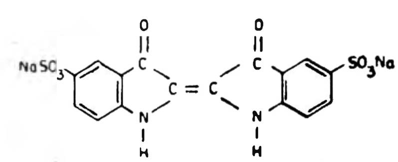
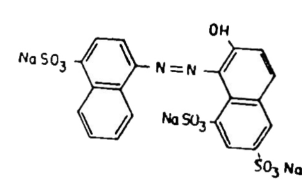
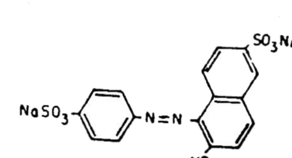
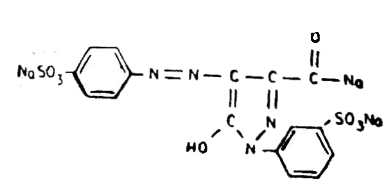
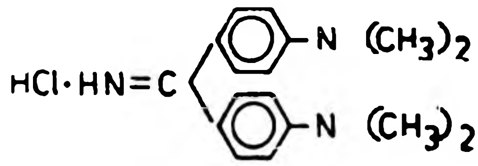
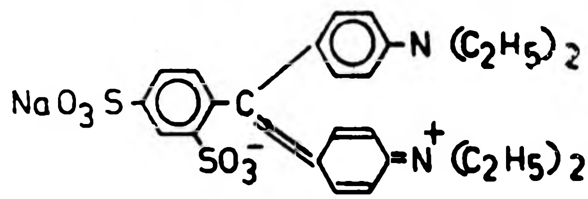
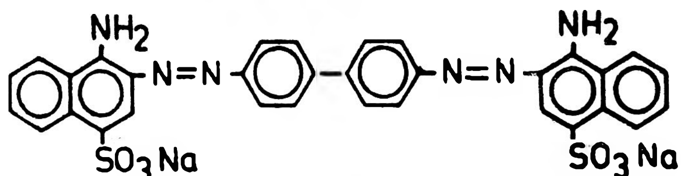
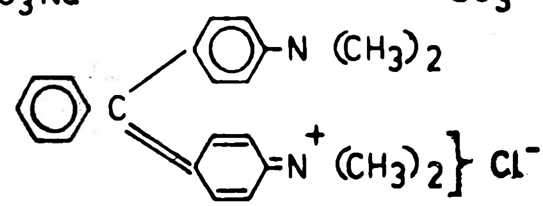
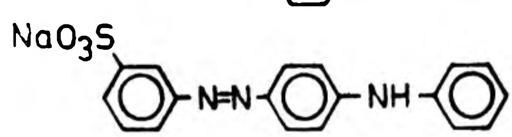
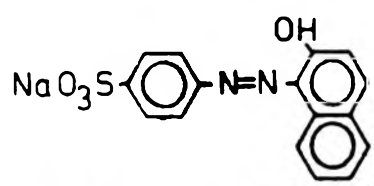
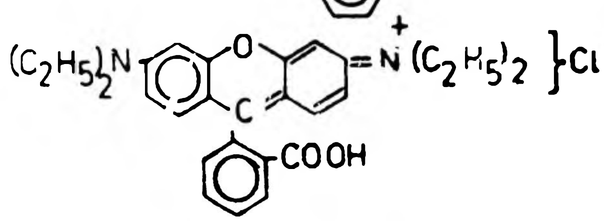
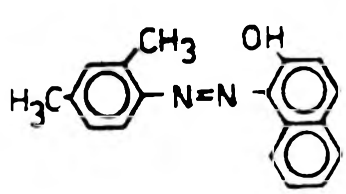
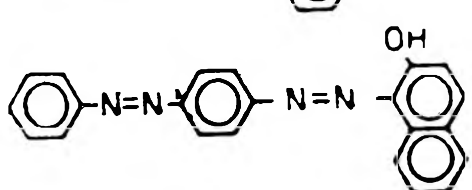
Erythrosine	C. I. Food Red 14 (45430)	Xanthene	
Fast Green F C F	C. I. Food Green 3 (42053)	Triaryl-methane	
Fast Red E	C. I. Acid Red 13 (16045)	Monoazo	
Green S (Wool Green BS)	C. I. Food Green 4 (44090)	Triaryl-methane	
Indigo Carmine	C. I. Food Blue 1 (73015)	Indigoid	
Poncean 4 R	C. I. Food Red 7 (16255)	Monoazo	
Sunset Yellow F C F	C. I. Food Yellow 3 (15985)	Monoazo	
Tartrazine	C. I. Food Yellow 4 (19140)	Pyrazolone	

TABLE 2. COMMONLY ENCOUNTERED NON-PERMITTED COLOURS

Common name	C.I. Name & Number	Chemical class	Structure
Auramine	C.I. Basic Yellow 2 (41000)	Diaryl-methane	
Blue V R S	C.I. Food Blue 3 (42045)	Triaryl-methane	
Congo Red	C.I. Direct Red 28 (22120)	Diazo	
Malachite Green	C.I. Basic Green 4 (42000)	Triaryl-methane	
Metanil Yellow	C.I. Acid yellow 36 (13065)	Monoazo	
Orange II	C.I, Acid Orange 7 (15510)	Monoazo	
Rhodamine B	C.I. Food Red 15 (45170)	Xanthene	
Sudan II	C.I. Solvent Orange 7 (12140)	Monoazo	
Sudan III	C.I. Solvent Red 23 (26100)	Diazo	

availability and relative cheapness constituting a serious health hazard. Enforcement of regulations to check adulteration has not been very effective and as such colouring of commonly edible foodstuffs with non-permitted colours occupies a top place in the list of social evils in our country.

Extent of Adulteration

A survey to find out the extent of adulteration and to identify typical adulterants was undertaken at this Research Centre by Khanna *et al*[1]. Data on four lakh samples of foodstuffs drawn from Uttar Pradesh (India) during a period of 13 years was computed and analysed. The study revealed that, on an average, the extent of adulteration in day-to-day eatables was around 25 per cent. Maximum adulteration of 40 per cent was noted in non-dairy eatables, followed by 33 per cent in milk, 15-16 per cent in edible oils, ghee, butter and dairy products, 13 per cent in cereals and pulses, 4 per cent in hydrogenated vegetable oils and 19 per cent in the remaining samples. Non-permitted colours constituted a major group of adulterants and were indiscriminately used in sweets, beverages, confectionery, spices and condiments, pulses[2] and occasionally even in oils.[3]

A study undertaken by Indian Toxicological Research Centre (ITRC) revealed that 70 per cent coloured samples examined contained non-permitted colours. Six commonly used colours out of the 18 non-permitted dyes detected in the foodstuffs were placed in the following order on the basis of their frequency of use: metanil yellow, 29 per cent; orange II, 11 per cent; auramine, 9 per cent; rhodamine, 13 per cent; Blue VRS, 6 per cent and malachite green, 4 per cent. The results are summarised in Tables 3 and 4.

TOXICITY STUDIES ON NON-PERMITTED COLOURS

In view of the widely prevalent practice of adulteration of foodstuffs which goes unchecked, it was of interest to review the toxicity profiles of the non-permitted dyes. Since the published information on metanil yellow was fragmentary, detailed investigations were conducted on short term toxicity of this dye.

Metanil Yellow

Preliminary experiments have shown that a single intratesticular injection of metanil yellow (10 mg/kg body weight) in rats produced irreversible degeneration of the seminiferous tubules. The interstitium appeared to regenerate after initial atrophy[4]. Oral administration of 3 per cent of this dye daily for 90 days, produced degenerative changes in the gametogenic elements of guinea pig testes[5]. Testicular lesion were also observed in mice after intraperitoneal administration of metanil yellow (25 mg/kg body weight) for 60 days[6]. The epithelium had several binucleate, trinucleate and tetranucleate pycnotic spermatocytes. At 60 days, necrosis was severe; the formation of multinucleate giant cells and vacuolation were common. Testicular degeneration and subsequent arrest of spermatogenesis

TABLE 3. FREQUENCY OF INDIVIDUAL COLOURS[2]

Colour	Total number	% within the group (permitted or non-permitted)	% of total colours (permitted and non-permitted)
Permitted			
Tartrazine	2043	38.5	12.2
Sunset Yellow	1812	34.3	10.8
Carmoisine	78ç	14.8	4.7
Ponceau 4R	300	5.7	1.8
Amaranth	272	5.1	1.6
Erythrosine	71	1.3	0.4
Indigo Carmine	13	..	..
Fast Red E	2	..	..
Non-permitted			
Metanil Yellow	4883	42.3	28.9
Orange II	1903	16.6	11.4
Auramine	1581	13.8	9.5
Rhodamine B	1253	10.9	7.5
Blue VRS	1037	9.1	6.2
Malachite Green	586	5.1	3.5
Others*	263	2.5	1.5

*Colours such as red 6B, sudan II, sudan III, congo red, brilliant, crocein scarlet, methyl violet, butter yellow, acid magenta, fluorescein, naphthol yellow, nigrosine, onion yellow and inorganic pigments like lead chromate, copper sulphate, iron oxide, etc.

TABLE 4. COLOURS IN INDIVIDUAL EATABLES[2]

Eatables	Total number	Permitted colours (nos)	Non-permitted colours (nos.)	Adulteration (%)
Sugar confectionery	1903	835	1068	56
Soft drinks	755	729	26	3
Ice candy	462	334	128	28
General confectionery	190	74	116	61
Tobacco (*surti*)	160	6	154	96
Country wine	124	116	8	6*
Chilli powder	81	..	81	100
Tomato ketchup/sauce	73	66	7	9
Turmeric	64	..	64	100
Heeng	60	2	58	97
Pan ka Masala	32	19	13	41
Saffron	15	2	13	87
Sago papar	14	1	13	93
Tea	5	5	..	..*

*These figures should be regarded as 100% adulteration because addition of colour (even permitted) in these preparations is totally prohibited.

was again confirmed by histopathological and biochemical parameters in sub-acute feeding experiments in rats[7]. Cytological studies revealed several chromosomal changes. Stickiness and clumping of chromosomes was seen invariably. Chromatin bridges with single and double strands were also noted after 15 and 30 days[6]. More recent work of Vaidya and Godbole[8] has shown that the dye has the ability to break human leucocyte chromosomes *in vitro*, causing chromatid and isochromatid breaks only. The number of breaks per cell as well as the percentage of cells affected was found to increase with increasing concentration of the dye.

The effect of metanil yellow on the haemopoietic system of rat fed 0.1, 0.5 and 3.0 per cent levels of the dye mixed in the routine laboratory diet, daily for 90 days, was studied by Mehrotra *et al*[9]. A significant decrease in neutrophils and eosinophils and an increase in lymphocytes and monocytes was observed at 3.0 per cent level of the dye. Plasma fibrinogen showed only an insignificant decrease but the coagulation time was prolonged. Raza *et al.*[10] found that oral feeding of metanil yellow resulted in a decreased gastric mucin content in rats. However, there was no ulceration and change in the total volume of gastric juice. Srivastava *et al.*[11], while studying the *in vitro* biotransformation employing liver slices, have shown that the dye splits into two metabolites, namely, metanilic acid and p-aminodiphenylamine. The latter metabolite has the ability to bind to proteins, especially through the acid amino acids, aspartic and glutamic acids[12]. Raza *et al.*[13] have shown that metanil yellow and its metabolite p-aminodiphenylamine inhibit *in vitro* utilization of glucose by both isolated rat seminiferous tubules and everted gut sacs. Metanilic acid, the other azo linkage breakdown product, was found to be safe. The rate of absorption of metanil yellow and its above two metabolites by the everted gut sacs of rat has also been examined[13]. In case of metanil yellow it was observed that the absorption is more at ileal region than at duodenal region. The absorption of p-aminodiphenylamine presumably, due to its lipophilic nature, was more efficient than metanil yellow. The binding ability of metanil yellow and its metabolite p-aminodiphenylamine to serum and tissue proteins has also been studied[14]. Serum albumin was found to possess high affinity for metanil yellow whereas globulin showed high affinity towards p-aminodiphenylamine. A rough estinate of the annual intake of metanil yellow and its highly toxic metabolite para amino diphenylamine is given in Table 5.

TABLE 5. APPROXIMATE CONSUMPTION OF METANIL YELLOW

Coloured items usually consumed	Metanil yellow intake/ head/yr (g)
Jalebi	0.79
Sheermal (Tanduri bread one surface coloured)	0.67
Pulao	0.96
Besan Namkin	1.05
Bundi Laddu	0.36
Turmeric Powder	0.07
Total	3.90
Expressed as intake of p-amino diphenylamine	1.91

Orange II

Oral feeding of the dye at 0.5 to 5.0 per cent dietary levels to rats daily for 90 days produced significant increase in liver and spleen weights. Retarded growth and low haemoglobin and haematocrit values were observed at 1.0, 2.0, and 5.0 per cent levels of the dye[15]. The feeding of orange II at 1.0 and 5.0 per cent levels to male and female rats for 90 days resulted in marked pathological lesions in kidney and spleen[16]. In chronic studies rats receiving 0.75-1.5 per cent of this dye for 65 weeks showed 100 per cent mortality[17]. Singh and Khanna[18] have shown that a single intratesticular injection of orange II at a dose level of 1 mg/100 g body weight produced degenerative changes in the seminiferous tubules of rat testis. On oral feeding for 45 weeks the dye produced hepatic lesions in the form of focal necrosis and proliferation of bile duct[19]. There occurred a reduction in total RBC count and haemoglobin content. The general blood picture and absolute values were suggestive of normocytic hypochromic anaemia. Presence of Heinz bodies in the red blood cells was prominent. Most of the body organs, viz., kidney, heart, lung, stomach and intestine presented normal appearance.

Auramine

Statistical observations recorded by Case and Pearson[20] reveal that the number of deaths due to bladder tumour in workers engaged in the manufacture of auramine in Britain during 1910 to 1952 was significantly more than the incidence of deaths due to bladder tumour in the general population. Laboratory experiments conducted later showed growth inhibition, hepatic dysfunction, marked damage to kidney tubules and increased mortality rate in rats[21] and hypotensive effects in rabbits, dogs and cats[22]. Subcutaneous fibrosarcoma, hepatoma, intestinal carcinoma, kidney adenocarcinoma and transitional cell carcinoma of the urinary bladder were recorded after long-term administration in rats[23]. Liver tumours were recorded in 92 per cent rats when fed on a diet containing 0.1 per cent auramine over a period of 87 weeks[24].

Rhodamine B

Oral feeding of this dye at 1 per cent level for 90 days caused retardation of growth and liver lesions in rats[25,26]. The dye is reported to cause haemolysis[27]. Prolonged feeding produced degenerative changes in liver and kidney parenchyma[28]. Repeated subcutaneous injections resulted in the development of sarcoma within 15 months in 50 per cent of the surviving animals[29,30]. The dye at a concentration of 0.5 per cent caused increased mutation rate in *Escherichia coli*[31].

Blue VRS

Growth retardation in male rats[32] and leukaemia in female mice[33] were reported after oral administration. Mannell and Grice[34] reported ulceration and abscess formation in rats at the site of repeated weekly subcutaneous injections which resulted in a few cases in the development of rhabdomyosarcomas. Repeated injections of 0.4 ml of 4 per cent aqueous solution of the dye into the posterior thigh muscles caused pleomorphic rhabdomyosarcomas[35]. Development of tumour was also recorded after the injection of the dye to male and female rats. The dye was presumed to be carcinogenic on the basis of animal experimets[36].

Malachite Green

Intravenous injection in rats of a 50 per cent lethal dose of this dye caused anoxia—like changes in the electrocardiogram. The ECG indicated bradycardia with atrioventricular block reaching complete atrioventricular dissociation[37]. Hypoxia could not be seen 7 hr post-injection presumably because rats can detoxify malachite green in the liver. Intramuscular and intraperitoneal administration of 20-25 per cent lethal dose of malachite green produced alopacia and lowered the fertility rate in female rats[38]. Cell degeneration and inhibition of capillary circulation in liver, spleen, kidney and heart have also been reported[28]. Malachite green when given with drinking water for 6 months produced sterility and abnormalities in skin, eyes, lungs and bones and teratogenic effects upto the 12th untreated generation of rats. The dye also led to increased incidence of tumours in lungs, breast and ovary[39,40]. Male and female rats fed 0.3 and 3.0 per cent of this colour died within one week. Significant decrease in food intake and growth rate and an increase in relative liver weight was observed in female rats given 0.3 per cent of this dye for 64 weeks[41]. On the basis of the above experimental observations, the Joint FAO/WHO Expert Committee on Food Additives (1965) agreed that there is some evidence of carcinogenic effects of this dye.

Congo Red

Vrbovsky and Selecky[22] observed that a dose of1.5 mg/kg body weight of this dye produced a hypotensive effect in rabbits, dogs and cats. Dogs and cats were less sensitive. Though there was no correlation between the production of malformations and maternal weights, the dye resulted in the development of hydrocephalus, hydronephrosis and ocular defects in the foetus after a single intraperitoneal injection of 14 or 20 mg/100 g body weight on the 8th day of pregnancy[42].

Sudan II

Not much work has been done on this colour. In one report the dye when fed to rats at 1-20 per cent levels showed cumulative toxicity and all the animals were reported to have died within 3-4 months[43].

Sudan III

The dye administered to rats through oral or intraperitoneal routes produced lesions in kidney[44] and liver[45,46]. At dose levels of 0.25-1.0 g/kg body weight it resulted in hyaline, fatty and hydropic changes at the junction of the outer and middle thirds of liver lobules within 48 hr. All the lobules were involved within 72 hr. Patches of infraction resulted in the subsequent development of liver cirrhosis[46]. Among various laboratory animals, rabbit liver was found to be highly susceptible to the toxic response of Sudan dyes.

Impurities in Food Colours

There has been a growing concern in the recent years over the presence of impurities in food colours. In 1974, the Joint FAO/WHO Expert Committee on Food Additives recommended that increased attention be given to reduce trace element impurities in food colours and that particular attention be paid to insuring that the free amine content of colours is kept below 0.02 per cent. The use of sophisticated analytical techniques such as high pressure liquid chromatography has resulted in the identification of impurities like α-and β-naphthylamines in certain azo food colours. These contaminants arise most likely from non-sulphonated amine moieties which may occur as impurities in the starting raw materials[47]. In this regard, the EEC countries specifically require that a food colour should not contain more than 0.01 per cent free aromatic amines, no more than 0.5 per cent intermediate synthetic products other than free amines and above all no detectable amounts of β-naphthylamine. benzidine or 4-amino biphenyl or their derivatives. Also, a food colour should contain not more than 1-3 ppm arsenic, 20 ppm chromium, 10 ppm each of copper and lead. A recent study by Khanna *et al.*[48] revealed high levels of trace metals in a number of food colours used in India. It has been felt that restrictions should be imposed on metal contaminants such as cadmium, cobalt, manganese, nickel and zinc. At the same time, the maximum allowable concentration (MAC) of these metals permissible in food colour, if laid, will encourage the industry to select good quality raw materials, processing equipments and containers and ultimately eliminate the inherent additional health hazards to consumers.

Safe Food Colours

From the foregoing discussion, it is apparent that some of the commonly encountered non-permitted colours are highly toxic. Furthermore, some recent reports have cast doubts about the complete harmlessness of even permitted colours like Amaranth and Ponceau 4R. Though both these colours are still retained in the Indian permitted list, their maximum allowable concentration in eatables has been recommended to be slashed down to 15 ppm from 200 ppm. The toxicity profile of a few other permitted colours such as erythrosine, fast green FCF, indigo carmine and tartrazine has been discussed earlier[49].

Because of the conflicting toxicity reports on the permitted colours and the indiscriminate use of non-permitted colours, the Central Committee for Food Standards, India have expressed great concern in their recent meetings. The Council of Health Ministers and expert members, arriving at broad concensus, gave due consideration to the suggestion of imposing a total ban on the use of synthetic coal-tar dyes in all foodstuffs. The need of the hour seems to be to initiate a thorough rechecking of the toxicity of all food colours and establish, once for all, their safety or otherwise under Indian dietary, climatic and socio-economic conditions. Efforts should also be made to encourage the discovery of safe colours either by synthesis or extraction from natural sources. Focus should be on the development of processes for new viable and cheaper natural sources and extraction methods to produce and make available sufficient quantities of natural pigments as substitutes to synthetic coal-tar dyes.

Natural pigments (Table 6) did not get encouraging response due to some of the inherent drawbacks such as their stability and tinctoreal validity range but these disadvantages are obviated to a large extent by their relative freedom from toxicity.

A considerable amount of work on the isolation, synthesis and characterization of natural pigments is being done in India. Among the CSIR group of laboratories, National Chemical Laboratory, Pune, under the leadership of Drs. K. Venkataraman and A. V. Rama Rao, has made significant contributions. Isolation of new pigments from *Artocarpus heterophyllus*, *Gardenia lucida* and lac larvae and stick lac, namely, the yellow pigment Erythrolaccin and laccaic acid are worth mentioning. Similarly work in this direction has also been contributed by Central Food Technological Research Institute, Mysore and Central Leather Research Institute, Madras. Exhaustive work on plant pigments has come from the Chemistry Department, Delhi University under the guidance of the late Prof. T. R. Seshadri. Research on similar lines is being

TABLE 6. NATURAL FOOD COLOURS PERMITED IN INDIA

Common name	C. I. Name & number	Colour
Annatto	C. I. Natural Orange 4 (75120)	Yellow to peach
β-apo-8′-carotenal	C. I. 40820	Light to dark orange
β-apo-8′-carotenal ethyl or methyl ester	C. I. 40825	Yellow to orange
Canthaxanthin	C. I. 40850	Pink to red
Caramel	—	Brown
β-Carotene	C. I. Natural Yellow 26 (75130)	Yellow to orange
Chlorophyll	C. I. Natural Green 3 (75810)	Green
Curcumin (Turmeric)	C. I. Natural Yellow 3 (75300)	Yellow to orange
Ratanjot	C. I. Natural Red 20 (75520/75530)	Red to purple
Riboflavin (Lactoflavin)	—	Yellow
Saffron	C. I. Natural Yellow 6 (75100)	Yellow to orange

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carried out at Bombay University by Prof. A. B. Kulkarni and his associates and at Chemistry Departments of Allahabad, Aligarh and Karnataka Universities. The work of Prof. S. Sankara Subramanian at the Chemistry Department of Jawaharlal Institute of Postgraduate Medical Education and Research, Pondicherry and that of Dr. T. R. Govindachari's group at CIBA Research Centre, Bombay is most outstanding in the field of flavanoids. The Chemical and biochemical aspects of carotenoids have been ably handled by Prof. H. R. Cama and his associates at Indian Institute of Science, Bangalore. Besides these, pigment isolation from *Acacia catechu* or *Acacia arabica*, i.e. catechin which is being consumed in the crude form of *Katha* by millions of betel chewers for centuries needs active consideration. Catechin which gives brown colour in aqueous extracts and bright pink in alcoholic solutions could be made use of in soft drinks and alcoholic beverages. Similarly, pigments from fruits of *Tarminalia chebula* (Hindi: *harr*), *Indigofera tinctoria*, *I. sumatrana* (Hindi: *neel*); tea leaves and coffee powder; sugarcane waste, beet sugar extracted pulp; skin of red fruited tamarind; various leaves, flowers, fruits, vegetable and fodder plants could lead to attractive sources of natural edible colours. Pigments may be derived from edible mushrooms, insects, flamingoes, exotic birds, crustacea and fishes. Despite all these developments, not much attention has been paid to assess the suitability of these pigments as substitutes to existing food colours. There is thus an urgent need for critical studies for evolving suitable and acceptable natural pigments which could be adopted as safe food colourants after obtaining clearance from toxicologists.

Non-absorbable Polymer Colours

A second line of action in this regard has been the recent developmet of a new class of non-absorbable polymeric food dyes[50-52]. Polymeric dyes of controlled polymerization and of a selective size range and high purity are currently being developed as a commercial product at Dynapol Corporation, Palo Alto, California, U.S.A. In principle, the toxicity risk to man can be practically reduced if the dye is prevented from being absorbed in the intestinal tract. Claims have been made that these non-absorbable dyes offer a potential for increased margin of safety together with colour and functional properties in food equal to, and in many instances, superior to the presently permitted food dyes. Some toxicity studies have been completed and others are under progress. A petition seeking approval of the polymeric dyes for food use is shortly to be submitted to the Food and Drug Administration, U.S.A. Upon approval, it is hoped that non-absorbable polymeric colourants may prove a more viable alternative to presently used synthetic dyes.

Conclusion

The social evil of adding non-permitted colours must be fought at all levels. There should be a more vigilant enforcement of Food Adulteration Act by different state authorities. Scientists can only highlight the problem based on their investigations. Social workers and Consumer Protection Societies must use mass media to bring out the social implications of food adulteration of which addition of non-permitted and unsafe colours is only a small fraction.

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Sensory Evaluation in Quality Control of Foods

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The Central Food Technological Research Institute came into existence in 1950 under the leadership of Dr V. Subrahmanyan and gradually eleven commodity oriented divisions were established for gaining basic information as also processing data. When all these divisions started their work, product development gained more importance and along with it the necessity for quality control of raw materials, intermediate and final products. Initially a small group started functioning on this aspect in the Division of Biochemistry. Later the other Disciplines specialising in particular commodities took over the detailed work.

Quality control acquired new dimensions in the system of Research and Development with the Council of Scientific and Industrial Research giving a new orientation, in tune with the changing needs of the country in 1964. The new policy of the Council of Scientific and Industrial Research laid more stress on commercial utilization of technologies developed in its laboratories. As a consequence of this policy the incorporation of consumer requirements as an important quality parameter into product development became a necessity.

Any food must give the consumer satisfaction and pleasure if it has to be accepted and become part of his eating habits. This acceptance naturally depends primarily on those qualities he can readily perceive and experience. These are the colour and appearance, taste, texture and aroma of foods which are the sensory responses of the consumer to the food. For measurement of the sensory responses in the form of estimates of individual dimensions of overall quality, we have to rely on human panels. Though these attributes are responses to the physico-chemical characteristics of the food materials, their measurement is complicated because of the variety of compounds and structural features and their interactions which are many. Besides appreciation of individual attributes, their relation to overall quality is related to experience of individuals and sections of population and also socio-economic factors. Even empirical instrumental methods are not available which integrate the measures of all these stimuli that correlate with the sensory estimation of the individual attributes and much less with the overall quality judgement for acceptance. Since food is for eating and not mere mention, it is appropriate it passes the acceptance test. However, since each variation of a product or a formulation could be tested at the consumer level, it became necessary to standardise conditions of testing with selected and trained panel under optimal conditions. The reasoning is that if by sensory testing a product will be approved by such a critical panel, the consumer who is generally less critical or sees it as a whole and not analytically will also approve the product. If such a product fails in the market it cannot be due to deficiencies in sensory attributes but due to other marketing parameters.

Wine tasting, tea tasting and to some extent cheese tasting were known for a long time as specialised skills. Sensory tests came into being in food processing industries about the end of 19th century in the form of routine examinations carried out by a few experienced or top management people at the production centres. This was soon proved inadequate as a large number of products produced, after being accepted by the experts, were rejected by the general consumer and the stocks piled up in the market. It was only after 1950 when the bias factors affecting the human judgement in the evaluations by few came to be recognised, the development of methodology to overcome this difficulty started, that this particular branch of Science, evaluations of the quality of food, gathered momentum. Large variations in the measuring instrument, the human being, required calibration through rigorous methods of selection and training; the scale of measurement needed modification as the sensory distance between any two consecutive points used as a scale was not always equal. Engineering parameters contributed to "between batch" variability as the size of operations increased. These variations made it mandatory on the part of the sensory analyst to use larger panels and adopt strict statistical planning and analysis in the testing methodology. Vast quantities of data result from the tests and thanks to the advent of desk-top and big computers, the analysis part was rapidly developed to accelerate the growth of sensory evaluation. The new methods of analysis not only study sensory evaluation data but also tackle the problem of their correlations with a number of physico-chemical data of the raw materials and final products.

These developments naturally interested the Scientists at this Institute, the premier institution dealing with food science and technology and impressed the management about the necessity of creating facilities and developing expertise in the field of sensory evaluation. Thus a small group started this work under the erstwhile Discipline of Spices and Flavour Technology during 1966. The laboratory facilities, scientifically planned and designed to enable the panelists to concentrate and give required judgements with least disturbance and conditions minimising possible bias were established in the course of the next few years. The unit was graduated to an independent group in July 1970.

The Discipline is currently geared to tackle different developmental tasks in collaboration with other disciplines, and if required by outside institutions as well as do research on methodology, formulate standards relating to code of practice on sensory evaluation of different food and beverages and impart training in the field of sensory evaluation.

Selection of raw materials, adaptation of processes to suit available raw materials, development of a product similar to a successful product in the market (import substitution and export promotion) or the development of a new product having the characteristics desired by the consumer, assisting in the packaging profile to suit a product and storage conditions, the performance of newly developed processing technologies-all require the use of sensory evaluation to assure that the consumer will accept the innovations produced by R & D work. The Discipline is fulfilling all these multifarious needs through participation in various R & D projects, which need the expertise in this field. For the various products developed by these R & D projects, the problem to be assessed is defined first, then the product profiles developed by interacting with project members and the methodology to suit the problem selected. Suitable panelists are trained for the evaluation of particular products and finally the evaluation report is drawn up with recommendations. Such evaluations of quality over the years have yielded useful information on a variety of problems at all stages of handling, processing and storage of foods and beverages.

Some particular cases where the decision on quality mainly depended on sensory evaluation and the Discipline took an active part are: effect of maturity at harvest, mode of transportation and the period of storage on the quality of apples; acceptable levels of fish flour and MPF in different dishes; acceptance trials of Balahar with children; effect of enrichment of a traditional savoury product, *chakli*, with different levels of protein enrichment on its sensory quality; development of flavour formulation for cola type beverages to replace a popular cola beverage which has an independent image of its own; pilot consumer evaluation of three types of cola beverages in the market; quality change to find optimum ageing of fruit wines; optimising formulation for convenience products like *Rasam* and *Sambar* mix; comparison of quality of pork, beef and mutton sausages; influence of different methods of hanging postures and conditioning on the quality of meat.

The Discipline has also kept in view the correlation of objective-subjective results and establishment of valid relations of the physico-chemical to the sensorily perceived parameters with a view to developing objective methods for the determination of sensory attributes of food which are difficult to determine subjectively such as pungency, texture etc. Highly significant correlations of sensory pungency to instrumentally isolated and estimated pungency stimuli has been established in the case of chillies, pepper and ginger.

Another important quality of spices is the aroma and it is necessary to distinguish excellence in aroma quality among genuine spice samples. This is done by aroma profiling technique.

The existing profiling technique has been optimized and made objective by training the panelists with the total aroma fractionated into simpler components. More recently, the versatile thin-layer chromatography technique has been adopted for this fractionation and recombination of selected components. By this it has been shown that it is possible to evaluate horticultural varieties of pepper and ginger.

In collaboration with Indian Standards Institution the Discipline has prepared several standards relating to code of practice and methodology in sensory evaluation. It is also geared to train personnel in the field of sensory evaluation.

With the recent developments in the field, using psychophysical laws for evaluation of sensory perceptions, the subject has taken a new turn. These methods are to be tested and adopted under the conditions existing here in the days to come. The sensory quality of foods and beverages is expected to demand greater attention in future in the economy of the country as the plan is for increase in production with expectations of export to the competitive international market. With the steady increase in urban and working population, processed foods and institutional cooking are bound to find their place in the eating habits of the people as a consequence of which sensory evaluation has to become more and more important.

The authors offer their respectful tribute to the foresight and all embracing interest of Prof. V. Subrahmanyan who made the development of this specialisation possible.

Some Contributions to Biochemistry in Relation to Food Science and Technology

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The Discipline of Biochemistry and Applied Nutrition is one of the foundation divisions of the Institute. The Discipline had its origin in the Biochemistry Department of the Indian Institute of Science, Bangalore headed by the late Dr V. Subrahmanyan, and provided the necessary nuclei of talent for the development of several activities of other research disciplines of the Institute. Primarily devoted to basic and application-oriented basic researches, the activities of the Discipline have ranged over several areas of biochemistry in relation to natural foods, their preservation, processing and nutritional evaluation. The Discipline has played a notable role in the developmental activities leading to the practical application and large scale production of protein-rich foods, particularly formulated for children and infants of vulnerable groups.

Most prominent among the application-oriented researches may be mentioned the development of Amul Baby Food and the Indian Multipurpose Food. Others are preparation of fructose syrup from the stem of the Agave plant by simple acid hydrolysis, a procedure for incorporating calcium into casein based upon the use of calcium hydroxide in sucrose solution and preparing calcium caseinate, a process for the preparation of high-calorie, protein-rich, precooked, ready-to-eat products suitable for the Indian army-developed during the emergency of the Chinese conflict in 1962, and preparation of blended vegetable protein hydrolysates suitable for therapeutic use in the treatment of protein malnutrition and other clinical conditions requiring intensive protein therapy. A brief outline of the major researches and the more important findings over the past thirty years is presented here.

NUTRITIOUS DIETARY FORMULATIONS

Roots and Tubers as Partial Substitutes for Cereals

In view of the shortage of cereals in this country in the year 1949, attempts were made to introduce tapioca and sweet potato as partial substitutes for cereals, and determine the extent to which these could replace cereals without affecting the overall nutritive value of this diet. Experiments on albino rats and human beings established that 25 per cent of cereals could be replaced by tapioca or sweet potato flours without affecting growth and health of children.

Rice Substitutes from Tapioca and Groundnut Flours

Studies were carried out to prepare simulated rice substitutes with the shape of rice grains from blends of tapioca, groundnut and wheat flours and to assess their nutritive value. A rice substitute based on tapioca 60 parts, groundnut flour 15 parts and wheat semolina 25 parts could be used in the diets of children without affecting their growth and health.

Infant Foods

A process for the preparation of infant food from buffalo milk was standardised. Feeding trials with infants showed that the food promoted good growth. The process was taken over by the Kaira District Cooperative Milk Producers' Union and successfully marketed under the trade name "Amul" Infant Food. The development of the infant food earned for the research workers concerned the 'Kidwai Prize' of the I.C.A.R., New Delhi. This process helped save considerable foreign exchange for the import of infant foods from abroad. A process for the preparation of malted milk powder with and without cocoa was standardised. The products were highly acceptable.

Multipurpose Food (MPF)

A process for the preparation of Indian Multipurpose Food based on 75 parts of groundnut flour and 25 parts of Bengal gram flour and fortified with calcium salts and vitamins was standardized. The food was made available in 3 forms: (*i*) seasoned with spices and salt, (*ii*) unseasoned, (*iii*) unseasoned with added skim milk powder. The food was an excellent supplement to the diets of children, and was quite effective in the treatment of Kwashiorkor also. It is now being manufactured by a local enterpreneur.

LESSER KNOWN FOODS

The nutritional evaluation of a number of lesser known foods used in times of dire food shortage revealed some potential protein-rich food sources. Among these, mention may be made of the seeds of *Amaranthus paniculatus* (Rajgira) and *Bambusa arundinaceae* (Bamboo rice), the former as a good breakfast cereal after heat puffing and the latter as a good substitute for rice but of much higher protein content and nutritive value. Although the seeds of *Sesbania grandiflora* Pers. contained nearly 70 per cent protein, the biological value of the protein was low because of the extreme deficiency of methionine. The Agave stem, a famine food, was found to be a potential source for the preparation of an edible and nutritious fructose syrup.

NUTRITIONAL BIOCHEMISTRY

Vitamins

In the early phases, the influence of dietary protein and other nutritional factors on the composition of the liver was studied. An interesting observation made was the influence of vitamin B_{12} on the regeneration of nucleic acids and proteins in the liver of the fasted rat. Other aspects that received attention were the inter-relationships between vitamins of the B-complex and several metabolic functions of the liver.

Vitamin B_{12} content of milk and other animal foods and liver extracts was determined by microbiological methods. The results showed that vitamin B_{12} was present in two forms, *viz.* hydroxycobalamine and cyanocobalamine. The hydroxy-form was destroyed when the food material was subjected to autoclaving at 15 psi for 30 min. The effect of vitamin B_{12} deficiency on the liver enzymes (dehydrogenases) of rats was also studied.

Studies on some aspects of the influence of pyridoxine deficiency on the biochemical functions of subcellular fractions of the rat liver indicated that during protein and vitamin B_6 deficiency, there is a lowering of the cytoplasmic and mitochondrial transaminase activities respectively. The levels of some key enzymes such as the aminotransferase in liver and the pancreatic proteolytic enzymes are being analysed in experimental protein and/or calorie deficiency conditions.

The ascorbic acid status of the rat was influenced by the quantity and quality of dietary protein. Addition of sulfa drugs to the diets caused inhibition of the biosynthesis of ascorbic acid.

Vitamin A deficiency in rats led to (*i*) decreased retention of sulphate ions, (*ii*) increased free aryl sulphatase A in the leukocytes, (*iii*) increased ganglioside content in the retina of post-weaning rats, (*iv*) decreased adenosine deaminase activity in the kidney and lung tissue, and (*v*) alteration of glycoprotein profiles in the erythrocytes.

Nutritional Evaluation

Studies were carried out on the metabolism of nitrogen, calcium and phosphorus in children on poor diets based on different cereals, millets such as rice, wheat, jowar, ragi and maize. The effects of supplementation of these diets with protein supplements on nitrogen metabolism was also studied. Results showed that the children maintained low nitrogen balance on poor cereal diets and supplementation with protein foods markedly increased nitrogen balance.

The calcium and protein-bound phosphorus in calcium caseinate was fully available for growth and other physiological needs in children and experimental rats. The isolated phosphopeptides of casein, however, did not exert any specific influence on calcium or phosphate absorption from the gut, although they were quite effective in preventing its precipitation in the lumen under physiological conditions.

Blends containing cereals, oilseed cake flours and legume flours were found to possess a protein efficiency ratio of about 2.0 or more and had a marked supplementary value to diets based mainly on cereals. Amino acid supplementation studies on experimental animals and children showed that lysine and threonine are the limiting amino acids in mixed diets based mainly on cereals or millets. A technique based on the determination of free amino acid levels in blood plasma was found to be good in predicting the limiting amino acids in pulses and processed food products like weaning foods.

Proteins

Rats maintained on increasing casein diets (3, 10, 18 and 54 per cent) showed varying enzyme activities in the livers. The L-aspartate, L-leucine and L-alanine: 2-oxoglutarate aminotransferase activities in rat liver mitochondria increased with the dietary protein content. The ATP ases were unaffected.

Rats fed petroleum yeast supplemented with methionine showed PER close to that of casein diet and compared favourably with the latter diet, with respect to many of the parameters, fertility, gestation, viability and lactation indices during four successive generations of animals. A greater urinary excretion of uric acid and allantoin was observed in these rats.

Polished jowar fed to rats showed lower PER (overcome by lysine addition) and negative nitrogen balance.

Carbohydrates

Ragi starch was similar to corn starch with respect to its *in vitro* digestibility and support of growth in rats. Ragi flour fed to rats showed lesser digestibility of carbohydrates and lower nitrogen retention. Whole field bean and kernel but not the husk included in the diets fed to rats, reduced the food transit time. The feeding of all the three increased the fecal bulk of rats.

Lipids

Studies were carried out on the refining, shelf life and nutritive value of oils from cotton seeds, safflower seed and niger seed. These oils were fully digested by the rat and had the same growth promoting value as cow's ghee. Sal fat, a potential cocoa butter substitute, fed to rats was found to support normal growth and exert no adverse effects on blood constituents or on various organs. Generation experiments showed that litter numbers and litter weights were normal.

Ragi lipids fed to weanling rats at 1.5 and 10 per cent was found to be similar to groundnut oil. Defatted cowpea and cowpea fat in contrast to those of ragi, showed cholesterol lowering effect in serum and tissues. Cowpea fat was also effective in preventing atheroma in rabbits.

Metabolic Interrelationships

A new facet of the interrelationship between protein and carbohydrate metabolism was brought to light in the favourable influence of ingested protein on glucose tolerance and blood sugar levels of both diabetic and normal subjects first demonstrated in this laboratory. Long-term studies have also revealed the favourable influence of protein supplements on the insulin requirements and clinical status of diabetics of the adult-onset type. Bioassays of plasma insulin activity using the rat epidydimal fat pad technique have shown that the above effects of protein are due to stimulation of insulin secretion.

The metabolism of amino acid in protein-calorie malnutrition (Kwashiorkor), especially histidine, tyrosine and phenylalanine, has been examined. Increased urinary excretion of the N-acetyl derivatives of the amino acids like phenylalanine was also observed. In sequel, the metabolism of acyl amino acids was investigated in some detail using microoraganisms (*E. coli*) as convenient metabolic model systems.

PLANT BIOCHEMISTRY

The starch synthesizing enzymes of the tapioca root were studied. The biosynthesis of oligosaccharides and fructans by transfructosylases in *Agave vera cruz* was elucidated.

Studies on the germinating seedlings of *Sesbania grandiflora* Pers revealed a very high regeneration of ascorbic acid and also of sucrose on germination in the dark. The carbohydrates of the inner coat (tegmen) of the seeds which consist mainly of galactomannans have been shown to contribute the hexose precursors required for these biosynthetic activities.

Groundnut on germination showed a decrease in the oligosaccharide, lipid, pentosan fractions and an increase in the starch content.

The biochemical activities of mitochondria from plant sources, particularly some of the indigenous fruits, such as the mango, were investigated. Plant growth regulators like beta-naphthoxyacetic acid and related compounds were shown to inhibit oxidative phosphorylation activity and other properties of these mitochondria. Similar effects were observed in rat liver mitochondria also.

The turnover rate of organic acids in mangoes was found to be much higher compared to oranges or bananas. They led to the formation of sugars in mangoes and to carbon dioxide in the other two fruits.

The enzyme phosphoenol pyruvate carboxy kinase (PEPCK) absent in raw mango increased as the fruit ripened. Phosphoenol pyruvate carboxylase present only in the preclimacteric fruit had lesser activity than PEPCK. This enzyme was purified 50-fold and its properties studied.

Thiobendazole (a systemic fungicide) was found to inhibit the mitochondrial succinate dehydrogenase activity by 20-60 per cent in both chill-sensitive and chill-resistant plant tissues. It inhibited the mitochondrial respiratory chain enzymes in germinating seeds.

METABOLISM OF AMINO ACIDS

α, γ-Diaminobutyric acid (DABA) in the free state and α, β-diaminopropionic acids (DAPRO) in oxalylated form are present in the seeds of many plants, and they are consumed as food, e.g., *Kesari Dhal.* These compounds are toxic. It was not clear how these compounds were degraded in nature. It has been established that α, γ-DABA is degraded in bacteria *via* aspartic semialdehyde, aspartic and oxaloacetic acids. Free DAPRO is degraded to pyruvate by cell-free bacterial L-DAPRO-ammonia lyase. The enzyme has been purified to homogeneity (30-fold) and its characteristics determined. Rat also metabolises DAPRO but the mechanism is not clear.

A sensitive enzymatic method of estimation of the neurotoxin content of food materials has been developed: the neurotoxin content indicates the degree of adulteration of legumes with *Kesari Dhal.*

Pyrrolidone carboxylic acid occurs free in many tissues (skin) and as the N-terminal amino acid in many proteins. Not much was known about the degradative metabolism of this compound. Studies with ^{14}C-pyrrolidone carboxylic acid have indicated that dehydrogenation and hydroxylation of the pyrrolidone ring followed by dehydrogenation is coupled to electron transport.

Although most proteins have free N-terminal groups, a few contain acetylated N-terminal groups (tobacco mosaic virus, haemoglobin, et.c). During work on bacteria, it was noticed that growth in presence of chloramphenicol led to an accumulation of N-acetyl proteins and peptides. Studies to elucidate the above have led to the finding that the bacteria contain an enzyme which acetylates free phenylalanine to acetyl phenylalanine by Ac-CoA. This enzyme has been purified to homogeneity. However, it does not acetylate Phe-t. RNA and hence the mechanism of formation of acetyl N-phe. peptide (protein) is not clear yet. Another aspect of this work is the degradation of acetyl DL-phenylalanine. There seem to be two different acylases. The D-acylase is present in the cell-free extract (CFE) and has been purified to homogeneity. In this organism, L-Phe seems to be degraded *via* Phe. pyruvic and Phe. acetic acids: enzymes for these transformation have been demonstrated in CFE of the bacteria.

BIOCHEMISTRY OF PESTICIDES

The metabolic studies on two rodenticides—norbormide and ∝-naphthyl thiourea (ANTU) and their biochemical effects have shown some peculiar changes. In the case of norbormide, there is a 100 per cent, increase in blood glucose level of rats (1-2 mg/100 g body weight), while ANTU leads to uremia as well as hyperglycemia.

Tricalcium phosphate used as an inert dust insecticide is ingested by the insect larvae and leads to glycogen and fat depletion and consequent death. Using radioactive calcium phosphate, a method has been devised to determine the food intake of the insects.

A sensitive biological method for the assay of the toxic components present in guar bean meal has been standardised using insect larvae of *Corcyra cephalonica*. The nature of these components is yet to be studied.

The responses of two strains of *Neurospora crassa* to the isomers of the insecticide hexachlorocyclohexane-γ-BHC, δ-BHC and X_3 factor were found to be inositol dependent or resistant. Young albino rats administered β-BHC (800 ppm) showed altered enzyme levels in liver, kidney and blood, hyper albumin-globulinemia and fatty liver. In these rats, the drug metabolising enzymes were induced and the liver microsomal RNA lowered along with the RNAse activity.

ENZYMES

Basic studies on enzymes of interest to food industry such as glucoamylases, pectinases, phosphatases and lipase (of rice bran) were carried out. The glucoamylases I and II from *A. niger* were purified to homogeneity and characterised. Their amino acid composition was similar, but molecular weight, carbohydrate content etc. differed. The carbohydrate portion of the enzyme was found to be necessary for stability but not for its activity or antigenecity. The enzyme protein was found to contain mostly mannose linked directly to the serine/threonine moiety.

The degradation of hydroxycitrate occurring in some food materials notably *Hibiscus sabdariffa* and *Garcinia indica* was studied using a *Micrococcus* strain of bacteria. In this connection, the mechanism of action of isocitric dehydrogenase was studied.

The occurrence of aspartic-glutamic transaminase in the tender field bean (*Dolichos lablab*) and the participation of ferrous iron in the reaction were demonstrated.

Two regulatory enzymes of the pathway of biosynthesis of the aspartate family of amino acids in microorganisms and some plant materials were studied in some detail in order to understand the biochemical basis of this phenomenon. Homoserine dehydrogenase and aspartokinase of a bacterium *Serratia marcescens* were studied in detail and homoserine dehydrogenase obtained in a homogeneous state. There is a very pronounced inhibition by threonine and repression by methionine which is another end-product. Work on enzymatic aspects of this pathway in plants has not been fruitful but radioactive studies indicate that the pathways (of biosynthesis of the aspartate family of amino acids) are similar in plants and in bacteria.

Conditions for lysine synthesis by a mutant of *Micrococcus glutamicus* was standardised. Among the enzymes involved in synthesis in the parent and mutant strains, the significant observations were the lack of homoserine dehydrogenase in the latter leading to hyperproduction of lysine and the difference in feed-back inhibition control on aspartokinase. The enzyme meso-diaminopimelic acid decarboxylase was purified 700-fold.

The technique of immobilized enzymes was tested for the conversion of transaconitic acid to citric acid by encapsulating cells of *Pseudomonas transaconitate* in polyacrylamide gel. More recently the enzymes involved in instant tea manufacture are being studied using the above technique.

SPICES

The spices red pepper (chillies), turmeric, black pepper and their respective active principles capsaicin, curcumin and piperine were investigated for their influence on growth, blood constituents, various organs and nitrogen balance in albino rats. Red pepper, black pepper and their active principles fed to rats at levels close to human intake were found to be quite safe. Turmeric and curcumin when fed to rats at levels even higher than the normal human intake did not cause any adverse effects. Preliminary investigations have indicated that both red pepper and capsaicin may influence beneficially the transport and metabolism of lipids. Ingestion of curcumin reduced the blood and liver cholesterol levels in experimental rats fed a hyper-chlolesterolemic diet.

Capsaicin fed to rats or rabbits is not excreted as such in the feces or urine. Rabbits fed capsaicin excrete more of glucuronides than sulphates as conjugates. Rats fed curcumin absorb it to the extent of 50 per cent and excrete more of sulphate than glucuronides as conjugates in the urine.

CHARACTERIZATION OF MAJOR NUTRIENTS

Proteins

Groundnut proteins isolated by acid and alkali extraction methods were compared for their solubility and emulsifying properties. The effect of acetylation and succinylation of the proteins to varying extents on solubility, viscosity, fluorescence and difference spectra and also the rates of proteolysis by chymotrypsin and trypsin were studied.

k-casein from buffalo milk was purified and found to differ slightly with respect to peptide pattern after tryptic digestion, from the corresponding casein from cow's milk.

Several varieties of wheat were studied for their proteins such as albumin, globulin, gliadin soluble and insoluble glutenins in relation to their chapathi making quality. The differences in dough development and dough stability of the different varieties could be related to the qualitative differences among their glutenins and the quantitative differences in the relative amounts of gliadin, glutenin and residue proteins.

The major globular proteins of Bengal gram were shown to be polymorphic by modern fractionation procedures of gel filtration and ultracentrifugal analysis. The major components were shown to disaggregate into subunits on treatment with protein denaturants such as urea.

Black gram was found to contain a foam-forming (surface-active) protein which was responsible for the textural quality of *idlis* and other leavened food preparations.

Italian millet (14 varieties) developed at the University of Agricultural Sciences, Bangalore, was analysed for their proximal constituents and found to contain 11.1—19.7 percent protein. Prolamines (45 per cent) and glutelins (16 per cent) constituted the major proteins.

A haemagglutinin from *Dolichos lablab* was purified to homogeneity and found to be a glycoprotein with 2-3 per cent carbohydrate. The biological activity of the protein was stable between pH 2 and 8. Succinylation abolished its activity on rabbit erythrocytes.

Carbohydrates

The stem of *Agave vera cruz* was found to contain polymers of fructose having a branched structure as the sole reserve carbohydrate. The structure of six oligosaccharides occurring in the stem were established by techniques of methylation, GCMS and NMR spectroscopy. The presence of similar compounds in garlic and onion was observed. The oligosaccharides in groundnut and sesame were characterised and differences in varieties observed. Groudnut starch was purified and found to be similar to legume starches in its properties. The structures of two pure hemicelluloses, a branched xylan and a linear glucomannan, isolated from groundnut were elucidated.

Sesbania grandiflora seeds were found to contain a reserve galactomannan. Black gram was found to contain an arabogalactan of very high molecular weight which has an important functional role in the spongy texture of leavened foods prepared from black gram.

Lipids

Coconut lipids were characterised. The polar lipids showed a higher iodine value than the neutral or total lipids. The paring oil (from brown testa and the white layer together) showed a higher percentage of unsaturated fatty acids than coconut oil. The unsaturated fatty acids in coconut lipids decreased with maturity. Desiccated coconut along with roasted pulse powder had a shorter shelf life than either. Such products were preserved better using antioxidants. The coconut cuticle had a higher specific activity of lipase than the endosperm; the enzyme could be inactivated by steaming for 20 minutes. Lipoxygenase activity was not detectable in tender or mature coconuts.

Ragi was found to have nearly the same amount of neutral, glyco-and phospholipids as pulses. The fatty acid composition was also similar.

OTHER INVESTIGATIONS

Among the more important ad-hoc investigations may be mentioned the colorisation of vanaspati (hydrogenated vegetable fat) so as to prevent its potential use as an adulterant for butter fat. Although a safe patent or latent coloriser could not be developed, turmeric (or curcumin) and phenolphthalein appear to be the more promising colorants. As an alternative procedure, the Baudoin test based on the detection of sesame oil (sesamolin) compulsorily added to the hydrogenated fat was modified and adapted for household testing and an inexpensive kit for carrying out 20-30 tests was developed.

In collaboration with the Indian Standards Institution, specifications for sago were worked out on the basis of analyses of a large number of samples received from the industry. Other commodities for which similar analytical information was furnished to the ISI are saffron, asafoetida and honey.

Fat emulsions suitable for intravenous alimentation in humans have been prepared and are being tested in animals. Other aspects which have been investigated are the dietary protective factors in experimental peptic ulcer and possible role of proteinases-inhibitors in liver cirrhosis.

Utilization of Sewage for Crop Production

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The late Prof. V. Subrahmanyan's deep interest in sewage and soil was apparently derived from his early association with Prof. G. J. Fowler and Sir E. J. Russell, who were leading figures in the fields of sewage treatment and soil management, respectively. In the thirties and forties Prof. Subrahmanyan and his associates published a number of papers on the role of organic matter in plant nutrition and allied aspects[1-12]. Dr. R. Rajagopalan and one of us (SCP) were two of his associates who investigated the utilization of sewage for crop production with financial assistance from the Indian Council of Agricultural Research. The results of this research extending over a period of about 13 years and the results of later research on this subject and on other aspects of soil processes are briefly reviewed in this paper.

Sewage is water after it has been used by a population provided with underground water carriage system for removal of human wastes from the residential area. This waste water contains a considerable amount of the elements of plant nutrition originally removed from the soil by the crops which were consumed by the community. Sewage contains many substances in suspension and in solution, in addition to harmful and pathogenic organisms and may, therefore adversely affect the quality of the crops raised on it.

In early studies on problems of sewage disposal which began in Britain in the forties of the last century, land was used sometimes only as a filter medium for the treatment of sewage and at other times it was used exclusively for broad irrigation for growing crops. From the early years, those who used sewage for growing crops observed that the soil gradually developed "sewage-sickness" which was manifest in the poor growth of plants and steady decrease in the yields of crops. It was not known how sewage brought about sickness of the soil, although Russell[13, 14] recorded that the sickness was due to the presence of protozoa such as the species of *Amoeba*, *Colpoda* and *Vorticella* as a detrimental factor to the bacteria which were considered as the most important organisms for the oxidation of the organic matter. It was also not known how the sewage matter, a natural waste, is oxidized and brought back into the cycle of nature.

The problem of sewage disposal in the early days became so serious that a quick practical solution by its mere disposal on land or in a water course was preferred to a procedure based on a more systematic investigation on the behaviour of sewage in soil, water or under other conditions. Rather empirical attempts, such as the development of chemical precipitation, anaerobic treatment of sewage in septic tanks, and in the development of different types of filters—"bacteria beds" like the "contact bed" and percolating or trickling filters eventually led to the development of the activated sewage process. In these, some evidence was obtained which broadly indicated two features: the maintenance of aerobic conditions in the purification system and the presence of proper organisms.

Cause and Control of "Sewage Sickness" of Soil

Continued research at Bangalore showed that sewage-sickness of soil is similar to the sickness of heavily manured soils and that it is due to lack of adequate aeration of the soil. The sewage-sick soil and other sick soils could be treated by ploughing and resting the soil, by surface heating of the soil and by judicious application of lime[15].

It was observed that surface heating of soil brings about the formation and stabilization of water stable aggregates which promote better aeration of the soil and better growth of plant roots for increased production of crops[16, 17].

Suitable Soil and Crops for Sewage Farming

Extensive experiments were carried out with different types of soil (sandy soil, clayey soil, etc.) and different types of crops by irrigating the crops with sewage and clean water in different proportions, by applying sewage at different stages of the growth of crops and at other times applying water, by following the process of nitrification and other oxidative changes in the soils[15, 18–30]. The more important results are: (*a*) the soil most suited to sewage irrigation is sandy soil; (*b*) the crops more suited to sewage farming are fodder crops and certain industrial crops like sugarcane; (*c*) vegetables and other leafy crops grown on sewage are heavily infected with the bacteria from the sewage. Even the fifth consecutive washing of these vegetables, particularly the salad vegetables, with clean water showed bacterial counts as in grossly polluted water samples and so, such vegetables should not be grown on raw sewage in the interests of the health of the community[29]. Only such crops as would undergo drastic treatment before they go to the community for consumption might be grown on sewage. But it would be better to treat the sewage before it is used for crop irrigation.

A Successful Sewage Farm

Apart from the experiments indicated above, many other experiments were carried out at Bangalore and the results of these experiments were applied to the development of a sewage farm at Madurai (Tamil Nadu). The municipal sewage farm at Madurai, to which we gave advice and assistance for about 3 decades became one of the best laid-out and well managed farms. The farm was laid out at a distance of about 4 miles away from the town. The soil on the farm covering an area of about 120 acres (to treat about 2 million gallons of sewage per day), to start with, was mostly gravelly and had a general gradient of about 1-in-100. The farm land was provided with suitable under-drains consisting of earthen pipes. The land filtered sewage effluent flowed down into an effluent channel in which a variety of organisms, such as bacteria, protozoa, algae, earthworms, snails, fishes and water snakes developed. The occurrence of fishes suggested the use of the sewage effluent for fish culture and a fish pond was made.

Guinea grass for which there was a great demand could be grown. The yield was very good (about 100 tons per acre per annum) which was a source of continuing revenue to the Municipality of Madurai.

There was, however, a problem with this sewage farm and that was the hookworms from which the farm farm labourers suffered. Remedial measures were treatment of the sewaged land with lime and ferrous sulphate and providing the labourers with gum boots for use while working on the farm. In these and other ways the Municipal Sewage Farm at Madurai proved a practical and economic proposition. There is still scope for further improvement of such a farm.

A Biological Factor

Whitish masses of peritrichous ciliate protozoa particularly of the species of *Carchesium* and *Epistylis* were observed in the sewage effluent more especially on the sides of the channel throughout the year and in all seasons. The fishes were found to feed on these protozoa. Such protozoan masses were observed in the effluents from the percolating or trickling filters in different parts of India in the course of our extensive studies on the different sewage purification systems.

In 1909, Fowler[31] observed at Manchester: "The effluent from the percolating filter is, except for a small amount of suspended humus, clear and bright, non-putrefactive, and practically saturated with dissolved oxygen. Nitrification is well advanced, and the four hours' oxygen test and albuminoid ammonia are below the 'limits of impurity' of the Mersey and Irwell Joint Committee. Yet considerable development of *Carchesium* takes place in the outlet channel, with, as has been found, simultaneous diminution in the dissolved oxygen content". He inferred from these observations that *Carchesium* could grow in effluents which would be passed as satisfactory from the chemical point of view of the quality of effluents. But later work done in the Department of Biochemistry, Indian Institute of Science, Bangalore, on the quality of effluents by the application of chromatographic technique showed that the land-filtered sewage effluent and effluents from percolating filters contained amino acids which are the source of nitrogen for the protozoa such as the species of *Carchesium* and *Epistylis*[32–35]. These observations led on to further investigations on the occurrence and activity of different forms of protozoa in sewage and soils.

The Protozoa in Sewage and Soils

Raw sewage contains no appreciable amount of dissolved oxygen and for this reason the protozoa which require oxygen for their activity and development do not normally develop in sewage but remain in an inactive state or as cysts. As soon as a certain concentration of oxygen builds up in sewage by its exposure as a thin layer, by dilution with clean water, by filtration; or by any artificial method, the protozoa develop and multiply utilizing the nutrients in the sewage. The protozoa that develop in sewage have been traced to the soil washings entering the sewerage system.

Among the protozoa that develop in sewage under aerobic conditions, the peritrichous ciliates or Vorticellids are the most dominant. They not only metabolise and transform the organic matter in the sewage but separate the water in the sewage with the least amount of the original sewage matter. The sludge and the effluent formed by the protozoa are most evident and appreciable in the activated sludge process of the sewage treatment. The oxidised sludge and effluent from this process may be hygienically used for soil fertilization and crop production, as the sludge concentrates the nutritents in the sewage and the oxidised effluent be safely used for crop irrigation.

Sewage Treatment, an Intensified Soil Process

The studies outlined above and other observations made in the laboratory and under field conditions have brought out a point of considerable significance in soil science and in the changes in waters. The activities of Vorticellid protozoa in sewage under aerobic conditions may not be perceptible in moist soil because enough organic matter and water are not present in ordinary arable soil for these relatively large forms of protozoa to develop and multiply. There are, however, smaller forms of protozoa such as the species of *Colpoda*, *Colpidium Balantiophorus* and simple *Vorticella* which bring about changes similar to those brought about by large Vorticellids in activated sludge or in organically polluted waters. The changes brought about by the protozoan activity are broadly aggregation of the organic and inorganic colloids and other materials in the systems: in one case (sewage or organically contaminated water) stable compact flocs of sludge are formed and stabilized and in the other case (soil) water stable soil aggregates are formed and stabilized[36–38]. The water stable sludge floc and the soil aggregate are apparently the fundamental factors in the medium of water and in agricultural soil, respectively, for the productivity of these systems[39].

This is one of the main results of the intensive and extensive investigations on the utilization of sewage for crop production carried out at Bangalore for over four decades. The similarity between sewage and soil was suggested by Russell[40], Barritt[41] and Fowler[42] many years ago. Russell[40] stated that the nitrogen changes occurring in sewage and soil are similar, the only difference being that they take place more quickly in sewage than in soil. Barritt[41] reported that "the process of nitrification in soils and sewage filter beds is essentially the same". Fowler[42] stated that activated sludge and arable soil are similar living systems, and that the chemicals which eliminated the protozoa in the soil also eliminated the protozoa in the activated sludge. Beyond these suggestive statements by Russell, Barritt and Fowler, there is no clear evidence in the literature to consider sewage and soil as similar systems.

A New Point in Soil Science

The work briefly summarised above on the utilization of sewage for crop production seems to have a considerable bearing on soil science, particularly on the formation and stabilization of water stable aggregates on which work has been going on for over a century in different parts of the world. Wollny[43], who is regarded as the father of soil conservation or soil physics, recorded in 1897 his concept of crumb structure of water stable aggregates which are so essential for soil conservation and productivity, and since then this has been a vital subject of extensive investigation in different parts of the world. Allison[44], who devoted the best part of his scientific life in the investigation of water stable aggregates, expressed his view four years before his death in 1972 as follows: "Our understanding of soil aggregate formation and stabilization is probably as unsatisfactory at the present time as that of any other phase of soil science". He made this statement, as he added, "regardless of the existence of an extensive literature on the subject".

In this connection further experimental work was carried out at Bangalore, which showed that there are at least half a dozen factors in the formation and stabilization of water stable aggregates, namely, temperature[16, 17], moisture[45], chemical fertilizers under certain conditions[46] and certain protozoa like the species of *Colpoda*, *Colpidium* and *Vorticella*, which occur in all soils of the world[37, 38].

It is a curious fact that precisely the same types of protozoa which Russell[13, 14] identified as a detrimental factor in soil causing sickness of the soil are now shown to be of fundamental importance and significance in the productivity of soil. This is the new point in soil science derived from the continued study at Bangalore of sewage and sewaged soil, which is likely to be of growing interest and importance.

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Developing R&D Food Engineering Facilities

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Situation

While the importance of engineering in the development of food processing industries was recognised during the early planning of CFTRI, the details of an organisation to suit the needs of an institute devoted to food technological research in a developing country were not clearly defined. In the initial equipping of a food engineering division therefore, the choice of equipment depended to a large extent on the proejcts taken up for investigation. Due to the paucity of trained personnel in the field, this choice had to be entrusted to chemical engineers with no formal training in food processing industry, but could still be depended upon to undertake the task through intelligent study of its existing and developing requirements. Later, it was possible to secure the services of chemical engineers with a sound background of biochemical and biological processes.

It is appropriate to recall at this stage an aspect of early organisation of the CFTRI at Mysore. The Council of Scientific and Industrial Research had acquired a large and beautiful mansion, a palace belonging to the earstwhile royal family, for housing the institute. Although a large part of the building could be adapted, with some alterations and additions, to house a number of laboratories in various Disciplines, completely new buildings had to be constructed to house the engineering facilities required for general maintenance, as well as the more important design and construction workshops needed for process development.

Planning Food Process Engineering

The initial efforts were directed towards acquiring equipment for a variety of unit operations in food processing, which are common also to chemical engineering—evaporation, milling and pressing, solvent extraction, etc. In most cases, the material of construction had to be stainless steel from hygienic considerations. In the state of the chemical engineering industries in India at the time, this made it necessary to organise a design and construction workshop on a far more elaborate scale than would normally be required in an industrially developed country. Mysore city is itself not an industrial town, and is far removed from industrial centres like Bangalore or Bombay. Thus mechanical engineering and design facilities had to be developed by training skilled workers *in situ*.

The need for the creation of such facilities, to be housed in a separate new technology block, had been recognised by Dr V. Subrahmanyan, the Founder-Director. As the institute developed, the design details had to be significantly altered from those envisaged at the planning stage. This involved a lot more capital expenditure, besides efforts in new lines of work that were not familiar. It should be said to the credit of Dr Subrahmanyan that not only did he appreciate the importance of building these facilities, but also gave unstinted support to proposals from the workers entrusted with the organisation and conduct of such work.

In organising the Division of Food Engineering, two main facilities were envisaged: one equipped for process development, and another for design and construction of equipment. The former was equipped with a variety of equipment for unit operations, and numerous additions were made over the years. This served not only to assist other Disciplines in carrying out certain unit operations of a type and in quantities not possible with ordinary laboratory equipemnt, but also to run batch or semi-continuous processes using selected units, grouped together with auxiliary equipment, so as to provide design-data for process scale-up.

Mechanical engineering workshops for design and construction of equipment were organised on a far more elaborate scale than envisaged in the initial plan, or were perhaps common among research institutes founded in the early fifties. The engineering workshops were also expected to help in the general maintenance of other departments, and staff and facilities for civil engineering design and construction formed part of the Division.

The construction of such facilities made the CFTRI one of the best-equipped laboratories in the country' and has later also served as a valuable means by which to train food technologists, not only from India but from other developing countries.

Some Pioneering Efforts

Among the early projects investigated and developed by the workers of the food engineering division may be mentioned the following:

1. Pioneering work on solvent extraction of rice bran oil.
2. Solvent extraction of oil-bearing materials for simultaneous production of edible oil and meal, using both hydrocarbon solvents and alcohol.
3. Processes for simultaneous dehydration, and extraction of oils and production of edible meal, from materials like copra.
4. Solvent processing of fruits for the extraction and concentration of their juices, and production of by-products.
5. The use of solvent systems, especially alcohol and low-boiling hydrocarbons like-hexane and heptane, in the simultaneous dehydration and extraction of oleoresins from spices like ginger. This was an extension at CFTRI of the work of the writer at the Indian Institute of Science, Bangalore.
6. Process scale-up, and establishing of a 3 tonne/day groundnut protein isolate plant.
7. Design and fabrication of several bench-scale items of food processing equipment which could be used to collect engineering data; this enabled CFTRI to offer, for the first time in India, commercial scale designs and not just laboratory based technology.

Broad-based Training

The technologists and engineers associated with initiating and developing food engineering at the Institute could claim to be far more suitable generally in assisting other developing countries than those trained and experienced in highly-industrialised countries. The training provided them with confidence in offering consultancy arrangements, and in some cases even in taking up turn-key assignments to set up food-processing plants both in India and abroad. The writer recalls in this connection his experience in India of upscaling some fine chemical industries from process development to production nearly 50 years ago. A technologist then had to be far more versatile, and broad-based in his training, to make a success of his assignment in a developing country. Narrow specialisation in a particular field, though undoubtedly valuable in some instances, would, in the conditions then prevailing in most developing countries of the world, have often made them feel utterly helpless in tackling their problems. Training both as a food technologist and as a food engineer would enable such men to take up assignments in these regions with a greater degree of confidence than those trained as a food engineer or as a food technologist following American practice. United Nations organisations such as FAO would do well to remember this in their endeavour to assist the developing countries of the world in organising training programmes intended to provide personnel to man various porjects.

A Tribute

The writer was associated with Dr Subrahmanyan in one way or the other for a period of nearly four decades, first as a student at the Indian Institute of Science, Bangalore (where Dr Subrahmanyan began his career as a lecturer in the Department of Biochemistry), and subsequently in Mysore as his colleague, charged with the task of organising the disciplines of food engineering and process development. He would like to take this occasion to pay his tribute to a shrewd and practical-minded science administrator who, despite his rather closed ivory-tower existence as a Professor of Biochemistry for two decades at the Indian Institute of Science, was able to cultivate a wide and sympathetic attitude towards the needs of other scientific and technological disciplines and workers in the organisation of CFTRI, which is now recognised as a premier organisation in this part of the world for the development of food science and technology. It is this personal quality that enabled him to raise this institution on proper foundations, on which successive generations of new and distinguished talents could build an edifice that has been able to play a significant role in national development.

Activities of the Paddy Processing Research Centre, Tiruvarur

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The Paddy Processing Research Centre (PPRC), Tiruvarur was founded under the dynamic leadership of the late Prof. V. Subrahmanyan in the year 1969, and has been engaged in various lines of research work on the pre-and post-harvest technology of paddy. PPRC is jointly financed by the Department of Food of the Government of India, the Food Corporation of India and the Tamilnadu Civil Supplies Corporation Ltd.

The major lines of work in which it is currently engaged cover a fairly wide ground such as (*i*) pre-harvest treatment of standing paddy crop to quicken ripening during humid and overcast weather, such as prevails during the *kuruvai* season in Thanjavur district, (*ii*) temporary preservation of high moisture paddy to prevent heating, discolouration and development of bad smell, (*iii*) production of parboiled rice without any off-odour or taste made by conventional cold soaking method, (*iv*) continuous steaming of parboiled paddy made by the hot-soaking method, (*v*) pressure parboiling of paddy, (*vi*) modernization of 'huller' type rice mills, and (*vii*) stabilization of rice bran.

Details of the work carried out during the last decade at this research centre on the above aspects are described in this article.

Quickening Paddy Ripening

During the *Kuruvai* season, farmers in Thanjavur district face a very serious problem by way of continued humid weather with overcast skies which persists for weeks. The paddy crop cannot be harvested because quick drying facilities are not available. To overcome these difficulties the PPRC, under Prof. Subrahmanyan's guidance evolved a simple method of spraying the standing paddy crop with sodium chloride solution (15-20 per cent). The spraying has a spectacular effect. Within 48 hours of spraying, the grain moisture drops down to 18 per cent from a level of 22-24 per cent. The grains acquire a uniform yellow colour, harden very fast and the paddy can be harvested at least one week earlier than the untreated control crop. The yield is higher, and early harvest permits the farmer to prepare the land for the next crop.

Preservation of High-moisture Paddy

Most wet-season paddy has to be harvested at fairly high moisture levels and cannot be dried at all for quite a few weeks for lack of sunlight. This wet paddy is very difficult to preserve. Respiratory and allied metabolic processes continue resulting in heating of the paddy, which is attended by a loss of dry weight. Even germination may set in, bringing with it localized heating and consequent discolouration of the rice kernel, and loss in dry weight. In most instances, there is active fungal growth, which not only causes considerable quality deterioration but brings in toxic hazards by way of development of mycotoxins.

Work at PPRC was directed to control these numerous spoilage changes. One suggested treatment was the packaging of high-moisture paddy under relatively anaerobic conditions in a proper container (which acts as moisture and gas barrier) after suitable chemical treatment. The chemical treatments suggested for the purpose are: treatment with (*a*) sodium chloride at 6 per cent level, (*b*) sodium chloride at 1 to 2 per cent level along with calcium chloride at 0.1 per cent level, and (*c*) calcium chloride alone at 1.5 per cent level.

The chemically-treated material is packed in gunny sacks laminated on the inner side with 150-gauge poly-vinylchloride or high-density polyethylene of 300-gauge thickness. These plastic materials may also be used as loose liners inside ordinary gunny sacks.

Though such a treatment does preserve the high-moisture paddy for 3-4 weeks, the moisture content is not reduced to any appreciable extent. This means that the paddy has to be sun-dried before marketing. For meeting this requirement, dry powdered salt (5 per cent on the weight of paddy) was mixed with paddy husk powder (30-40 per cent on weight of paddy) and this mixture was thoroughly mixed with moist paddy. This treatment assured uniform coating of salt on every grain. The husk powder acted as a carrier for salt as well as an adsorbent for the water released from the paddy by the osmotic effect. In about 24 hours a drop from 26-28 per cent to 18 per cent moisture level was achieved by this method.

Parboiled Rice

Over 90 per cent of the parboiled rice in India is produced by conventional methods, wherein paddy is soaked in cold water for 24 to 72 hr and then steamed. During such soaking, certain fermentative changes occur leading to the production of bad smell, off-flavour and taste in the rice. Moreover a certain amount of soluble material from the paddy migrates into the soak water and gets lost. This loss may reach a level of 1 to 3 per cent on the weight of paddy. The cause is mainly anaerobic microbial activity, and Prof. Subrahmanyan thought of the idea of using an oxygen donor which would keep the soak water in a steady aerobic condition thus suppressing anaerobic microbial activity. He suggested the use of sodium chromate dissolved in the water at 0.5 kg per tonne of paddy being soaked. Large scale trials at the Kuttalam Rice Mills, have confirmed its utility. The yield of polished rice was increased by 1 per cent and the off-smell in the rice was also totally eliminated. The results were so impressive that a large number of millers in Tamilnadu Kerala, Pondicherry and Andhra Pradesh have adopted this method on a large scale. The National Institute of Nutrition, Hyderabad has confirmed that the level of chromium retained in the parboiled rice produced by this method is not absorbed in the human system and does not pose a health hazard. Final clearance for its use is awaited from the Ministry of Health, Government of India.

Other chemicals like formaldehyde, quarternary ammonium bases, hexamethylene tetramine and chlorine, which have bactericidal and bacteriostatic properties have been successfully used for the same purpose. These are also awaiting clearance from the Ministry of Health.

Pressure-parboiling: To shorten the time required for parboiling and to give a maximum yield of parboiled rice, a method called pressure-parboiling has been developed at PPRC. This method has been adopted on a large scale by over 200 rice mills in Punjab, Haryana, UP, Bihar, West Bengal and Andhra Pradesh, and 8 mills in Nepal. The processing time for production of parboiled rice is reduced to about 1.5 hr. Because of the low moisture content (23 per cent) of the parboiled paddy produced by this method, a shorter time is required for drying; the out-turn of parboiled rice is also greater than in other methods of parboiling.

A very cheap method of pressure-parboiling without the use of a boiler, that can be adopted very easily in rural areas, has also been developed at PPRC. The cost of a boiler and need for a boiler licence are eliminated, and the method can be used for custom parboiling. Freshly-harvested paddy can be parboiled straightaway without drying the crop, thus reducing the working cost on drying and storage of raw paddy.

Another development is the application of pressure-parboiling to produce bulgar wheat at low cost. About 15 tonnes of wheat were bulgarized by this method, which if properly applied can effect a big saving in the country's expense on production of *Balahar* (which contains imported bulgar wheat), and may even have good export potential.

The method was also tried with certain modifications to see if the toxic material present in *kesari* dhal (*Lathyrus sativus*) can be destroyed. 97 per cent destruction of toxin was attained. Further work is being carried out.

Sand parboiling and drying: Attempts made at PPRC were successful in achieving simultaneous parboiling and drying of paddy using sand or paddy husk powder in a fluidized state as the medium, the process taking just 15-20 min. Pilot plant work to make the process continuous has been taken up.

Modernization of Rice Mills

The PPRC has also worked out a low-cost procedure for modernization of a huller rice mill for milling of parboiled paddy. The additional units required are (*i*) precleaner (locally fabricated), (*ii*) rubber sheller (without blower), (*iii*) paddy separator (the existing winnower/grader can be modified to function as a paddy separator also), (*iv*) polisher (available huller can be used for polishing), (*v*) rice grader with aspirator, and (*vi*) bran purifier. The total cost of modernization is about Rs 24,000. Several hundred mills have adopted this method and it is spreading fast to other states. In working, 3 to 5 per cent of paddy is allowed along with brown rice for polishing, and hence the modified type of separator developed by PPRC is installed in these units.

Mechanical Separation of Ergot-infected Bajra Grains

Another important study was on the mechanical separation of ergot-ridden bajra grains. A single pass of these through a Schule gravity separator in a modern rice mill gave an 80 per cent separation, and by repassing nearly 100 per cent separation of infected grains was achieved. Large scale trials were carried out at the Modern Rice Mill, Tiruvarur.

Bran Stabilisation and Edible-grade Rice Bran Oil

This work was carried out by a team under Mr Pillaiyar's leadership. With the full financial support of FCI, a steam heated stabilizer loaned from CFTRI was installed at an FCI mill at Sembanarkoil and standardized for use. Based on these trials FCI has installed five bran-stabilizer units at their modern rice mills for on-spot stabilization of bran, and production of low FFA rice bran oil by solvent-extraction on a large scale. Refined rice bran oil and vanaspati have also been produced from such rice bran oil.

Hot air stabilizer: As most rice mills producing raw rice do not produce steam, there is urgent need for a bran stabilizer that can operate on heat sources other than steam. To meet this requirement, a husk-fired furnace to produce hot air has been evolved at PPRC. Trials have been very successful and many mills are adopting the furnace both for raw and parboiled rice bran.

By-product Utilisation

Under Mr Vasan's leadership successful work has been done at PPRC on a cheap and effective method for separating rice germ during the milling operation. Rice germ is a cheap source of valuable food protein. Work is continuing on the isolation of pure protein from rice germ.

Use of Paddy Husk Ash

Due to the sharp rise in the price of petroleum based fuels and the shortage of coal, paddy husk has become a valuable source of fuel. Work is in progress at PPRC on the optimum utilisation of paddy husk energy.

The by-product paddy husk ash resulting from the utilisation of paddy husk as a fuel is a valuable source of silica which has numerous uses in glass and allied industries. A cheap method of extracting sodium silicate (which finds extensive use in soap industry as a foaming and wetting agent) has been worked out at PPRC, and a pilot plant is being set up at Annamalai University campus. An even cheaper method of producing sodium silicate by cold extraction has been successfully evolved at PPRC and small pilot plant trails have been successful.

Laboratory trials have been successful at PPRC for producing activated charcoal from paddy husk and paddy straw.

Processes for hardboard, using paddy husk ash and paddy straws which can be used for partition walls in village huts and for providing fire proof roofing at a very cheap rate has been worked out. Laboratory trials are in progress at PPRC to study the *modus operandi* for producing cellulose acetate from paddy straw and paddy husk.

The dynamic leadership and the critical scientific acumen of the late Professor Subrahmanyan cannot be replaced. The PPRC is trying hard to keep his image illuminated and the impress of his leadership intact.

Prof. V. Subrahmanyan — Some Personal Reminiscences

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I consider it a rare privilege to write about Dr V. Subrahmanyan, who was to me a dearly loved teacher, friend and benefactor.

I have known him for over four decades and a half. He and my father were closely associated with the scientific Journal *Current Science* and later with the Indian Academy of Sciences from early 1930's. I first met him when he attended one of the early editorial meetings of *Current Science*. From then on, we used to see a lot of each other and the Subrahmanyan's family came to be regarded as "First friends of the family".

Dr Subrahmanyan's form was somewhat of a short build, with an intelligent smiling face. He was always very alert and active hardly ever appearing jaded even after an enduring day. Sartorially, he was fastidious always well dressed in his dark blue or brown, checked or striped suit and was particularly attached to them hardly ever changing his costume theme.

As a Professor of Biochemistry

When I obtained my post-graduate degree in chemistry in 1940, Prof. Subrahmanyan was so good as to offer me a research scholarship for working under him. From the very beginning, I realised that he was exacting but kind and that he would keep pegging away at problems never ceasing until he had got over them.

Under his guidance, I was initiated into research on the chemical nature of rennin. Working alongside with us, he infused great interest in work and the spirit of scientific research. He would say we should keep "Many irons in the fire" and concomittantly made us take up a new investigation on oxidative digestion method for nitrogen estimation and allied problems. When a new idea crossed his mind he was up and trying it on regardless of time and fatigue. He would not leave anything half done or allow his associates to leave the laboratory until a satisfactory account of work for the day was obvious.

A Transition Period

The period I am referring to was one, when the country was under British rule and the Second World War was raging resulting in material scarcity in the country both for the military and the civilian population. It became imperative that either the materials so far imported or their substitutes had to be produced in the country. The vitally necessary food materials had to be saved from spoilage. It was at this moment that Dr Subrahmanyan stood tall when faced with the mammoth situation. He very soon geared up a good part of the department of biochemistry to work on the production of biochemical products needed both by the defence forces and the civilian population.

Soon, my fellow research scholars and I were associated with Dr Subrahmanyan in the development and standardization of methods for producing rennet and food colours needed by the armed forces. Simultaneously he guided other teams to work on pancreatin and production of pituitrin. He organised groups to work on the development of adhesives resistant to water, and disinfectants from essential oils. Thus in a flash he set up a very versatile programme of developmental work in applied science.

Many of the processes developed were taken up by the industry on royalty basis and the production of others was undertaken by the Institute and the products were sold to the government for use by the armed forces. The efforts earned appreciation and benefits to the Institution and the participants. Dr Subrahmanyan was high minded and generous and saw to it that all the workers concerned participated in the fruits of the results of their efforts however directly or remotely their connections were to the cause. He had a canny way of keeping all pleased and enthused with work.

Pioneer in Food Science

When the Second World War spread global with the entry of Japan the food situation became harder. The government introduced rationing, and large stocks of essentially needed food grains had to be built up with the attendant problems of protecting them from ravages of weather and pest havoc.

With his foresight, Dr Subrahmanyan established a food technology section in the biochemistry department with selected enthusiastic scientists. The small unit started working on processed products from the protein-rich soya bean and successfully produced nutritious products from it. The armed forces, governments and private industrialists requested us to solve problems concerning food processing and storage. One such problem was "the spoilt fruit and nut ration" referred to by the Armed Forces. We luckily struck upon the idea of salvaging a high percentage of the ration by using the high temperature short time process. With Dr Subrahmanyan to think was to act. We availed of the facilities of a nearby potato dehydrating plant and many tons of the product were salvaged.

Word went round and problems of spoilage of food-grains and flour in storage began to be referred to Dr Subrahmanyan. Within a few months, many thousands of bags of foodgrains and flour were reconditioned producing pest-freed and freshened up food.

Appreciative of the contributions made by him to their cause in matters of the food problem, the Civil and Military Station Authorities of Bangalore mentioned their intention to make recommendations for conferment of a British Government title. Dr Subrahmanyan reacted to this in a way few fellow men would have done. He immediately replied that if honour is proposed to be conferred, it must be on his devoted assistants who did so much for the war effort, and not on him. He soon followed it up by recommending the names of two of the concerned assistants.

As a Builder of CFTRI, Mysore

The end of the war left a very distressing food situation leading to famine and starvation deaths in various parts of the country. The Government of India set up a directorate of food. The Indian Science Congress session of 1946 stressed the need for more research in food science and technology as also the need for establishing an institute for these functions. Based on the report of a scientists team, the Government of India through the Council of Scientific and industrial Research, favoured the proposal for setting up a Central Food Technological Research Institute. The CSIR chose Dr V. Subrahmanyan for the task, as he was richly endowed with experience and abundant enthusiasm and appointed him the planning officer. He took me as his technical assistant and our association continued uninterrupted.

The task ahead was of manifold nature: planning the laboratory, deciding on its location in this vast country, getting a building constructed or acquiring an existing suitable building for housing the laboratory with adequate space, equipping, staffing and get it going. To do all this vis-a-vis the strict Government rules at each step was hard business.

Driving himself hard and me along with him he completed the plans for the proposed institute in a comparatively short time, and even attended to its early printing as a booklet. The plan was approved soon after. Dr Subrahmanyan was always for getting a thing done well and that too quickly.

His perspicacious mind suggested that it is best to acquire a suitable building with adequate space which could be moved into without a long wait—permitting quick conversion into a laboratory. He addressed various Governments in the country and got varied responses, but most of the offers were unacceptable for one reason or the other. The most promising offer was from the Government of Mysore. He was aware of many suitable palatial buildings in Bangalore and Mysore which could be adapted comparatively easily to a laboratory and make possible early functioning provided they could be made available for this purpose by the Government. He had letters addressed to the Government of Mysore by the Ministry of Scientific Research seeking their kind co-operation in making available a suitable building with grounds for housing it.

The Government of Mysore had also at this stage, generously offered a palatial building called "Cheluvamba Mansion" to the World Health Organization for housing their Indian head-quarters. As luck would have it, within a few days the WHO announced their intention to locate their headquarters in Delhi leaving the palatial building in Mysore deobligated in respect of its disposal. Now was the time for Dr Subrahmanyan to secure this building for the proposed Food Technological Research Institute.

Dr Subrahmanyan had to exert his persuasive ability to the utmost to steer the situation and present the strong points in favour of the establishment of the Institute in the mansions at Mysore.

At a high level meeting of the Government of Mysore, Dr Subrahmanyan brought out the large hearted argument, that "The Government of Mysore in donating the building to the Government of India were donating it to themselves, for, India was all one Union of States"; and by this donation the State Government would be putting Mysore on the map of the world of science as the proposed institute would not only have national but international importance. He also recalled the precedence, how with great generosity and forethought, the Government of Mysore aligning themselves with the munificence of Sri Dorabji Tata donated vast land and voted subsidy some decades ago for the establishment of the Indian Institute of Science in Bangalore, which now meant so much to the country and the State of Mysore. The twin arguments came as a breath of fresh air on the assembly and the Government of Mysore took the decision to donate the building to the CSIR for locating the Central Food Technological Research Institute. Dr Subrahmanyan personally arranged for the formal taking over of the building on behalf of the nation by Hon. Prime Minister Pandit Jawaharlal Nehru, who was visiting the State in November 1948.

Dr Subrahmanyan now saw the institute through its teething troubles with undiminished vigour, he hustled the fitting up of the building for conversion into a laboratory. The CSIR research schemes on related subjects and schemes sponsored by other scientific bodies formerly guided by Dr Subrahmanyan in the Indian Institute of Science were transferred to the new Institute. Subsequently with the transfer of the Indian Institute of Fruit Technology from Delhi to CFTRI, the institute started fully functioning within two years of planning it.

The Institute was really ready for formal opening well ahead of October 1950. The formal inauguration was, however, postponed till then, as the then Director General of Scientific and Industrial Research wanted the inaugural functions of the National Physical Laboratory and the National Chemical Laboratory before hand. The Institute was formally inaugurated by Sri C. Rajagopalachari in October 1950, and in his inaugural speech, he announced amidst great applause that Dr V. Subrahmanyan, who planned the CFTRI, found it a home and set it functioning would also be its first Director. Thus gloriously fructified his untiring efforts in establishing CFTRI.

In the thirteen years of his leadership, the CFTRI which started modestly grew to great heights winning international recognition for its work and many rewards to Dr Subrahmanyan for his merits.

In 1963, Dr Subrahmanyan relinquished his post of Director of CFTRI on reaching the age of superannuation. It is said that military generals do not retire. So was the case with him. He did not retire from his scientific research, but with zeal as ever, he was active till the sad end came in January 1979.

A Great Administrator

As an administrator he was very able and carried his associates with him giving them due prominence on occasions. It is human nature to take less botheration on oneself and take the easy way. With Dr Subrahmanyan it was not so. When he saw a just cause and a possible fruitful result, he would not spare himself until the conclusion of the task. His subordinates felt their interests safe in his care. He stood by them in their difficult moments. He would sooner take the blame on himself than see a subordinate suffer for minor lapses inevitable in public service. He punished few, but rewarded many. Combined in him were high technical faculty and managerial skill.

An Outstanding Personality

As a person Dr Subrahmanyan stood apart as a celebrity. He had the scholarship and bearing which we associate with distinguished men of science. He faced upto trials and conflicts and solved but never side stepped them. The principle he held for himself in life and exhorted his students and colleagues to follow was to aim high in life and endeavour by all means to achieve it. Not many endowed with less animation and steadfastness fulfilled it so well and completely as he did. He was an eloquent and impressive speaker. When he spoke or wrote, the intellectual level was evident and showed erudition but not self-importance. He shunned engagements which would distract him too much from his main purpose, but was not a recluse. He was a Rotarian for sometime, played tennis and attended and spoke wittily at all staff social meetings and valued social graces.

His hobbies were few, confined to vegetable and rose gardening. At times, he could boast of excellent harvests of tomatoes and roses from his garden. Dr and Mrs Subrahmanyan were excellent hosts. Although a sparse eater himself, his tables were always prodigiously laid for the guests.

His relations with the domestics were as cordial as with the colleagues. He treated them sympathetically and generously which they reciprocated with full heart and served him loyally for long. Dr Subrahmanyan stood for "Love beareth all things, believeth all things, topeth all things and endureth all things."

His achievements in life were amazing. He left us wondering, how such a small head was packed with so much wisdom and so small a body had the mammoth energy to do all he did. There are now hosts of his students and colleagues most of whose achievements are high and they owe him all they have gained.

There is an old chinese proverb which says "*Each generation builds a road for the next.*" The road has been built for us; it is incumbent upon us in our generation to build the road for the next.

INSTRUCTIONS TO CONTRIBUTORS

1. Manuscripts of papers should be typewritten in double space on one side of the paper only. They should be submitted in **triplicate.** The manuscripts should be complete and in final form, since no alterations or additions are allowed at the proof stage. The paper submitted should not have been published or communicated anywhere.

2. Short communications in the nature of letters to the editor should clearly indicate the scope of the investigation and the salient features of the results.

3. Names of chemical compounds and not their formulae should be used in the text. Superscript and subscripts should be legibly and carefully placed. Foot notes should be avoided as far as possible.

4. **Abstract:** The abstract should indicate the scope of the work and the principal findings of the paper. It should not normally exceed 200 words. It should be in such a form that abstracting periodicals can readily use it.

5. **Tables:** Graphs as well as tables, both representing the same set of data, should be avoided. Tables and figures should be numbered consecutively in Arabic numerals and should have brief titles. Nil results should be indicated and distinguished clearly from absence of data.

6. **Illustrations:** Line drawings should be made with *Indian ink* on white drawing paper preferably art paper. The lettering should be in pencil. For satisfactory reproduction, graphs and line drawings should be at least twice the printed size. Photographs must be on glossy paper and contrasty; *two copies* should be sent.

7. Abbreviations of the titles of all scientific periodicals should strictly conform to those cited in the World List of Scientific Periodicals, Butterworths Scientific Publication, London, 1962.

8. **References:** Names of all the authors should be cited completely in each reference. Abbreviations, such as *et al.*, should be avoided.

   In the text, the references should be included at the end of the article in serial order.

   Citation of references in the list should be in the following manner:

   (*a*) *Research Paper:* Menon, G. and Das, R. P., J. sci. industr. Res., 1958, 18, 561.

   (*b*) *Book:* Venkataraman, K., The Chemistry of Synthetic Dyes, Academic Press, Inc., New York, 1952, Vol. II, 966.

   (*c*) *References to article in a book:* Joshi, S. V., in the Chemistry of Synthetic Dyes, by Venkataraman, K., Academic Press, Inc., New York, 1952, Vol. II, 966.

   (*d*) *Proceedings, Conferences and Symposia:* As in (*c*).

   (*e*) *Thesis:* Sathyanarayan, Y., Phytosociological Studies on the Calcicolous plants of Bombay, 1953, Ph.D. thesis, Bombay University.

   (*f*) *Unpublished Work:* Rao, G., unpublished, Central Food Technological Research Institute, Mysore, India.

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