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Litchi (*Litchi chinensis* Sonn.) Fruit : Influence of Pre- and Post-harvest Factors on Storage Life and Quality for Export Trade - A Critical Appraisal

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One of the most crucial factors that markedly influences the profitability in the marketing of fruits at places far away from the site of production, is the time interval after harvest or the post-harvest life of the commodity at ambient conditions, till it reaches the consumer. Monetary benefits to the producer depend on several factors like harvesting, maturity at harvest, conditions of packaging, transport and storage of the fruits. Litchi (*Litchi chinensis* Sonn) is a highly priced sub-tropical fruit and is in great demand in the European market. One of the major problems during post-harvest handling, transport and/or storage, is the browning of the rind of litchi fruit, besides curtailment of its storage life by ageing and decay. Litchi fruits can be stored for about 3 days under ambient conditions (20-35°C, RH-40-90%). However, their storage life can be extended by various chemical and physical pre- and post-harvest treatments to control weight loss, ageing and decay. Studies carried out around the world during the last four decades reveal that, the storage life of litchi at ambient conditions could be extended upto 2 weeks by the application of various chemical/physical treatments. Under refrigeration, they could be stored for about a month. There is however, a need to further extend the shelf-life of this commodity without sacrificing quality, in order to make the export trade more remunerative. The export trade for fresh litchi fruits is gaining considerable importance with the ever increasing demand for this fruit in European and Middle east-markets. However, India's share in the export trade of this fruit is negligible, although India is the second major producer of this fruit next to China. In view of the importance of litchi fruit in world trade, an attempt has been made in this review to critically appraise the current status of scientific and technological advances made in understanding the physiology and biochemistry and the post-harvest handling, packaging, transport and storage of the fruit, in order to plan strategies for future R & D activities to establish a sound base for export trade on a strong scientific and technological foundation.

Keywords: Litchi fruit, Pre- and post-harvest treatments, Storage life, Quality, Export trade, Packaging.

The litchi fruit, also spelt as lychee (*Litchi chinensis* Sonn.) Syn. *Nephelium litchi* belonging to the family Sapindaceae, is a popular fruit of South-East Asia and is indigenous to Southern China. It was introduced to India by the end of 17th century (Goto 1960; Liang 1981). The litchi fruit has a white, juicy aril, which is surrounded by a reddish, prickly leather-like skin and has usually a shiny brown large seed at the centre of the juicy aril. The fruit is a good appetizer and is useful in dyspepsia and smallpox (Nijjar 1972). Litchi seeds are used in Indo-China to overcome intestinal troubles and in Malaysia, they are used as anodyne and prescribed in neuralgic disorders and orchitis (Wealth of India 1962). This exotic fruit has an unusual warm floral and sweet citrus flavour. Unfortunately, this delicate and pleasant flavour begins to change as soon as the fruit is picked from the tree. In particular, the warm sulfuraceous taste is fleeting (Johnston et al. 1980). The fruit, widely acclaimed for its flavour, is being grown as a commercial crop in sub-tropical Asia, Hawaii, South Africa and Australia. The fruits after harvest, are highly perishable and lose their bright red skin colour within a few days of holding at ambient temperatures of around 30°C (Macfie 1954).

India's export of fresh fruits represents only a very small fraction of the total annual production of over 40 million tonnes. In this context, there is considerable demand for fresh litchis in European and Middle-East markets (Normand and Bouffin 1995). Improved pre- and post-harvest handling practices are essential to maintain quality of the fruit to meet the competition in the export trade.

PRE-HARVEST MANAGEMENT PRACTICES

Overall orchard management and pre- and post-harvest handling practices play a vital role in determining the quality and post-harvest behaviour of litchi fruits. Detailed studies have not been carried out on the effect of cultivation aspects on the post-harvest quality of litchi fruits, but a good amount of research has been done on the effect of pre-harvest applications of various plant growth regulators and chemical treatments on the post-harvest quality and storage behaviour of litchi fruits and these are enumerated as follows :

* *Corresponding Author*

Flowering pattern and the effect of growth regulators on floral initiation

The time of flowering varies with genotype and environmental conditions. In the Northern hemisphere, flowering starts between November and February, while in the Southern hemisphere, it is usually between June and September. Litchi trees grown from air layers come to flowering stage at the age of 3-5 years (Higgins 1971), while seedlings take 8-12 years to flower (Loebel 1976). However, the grafted trees were found to flower earlier than air-layered trees (Bolt and Joubert 1980). It was found that spraying with Naphthalene Åcetic Acid (NAA) in autumn, promotes floral initiation in litchi trees, (Shigeura 1948; Bonner and Liverman 1953). Floral initiation is an essential step that regulates crop yields annually.

Fruit drop and its control

The initial fruit-set in litchi is very high, but a very little proportion of it is carried until maturity. The premature drop commences immediately after fruit-set and continues, till fruit maturity (Anon 1967), with most of the fruits abscising in the first 2-4 weeks. Misra et al (1973) stated that fruit drop started soon after fruit set, but was heavy during the first 4 or 5 weeks and receded as the season advanced. It was also noted that the incidence of fruit drop was more in the older trees than the younger ones. They also reported that, two sprays of NAA (20 ppm), one at the time of fruit-set and the other when the fruits were pea-sized, reduced the fruit drop from 76.08 to 61.13%. Different factors may contribute to fruit drop such as failure of fertilization, embryo abortion, hormonal imbalance and external factors like mineral nutrition, high temperature, low humidity and strong winds. Excessive drop curtails fruit yield. Hence, spraying of the panicles with growth regulators like gibberellic acid (GA_3) at 20-50 ppm. 2,4-dichlorophenoxy acetic acid (2,4-D) at 10-20 ppm and NAA at 20-30 ppm were found to be effective in minimising the fruit drop (Shukla et al. 1978; Singh and Lal 1980; Barua and Mohan 1984; Ghosh et al. 1988; Thakur et al. 1990). Sohan Singh and Dhillon (1981) found that fruit drop in cultivar 'Calcutta' could be effectively controlled (92-98%) by the application of 2,4-D at concentrations of 2 to 4 ppm. Also, foliar application of micronutrients such as boron and zinc reduced the rate of fruit abscision (Pujari and Syamal 1977; Verma et al. 1980). It was noticed that spraying of GA_3 or NAA or 2,4,5-T (trichlorophenoxy acetic acid), at 5 ppm concentration at 3 stages i.e., prebloom, just after browning of stigma and 15 days after browning of stigma, reduced the incidence of fruit drop without affecting fruit size (Shukla and Bajpai 1971). Xiang et al (1994) stated that pollination and fertilization stimulated the increase of cytokinin, indole acetic acid (IAA) and gibberellin content and decreased the abscisic acid content in the ovary after anthesis and these changes are related to fruit-set. It was also observed that fruit-set of cultivar "Yu Her-Pao" was enhanced and fruit drop was reduced by flower panicle thinning i.e., shortening the panicle length to 15 or 20 cm, thereby reducing the density of flower buds during the early stages of flowering (Lin 1994).

Developmental disorders- Fruit cracking

Considerable decreases in yields of quality fruits occur due to pre-harvest disorders like sun-burn and skin-cracking in litchi and pose serious problems to the development of the fruit (Kanwar and Nijjar 1976).

Varietal variations: Studies on sun-burn and skin-cracking of fruits in some varieties of litchi indicate that the extent of skin cracking ranged between 0.7 and 11.5% and sun-burn between 0.9 and 19.1% (Sanyal et al. 1990). On the other hand, Chadha and Rajpoot (1969) observed that in litchi, the extent of cracking was 27.4% in cultivar "Dehra Dun", 16.8% in "Muzaffarpur", 16.7% in "Seedless No. 1", 3.4% in "Calcutta Late" and 0.3% in "Seedless No. 2". Kanwar et al (1972) observed that in different cultivars of litchi at Gurdaspur in Punjab, the extent of damage due to cracking varied from 0.3 to 36.2%. It was also found that the early ripening cultivars such as "Muzaffarpur" and "Dehra Dun" were more susceptible to cracking than the late ripening ones such as "Calcutta Late", "Seedless Late" and "Seedless No. 2". The cultivar "Hong Kong" was found to be resistant to cracking (Kanwar et al. 1972; Kanwar and Nijjar 1984). However, Sharma and Ray (1987) reported that, practically no cultivar was absolutely resistant or free from cracking.

Mechanism of cracking and factors affecting fruit cracking

Teaotia and Singh (1970) suggested that, during drought period, strengthened tissues develop in xylem and phloem, which lose their ability to divide and enlarge. Soon after a dry spell, if water supply is increased, the meristematic tissues quickly resume growth, but not the strengthened tissues. Owing to the differential growth rates, harder

tissues rupture. It was also suggested by them that some incipient cracks originate at hypertrophied lenticels. The lenticel hypertrophy may be caused or promoted by excessively retarded transpiration accompanied by more water supply to the regions of hypertrophy. During the second phase of growth, there is rapid flesh growth, synchronised with the period of high temperature and low humidity, resulting in localised light brown blotches on the fruit skin directly facing the sun rays. The blotches become more intense in a few days and the area gets dried up. Simultaneously, due to rapidly growing flesh, a small radial rupture appears in the dried blotchy area (Kanwar et al. 1972).

There are various causes attributed to fruit cracking such as environmental, hormonal, nutritional, varietal factors, infestation by pest and diseases and others (Ranvir Singh and Singh 1993).

Environmental factors: Environmental conditions such as temperature, relative humidity and rainfall are associated with fruit cracking. Singh and Singh (1954) reported that hot winds might be the cause of cracking in litchi fruits. Hayes (1960) has found that dry heat along with dry hot winds at the time of fruit ripening is the main cause for fruit cracking. Kanwar et al (1972) have reported that, during rapid flesh growth, temperature higher than 38°C combined with humidity lower than 60%, is most favourable for fruit cracking in Punjab. It was also reported by Kanwar and Nijjar (1975) that sharp fluctuation in day and night temperatures coupled with heavy irrigation after dry spell could cause cracking. Lal and Mishra (1981) also reported that high temperature and low humidity at maturity and prolonged rains at ripening cause fruit cracking in litchi.

Hormonal factors: Bioassay of plant hormones in various components of cracked and normal fruits of litchi revealed that in cracked fruits, skin and seeds had lower levels of auxin and the aril contained higher levels of this hormone than those in normal fruits (Sharma 1983; Sharma and Ray 1987). The gibberellins (Sharma and Dhillon 1986), cytokinins and abscisic acid (Sharma and Dhillon 1988) levels were more in the skin, aril and seeds of cracked fruits than the normal ones. Application of NAA at 20 and 40 ppm concentrations resulted in reduced fruit cracking (Chandel and Sharma 1992).

Applications of lower concentrations (10 ppm) of 2,4,5-T and NAA reduced the number of cracked fruits in litchi (Prasad and Jauhari 1963). Suryanarayana and Das (1971) observed reduction of cracking of litchi fruits by 4 sprays of GA (40 ppm) followed by 2,4-D (10 ppm) and GA (20 ppm). Fruit cracking was reduced from 12 to 6% in "Early Large Red" cultivar of litchi, when sprayed with ethephon at 10 ppm at pea stage and again one month later (Shrestha 1981). Misra and Khan (1981) found significant reduction in fruit cracking by spraying 2,4-D (10 ppm) at pit hardening stage. Sharma and Dhillon (1987) found that cracking could be significantly reduced by the application of NAA (25 ppm).

Nutritional factors: It was found that foliar spray of 0.5% zinc sulphate reduced fruit cracking and fruit drop in litchi (Awasthi et al. 1975), while Chandel and Sharma (1992) found that application of $ZnSO_4$ spray at 1 and 2% levels reduced fruit cracking. Misra and Khan (1981) observed maximum reduction in cracking of litchi fruits by the application of 0.4% boric acid at pit hardening stage.

Soil moisture: Lal and Mishra (1981) and Lal (1984) observed that considerable loss of soil moisture and less frequent irrigations during fruiting season were associated with severe cracking in litchi fruits. Also, inadequate moisture during early growth period of fruit development results in hard skin and inelastic or sunburnt appearance and it may crack, when there is rapid aril growth after irrigation (Menzel 1984). In general, cultivars with relatively thin skin, few tubercles per unit area and round to flat shape are more prone to cracking (Kanwar et al. 1972). In a recent study, Chandel and Sharma (1992) found that irrigation at 20 and 40% depletion of available soil moisture reduced fruit cracking.

Effect of fruit cracking and chemical composition of fruits

Cracked litchi fruits were found to contain higher nitrogen, potash and phosphorous, but lower calcium and zinc than normal fruits. The normal fruits had higher moisture content (Sharma 1983; Sharma and Ray 1987; Sharma and Dhillon 1987).

GROWTH REGULATORS AND POST-HARVEST QUALITY

Application of NAA and ethrel hastens ripening of litchi fruits. Spraying of litchi panicles cv "Dehra Dun" with NAA (25 ppm) at time intervals of 7,11 and 15 days after first spray resulted in increased moisture content from 68.31 to 72.80%, total soluble solids (TSS) from 15.20 to 16.34%. Ascorbic acid content was increased from 14.35 to 15.85

mg/100 mg, when sprayed with 10 ppm NAA (Sharma and Dhillon 1985).

Mishra et al (1985) reported that foliar spray of urea at 20g/litre or GA_3 at 50 mg/litre three weeks prior to harvest, delayed ripening of litchi cv. "China" by 6 days. Krishnamoorthy (1981) reported that GA_3 treatment at 50 ppm also increased the moisture content of fruit. This may be due to the synthesis of alpha-amylase, which converts starch to reducing sugars and hence the osmotic pressure of the cell increases, thereby attracting more water inside. Application of GA_3 also increased pH and reduced acid content (Srivastava and Singh 1969). Spraying of 2,4-D reduced acidity and increased total sugars, while application of NAA increased reducing sugars (Srivastava and Singh 1969). Experiments carried out in cultivar "Rose Scented" by Misra and Khan (1981), revealed that application of 2,4-5-T at 10 ppm increased TSS from 15.84 to 18.70%. Apart from growth regulators, application of mineral nutrient like calcium chloride at 0.6%, 10-20 days before harvest, increased the pulp percentage (Roy Choudhury et al. 1992).

MATURATION AND HARVEST MATURITY INDICES

Maturation of fruit: The time taken by fruits to mature varies with genotype and environment. In India, Gaur and Bajpai (1977) reported, 53-55 days after fruit set for optimal fruit maturity of "Calcutta" cultivar. Optimum harvesting time of 'Muzaffarpur' litchi fruits was found to be 73-78 days after anthesis (Badiyala 1993). Biswas and Roy (1953) suggested that the optimum time for harvesting the litchi cultivar 'Bombai' is between 105 and 110 days. In general, litchi fruits, irrespective of the cultivar, come to harvest maturity between 55-80 days after anthesis.

Harvest maturity indices: The stage at which the fruits are harvested is one of the crucial factors deciding the quality of the fruit (Normand and Bouffin 1995). The different criteria recommended for judging litchi fruit maturity are :

-Days after fruit set

-Development of fruit colour

-Flatness of tubercles and smoothness of epicarp and

-Chemical changes in fruit.

The development of skin colour is one of the most dependable maturity indices, although fruit skin colour is distinct for each cultivar. However, in most cases, the colour of the fruit changes from green to pink on attaining harvest maturity. It has been reported that, fruits of litchi turn deep red, when fully ripe and the fruits harvested at this stage possess excellent fruit quality (Prasad and Jha 1978). Gaur and Bajpai (1977) reported that the bright pinkish-red colour stage as optimal for fruit maturity of "Calcutta Late" cultivar.

Besides colour development, the maturity of the fruit is also determined by the shape of the tubercles. When the fruit is mature, the tubercles become slightly flattened and the epicarp becomes smooth (Gaur and Bajpai 1977). Prasad and Jha (1978) reported that the activity of acid phosphatase in the pulp tissue increased with the degree of ripeness, whereas the degree of alkaline phosphatase declines rapidly during the same period, which could be used as a biochemical index of maturation.

Harvesting: Unlike many other fruits, the litchi fruits are harvested in bunches along with a portion of the branch containing a few leaves. This is said to prolong the storage life of fruits and at the same time, the tree also receives mild pruning. Harvesting is not done during or soon after rains, since wet fruits are more susceptible to spoilage during storage (Starin 1980). Also, the fruits are kept in the shade immediately after harvest to reduce quality deterioration due to direct exposure to sun (Bose and Mitra 1985).

Yields: The yield of litchi fruits is a highly fluctuating factor depending on the variety, age of the plant, environmental factors, incidence of pests and diseases and the overall management of the orchard. The litchi trees begin to bear fruits from 3 to 5 years after planting in North India and 6 to 7 years in South India and the yield per tree increases, till they attain 20-25 years old (Singh et al. 1963). A great variation in fruit yield among varieties has been observed. A minimum yield of 60 kg per tree was obtained from "Early Seedless" cultivar, whereas "Calcutta Late" cultivar gave a maximum yield of 130 kg (Jawanda and Singh 1977). Similarly, Badiyala and Awasthi (1991), reported a maximum yield of 38 kg/ tree from "Dehra Dun" cultivar and a minimum yield of 9.60 kg per tree from "Seedless Late" variety. In Himachal Pradesh, the yield also varies with locality. An average yield from a matured tree varies between 90 and 150 kg in Hawaii (Popenoe 1920), 100 and 125 kg in South Africa (Marloth 1947) and 90 and 135 kg in Queensland (Stephens 1955). In India, an average yield of 80 and 150 kg has been reported in the State of Uttar Pradesh by Vyas (1938). A similar observation was made by Nijjar

TABLE 1. PHYSICAL CHARACTERISTICS OF LITCHI FRUIT

Cultivars	Fruit wt. g	Pulp wt. %	Peel wt. %	Stone wt. %
'Bedana'	14.3±5.9	70.7±1.9	18.7±0.6	10.6±2.0
'Bombai'	19.0	62.2	17.9	19.9
'Calcutta'	16.6±2.3	53.5±8.3	12.2	14.4±11.7
'Dehradun'	19.0±2.0	52.9±12.2	13.6	12.3±8.9
'Desi'	16.6	65.6	13.3	21.1
'Early large of red'	21.1±0.1	63.3±21.2	12.3	3.4±0.1
'Elachi'	15.7	73.6	13.8	12.6
'Kasba'	15.9	62.9	17.6	19.5
'Muzaffarpur'	19.4±1.4	61.7±10.7	14.4±10.8	14.8±6.0
'Nagarpal'	17.2	66.5	11.7	21.8
'Purbi'	18.5	60.2	16.9	22.9
'Rose scented'	20.3±1.1	52.9±13.8	15.0	10.7±7.6
'Saharanpur'	17.7	37.3	NA	3.2
'Seedless No.1'	8.3	65.6	26.6	7.8
'Seedless No.2'	18.1	64.6	18.1	17.3
'China'	19.8	54.3	24.9	20.8
'Mclean'	17.9±2.7	49.6±9.6	19.0	12.6±9.2
'Gee Kee'	14.6	72.6	21.1	6.3
'Tai So'	18.7	65.5	19.0	15.5
'Wai Chee'	17.1	68.2	28.7	8.1
SEM	17.3±0.6	61.2±2.0	17.6±1.1	13.8±1.4

NA: Not available

Sources: Chadda and Rajpoot (1969) Bose and Mitra (1985), Ajay Singh et al (1987), Ghosh et al (1988), Sharma and Ray (1987), Badiyala and Awasthi (1991), Tripathi et al (1987).

• Fig. without SD are derived from single source

(1972) on the average yield of litchi trees under Indian conditions. Taking the number of trees per hectare (with a spacing of 10 x 10 M), as 100 and average yield per tree as 100 kg, the yield per hectare would be around 10 tonnes.

PHYSICO-CHEMICAL COMPOSITION OF FRUIT

Physical attributes: The weight of litchi fruit ranges from 8.27 to 21.1 g, the edible portion i.e., pulp weight ranging from 37.30 to 73.6%. Peel weight and stone weight range from 11.73 to 28.7% and 3.2 to 22.9%, respectively (Table 1).

Chemical composition: Data on the chemical composition of different cultivars of litchi are tabulated in Tables 2-4.

Acidity: Acidity of the fruit varies from 0.3 to 1.1% for different cultivars (Table 2). The pulp acidity also varies from place to place, ranging from 0.26 to 0.57% in Punjab, 0.21 to 1.01% in U.P. 0.39 to 1.24% in West Bengal and 0.60 to 0.68% in Bihar (Ghosh et al. 1988; Chakraborthy et al. 1980). Chan et al (1974) found the organic acid composition of the fruit as: malic acid-4.16, citric acid-0.52, succinic acid-0.04 and levulenic acid-0.01 meq/100g of the pulp of cultivar "Brewster".

Carbohydrates: The TSS of different cultivars of litchi varies from 16.8 to 20.50° Brix (Table 2). Glucose is the major sugar present in litchi fruit

TABLE 2. CHEMICAL COMPOSITION OF LITCHI FRUIT

Cultivars	TSS, %	Acidity, %	Sugars, % Total	Sugars, % Reducing	Ascorbic acid, mg/100g	TSS/acid ratio
'Bedana'	19.0±1.2	0.4±0.2	14.7±1.9	10.4±2.1	30.9±4.9	46.3
'Bombi'	17.7	0.41	15.4	11.4	17.2	42.1
'Calcutta'	19.7±1.9	0.4±0.3	13.2±2.4	9.1±0.8	30.9±4.9	46.9
'Dehradun'	19.6±1.8	0.3±0.1	15.4	9.6	NA	57.6
'Desi'	17.6±0.5	0.5±0.3	13.3±0.9	9.2	24.3±5.5	35.2
'Early large red'	19.3±1.8	0.7±0.3	15.5±0.5	10.9±0.3	29.0±9.4	26.4
'Elachi'	17.5	0.5	15.5	11.7	17.6	38.9
'Kasba'	16.8	1.1	13.4	8.9	22.6	14.7
'Muzaffarpur'	19.6±1.5	0.5±0.2	15.6±0.5	8.9±0.3	32.1±12.3	39.2
'Nagarpal'	17.6	0.8	15.6	11.1	21.7	22.6
'Purbi'	18.2±0.9	0.8±0.3	14.7	9.8	20.3	24.3
'Rose scented'	19.5±1.9	0.6±0.3	13.3±0.7	9.7±0.5	20.9±3.1	33.6
'Saharanpur'	17.3	0.5	NA	NA	NA	37.6
'Seedless No, 1'	18.4	0.4	15.8	3.4	32.4	52.6
'Seedless No. 2'	17.2	0.5	12.2	10.0	43.6	35.1
'China'	20.5	0.6	NA	NA	NA	40.0
'Mclean'	18.2±1.4	0.9±0.4	13.7	9.4	24.3	20.9
'Gee Kee'	18.9	NA	NA	NA	NA	NA
'Tai So'	17.0	NA	NA	NA	NA	NA
'Wai Chee'	18.6	NA	NA	NA	NA	NA
SEM	18.4±0.2	0.6±0.2	14.5±0.3	9.6±0.4	26.3±1.7	36.1±2.6

Sources: Same as in Table-1.

TABLE 3. AMINO ACIDS, PHENOLS AND PECTIN CONTENTS OF LITCHI

Cultivar	Amino acids, mg/100g			Total phenols, mg/100 g	Total pectins, %
	Trypto-phan	Methio-nine	Tyro-sine		
'Bedana'	13.0	2.8	1.4	151	0.67
'Calcutta'	14.0	2.4	1.4	116	0.65
'Desi'	NA	NA	1.9	NA	NA
'Early large Red'	14.0	2.1	NA	127	0.55
'Muzaffarpur'	16.0	2.6	NA	143	0.71
'Rose scented'	NA	NA	1.1	NA	NA

NA: Data not available.

Sources: Chadda and Rajpoot (1969), Bose (1985), Ajay Singh et al (1987), Ghosh et al (1987), Sharma and Ray (1987), Badiyala and Awasthi (1991)). * Fig. without SD are derived from single source

with smaller amounts of fructose and sucrose (Mathew and Pushpa 1964). The reducing sugars in different varieties range from 3.4 to 11.7%, while the total sugars range from 13.2 to 15.80% (Table 2). Carbohydrate contents of different varieties of litchi range from 13.6 to 17.9% (Wealth of India 1962).

Fats, proteins and amino acids: The fat contents in 4 varieties of litchi were reported to vary from 0.21 to 0.35% (Ajay Singh et al. 1987). Protein contents range from 0.33 to 1.20% in litchi varieties "Early Large Red", "Calcutta", "Bedana", "Muzaffarpur", "Desi" and "Rose Scented" (Ajay Singh et al. 1987; Tripathi et al. 1987). The major amino acids identified in litchi fruit are methionine and tryptophan(Table 3). Alcoholic extracts of litchi aril revealed the presence of other amino acids such as glutamic acid, serine, alanine, leucine, isoleucine, valine, lysine, threonine, tyrosine and aspartic acid (Farooqi and Kaul 1963; Tripathi et al. 1987; Ajay Singh et al. 1987).

Minerals and vitamins: The mineral elements present in considerable amounts in litchi fruit are sodium, potassium, iron, phosphorus, calcium, copper and zinc (Table 4). Litchi fruit contains, apart from ascorbic acid, minor quantities of other vitamins like thiamine (25 mg), nicotinic acid (0.4 mg) and riboflavin (61 mg) per 100 g of fresh pulp (Wealth of India 1962). Ascorbic acid content ranges from 17.2 to 32.4 mg per 100 g. of fresh pulp (Table ?)

Flavour components: The volatile constituents of litchi investigated by the combined technique of gas chromatography - mass spectrometry revealed the presence of 48 different volatiles. The litchi owes its citrus flavour to the presence of limonene, geraniol and neral, while its floral character is mainly due to the presence of ß-phene ethyl alcohol and its derivatives. Also, certain terpenoids comprise the major portion of the volatiles (Johnston et al. 1980). Toulemonde and Beauverd (1984) identified 89 volatiles from head space analysis of litchi. They considered that methyl esters of various alcohols as well as limonene, rose oxide, nonanal, decanal, citronellyl and geranyl alcohols and acetates to be responsible for the fruity floral and citrus notes of litchi fruits. Neutral volatiles in litchi have been reported by Frohlich and Schreier (1986). They have identified 14 alcohols, 4 carbonyl compounds, 4 ethers, 3 esters, 14 hydrocarbons and 1 furanone derivative by capillary gas chromatography and Fourier Transform Infrared Spectroscopy. Methyl branched C_4 alcohol has been found to be a major compound among the major litchi volatiles. Among the alcohols, a series of C_6 compounds have been detected, which are well known as secondary volatiles formed after cell disruption from unsaturated fatty acids due to lipoxigenase-hydroperoxide lyase activity. It is obvious that these volatiles could not be detected during the head

TABLE 4. MINERAL COMPOSITION (mg/100 ml) OF LITCHI CULTIVARS

Minerals	'Badana'	'Calcutta'	'Desi'	'Groff'	'Rose scented'	Average
Calcium	3.8	3.4	3.1	7.16	4.50	4.39
Phosphorus	NA	NA	NA	5.76	NA	5.76
Magnesium	NA	NA	NA	5.08	NA	5.08
Sodium	16.90	33.30	14.40	NA	13.80	19.60
Iron	0.91	0.43	0.60	NA	0.60	0.66
Copper	0.30	0.23	0.4	NA	0.32	0.30
Zinc	0.25	0.23	0.26	NA	0.26	0.25
Manganese	0.04	0.02	0.04	NA	0.03	0.03
Potassium	16.60	19.30	17.50	37.30	12.00	20.54
Lead	0.10	0.10	0.10	NA	0.13	0.11

NA: Data not available

Sources: Tripathi et al (1987); Robert et al (1984)

space analysis of the whole fruit as done by Toulemonde and Beauverd (1984).

PHYSICO-CHEMICAL CHANGES DURING FRUIT GROWTH, MATURATION AND DEVELOPMENT

Litchi fruit called as 'summer sweet' is a single seeded nut and varies in size and shape according to the cultivar. There are also seedless cultivars of litchi. It takes around 80 d from fruit set to attain maturity. The growth or development of litchi clearly indicates that the fruit growth follows a typical sigmoidal pattern (Fig. 1).

Physical changes: Kanwar et al (1972) observed in two cultivars of litchi i.e., "Calcutta Late" and "Seedless No. 1", that the fruit growth in terms of fruit/seed length and dia had 2 distinct phases of growth. During the first phase, the seed growth occurs with relatively no growth of flesh and during the second phase, the rate of flesh growth overtakes the seed growth.

Litchi fruits consist of a tough pericarp, a thick edible translucent aril and a single seed. The thickness of the pericarp/cuticle progressively decreases from 8.75 µm at 21 days after anthesis to 1.88 µm as the fruit matures. This thinning has been attributed to the expansion of the invaginated pericarp during fruit development. Concurrent with aril expansion, minor cracking of the pericarp surface was observed (Underhill and Critchley 1992). Weight of the fruit decreases after ripening, mostly due to desiccation of the deteriorating fruit. Studies carried out by the same authors on respiration and ethylene production during ontogeny of the fruit revealed that, ethylene production rapidly decreased and became undetectable, when litchi was about 4% of its final weight. Some ethylene is produced, when deterioration sets in. Respiration rate decreased as the fruit matured (Akamine and Theodore 1973). In cultivars 'Deshi' and 'Kasba', the total chlorophyll contents declined rapidly during ripening and senescence (Jaiswal et al. 1987).

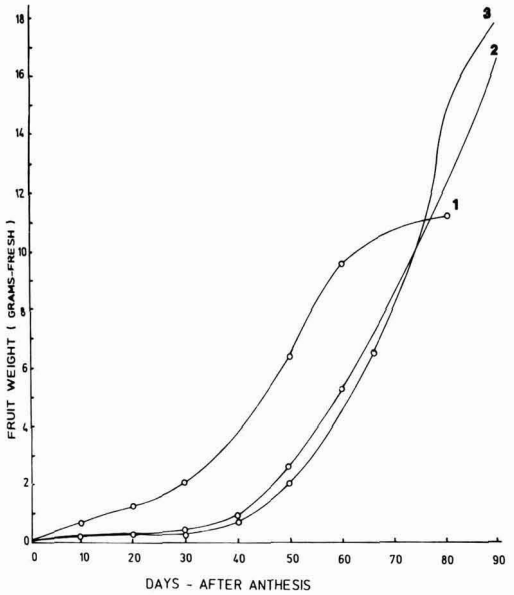

Fig. 1. Fruit growth curves plotted from the data of 3 different research reports. *Sources:* 1 - Robert et al (1984); 2 - Akamine and Theodore (1973) and 3 - Underhill and Critchley (1992).

Changes in chemical constituents

Chlorophyll: Underhill and Critchley (1992) reported that throughout growth and development, the green pericarp remained photosynthetic with chloroplasts distributed in the upper mesocarp. The chlorophyll content increased upto 69 days after anthesis and thereafter declined rapidly, with a small amount of chlorophyll still being present in the pericarp at maturity (Jaiswal et al. 1987).

Anthocyanins: Anthocyanin synthesis coincided with chlorophyll degradation, with the concentration of anthocyanins increasing progressively as the fruit matured (Underhill and Critchley 1992). Chlorophyll breakdown before the synthesis of anthocyanin occurs on 50th day for "Groff" and 60th day for "Guiwei" and "Mei" cultivars. The cultivar "Shuidong" showed a decrease in chlorophyll content but no marked synthesis of anthocyanin was seen due to an unbroken spell of cloudy and rainy weather during its maturation. The relationship between skin colour and maturity was cultivar dependent. Robert et al (1984) found significant anthocyanin production, when the fruit was half-developed in 4 cultivars of China. The bright red colour of litchi is attributed to the presence of various flavonoid pigments, which include 3 major anthocyanin pigments like cyanidin-3-glucoside, cyanidin-3-rutinoside and malvidin-3 acetylglucoside (Lee and Wicker 1991). Other components observed are pelargonidin 3-glucoside, pelargonidin 3,5 diglucoside, quercetin-5-glucoside, quercetin, kaemferol, derivatives of quercetagetin pentamethyl ether, 2,4-dihydroxy-chalcone etc., which are detectable at all stages of ripening and senescence (Jaiswal et al. 1987; Prasad and Jha 1978).

The anthocyanin pigments were vacuole bound, first appearing in the upper mesocarp tissue beneath the pericarp protuberance apex. Distribution was progressively extended to form a continuous

layer throughout the mesocarp (Underhill and Critchley 1992).

Other constituents: Studies conducted on 4 cultivars- "Groff", "ShuDong", "Guiwei" and "Mei selection", indicated that the most significant changes during fruit growth are the increases in sugar contents and decrease in organic acids. There was decrease in sucrose content and a gradual decrease in fructose and glucose in cultivar "Groff". In cultivar "Mei selection", a slow increase in all the above 3 sugars was observed (Robert et al. 1984). The different levels of sugars observed could be attributed partly to the difference in the *in vivo* activity of invertase (Chan et al. 1975). Acidity decreased from 65 meq/100g to 15 meq/100g, as the fruit increased in weight. The major change was in succinic acid, which declined from 350 meq/100g to 0.4 meq/100g. Chan et al (1975) have reported low level of succinic acid in mature fruit of "Brewster". Malic acid, which makes up the principle acid in litchi fruit, decreased to 1/4th of its initial value. Citric acid remained low during the entire fruit development. It was also noted that the total aril phenols decreased during initial growth phase and remained low during the rest of the growth period.

Ascorbic acid content of the pericarp declined during development with only very low concentrations present at maturity. The pH of the pericarp homogenate gradually increased during development, rising from 3.6 immediately after anthesis to 4.0 at maturity. However, Robert et al (1984) found rapid increase in pH of whole fruit during development.

RIPENING AND SENESCENCE

Litchis normally ripen on the tree and unless harvested, remain attached even in the deteriorated condition. The ripening process in this fruit is not accompanied by an upsurge of respiratory activity of the fruit and is therefore, classified as "non-climacteric" type. Ripening and senescence of litchi are rapid and the fruits thus have a short life-span. Ripening initiation starts 53 days after anthesis in cv 'Deshi' and 39 days after anthesis in cv "Kasba", with the first visible sign of red colour development on green fruit rind. Fully ripe stage is characterised by development of pinkish red colour of the whole fruit i.e., 67 days after anthesis in "Deshi" and 53 days in "Kasba". Over-ripe fruits are bright pinkish red and senescent fruits turn completely brown in 88 days and 74 days after anthesis in "Deshi" and "Kasba", respectively. Browning of rind has been considered as an index of senescence, signalling increasing deterioration of fruit quality (Jaiswal et al. 1987).

STORAGE OF LITCHI

The shelf-life of fresh litchi fruits at room temperature is less than 72 h (Macfie 1954). It keeps longer at low temperature (Fig. 2), but the storage period varies considerably. For instance, according to Karmakar and Joshi (1940), litchi fruits could be stored in good condition for about three months at 0-5°C, whereas Choudhury and Banerjee (1959) reported that 'Muzaffarpur' litchis could be stored for 3-4 weeks only at 2-3°C. Mukherjee (1954) could store litchi fruits for about 2-3 weeks at 7°C, after placing them in perforated polyethylene bags. Pre-cooling helps to maintain satisfactory quality during storage (Thompson 1954). Moreuil (1973) also recommended hydrocooling of litchi at 0-2°C and then packing them in non-perforated sealed polyethylene bags and a continuous cold chain, to maintain perfect colour and odour for about one month during transport, storage and distribution.

Physiological changes during storage

The first visible effect of storage on the fruits, is the change in the colour of skin which begins to turn brown in 2 or 3 days at both ambient and low temperature storage (Chen and Hong 1992). In the case of room temperature, the fruits shrink in size and become unmarketable and get fully spoiled

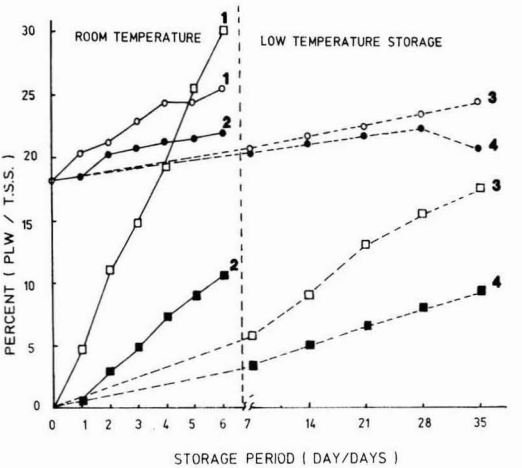

Fig. 2. Effect of post-harvest storage at ambient (-) and low (---) temperatures on the total soluble solids (o) and physiological loss in weight (□) untreated (1&3) and treated (2&4) Litchis (NaOCl -- 2 mins dip) and packed in polyethylene bag).

in 5-6 days (Choudhury and Banerjee 1959). Further with 'Muzaffarpur' litchis, it was also noted that, at room temperature, the fruits lost 9-15% of their weight, total acid, alcohol soluble solids and vitamin C within 5 days of storage. During cold storage, total sugars in the pulp, however, increased considerably (3-4 times) probably due to interconversion of organic acids and insoluble polysaccharides. (Choudhury and Banerjee 1959; Verma and Roy 1953).

The work done by Gaur and Bajpai (1979) in cultivar "Calcutta" on post-harvest physiology also revealed that both at room and low temperatures, moisture content, fruit weight, fruit length and dia decreased, while specific gravity, total soluble solids, taste, flavour and aroma of the fruits increased during storage.

Changes in anthocyanin during storage

Lee and Wicker (1991), found that the total anthocyanin was 1.68 mg/g fresh weight of litchi in the cultivar "Brewster" on the second day after harvest, which gradually increased to 2.06 mg/g after 15 days of storage and thereafter decreased gradually. There was a decrease in monomeric anthocyanins and increase in polymeric pigments. More than 42% of total anthocyanin pigments were lost after 48 days of storage at 4°C. Among the anthocyanins, the loss of cyanidin-3-glucoside during storage was much higher (33.3%) compared to the loss of 22.3% or 11.1% of the other two major anthocyanins i.e., cyanidin-3-rutinoside and malvidin 3 acetyl glucoside, respectively. Conversely, the polymeric pigments increased from 20.9 to 35.7% after 29 days of storage. Towards the end of the storage period, polymeric pigments were more predominant suggesting that during storage, the litchi anthocyanins are progressively converted or oxidised into more stable polymeric pigments, probably resulting in the browning of the pericarp.

Factors affecting pigment stability

Effect of pH: The stability of anthocyanin is dependent on its structure (Pifferi and Cultrera 1974), which is a direct function of pH (Lukton et al. 1956; Jurd 1972). As the pH increases, the anthocyanin is progressively converted by a reversible process into a colourless carbinol base. In weak acid or neutral media, anthocyanins are present mostly in a colourless form known as pseudobases, which are believed to have the carbinol structures. These pseudobases are reconverted into the highly coloured cations under strong acidic conditions. This suggests that the decolourising activity is definitely pH dependent and is operative in the pH range of 3-4.5 (Huang 1955). Anthocyanin stability is greatest below pH 3 (Brovillard 1982). In the carbinol form, anthocyanins appear to be more vulnerable to enzymatic breakdown. The pH of litchi fruit is known to increase during storage (Tongdee et al. 1982), due to which the anthocyanins may undergo a change in their structure, affecting the stability of the pigment and colour expression. The importance of pH has also been indicated (Zauberman et al. 1991).

b) *Ascorbic acid and pericarp browning:* The potential importance of ascorbic acid on the pericarp browning, stems from the fact that ascorbic acid facilitates anthocyanin degradation, due to hydrogen peroxide, an oxidation product of ascorbic acid (Silver Blatt et al. 1943), inducing anthocyanin breakdown (Starr and Francis 1968). Though polyphenol oxidase (PPO) will degrade anthocyanins, it preferentially oxidises other phenolic substrates present along with anthocyanins. Pifferi and Cultrera (1974) demonstrated the selective degradation of ascorbic acid, leaving the anthocyanins present in sweet cherry. Further, the increased ascorbic acid oxidation in necrotic litchi pericarp has been reported by Joubert (1986), who postulated that the reduction in ascorbic acid occurred concurrently with increased polyphenol oxidase catalyzed degradation of anthocyanin during pericarp browning.

Ethylene and pericarp browning: Jiang et al (1986) suggested that ethylene may mediate browning by acting as a polyphenoloxidase promoter. Although ethylene production in litchi after harvest is low, subsequent post-harvest infection can increase the endogenous ethylene levels (Underhill 1992).

Post-harvest diseases of litchi

Prasad and Bilgrami (1974) reported that *Aspergillus flavus, A. nidulans, A. niger, A. quadrilineatus, A. variecolor, Botryodiplodia theobromae, Colletotrichum gloeosporioides* and *Cylindrocarpon tokinense* are the principal pathogenic fungi that cause spoilage of litchi at the post-harvest stage.

Greenish brown rot (Alternaria sp): This disease has been noticed in West Bengal. The disease appears as a light greenish brown area around physical injury. It is more prevalent during summer. At later stages, mycelial mass and abundant

sporulation appear on the surface with the inner fleshy tissue becoming blackish and pulpy (Dasgupta and Mandal 1989).

Black mould rot (Aspergillus niger): Black mould rot has been recorded from Bihar and West Bengal (Prasad and Bilgrami 1974). The infection develops mostly near the distal end of the fruit or around any slight injury. Diseased fruits exhibit water soaked brown discoloration with mycelial and black sprouting mass.

Pedicel end rot (Botryodiplodia theobromae): This is one of the most important diseases of litchi in U.P., Bihar and West Bengal (Srivastava 1964; Prasad and Bilgrami 1974). This rot mostly starts from the pedicel end of the fruit but occasionally from other parts too. Diseased fruit turns brown at the infected site, which gradually changes to brownish black.

Fungal growth has been another factor associated with the browning reaction in litchi fruit (Nip 1988). Enzymes derived from moulds are believed to play an important role in anthocyanin pigment degradation and browning reactions (Huang 1955). Also, several experiments carried out by Huang (1955) on decolorization of anthocyanin have revealed that the catalyst responsible for the decolorization process is pH-dependent, non-dialyzable, heat labile and is consequently enzymic in nature.

Physical/physiological disorders

Physiological browning in litchi is the most serious problem in marketing, being possibly associated with the desiccation of fruits. In the markets of West Bengal, this disorder is noticed during summer. Browning starts mostly from the distal end of the fruit. The entire pink colour of the fruit disappears and turns brown. Such fruits emit off-flavour, often associated with fermentation by yeast, without producing any other external symptom. Browning is known to occur due to desiccation, heat injury, senescence or as a consequence of insect or pathogen attack (Dasgupta and Mandal 1989).

Polyphenol oxidase and pericarp browning: The anthocyanin pigments in the peel of litchi fruits, which contribute to its bright red colour, like in other fruits are relatively unstable and lose their bright attractive colour during storage (Campbell 1959; Shu et al. 1990). Browning of fruit tissue is usually associated with enhanced enzymatic activity, especially, peroxidase (POD) and polyphenoloxidase (PPO) (Joslyn and Ponting 1951; Peng and Markakis 1965). Bagshaw et al (1991) observed that the loss of water from the pericarp would be the principal factor responsible for the browning of litchi fruits. Browning commences as soon as the loss of water from the peel attains 20% and would be complete, when the loss is 60 to 70%. This drying would induce cellular plasmolysis and the liberation of polyphenol oxidase (PPO) and peroxidase (POD). Bruised litchi fruits showed higher PPO and POD activities (Joubert and Lelyveld 1975). Huang et al (1990) found that decrease in POD and increase in PPO activities coincided with the onset of discoloration of fruit.

The correlation between PPO activity and pericarp browning in litchi was shown by Lin et al (1988). PPO activity increases rapidly after harvest, reaching the peak activity in 48 h. However, there was no significant change in the amount of total anthocyanin content. PPO inhibitors like SO_2 have been effective in reducing pericarp browning in litchi. Goodman and Markakis (1965) observed that in addition to enzymatic inhibition, SO_2 combines with anthocyanin, forming an anthocyanin-SO_3H complex (Jurd 1964) and the resultant electron withdrawing effect of this complex has been suggested to increase pigment stability (Markakis 1982).

Underhill (1992) gave a few more plausible explanations for the browning of litchi fruits. He suggested that browning may also be caused by oxidation of phenolic compounds other than anthocyanin. Under long-term cold storage conditions of around 4 weeks, the litchi pericarp turns brown even under high moisture conditions. This is closely related to the whole fruit senescence and PPO activity. Huang et al (1990) reported increased PPO activity in the pericarp (exocarp) after 29 days of storage at 4°C.

Extension of storage life of litchi by the control of discoloration and browning

Treatments used by different workers to extend the storage life and also to reduce/prevent browning and rotting of litchi fruits during post-harvest storage are listed in Tables 5 and 6. It is evident from Table 5 that, at ambient conditions, litchi fruits could be normally stored for about 5 days, which could be extended to 12 days by appropriate treatments. Sharma and Ray (1987) found that litchi cultivar "Shahi" treated with 100 ppm borax and stored in perforated polyethylene bags of 100 gauge could be stored for about 12 days at ambient conditions. Similarly, Huang and Scott (1985)

TABLE 5. EFFECT OF ANTI-MICROBIAL AGENTS AND PLANT GROWTH REGULATORS ON THE SHELF LIFE OF LITCHI (ROOM TEMPERATURE)

Treatment	Storage period, days	Reference
Alar + $CaCl_2$	7.0	Nagar (1994)
Bavistin-100ppm	10.5	Sharma and Ray (1987)
Benomyl (0.05%) hot (52°C) for 2 min. and packed in punnets and over wrapped with cling PVC film	4-6	Huang and Scott (1985)
Borax- 100ppm	11.5	Sharma and Ray (1987)
$CaCl_2$-100ppm	8.5	-do-
$CaNO_3$ 0.5% or 1.0%	7.5	Patra and Sadhu (1992)
Copper sulphate- 25 ppm	7.5	Sharma and Ray (1987)
—do— 50 ppm and packed in perforated polyethylene bags	7.0	Singh (1957)
Ethylene dibromide fumigation and stored in modified atmosphere of 9.6% CO_2, 11.4% O_2	5.0	Akamine (1960)
Kinetin (5 ppm)	8.5	Sharma and Ray (1987)
Sodium hypochloride (2%)-3 min. and packed in ventilated polyethylene bags	7.0	Gaur et al (1978)
Sodium salt of dehydroacetic acid- 1.5% (5 min)	10.0	Dennison and Hall (1958)
Wax emulsion 9% SOPP (0.5%)	6.0	Garg and Ram (1972)

reduced browning and rotting upto 7 days at ambient conditions by dipping the fruits in 0.05% hot benomyl at 52°C for 2 min and packed in polyvinyl bags of 0.04 mm thickness. Following the same treatment, Tongdee et al (1982) and Scott et al (1982) have found that litchi fruits could be stored for 40 days at 0-5°C. Gaur and Bajpai (1977) could store the cultivar "Calcutta" for 6 days at room temperature after treating the fruits with 2% sodium hypochloride for 3 min and packing in perforated polyethylene bags.

Treatments with ascorbic acid solution (0.6-2.4g/l), citric acid solution (0.1-0.2 N), sulphur dust, 1-3% SO_2 solution or sodium salt of dehydroacetic acid (1.0-1.5% solution) were found to be ineffective in preventing browning at room temperature (Akamine 1960).

Some of the treatments, however, improved the fruit quality by increasing total soluble solids, ascorbic acid, total sugars etc. For instance, treating fruits with 100 ppm borax, increased the total soluble solids by 1.7% and also storage life by 11.5 days (Sharma and Ray 1987). Similarly, treatment with benomyl (0.05%) at 52°C for 2 min gave increased ascorbic acid and total soluble solids with decrease in acidity (Huang and Scott 1985),.

It is obvious from Table 6 that lowering the storage temperature increases the shelf life of litchi fruits. The recommended optimum low temperature and relative humidity are 0°C and 90%, respectively and the expected storage life is around 5 weeks (IIR 1979). Storage life can be extended further by different physical and chemical treatments (Tables 5 and 6).

Sulphur dioxide treatment: Treatment of litchi fruits with SO_2 is commercially practised by exporters

TABLE 6. STORAGE OF LITCHI AT LOW TEMPERATURE

Storage temp, °C	Chemical/Packing treatment	Storage life, days	Reference
2	Hydrocooled and packed in non-perforated polythene bags	30	Moreuil(1973)
2-3	Wire netting boxes 'Muzaffarpur'	21-30	Chaudury and Banerjee (1959)
3	Paper boxes with PVC covers	14	Hu et al (1979)
0-3	Dip in 2% Na hypochloride soln for 5 min. and packed in ventilated polyethylene bags 'Calcutta'	25	Gaur and Bajpai (1979)
0-3	Treatment with 125 ppm benlate (2 min) and stored in perforated polybags 'Late Seedless'	35	Bhullar et al (1983)
0-3	Treatment with 125 ppm benlate (2 min) + dip in 6% wax emulsion (1 min)	35	—do—
0-5	Dipping in hot (52°C) benomyl (0.05%) for 2 min. and packed in perforated polybags	40	Tongdee et al (1982)
4.4	Non-perforated vessels with a gaseous atmosphere of air to CO_2 ratio of 3:1	30	Datta et al 1963)
4.4	Polyethylene bags with moss or paper shavings	21	Mukherjee (1956)
5	Polyethylene bags with absorbent cotton	21-31	Mukherjee (1957)
7	Perforated polyethylene bags	30-35	Campbell (1959)
7.2	Perforated polybags with a valve	14	Mukherjee (1956)
8	Treated with thiourea (1:20 dil) (8 min.dip) and stored in plastic bags	30	Chang (1967)
12.7	Polyethylene bags and stored in closed cartons	17	Akamine (1960)

to control litchi pericarp browning (Normand and Bouffin 1995). Sulphur dioxide is a well known inhibitor of PPO. It also combines with anthocyanin to form a stable complex (Markakis 1982). Sulphuring is known to lower the pH of the pericarp of the fruit, which prevents the anthocyanin from reversible transformation into a non-coloured carbinol base. To fumigate one tonne of fruits, 625 g of sulphur is burnt and the fruits are kept in contact with the liberated SO_2 for about 20 min (Velain 1988). Application of this technique has been successfully undertaken by a few exporters in the Reunion (Normand and Bouffin 1996). Since 1990, the limit of residue tolerated in the pulp at the time of marketing has been fixed at 10 ppm (Normand and Bouffin 1995).

Pericarp colour retention: Pericarp colour plays a vital role in export trade, as export markets demand red fruits. Fumigation of litchi fruits with 1.2% SO_2 has been reported to inhibit PPO activity (Goodman and Markakis 1965). This treatment also causes rapid bleaching of the pericarp, due to the formation of a colourless anthocyanin - SO_3H complex. Recent experiments by Fuchs et al (1993), on litchi cultivar "Mauritius" and "Floridian" revealed that treatment of SO_2 fumigation followed by acid dip was effective in retaining the red colour of the pericarp. They suggested that SO_2 treatment significantly increased the permeability of the plasma membrane, thus enabling penetration of the acid to the cell vacuoles, where the anthocyanins are located and hence leakage of the pigments of acidified cell wall of the fruit peel might occur. Dipping the fruits in acidic solution after SO_2 treatment helps in rapid recoloration of the peel to its original red colour. Kaiser (1994) reported that dipping litchi fruits in a "zero" pH solution after blanching in boiling water at 98°C for 30 sec, was most effective in retaining the red colour of the pericarp upto 5 weeks, when stored at 1°C. However, internal browning of the flesh was observed. Later, Kaiser et al (1995) have come out with a novel technique of using steam instead of boiling water to prevent internal browning. The fruits were treated with steam for 2 sec (95°C), followed by immersion for 4 min in a "zero" pH solution and then dipped in 1% Vapor gard solution. The fruits remained firm with no internal browning and were in acceptable condition after 28 days of storage at 1°C. Results of experiments with cultivar "Tai So" fruits showed that acidification of the fruits with 1N HCl resulted in immediate improvement of pericarp colour of the SO_2 - treated fruits. Acidification did not affect the eating quality of the aril (Underhill et al. 1994).

Dipping the fruits in 4% dilute hydrochloric acid (pH 0.5) allows to regain their initial red colour permanently. Acidification acts at different levels and modifies the structure of the pigments, thereby inhibiting the enzymatic degradation indirectly (Underhill et al. 1992) . It reduces the PPO activity at pH 6.5 and also increases the stability of the anthocyanins. Hydrochloric acid dissociates the SO_3H - anthocyanin complex and liberates SO_2 and hence reverses the phenomenon of discoloration (Markakis 1982).

Packaging

Careful handling and proper packaging of fruits play an important role in maintaining freshness and quality of fruits as well as preventing damage or decay during transit. The leaves of *Ravenala madagascariensis* were used to maintain the freshness of fruits during transport as cushioning material along with the packing material (Moreuil 1973). The Chinese sometimes sprinkle the fruits with salt solution and pack them in bamboo for shipment to distant markets (Popenoe 1948).

The containers conventionally used in India for packing litchi fruits are bamboo baskets of different shapes and wooden crates. Thompson (1954) recommended pre-cooling of fruits with water prior to packing, transport and storage to maintain fruit firmness and flavour.

Marketing of litchi in local markets in Asia and export trade

Litchi fruits in local Asian markets are sold traditionally in clusters or bunches (twigs with fruits and leaves) within 1-3 days after harvest, transported in baskets, weighing about 20-25 kg and without any post-harvest treatments. However, in recent years, there are a few growers, who pack litchis in 4-5 kg cartons, either as bulk packs without PVC wrap or in punnets with PVC wraps and send to local markets in Thailand, Singapore etc. This method is gradually picking up.

Export trade of litchi

Litchi fruits are popular in most Asian countries and significant quantities are traded in each season. The estimated production of litchi in India is 9 lakh tonnes and ranks second next to China (Gerhard 1994). In India, marketing of litchi in fresh form was restricted till recently mainly to the

local markets. With the development of quick and improved transport network, it is now transported to distant places. Recently, the Agricultural and Processed Produce Export Development Authority (APEDA) initiated a study to be undertaken by National Council of Applied Economics Research (NCAER) to examine the export competitiveness of farm produce and fruits including mango, grapes, banana, apple, sapota, litchi and processed fruit products. The study showed that banana, grapes, litchi and sapota are highly export competitive (Ghosh 1995).

The marketing season of litchi in India is limited to late May and June and due to the short shelf life, it requires swift and careful handling. In 1993, about 5 tonnes of litchi were exported to Great Britain by air on a trial basis by NAFED (National Agricultural Co-operative Marketing Federation). Because of inadequate facilities to precool, grade and pack the fruit, the results were not encouraging. Later, mobile precooling units were installed to assist the farmers. Plans have been finalised to provide a packing, which protects the fruit and serves as a display. Some experts in post-harvest technology from abroad have been invited to demonstrate and train the farmers and exporters in the production area. The exporters are aiming at shipping by air between 100 and 150 tonnes of litchi to Great Britain, France and Germany. The APEDA is also assisting farmers and exporters to make the venture successful (Gerhard 1994).

In the world trade, Hong Kong and Singapore markets are well serviced, highly competitive and have very high standards for imported produce. Most of the consumers prefer large, highly coloured, sweet litchi fruits with small seeds and firm flesh. In 1983, Hong Kong imported 7500 tonnes of litchis of which 80% came from China and the remainder from Taiwan. Most of the fruits entered between June and July. Singapore imported 4400 tonnes with 90% of the fruit from Taiwan and 10% from Taiwan. More recently, significant quantities have also been exported by Thailand. Prices ranged from 1 to 11 Australian dollars per kg, depending on the cultivar, fruit quality and the time of supply. The U.K., France and FRG import about 10,000 to 12,000 tonnes of litchi, mainly from Madagascar and South Africa, with smaller quantities from Reunion, Mauritius and Israel. Fruits are normally available from November to early March (from July in the case of Israel), with peak supplies during mid December to late January. Prices ranged from 4 to 10 Australian dollars per kg (Menzel et al. 1993).

In Australia and South Africa, litchis are detached prior to sale. A machine for destalking litchis has been developed in Australia (Normand and Bouffin 1995). In order to prevent the loss of the bright red skin colour and browning of pericarp and rotting, dipping the fruits in benomyl suspension (0.5 g per litre) at 50°C for 2 min and packing in punnet packs with PVC over wraps that allow litchis to be displayed to the consumer, is commercially practised in Australia both for internal and export trades (Menzel et al. 1993). The punnet pack allows the fruit to be stored for 1 week at room temperature. Cool storage at 5°C will extend post-harvest life upto 2 weeks with minimum loss of quality in some cultivars, but storage for longer periods (3-4 weeks) must be done at 7°C to avoid skin browning. Above 7°C, disease incidence increases.

Litchis shipped to Europe from South Africa and Madagascar and more recently air-freighted from Israel, are normally treated with sulphur to prevent browning. The fruit is placed in a closed container and 50-150 g of sulphur/cubic metre of air is burnt in the enclosed space for 20-30 min. SO_2 bleaches the fruit to pinkish cream colour. Immediately after SO_2 treatment, fruits progressively turn to orange red. SO_2 treatment besides extending storage life, overcomes the need for specialised packaging and handling. However, there is evidence of sulphur residues and pulp tanning (Menzel et al. 1993).

In the Reunion, litchi fruits are fumigated with SO_2 in batches upto 1 tonne in specially designed fumigation chambers (Normand and Bouffin 1995). The design and the process of SO_2 fumigation including concentration and duration of treatment has been standardised after several commercial scale trials.

FAO/WHO quality standards for export of litchi

The draft standards (at step 7), were revised, based on the discussion in the fifth session of Codex Alimentarius Commission held at Mexico city, September 5-9, 1994 and the Revised Draft Codex Standard for litchi at step-8 was circulated to different Governments for its implementaion during the next meeting in February 1996. While revising the draft at step-7, the suggestions from ECE countries were incorporated to make the Codex Standard for litchi as close as possible to

the UN/ECE standards (FAO/WHO Standards Draft Report 1994). The salient features of the Standards for fresh litchis are given below:-

The revised draft Çodex Standard for Litchi (at step-8)

Definition of produce: This standard applies to commercial litchi varieties (cultivars) grown from *Litchi chinensis* Sonn. of the Sapindaceae family, to be supplied fresh to the consumer after preparation and packaging.

Minimum requirements: In all classes, subject to the special provision for each class and to the tolerance allowed, the litchis must be whole, sound excluding produce affected by rotting or deterioration that renders it unfit for consumption; clean, being practically free from pest and damage caused by pests; free from damage or abrasion; practically free from brown markings; free from abnormal external moisture except for condensation following removal from cold storage, free of foreign smell or taste (this provision allows smell caused by a conservation agent used in compliance with corresponding regulations).

The litchis must be carefully picked and must be sufficiently developed and mature **(the total soluble solids to acid ratio should be not less than 35** with the specified method of determination of TSS and acidity). The development and state of litchis must be such that they can withstand transportation and handling and arrive at their destination in satisfactory condition.

The colouring of litchi may vary from pink to red in the case of untreated litchis and from pale yellow to pink for litchis that have been fumigated with sulphur dioxide.

Classification

Litchis are classified into three classes:

Extra class: Litchis in this class must be of superior quality. They must have the shape, development and colouring that are typical of the variety or varietal type. They must be free of defects, with the exception of very slight superficial defects, provided that these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package.

Class I: Litchis in this class must be of good quality and characteristic of the variety or varietal type. However, the following slight defects are admissible, provided they do not affect the general appearance of the produce, its quality, the keeping quality or presentation in the package: slight misshaping; a slight colour defect; slight skin defects, provided these do not exceed a total area of 0.25 cm^2.

Class II: This class includes litchis, which do not qualify for the higher classes, but satisfy the minimum requirements listed below:-

The following defects are admissible, provided the litchis retain their essential characteristics as regards quality, conservation and presentation: defects in shape; defects in colour; skin blemishes on condition that their total area does not exceed 0.5 cm^2.

Provisions concerning sizing

Size is determined by the **maximum equatorial diameter,** the minimum size for **extra class is 33 mm.** The minimum size for classes **I and II is 20 mm** and a **maximum size range of 10 mm between fruit** in each package is permitted.

Provisions concerning tolerance

Quality and size tolerances are allowed in each package for produce not satisfying the requirements of the class indicated.

Quality tolerance

Extra class-Five percent by number or weight of litchis not satisfying the requirements of this class, but meeting those of class 1 or exceptionally, coming within the tolerances of that class.

Class I: Ten percent by number or weight of litchis not satisfying the requirements of this class, but meeting those of class II or exceptionally, coming within the tolerance of that class.

Class II: Ten percent by number or weight of litchis satisfying neither the requirements of this class nor the minimum requirements, with the exception of produce affected by rotting or any other deterioration rendering it unfit for consumption.

Size tolerance: In all classes, 10% by number of weight of litchis not conforming to the minimum size, provided, however, that the diameter is not less than **15 mm in all classes,** and/or the maximum size range of 10 mm.

Provisions concerning presentation

Uniformity: The contents of each package must be uniform and only contain litchis of the same origin, variety or varietal type, quality, size and also colour in the case of extra class. The visible part

of the contents of the package must be representative of the entire contents.

Packaging: Litchis must be packed in such a way that the product is protected properly. The materials used inside the packages must be new, clean and of a quality so as to avoid, causing any external or internal damage to the produce. The use of materials, particularly of paper or stamps bearing trade specifications, is allowed, provided the printing or labelling has been done with non-toxic ink or glue. Litchis shall be packed in each container in compliance with the Code of Practice for the Packaging and Transport of Tropical Fresh Fruits and Vegetables. However, the presence of a limited number of fresh leaves is permitted, where litchis are presented in bunches.

Description of containers: The containers should meet the quality, hygiene, ventilation and resistance characteristics to ensure suitable handling, shipping and preserving of the litchi. Packages (or lot if the produce is presented in bulk) must be free of all foreign matter and smell.

Presentation: The litchis must be presented either individually or in bunches. In the former case, the pedicel must be cut at the first knot and the maximum length of the stalk must not extend more than 2 mm beyond the top of the fruit. When presented in bunches, each bunch must include more than 3 attached and well-formed litchis. The branch must not exceed 15 cm in length.

In the case of other requirements such as marking and labelling (containers destined for the final consumer, non-retail containers), contaminants (heavy metals, pesticide residues) and hygiene are followed as in the case of other fruits specified in FAO/WHO Standards, 1994.

Summary and conclusion

Litchi (*Litchi chinensis* Sonn.) is a juicy fruit relished for its sweet taste and delicate flavour. It is grown as a commercial crop in sub-tropical Asia, Hawaii, South Africa and Australia. In India, their cultivation is restricted mainly in hilly areas. Although litchi production is fairly large, considerable amount goes waste during the post-harvest period due to various reasons such as physiological disorders, fruit cracking, pericarp or rind browning and a very short life span.

Growth regulators like NAA, IAA, GA_3, 2,4-D and 2,4,5-T have been found to be effective in enhancing fruit set and reducing fruit cracking. Growth regulators also have a positive effect in improving the post-harvest quality of litchi fruits by increasing their total soluble solids, total sugars and reducing acidity. Litchi fruits are harvested, when they are fully ripe and their maturity indices vary with the cultivars. The average yield per hectare works out to be around 10 tonnes with the spacing of 10 x 10 m.

Litchi fruit growth follows a typical sigmoidal pattern. During ripening, chlorophyll content of the fruit decreases, concurrent with the increase in the total anthocyanins, which contribute to the attractive red colour of litchi fruit. Unfortunately, this bright red colour deteriorates rapidly within few days, when the fruits are stored at room temperature and fruits turn brown, lowering consumer's preference. Litchi fruits can be stored for 3 to 5 days at ambient condition after which they rot and decay. However, low temperature storage coupled with various physical and chemical treatments have been effective in extending the storage life to around 3-4 weeks. The optimum low temperature recommended for storage of litchi is 0-1°C. Commercially, the fruits are stored at 5°C which extends the post-harvest life of litchi upto 2 weeks. Pericarp browning in litchi is mainly attributed to the action of polyphenol oxidase on anthocyanins. Various factors like pH, ascorbic acid and ethylene play a vital role in anthocyanin pigment stability. SO_2 fumigation is the treatment used on a commercial scale to control pericarp browning. Although SO_2 leads to bleaching of the skin of litchi fruits, they are made to regain the original red colour by giving acid dip following SO_2. Rotting can be prevented by treating the fruits with hot benomyl at 52°C for 2 min. The tolerance limit of residual benomyl in litchi pulp has been fixed as 10 ppm.

There is considerable demand for fresh litchis in the International trade. Work is yet to be undertaken extensively on barrier film packaging of litchi to extend post-harvest shelf life and to study the mechanism of anthocyanin breakdown to get a clear-cut idea of litchi pericarp browning.

Keeping in view of the standards laid down for the export of fresh litchis, an integrated system based on the comprehensive knowledge of the pre- and post-harvest handling, packaging, transport and storage for each of the cultivars of litchis is essential. In such a system, Modified Atmosphere Packaging (MAP) coupled with active packaging, will enable to extend the storage life of litchis without sacrificing their quality, to the desired extent required for the export trade.

References

Ajay Singh, Abidi AB, Srivastava S (1987) Variation in quality traits of litchi (*Litchi chinensis* Sonn.) cultivars, J Food Sci Tech 24:264-266

Akamine EK (1960) Preventing the darkening of fresh lychees prepared for export, Hawaii Agriculture Experiment Station Technical Programme Report, p 127

Akamine EK, Theodore G (1973) Respiration and ethylene production during ontogeny of fruits. J Am Soc Hort Sci 98(4):381-383

Anon (1967) Studies on fruit set, fruit drop and quality of litchi varieties. Ann Prog Report Dept of Hort, PAU, Ludhiana, p 88

Awasthi RP, Tripathi BR, Singh (1975) Effect of foliar sprays of zinc on fruit drop and quality of litchi. Punjab Hort J 15:14-16

Badiyala SD (1993) Maturity standards for 'Muzaffarpur' litchi fruits. South Indian Hort 41(4):223-224

Badiyala SD, Awasthi RP (1991) Physico-chemical characteristics of some litchi (*Litchi chinensis* Sonn.) cultivars grown in Kangra valley. Indian Food Packer 45(1):42-45

Bagshaw J, Underhill S, Prasad A (1991) Lychee skin browning: Its causes and control. Australia Lychee Yearbook pp 9-13

Barua PC, Mohan NK (1984) Effect of growth regulators on prevention of fruit drop in litchi (*Litchi chinensis* Sonn.) South Indian Hort 32(2): 92

Bhullar JS, Dhillon BS, Randhawa JS (1983) Extending the post-harvest life of litchi cultivar "Seedless Late". J Res (PAU) 20:467-470

Biswas S, Roy BN (1983) Studies on maturity standards of litchi (*Lichi chinensis* Sonn.) cv. 'Bombai' Prog Hort 15(3):187-189

Bolt LC, Joubert AJ (1980) Air layered litchi trees recommended for orchard establishment. Information Bulletin Citrus and Sub Tropical Fruit Research Institute 92:4-5

Bose TK, Mitra SK (1985) Fruits in India- Tropical and Sub-tropical. Nayaprokash, Calcutta: pp 420-448

Bonner J, Liverman J (1953) Hormonal control of flower differentiation In : Loomis WE (ed) Growth and Differentiation in Plants, Iowa State College Press, Ames, USA

Brovillard R (1982) Chemical structure of anthocyanin In: Markakis P (ed.), Anthocyanin. Academic Press, New York: pp 1-38

Campbell CW (1959) Storage behaviour of fresh "Brewster" and "Bengal" lychees. In: Proceedings of Florida State Horticulture Society 72:356-360

Chadha KL, Rajpoot MS (1969) Studies of floral biology, fruit set and its retention quality of some litchi varieties. Indian J Hort 26:124-129

Çhakraborthy S, Saha NK, Kamal Prakash, Bisht HC (1980) Studies on varietal suitability of litchi (*Litchi chinensis* Sonn.) for canning. Indian Food Packer 34:17-22

Chan HT, Simon CM, Kwok SCM (1974) Non-volatile acids in lychee. J Food Sci 39:792-793

Chan Jr HT, Kwok SCM, Lee CWQ (1975) Sugar composition and invertase activity in lychee. J Food Sci 40:772-774

Chandel JS, Sharma NK (1992) Extent of fruit cracking in litchi and its control measure. South Indian Hort 40(2):74-76

Chang KP (1967) Application of fungicide on the cold storage of litchi fruit. Taiwan Agric 5:79-83

Chen WJ, Hong QZ (1992) A study on the senescence and browning in the pericarp of litchi (*Litchi chinensis* Sonn) during storage. Acta Horticulturae Sinica 19(3):227-232

Choudhury JK, Banerjee M (1959) Physiological change in litchi during storage at normal and low temperature. Ind J Plant Physiol. Vol II:141-144

Dasgupta MK, Mandal NC (1989) Post-harvest pathology of perishables, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi

Datta SC, Sarkar KP, Lodh SB (1963) Storage behaviour of litchi (*Litchi chinensis* Sonn.) Sci Cult 29:405-406

Dennison RA, Hall CB (1957) Studies on the handling and preservation of lychee A R Fla Agric Expt Stat, pp 114

Farooqi MIH, Kaul KN (1963) Quantitative studies of sugars and amino acids from the aril of litchi fruit. Current Sci 6:183-184

FAO/WHO (1994) Revised Draft Codex Standard for litchi (at step 8) Joint FAO/WHO Standards Programme Codex Alimentarius Commission Draft Report of the 5th session of the Codex Committee on Tropical Fresh Fruits and Vegetables, Mexico City, 5-9 September

Frohlich O, Schreier F (1986) Additional neutral volatiles from litchi (*Lichi chinensis* Sonn.) fruit. Flav Fragrance J 1:149-153

Fuchs Y, Zauberman G, Ronen R, Rot I, Weksler A, Akerman M (1993) The physiological basis of litchi fruit pericarp colour retention. Acta Hort 34(3):29-33

Garg RC, Ram HB (1972) Effect of different concentrations of wax-emulsion on the storage behaviour of litchi (*Litchi chinensis* Sonn.) Prog Hort 3(4):33-39

Gaur GS, Bajpai PN (1977) Maturity standards for litchi fruits (*Litchi chinensis* Sonn.) cv 'Calcutta'. Prog Hort 9(3):11-17

Gaur GS, Bajpai PN, Azad CS (1978) Post-harvest physiology of litchi fruits-I. Prog Hort 10:63-77

Gaur GS, Bajpai PN (1979) Post-harvest physiology of litchi fruit. Prog Hort 11(2):5-16

Gerhard HB (1994) In : Gerhard HB (ed) Making Way for Indian Litchis. International Fruit World Agro Press Ltd. Switzerland 52(3):p 28

Ghosh B, Biswas B, Mitra SK, Bose TK (1988). Physico-chemical composition of some promising cultivars of litchi adapted in West Bengal. Indian Food Packer 42(1):34-37

Ghosh SP (1995) Fruits-attractive export opportunities In: Ravi N (ed) The Hindu Survey of Indian Agriculture, National Press, Kasturi Buildings, Madras, pp 117-119

Goodman IP, Markakis P (1965) SO_2 inhibition of anthocyanin degradation by phenolase. J Food Sci 30:135-137

Goto YB (1960) Lychee and its Processing In: Heinicke R (ed) Technical Papers of the First Pacific Rim Food Conference Honolulu: Hawaii Section of the Institute of Food Technologists 1:15-23

Hayes WB (1960) Fruit growing in India. Kitabistan, Allahabad, p 334

Higgins JE (1971) The litchi in Hawaii. Hawaii Agriculture Experiment Station Bulletin p 44

Hu ML, Chang WW, Liu TY (1979) Study on the post-harvest storage and handling of litchis. Research Report 147 Taiwan: Food Industry Research and Development Institute (English Abstract)

Huang HT (1955) Decolorization of anthocyanins by fungal enzymes. Agric Food Chem 3(2):141-146

Huang PY, Scott KJ (1985) Control of rotting and browning of litchi fruit after harvest at ambient temperatures in China. Trop Agric 62:2-4

Huang S, Hart M, Lee H, Wicker L (1990) Enzymatic and colour changes during post-harvest storage of litchi fruit. J Food Sci 55(6):1762-1763

International Institute of Refrigeration (1979) Recommendation for chilled storage of perishable produce. IIR Publication Boulevard Malesherbes, Paris p 70

Jaiswal BP, Sah NL, Prasad US (1987) Regulation of colour break during litchi (*Litchi chinensis* Sonn.) ripening. Indian J Exp Biol 25:66-72

Jawanda JS, Singh S (1977) Fruit yield, ripening time and fruit quality of litchi cultivars grown in Punjab. Punjab Hort J 17(3):122-125

Jiang J, Su M, Lee F (1986) The production and physiological effects of ethylene during ontogeny and after harvest of litchi fruits. Acta Physiologica Sinica 12:95-103

Johnston JC, Ronald CW, Hunter GLK (1980) Volatile constituents of litchi (*Litchi chinensis* Sonn.) J Agric Food Chem 28:859-861

Joslyn MA, Ponting JD (1951) Enzyme catalysed oxidative browning of fruit products In: Advances in Food Research Academic Press, New York pp 1-37

Joubert A (1986) Litchi In: Monselise SP (ed) Handbook of Fruit set and Development. CRC Press Boca Raton Florida pp 233-246

Joubert AJ, Lelyveld LJV (1975) An investigation of pre-harvest browning of litchi peel. Phytophylactica 7:9-13

Jurd I (1964) Reactions involved in sulphite bleaching of anthocyanin: J Food Sci 29:16-19

Jurd I (1972) Some advances in the chemistry of anthocyanin type plant pigments In: The Chemistry of Plant Pigments. Academic Press, New York, pp 123-142

Kaiser C (1994) Pericarp colour retention. J South African Soc Hort Sci 4(2):6-12

Kaiser C, Levin J, Wolstenholme BN (1995) Vapour heat and low pH dips improves litchi (*Litchi chinensis* Sonn.) pericarp colour retention. J South African Hort Sci 5(1):7-10

Kanwar JS, Nijjar GS (1975) Litchi cultivation in Punjab-Problems and prospects. Punjab Hort J 15:9-13

Kanwar JS, Nijjar GS (1976) Fruit development in relation to cracking in litchi (*Litchi chinensis* Sonn.) at Gurdaspur (Punjab). Haryana J Hort Sci 5:164-168

Kanwar JS, Nijjar GS (1984) Comparative evaluation of fruit grown in relation to cracking of fruits in some litchi cultivars. Punjab Hort J 24:79-82

Kanwar JS, Rajput MS, Bajwa MS (1972) Sunburning and skin cracking in some varieties of litchi (*Litchi chinensis* Sonn.) and the factors affecting them. Indian J Agric Sci 42:772-775

Kanwar JS, Nijjar GS, Rajput MS (1972) Fruit growth studies in litchi (*Litchi chinensis* Sonn.) at Gurdaspur (Punjab) Punjab Hort J 12;146-151

Karmakar DV, Joshi BM (1940) Cold storage of Indian fruits. Ind Farmg 1(1):173-177

Krishnamoorthy HN (1981) Plant Growth Substances Including Applications in Agriculture. Tata Mc Graw Hill Publ Co Ltd, New Delhi, pp 3-87

Lal H, Mishra SP (1981) Effect of irrigation frequency on fruit cracking and quality of litchi cv 'Calcutta'. Punjab Hort J 21:182-183

Lal RL (1984) Effect of irrigation frequencies on the yield and post-harvest changes in the quality of litchi fruits (*Litchi chinensis* Sonn.) cv "Rose scented", M.Sc., Thesis, GBAAU, Pantnagar

Lee HS, Wicker L (1991) Quantitative changes in anthocyanin pigments of lychee fruit during refrigerated storage. Food Chem 40:263-270

Liang J (1981) The litchi - Origin, utilization and development of its culture. J Agric Trinidad Botany Applied 28:259-270

Lin MW (1994) Studies on the pre-harvest fruit dropping of litchi cv "Yu Her-Pao" In: Lin HS, Chang LR (eds) Proceedings of a Symposium on the Practical Aspects of Some Economically Important Fruit Trees in Taiwan pp : 99-107

Lin Z, Li S, Chang D, Lin G, Li Y, Liu S, Chen M (1988) The changes of pigments, phenolics contents and activities of PPO and PAL in pericarp of post-harvest litchi fruit. Acta Botanica Sinica 30:40-45

Loebel R (1976) The litchi- Tropical Fruit Bulletin of New South Wales- Department of Agriculture 6:1-12

Lukton A, Chichester CO, Mackinney G (1956) The breakdown of strawberry anthocyanin pigment. Food Chem 10:427-432

Macfie GB (1954) Wrapping and Packaging of Fresh Lychees, Florida Lychee Growers Association Year Book 1:25-28

Mahendra Pratap Singh (1952) Mineral composition of fruits of the litchi (*Litchi chinensis* Sonn.) and loquat (*Eriobotrya japonica* Lindl.) Ind J Hort9(4):53-56

Markakis P (1982) Stability of anthocyanin In: Markakis P (ed) Anthocyanins as Food Colour, Academic Press, New York pp 163-178

Marloth RH (1947) The litchi in South Africa I. Varieties and propagation II. Cultural practices and marketing. Farming South Africa 22:824-870

Mathew AB, Pushpa MC (1964) Organic acid and carbohydrates of litchi. J Food Sci Tech 1:7

Menzel CM (1984) The pattern and control of reproductive development in lychee: A Review. Scientia Hort 22(4):333-345

Menzel CM, Simpson DR, Watson BJ (1993) Fruits of Tropical Climates In: Macrae R, Robinson RK, Sadler MJ (eds) Encyclopaedia of Food Science, Food Technology and Nutrition, Academic Press, London 3:2114-2118

Mishra KA, Syamal MM, Ray PK (1985) Use of chemicals to delay ripening of "China" litchi. Indian Food Packer 39(5):56-59

Mishra RS, Khan I (1981) Effect of 2,4,5-trichlorophenoxyacetic and micro nutrients on fruit size, cracking, maturity and quality of litchi cv 'Rose scented'. Prog Hort 13:87-90

Misra SK, Nauriyal JP, Awasthi RP (1973) Effect of growth regulators on fruit drop in litchi. Punjab Hort J 13:122-126

Moreuil C (1973) Some observations and experiments on the litchi. Fruits 28(9):637-640

Mukherjee PK (1956) Storage of litchi. Sci Cult 21(10):603-604

Mukherjee PK (1957) Preservation of natural colour of litchis under cold storage. Sci Cult 23:101-103

Nagar PK (1994) Physiological and biochemical studies during fruit ripening in litchi (*Litchi chinensis* Sonn.) Post-harvest Biol Technol 4(3):225-234

Nijjar GS 1972) Litchi cultivation. Punjab Agriculture University, Ludhiana (Monograph)

Nip WK (1988) Handling and preservation of lychee (*Litchi chinensis* Sonn.) with emphasis on colour retention. Trop Sci 28:5-11

Normand F, Bouffin J (1995) Improvement of the packaging and storage of litchi in the Reunion. Fruits 50(3):205-214 (French)

Patra DK, Sadhu MK (1992) Influence of post-harvest calcium treatment on shelf life and quality of litchi fruit. South Indian Hort 40(5):252-256

Peng CY, Markakis P (1963) Effect of phenolase on anthocyanins. Nature 199:597-598

Piffert PG, Cultrera R (1974) Enzymatic degradation of anthocyanins- The role of sweet cherry polyphenol oxidase J Food Sci 39:786-791

Popenoe N (1920) The Litchi, Manual of Tropical and Subtropical Fruits- McMillan Co. New York, pp 312-325

Popenoe N (1948) Manual of Tropical and Sub-tropical Fruits Hofner Press, New York, pp 312-333

Prasad A, Jauhari OS (1963) Effect of 2,4,5-trichlorophenoxyacetic acid and alpha napthalene acetic acid on drop stop and size of litchi fruits. Madras Agric J 50:28-29

Prasad SS, Bilgram RS (1974) Investigations on diseases of litchi VI. Post-harvest diseases of fruits in India. Plant Diseases Reporter 58(19): 1134-1136

Prasad VS, Jha OP (1978) Acid and alkaline phosphatase activity in fruit pulp during ripening of litchi. Indian J Plant Physiol 22(1):84-86

Pratt DE, Balkcom CM, Powers JJ, Mills LW (1954) Interaction of ascorbic acid, riboflavin and anthocyanin pigments. J Agric Food Chem 2:367-372

Pujari MM, Syamal NB (1977) The effect of foliar spray of growth substances and minor elements on fruit drop in litchi (*Litchi chinesis* Sonn.) In: Proceedings Bihar Acad of Agric Sci, Bihar Agric College 25(1):27-30

Randhawa GS, Chacko EK (1972) Export potential of some Indian fruits- Problems and prospects. Tropical Sci 12(1):37-47

Ranvir Singh, Singh AK (1993) Fruit Cracking In: Chadha KL, Pareek DP (eds), Adv Hort (4):2119-2127

Robert EP, Chen NJ, Deputy, Huang H, Cheng G, Feifei G (1984) Litchi growth and compositional changes during fruit development. J Am Soc Hort Sci 109(6):817-821

Roy Choudhury R, Kabir J, Ray SKD, Dhua RS (1992) Effect of calcium on fruit quality of litchi. Indian J Hort 49(1):27-30

Sanyal D, Ahsan A, Ghosh B, Mitra SK (1990) Studies on sun burning and skin cracking in some varieties of litchi. Indian Agriculturist 34(1):19-23

Scott KJ, Brown BI, Chaplin GR, Wilcox ME, Bain JM (1982) The control of rotting and browning of litchi fruit by hot benomyl and plastic film. Scientia Horticulturae 16:253-262

Sharma SB (1983) Studies on the cracking of litchi. Ph.D. Thesis, Punjab Agricultural University, Ludhiana

Sharma SB, Dhillon BS (1985) Effect of zinc sulphate and growth regulators on the quality of litchi fruits. Indian Food Packer 39:29-32

Sharma SB, Dhillon BS (1986) Endogenous levels of gibberellins in relation to fruit cracking in litchi (*Litchi Chinensis* Sonn.) J Res PAU 23:432-434

Sharma SB, Dhillon BS (1987) Effect of zinc sulphate and growth regulators on fruit cracking in litchi. Indian J Hort 44:57-59

Sharma SB, Dhillon BS (1988) Endogenous levels of abscisic acid in relation to fruit cracking in litchi (*Litchi chinensis* Sonn.) Agric Sci Digest 8:55-58

Sharma SB, Ray PK (1987) Fruit cracking in litchi-A review. Haryana J Hort Sci 16:11-15

Shigeura G (1948) Blossom bud formation and fruit setting in litchi. Biennial Report of Hawaii Agriculture Experiment Station p 138-140

Shu H, Hart H, Lee H, Wicker L (1990) Enzymatic and colour changes during post-harvest storage of lychee fruit. J Food Sci 55: 1762-1763

Shukla KS, Misra RL, Kaul MK, Prasad A (1978) Studies on pollen germination of certain fruits. Haryana J Hort Sci 7:162-164

Shukla RK, Bajpai PN (1971) Symposium on Recent Advances in Horticulture. UP Inst of Agric Sci Kanpur, pp 118-121

Singh R (1957) Improvement of packing and storage of litchi at room temperature. Indian J Hort 14:205-212

Singh S, Krishnamurthi S, Katyal SL (1963) The litchi fruit culture in India. Indian Council of Agricultural Research. New Delhi, pp 153-160

Singh US, Lal RK (1980) Influence of growth regulators on setting, retention and weight of fruits in two cultivars of litchi. Scientia Horticulturae 12(4):321-326

Silverblatt F, Robinson AI, King CG (1943) The kinetics of the reaction between ascorbic acid and oxygen in the presence of copper ion. J Am Chem Soc 65:137-141

Sohan Singh, Dhillon BS (1981) Fruit drop pattern in litchi (*Litchi chinensis* Sonn.) cultivars and its control by the use of auxins. Prog Hort 13(3-4):91-93

Srestha GK (1981) Effect of ethephon on fruit cracking of litchi (*Litchi chinensis* Sonn.) Hort Sci 16:496

Srivastava MP (1964) Studies on fungal diseases of some tropical fruits 1. A list of the fungi isolated from fruits and fruit trees. Phytopathol 50:250-261

Srivastava RP, Singh L (1969) Effect of growth substances on the quality of litchi. Hort Sci 1(2):1-6

Starin N (ed) (1980) Tropical and Sub-tropical Fruits Composition Properties and Uses. AVI Publishing Inc, Connecticut, USA

Starr MS, Francis FJ (1968) Oxygen and ascorbic acid in the effect of relative stability of the anthocyanin pigments in Cranberry juice. Food Technol 22:1293-1295

Stephens SE (1955) The litchi. Queensland Agri J B1:19-20

Suryanarayana V, Das RC (1971) Effect of 2,4-D, NAA GA and 2,4,5-T on fruit weight and fruit cracking in litchi (*Litchi chinensis* Sonn.) var. 'Muzaffarpur' Plant Sci 3:126-128

Teaotia SS, Singh RD (1970) Fruit cracking - A review. Prog Hort 2:21-31

Thakur S, Ramkumar, Brahmachari VS (1990) Effect of different growth regulators on fruit set, retention and size of litchi. Indian J Hort 43(3):305-308

Thompson SD (1954) Effects of pre-packaging and refrigeration on quality of lychees. Annual Report of Florida Agricultural Experiment Station p 113

Tongdee EC, Scott KJ, McGlasson WB (1982) Packaging and cool storage of litchi fruit. CSIRO Food Research Quarterly 42(2):25-28

Toulmonde B, Beauverd D (1984) Head space analysis-Trap desorption by microwave energy application to the volatile components of some tropical fruits In: Adda JC (ed) Progress in Flavour Research, Proceedings of the 4th Weurman Flavour Research Symposium, France

Tripathi VK, Kaphalia BS, Seth TD, Surjeet Singh (1987) Composition of litchi. Cultivars 41(4):7-10

Underhill SJR (1992) Lychee (*Litchi chinensis* Sonn.) pericarp browning. Trop Sci 32:305-312

Underhill SJR, Critchley C (1992) The physiology and anatomy of litchi (*Litchi chinensis* Sonn) pericarp during development J Hort Sci 67(4):437-444

Underhill SJR, Critchley C, Simons DH (1992) Post-harvest pericarp browning of lychee (*Litchi chinensis* Sonn.) fruit. Acta Hort 321:718-725

Underhill SJR, Gardiner S, Prasad A (1994) The use of SO_2 and low pH treatment to control lychee (*Litchi chinensis* Sonn.) pericarp browning In: Johnson GT, Highley E (eds) Proceedings of Workshop on Development of Post-harvest Handling Technology for Tropical Fruits, Thailand 16-18 July 1992 ACIAR, pp 30-35

Velain JM (1988) Rapport des activities d'exportation de litchi dans le cadre de la convention IRFA-SENEX Reunion. CIRAD-IRFA Reunion, p 19 (document interne) (French)

Verma SK, Jain BP, Das SR (1980) Preliminary studies on the evaluation of growth substance with minor elements in controlling fruit drop in litchi (*Litchi chinensis* Sonn.) . Haryana J Hort Sci 10:4-10

Verma UP, Roy RS (1953) Litchi storage at low temperature. Proc Bihar Acad Agric Sci 2: p 128

Vyas ND (1938) The litchi. UP Department of Agriculture Bulletin 12:1-10

Wealth of India (1962) Raw Materials, Vol I, CSIR, New Delhi, pp 145-148

Xiang X, Zhang ZW, Qui YP, Yuan PY, Wang BQ (1994) A study of fruit set physiology in relation to endogenous hormones in litchi (*Litchi chinensis* Sonn.) Acta Horticulturae Sinica 21(1):1-6

Zauberman G, Ronen R, Akerman M, Weksler A, Rot I, Fuchs Y (1991) Post-harvest retention of red colour of litchi fruit pericarp. Scientia Horticulturae 47:89-97

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Effect of Fermentation on Phytic Acid Content and *In Vitro* Digestibility of Starch and Protein of Rice-Blackgram *Dhal*-Whey Blends

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Rice and blackgram *dhal* were mixed in three different proportions i.e., 60:40, 70:30 and 80:20 (w/w). Further, 105 ml whey (a nutritious by-product of cheese industry) was added to 100 g of rice-blackgram *dhal* blends. Fermentation of such cereal-legume-whey blends at 35°C for 18 h brought a significant decline in phytic acid content. The phytic acid contents of various rice-blackgram *dhal* blends without and with whey ranged from 205.57 to 301.96 and 172.67 to 226.82 mg/100 g, respectively. Phytic acid content decreased to the extent of 26 to 37% over the control value. Whey incorporation and fermentation improved the starch digestibility and protein digestibility of all the rice-blackgram, *dhal* mixtures. Improvement in starch and protein digestibilities is related to the reduction in phytic acid content, which is known to inhibit amylolysis and proteolysis. A significant negative correlation was observed between phytic acid and starch and protein digestibilities.

Keywords: Fermentation, Cereal-legume-whey blends, Phytic acid, Polyphenols, Starch digestibility, Protein digestibility.

Instinct for eating a variety of foods is deep-rooted and is still evident in present day generation. A wide range of cereals and legumes has been playing an important role in this diversity, as they form important constituents in the diets of a majority of world's population.

Consumption of cereals and legumes together during the same meal gives a higher value to the quality of protein ingested than those eaten separately. Further, when cereal-legume mixtures are blended with milk or milk products such as butter milk and whey, it may be highly advantageous. Whey, a by-product of cheese industry is rich in lactose, vitamins, minerals and proteins of high biological value. Whey, which is produced in large amounts (85 million tonnes/ year) is disposed off to sewage system. Hence, the use of whey has been under active consideration, in the recent times. Incorporation of whey into cereal-legume blends will not only further improve their nutritive value but also avoid the environmental pollution, if utilized in a proper way.

Cereal-legume-whey blend will have better protein quality, good profile of carbohydrates and minerals. But their utilization may be limited due to the presence of inherent antinutritional factors like phytic acid in considerable amounts in cereals and legumes. Phytic acid is known to inhibit proteases and amylases (Deshpande and Cheryan 1984) and hence may result in lower digestibility of proteins (Knuckles et al. 1985) and reduce the starch digestibility (Yoon et al. 1983). Removal of this antinutrient by any of the processing methods is necessary to improve the nutritional quality of a blend containing cereals and legumes.

Since pre-historic times, fermentation has been known as a method producing, preserving and improving the nutritive value of foods, which are highly acceptable to man. In India, most of the fermented foods are prepared from the blends containing rice and blackgram *dhal*.

Therefore, in the present study, an attempt has been made to find out the effect of natural fermentation on phytic acid content and *in vitro* digestibilities of starch and protein of rice-blackgram *dhal*-whey blends mixed in different proportions.

Materials and Methods

The rice and blackgram (*Vigna radiata* L. Hepber) *dhal* used in this study were procured from the market in a single lot. These grains were cleaned of dust, stones, broken and wrinkled seeds and other foreign materials and were ground in an electric grinder (Cemotec 1090, M/s Tecator, Hoganas, Sweden), using 1.5 mm sieve. The milk used for the preparation of whey was collected from a dairy in a single lot.

Development of rice-blackgram dhal *blends :* Rice and blackgram *dhal* flours were mixed in the following three different proportions :

i) Rice + blackgram *dhal* (60:40-RBL I)
ii) Rice + blackgram *dhal* (70:30-RBL II)
iii) Rice + blackgram *dhal* (80:20-RBL III)

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These ratios were selected on the basis of composition of essential amino acids particularly lysine, methionine and cystine so as to achieve cereal-legume blends of good protein quality.

Preparation of rice-blackgram dhal-*whey blends:* For whey making, buffalo milk was standardized at 6% fat level. Citric acid (1%) was added to the milk to curdle and it was filtered to procure whey. This whey (105 ml) was mixed with each rice-blackgram *dhal* blend (100 g) and stirred to obtain a homogenous mixture.

Fermentation of rice-blackgram dhal-*whey blends:* All the rice-blackgram *dhal*-whey blends were allowed to ferment at 35°C for 18 h in an incubator.

Preparation of samples for analysis : The samples of raw, unprocessed rice, blackgram *dhal* and blends of unprocessed rice and blackgram *dhal* with and without whey and fermented cereal-legume-whey blends were oven-dried at 65°C to a constant weight. Dried samples were ground (Cemotec 1090, M/s Tecator, Hoganas, Sweden), using 1.5 mm sieve and stored at room temperature till further chemical analysis.

Chemical analysis : The phytic acid content was determined by the method of Haug and Lantzsch (1983). *In vitro* starch digestibility was determined by employing pancreatic amylase and then measuring maltose liberated by using dinitrosalicylic acid reagent (Singh et al. 1982). *In vitro* protein digestibility was carried out by the method of Akeson and Stahmann (1964), as modified by Singh and Jambunathan (1981). All the estimations were carried out in triplicate.

Statistical analysis : The data were subjected to analysis of variance in a completely randomised design and correlation co-efficients were derived according to standard statistical methods (Panse and Sukhatme 1961).

Results and Discussion

Phytic acid : The respective phytic acid values of rice and blackgram *dhal* were found to be 95.90 and 628.23 mg/100 g (Table 1). The phytate content of unprocessed blends of rice and blackgram *dhal*, prepared in three different proportions ranged from 205.57 to 301.96 mg/100 g. RBL I blend had the maximum amount of phytic acid content followed by RBL II and RBL III. Blackgram *dhal* had more concentration of this antinutrient than rice. RBL I had the highest, while RBL III had the lowest concentration of phytate. The phytate content of three different rice-blackgram *dhal* mixtures varied significantly.

TABLE 1. PHYTIC ACID AND *IN VITRO* DIGESTIBILITIES OF STARCH AND PROTEIN OF THE BLENDS CONTAINING RICE AND BLACKGRAM *DHAL* MIXED IN DIFFERENT PROPORTIONS (ON DRY MATTER BASIS)

Blends	Phytic acid, mg/100g	Starch digestibility, mg maltose released/g	Protein digestibility, %
Rice	95.90±1.26	51.30±0.23	56.66±0.51
Blackgram *dhal*	628.23±1.97	35.55±0.30	41.32±0.64
Blends of rice and blackgram *dhal*			
Rice+blackgram *dhal* (R:BL::60:40-RBL I)	301.96±1.51	45.49±0.19	50.50±0.27
Rice+blackgram *dhal* (R:BL::70:30-RBL II)	248.04±0.39	47.58±0.16	52.50±0.15
Rice+blackgram *dhal* (R:BL::80:20-RBL III)	205.57±3.34	49.20±0.09	53.54±0.08
Pooled S.E. (m)	1.00	0.12	0.20
Pooled CD (P<0.05)	2.90	0.36	0.61

Values are means ± SD of three determinations

The addition of whey to all the three unprocessed raw blends of rice and blackgram *dhal* reduced the phytate content significantly (P<0.05). Due to whey incorporation, a decrease in whey contents to the extent of 16 to 25% over the control value was observed in various rice-blackgram *dhal* blends (Table 2). As whey had no phytic acid, its addition in the rice-legume blends had a diluting effect, which reduced the level of this antinutrient.

Fermentation of rice-blackgram *dhal*-whey blends at 35°C for 18 h further reduced the phytate content significantly (Table 2). Fermentation could lower the phytic acid content of RBL I-whey blend i.e., from 226.82 mg/100 g in the unfermented mixture to 190 mg/100 g in the fermented mixture. Similarly, reduction in phytic acid level of RBL I whey and RBL III-whey blends was noticed. A decrease to the extent of 26 to 37% over the control value in phytate level was observed in three different fermented cereal-legume-whey blends.

The phytase activity is shown in various types of microflora (Lopez et al. 1983). This phytase activity may be partly responsible for reducing the phytic acid content in the fermented product. The inherent phytase activity in cereals and legumes may also be responsible for lowering the phytate content during fermentation of various cereal-legume-whey blends. Optimum temperature for phytase activity from plants and microbial sources has been known to range between 35 and 45°C. This may account for the greatest reduction in phytic acid content at 35°C. Phytic acid reduction

TABLE 2. EFFECT OF FERMENTATION ON PHYTIC ACID AND *In vitro* DIGESTIBILITIES OF STARCH AND PROTEIN OF THE BLENDS CONTAINING RICE- BLACKGRAM *DHAL* AND WHEY (ON DRY MATTER BASIS)

Blends	Phytic acid, mg/100g	Starch digestibility, mg maltose released/g	Protein digestibility, %
Unfermented blends of rice, blackgram *dhal* and whey			
Rice+blackgram *dhal* (R:BL::60:40-RBL I) + whey	226.82±1.39 (-25)	52.82±0.18 (+16)	62.62±0.30 (+24)
Rice+blackgram *dhal* (R:BL::70:30-RBL II) + whey	198.70±1.45 (-20)	55.82±0.16 (+17)	66.67±0.37 (+27)
Rice+blackgram *dhal* (R:BL::60:40-RBL III) + whey	172.67±1.24 (-16)	58.60±0.14 (+18)	69.60±0.30 (+30)
Fermented blends of rice, blackgram *dhal* and whey			
RBL I + whey	190.00±1.03 (-37)	65.96±0.28 (+45)	73.73±0.27 (+46)
RBL II + whey	168.60±1.50 (-32)	70.41±0.21 (+48)	78.75±0.42 (+50)
RBL III + whey	152.46±2.06 (-26)	73.80±0.30 (+50)	82.98±0.27 (+55)
Pooled S.E. (m)	1.00	0.12	0.20
Pooled C.D. (P<0.05)	2.90	0.36	0.61

Values are means ± SD of three determinations

Values in parentheses indicate % increase/decrease (+/-) over the control values

due to fermentation has been reported in various fermented food including *tempeh* (Riet et al. 1987), *rabadi* (Grewal 1992), blackgram sprouts (Chaudhary 1993) and *wadi* (Yadav and Khetarpaul 1994).

In vitro *starch digestibility* : The *in vitro* starch digestibility values (expressed as mg maltose released/g) of raw rice and blackgram *dhal* were 51.30 and 35.55, respectively (Table 1). In the raw blends of rice and blackgram *dhal*, RBL III had the highest starch digestibility followed by RBL II and RBL I. In this mixture, the starch digestibility varied in the range of 45.49 to 49.20 mg maltose released/g. The blend containing the lowest amount of blackgram *dhal* (RBL III) had the maximum starch digestibility. Lower the amount of legume in a blend, higher was the starch digestibility.

Upon addition of whey, the starch digestibility of the rice-blackgram *dhal* blends improved significantly. An increase to the extent of 16 to 18% over the control was found in various RBL blends (Table 2).

Fermentation further brought about an enhancement in the *in vitro* starch digestibility of various blends containing rice, blackgram *dhal* and whey. The starch digestibility of different unfermented cereal-legume-whey blends varied from 52.82 to 58.60 mg maltose released/g meal, whereas after fermentation, the increment was in the range of 45 to 50% over the control (Table 2).

Enhancement in starch digestibility during fermentation may be due to partial breakdown of starch to oligosaccharides by fermenting microflora (Cronk et al. 1977) or enzymes inherent in rice and blackgram *dhal*. Decrease in the concentration of phytic acid during fermentation, as noticed in this study may account for the improved starch digestibility, as phytic acid is known to inhibit amylolysis (Thompson and Yoon 1984). Soni and Sandhu (1990) reported a higher amylase activity in conventional blackgram *wadi* after 3 days of fermentation. Various workers have reported an improvement in starch digestibility during fermentation in different foods including soybean (Boralkar and Reddy 1985), cereal-legume blends (Goyal 1991), *wadi* (Yadav 1992), pearl millet (Gupta et al. 1993).

In vitro *protein digestibility* : There were significant (P<0.05) differences among the protein digestibility of rice and blackgram *dhal* (Table 1). The protein digestibility values of raw unprocessed rice and blackgram *dhal* were 56.66 and 41.32%, respectively. Depending on the rice and legume ratio in various RBL blends, RBL III had the highest protein digestibility (53.54%) followed by RBL II (52.50%) and RBL I (50.50%)

A significant (P<0.05) increase in the protein digestibility was noticed, when whey was added to unfermented blends of rice and blackgram *dhal* (Table 2). The protein digestibility of RBL I was 50.50% and was raised to 62.62% after fermentation. Similar trend was observed in RBL II and RBL III blends after whey incorporation. The % increase ranged from 24 to 30 in various RBL blends after the incorporation of whey in the blends.

The enhancement in protein digestibility brought about by fermentation of rice-legume-whey blends was significant (P<0..05) (Table 2). After whey incorporation, the protein digestibility of RBL I, II and III was raised to the extent of 24,27 and 30%, respectively, which further rose to the extent of 46, 50 and 55%, respectively, in the above blends, when these were fermented at 35°C for 18 h. Maximum improvement was noticed in fermented RBL III-whey blend followed by whey incorporated

RBL II and RBL I mixtures, respectively.

Proteolytic enzymes produced during fermentation may be responsible for increased protein digestibility (Wang and Hesseltine 1970; Steinkraus et al. 1965). An increase in amino nitrogen by fermentation signifies partial breakdown of proteins to peptides and amino acids, thereby improving the protein digestibility (Kao and Robinson 1978). Phytic acid, which is known to inhibit the proteolytic enzymes (Tan et al. 1984; Knuckles et al. 1985) is considerably reduced during natural fermentation (Table 2) and may partly be responsible for the increase in protein digestibility. Enhanced protein digestibility has been reported in various fermented foods including *tempeh* and *miso* (Kao and Robinson 1978), soybean (Grewal 1992), *wadi* (Yadav 1992), cereal-legume-buttermilk blends (Goyal 1991) and blackgram sprouts (Chaudhary 1993).

The results of the present studies have shown that blackgram *dhal* had a high content of phytic acid as compared to rice. Whey incorporation as well as fermentation led to a decrease in the content of phytic acid in rice and blackgram *dhal* blend. Fermentation brought about an improvement in starch and protein digestibilities (*in vitro*) along with a decline in the phytate content. A significant ($P<0.01$) and negative correlation was observed between phytic acid and *in vitro* digestibilities of starch and protein. Hence, consumption of products prepared out of such fermented cereal-legume-whey mixtures will raise the nutritional status of vegetarian masses, especially of developing countries.

References

Akeson WE, Stahmann MA (1964) A pepsin pancreatin digest index of protein quality evaluation. J Nutr 83:257-259

Boralkar M, Reddy NS (1985) Effect of roasting, germination and fermentation on the digestibility of starch and protein present in soybean. Nutr Reports International 3:833-836

Chaudhary K (1993) Nutritional evaluation and utilization of germinated and fermented blackgram (*Phaseolus mungo*). MSc Thesis, Haryana Agricultural University, India

Cronk TC, Steinkraus KH, Hackler LR, Mattick LR (1977) Indonesian *tape ketan* fermentation. Appl Environ Microbiol 33:1067-1073

Deshpande SS, Cheryan M (1984) Effect of phytic acid, divalent cations and their interaction on alpha amylase activity. J Food Sci 49: 516-519

Goyal R (1991) Nutritional improvement and utilization of the cereal-legume blends through fermentation. MSc Thesis, Haryana Agricultural University, Hisar, India

Grewal R (1992) Nutritional improvement of soybean through fermentation and its utilization in traditional foods of India. PhD Thesis, Haryana Agricultural University, Hisar, India

Gupta M, Khetarpaul N, Chauhan BM (1996) Preparation and nutritional value of wheat *rabadi* - An indigenous fermented food of India. Int J Food Sci Technol (In press)

Haug W, Lantzsch HJ (1983) Sensitive method for the rapid determination of phytate in cereals and cereal products. J Sci Food Agric 34:1423-1426

Kao C, Robinson RJ (1978) Nutritional aspect of fermented foods from chickpea, horsebean and soybeans. Cereal Chem 55:512-516

Knuckles BE, Kuzmicky DD, Betschart AA (1985) Effect of phytate and partially hydrolyzed phytate on *in vitro* protein digestibility. J Food Sci 50:1080-1082

Lopez Y, Gordon DT, Fields ML (1983) Release of phosphorus from phytate by natural lactic acid fermentation. J Food Sci 48:953-954

Panse YG, Sukhatme PV (1961) Statistical Methods of Agricultural Workers. 2nd edn, Indian Council of Agricultural Research, New Delhi

Riet WB, Wander, Wight AW, Gilliers JJL, Datel JM (1987) Food chemical analysis of *tempeh* prepared from South African grown soybeans. Food Chem 25(3):176-206

Singh U, Jambunathan R (1981) Studies on 'Desi' and 'Kabuli' chickpea cultivars. The levels of protease inhibitors, levels of polyphenolic compounds and *in vitro* digestibility. J Food Sci 46:1364-1368

Singh U, Kherdekar MS, Jambunathan R (1982) Studies on 'Desi' and 'Kabuli' chickpea cultivars. The levels of amylase inhibitors, level of oligosaccarides and *in vitro* starch digestibility. J Food Sci 47:510-512

Soni SK, Sandhu DK (1990) Biochemical and nutritional changes associated with Indian Punjabi *warri* fermentation. J Food Sci Technol 27:82-85

Steinkraus KH, Lee CY, Buck PA (1965) Soybean fermentation by *Ontjom* and *Neurospora*. Food Technol 19:1302-1307

Tan N, Wong K, de Lumen BO (1984) Relationship of tannin levels and trypsin inhibitor activity with *in vitro* protein digestibility of raw and heat treated winged bean. J Agric Food Chem 32:819-824

Thompson LU, Yoon JH (1984) Starch digestibility as affected by polyphenol and phytic acid. J Food Sci 49:1228-1229

Wang HL, Hesseltine CW (1970) *Safu* and *tao-chao*. J Agric Food Chem 18:572-575

Yadav S (1992) The preparation, acceptability and nutritional evaluation of *wadi* -An indigenous legume fermented product. MSc Thesis. Haryana Agricultural University, Hisar, India

Yadav S, Khetarpaul, N (1994) Indigenous fermentation of legume: Effect of phytate and polyphenolic content and *in vitro* digestivility of starch and protein. Food Chem 50:403-406

Yoon JH, Thompson LU, Jenkins DJA (1983) The effect of phytic acid on *in vitro* starch digestibility and blood glucose response. Am J Clin Nutr 38:835-842

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Effect of Precooling on the Quality of Mango (cv. 'Mallika')

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Effect of precooling on the storage life of mango (cv. 'Mallika') was studied. Various precooling methods adopted were hydrocooling (15 and 30 min), running water (15 and 30 min) room cooling (30 and 60 min), ice cooling (15 and 30 min) evaporative cooling and control (without any treatment). Precooling of mango fruits, immediately after harvest, delayed ripening, without any deterioration in fruit quality. However, all the methods used were not equally effective. Cooling the fruits under running cold (4-5°C) water for 30 min effectively lowered the fruit temperature by 16°C and significantly retarded the ripening, thereby extending the storage life by 3 to 4 days, while retaining fruit quality. Although ice cooling was the most effective method in reducing the physiological loss of weight, delaying ripening and maintaining higher fruit firmness, the sensory quality of these fruits was unacceptable, due to high spoilage. Evaporative and room cooling methods were not effective in enhancing the storage life of mangoes.

Keywords: Mango, 'Mallika', Precooling, Quality, Shelf life.

Mango is one of the important fruit crops grown in the tropics (Bhatnagar and Subramanyam 1971). In recent years, mango cultivation has greater significance in India because of its vast export potentialities (Mukunda and Thilak 1990). Therefore, preservation of the fruit in the fresh state for extended period, without loss of quality, needs immediate attention. Out of more than 1000 known varieties of mango (Singh 1990), only 10 to 12 are of commercial importance. Out of these, 'Mallika' is a new hybrid obtained by crossing 'Neelam' and 'Dashehari' (Subbaiah et al. 1990). In Karnataka, it is one of the most popular cultivars among the newly developed mango hybrids for its superior qualities, viz., higher fruit weight, regular bearing habit, better keeping quality, firm flesh with excellent organoleptic qualities (Subbaiah et al. 1990).

In order to reduce post-harvest losses and meet the requirements of fresh commodity market, its preservation in the fresh state is of commercial importance. During mango harvest season in India, the atmospheric temperatures rise to as high as 42°C. Such high temperatures have a detrimental effect on post-harvest storage life of the fruit. Therefore, lowering the temperature of mango fruits by precooling will help to increase their storage life.

Precooling involves rapid removal of heat from freshly harvested fruits and vegetables and prior to loading for transport to the markets and before storage (Ryall and Lipton 1973). The present investigation was carried out to study the effect of different methods of precooling such as water cooling, ice cooling and evaporative cooling on the quality of mango (cv. 'Mallika') fruits.

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Materials and Methods

Fully mature mango fruits (cv. 'Mallika') (TSS around 5.8°B) with uniform size and shape (group B) were harvested by hand picking from the trees in the mango orchard of the University and were immediately carried in plastic crates on head to the laboratory, where the fruits were subjected to various precooling treatments as below.

Treatment HC 15 : Fruits dipped in cold water (4-5°C for 15 min. (Hydrocooling)

Treatment HC 30 : Fruits dipped in cold water (4-5°C) for 30 min. (Hydrocooling)

Treatment RWC 15 : Cooling fruits under running cold water (4-5°C) for 15 min.

Treatment RWC 30 : Cooling fruits under running cold water (4-5°C) for 30 min.

Treatment RC 30 : Cooling fruits in cold room (2-4°C) for 30 min.

Treatment RC 60 : Cooling fruits in cold room (2-4°C) for 60 min.

Treatment IC 15 : Cooling fruits for 15 min. by covering with ice.

Treatment IC 30 : Cooling fruits for 30 min. by covering with ice.

Treatment EC: Cooling fruits by dipping them in cold water for about 30 min. and drying under fan till the water on the fruit surface evaporates completely (Evaporative cooling).

Control : Fruit stored at room temperature (24-26°C) directly without any treatment except thiobendazol treatment for 30 sec.

The total number of fruits used per treatment was 45 with three lots (replication) of 15 fruits

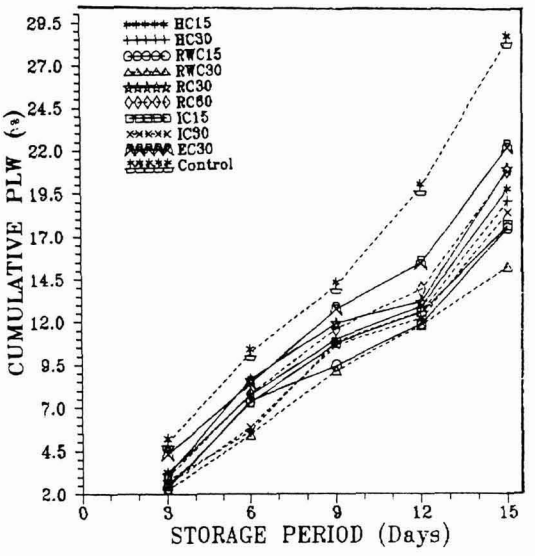

Fig. 1. Effect of precooling treatments on the cumulative physiological loss of weight of 'Mallika' mangoes during storage under ambient conditions

each. All the fruits were dip-treated with 500 ppm of thiobendazol solution to minimise the spoilage. The fruits were then dried in shade and stored in an open shelf in single layers under ambient conditions. Different parameters such as fruit temperature (immediately after treatment), firmness, days taken to attain edible ripeness, storage life and spoilage were observed and recorded. The fruit temperature was recorded by rupturing the peel and piercing the ordinary thermometer into the inner layers of the flesh (2-3 cm deep). Hand penetrometers (13.5 and 1 kg capacity) were used to record the fruit firmness (kg/cm^2). The chemical parameters such as TSS, starch, sugars, acidity and ascorbic acid content were analyzed by the procedures as described by Ranganna (1977). Sensory evaluation was carried out by a panel of 10 judges. Ten point scale (ranging from 2, very bad and to 10, very good) was used for the sensory analysis of the sample.

The experimental design followed was completely randomised design and the data were subjected to analysis of variance.

Results and Discussion

Physico-chemical changes : In various precooling treatments after harvest, the fruit temperature of 36°C was significantly reduced to 16.5 to 32°C at the end of the treatment. Treatment IC 30 was the most effective in reducing the fruit temperature from 36 to 16.5°C followed by treatment RWC 30, which reduced the fruit temperature to 20°C and the least effective was treatment EC (32.2°C) (Fig. 1). The PLW was significantly reduced by the treatment. The reduction in PLW in the treatment RWC 30 ranged from 2 to 8% over control (Fig. 1). The next best treatment was RWC 15 followed by treatments IC 30, IC 15 and the least effective was EC treatment. The time taken by the fruit to attain edible ripeness was the least (7 to 7.2 days) in case of control and the fruits precooled with EC treatment. The longest time was recorded in

TABLE 1. EFFECT OF PRECOOLING ON TSS, TOTAL ACID CONTENT (% MALIC ACID), DAYS TO ATTAIN OPTIMUM RIPENING, SHELF LIFE, SPOILAGE AND SENSORY EVALUATION IN MANGOES (cv. 'MALLIKA')

Treatments	Total soluble solids			Total acid			Days taken for optimum ripening	Fruit ripening, %			Shelf-life, days	Spoilage,%, 15th day of storage	Sensory characteristics				
	9D*	12D	15D	9D	12D	15D		3D	6D	9D			Freshness	Surface colour	Flavour**	Texture	Taste
HC15	20.8	21.9	19.7	0.6	0.3	0.1	9.6	0	0	73.3	11.2	4.5	7.9	7.6	8.1	7.1	8.1
HC30	20.5	21.0	19.9	0.9	0.4	0.2	9.6	0	0	80.0	11.8	4.4	7.3	7.6	7.6	8.6	7.3
RWC15	19.4	20.1	20.0	0.9	0.4	0.2	10.2	0	0	66.0	12.4	2.2	8.2	8.7	9.1	8.2	8.1
RWC30	19.3	20.1	20.3	0.9	0.4	0.2	10.4	0	0	66.0	12.6	2.2	9.2	9.1	9.1	8.9	9.8
RC30	21.2	21.5	19.2	0.7	0.3	0.2	7.2	0	6.6	100.0	9.2	15.6	6.3	7.1	7.3	6.1	6.3
RC60	21.2	21.4	19.3	0.6	0.3	0.1	7.8	0	13.3	93.3	9.8	15.6	6.7	6.3	6.1	6.1	6.3
IC15	19.4	21.0	19.9	0.8	0.4	0.2	10.2	0	0	53.3	11.2	17.9	5.1	5.3	5.3	5.1	5.1
IC30	19.5	21.0	20.0	0.9	0.4	0.2	10.2	0	0	53.3	11.2	17.9	5.1	5.1	5.1	5.8	5.3
EC	21.2	21.5	19.1	0.7	0.3	0.1	8.2	0	6.6	93.3	9.2	17.9	7.1	5.1	6.3	5.9	6.3
Control	22.4	21.5	19.0	0.7	0.3	0.1	7.2	0	20.0	100.0	9.2	31.1	6.3	6.3	6.4	6.4	6.3
SEM ±	0.43	0.12	0.20	-	-	0.02	-	-	-	-		-	0.54	0.69	0.60	0.83	1.50
CD(5%)	1.25	0.34	0.60	NS	NS	0.06	-	-	-	-	-	-	1.37	1.92	1.56	2.16	1.30

*D = Days

**Flavour = Combined effect of taste and smell ; NS = Non-significant

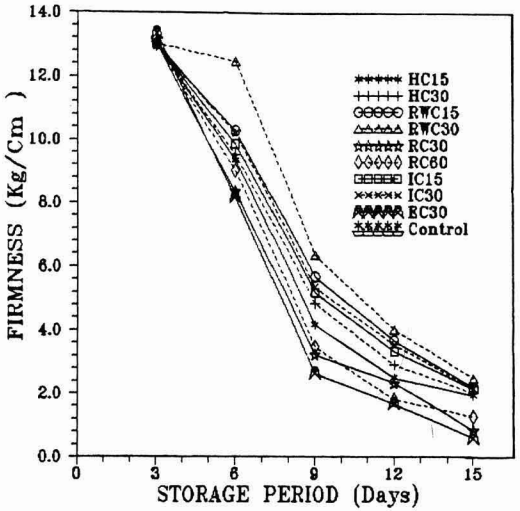

Fig. 2. Effect of pre-cooling treatments on the firmness of 'Mallika' mangoes during storage under ambient condition

treatments IC15 and IC30 and treatment RWC15 and RWC30 (Table 1). The firmness was gradually reduced as the storage period advanced. The treatment RWC30, being the best of all, maintained higher fruit firmness throughout the storage period (Fig. 2). The next best treatmentss were RWC15, IC15 and IC30. Among the treatments, EC, RC30 and RC60 maintained higher TSS, whereas treatments IC15, IC30, RWC15 and RWC30 maintained lower TSS (Table 1). The total titrable acidity of fruits was reduced gradually during the storage period irrespective of precooling treatments. On the 15th day of storage, the treatment RWC 20 was found to maintain the higher titrable acidity followed by treatments RWC15, IC15 and IC30. However, there was no significant change in ascorbic acid content due to treatments, although the more effective treatments tended to maintain higher ascorbic acid content.

Mango being a climacteric fruit, ripening is accompanied with an increase in PLW, TSS, reducing sugars and decrease in acidity, ascorbic acid, starch and firmness. The rate of these changes is influenced by storage temperature, relative humidity and other environmental conditions, the prominent among them being the storage temperature.

Low fruit temperature and low storage temperature slowed down the rate of increase in PLW (Kalra and Tandon 1983; Vazquez and Lakshminarayana 1985), TSS (Kapse et al. 1977; Singh and Chauhan 1982), sugars (Vazquez and Lakshminarayana 1985), starch (Mukherjee 1972) and carotenoids (Shukla and Bajpai 1970; Thomas and Oke 1983), while delaying the decline in firmness (Kalra and Tandon 1983).

It is evident that the rate of physiological and biochemical changes in fruits during ripening are dependent on temperature. Hence, the lower rate of these changes in fruits treated with IC 30, IC 15 and RWC 30 might be due to rapid removal of field heat. During this process, the rate of water loss due to transpiration might have been reduced, with suppression of intensity of respiration (Mitchell 1985). Activities of the enzymes, starch hydrolysis, pectin breakdown and the rate of decline in firmness leading to the release of calcium from the tissue may have also been affected (Kalra and Tandon 1983).

Ripening and storage life : Reipening of 'Mallika' mangoes was delayed in treatments RWC 30, IC 30 and IC 15 as compared to the control and other treatments (Table 1). This might be due to rapid removal of field heat from the mango. The respiratory activity in fruit, senescence and the rate of both production as well as action of ethylene, which is called ripening hormone, are temperature dependent. Due to the precooling treatment of fruits, which removed the field heat, metabolic activity and consequently the respiration rate (Shukla and Bajpai 1979; Singh and Chauhan 1982; Thomas and Oke 1983; Mitchell 1985) might have been reduced in addition to inhibition of ethylene production. The maximum shelf life was observed in the fruits precooled with the treatment RWC 30 (12.6 days) and RWC 15 (12.4 days) followed by treatments IC 15 and IC 30 (11.2 days). The least shelf life (9.2 to 9.8 days) was observed in treatments RC 30, RC 60, EC and control (Table 1).

Spoilage : The least per cent spoilage *(Diplodia natalensis)* was recorded by treatment RWC 30 and RWC 15 at ambient condition, when compared to EC treatment and control fruits, which were found to have more of spoilage throughout the storage period (Table 1). It has been reported that the spoilage in mangoes was reduced as the storage temperature was reduced form 30°C to 25°C (Kalra and Tandon 1983).

These findings suggest that the temperature and relative humidity control the spoilage. In addition, the running water might have washed away the microorganisms such as *Colletotrichum gloeosporioides* and *Diplodia natalensis*, which cause spoilage.

The greater loss of fruit due to spoilage in the treatments IC 30 and IC 15 might be due to chilling

injury caused by the contact of the ice with the fruit. The chilling injury was expressed by black patches on the surface, internal discoloration, uneven ripening and accelerated incidence of surface decay of the fruits (Kader 1985).

Sensory evaluation : The quality aspects such as freshness, surface colour, flavour, texture and taste were found to be higher in fruits precooled by treatments RWC30 and RWC15 (Table 1). The least, below normal (6 points), was scored in the fruits precooled with IC30 and IC15. Similar results were also observed by several researchers in mango varieties 'Dashehari' and 'Alphonso' (Mann and Singh 1976; Thomas and Oke 1983), guava 'Lucknow-49' (Singh and Chauhan 1982) and grapes (Birlinka and Queen of Vine yard) (Combrink et al. 1981).

The higher quality of the fruits precooled with treatments RWC 30 and RWC 15 might be due to high TSS and sugar content and less spoilage in ripe fruits as described earlier. The least score of sensory evaluation observed in treatments IC 15 and IC 30 may be attributed to more spoilage and chilling injury as well as uneven ripening.

The present study revealed that precooling of mangoes (cv. 'Mallika') immediately after harvest delayed ripening without any deterioration in fruit quality. Although ice cooling was very effective in reducing the PLW, delaying ripening and maintaining higher fruit firmness, the sensory quality of these ripe fruits was unacceptable, recording below normal score and with more spoilage. Evaporative and room cooling were not effective in enhancing the storage life of mangoes. The best method of precooling was found to be cooling the fruits with running cold water for 30 min. to internal temperature of 20°C.

The present results may be useful in Indian mango industry to reduce the post-harvest spoilage. However, further work is needed to standardise the method and duration of precooling so as to exploit on a commercial scale.

References

Bhatnagar HC, Subramanyam H (1971) Some Aspects of Preservation, Processing and Export of Mango and its Products, Export Group Meeting, Report No. UNIDO ID/WG Vienna/15, Austria 88/15

Combrink JC, Eksteen J, Laszlo JC, Truter AM (1981) Slow cooling of table grapes in polyethylene bags. Deciduous Fruit Grower 31:94-100

Kader AA (1985) Sources of information related to post-harvest biology and technology. In: Kader AA, Kasmire RF, Mitchell FG, Reid MS, Sommer NF, Thompson JF (eds). Post-harvest Technology of Horticulture Crops. Co-op. Extension, University of California, Davis, pp 1-2

Kalra SK, Tandon DK (1983) Ripening behaviour of 'Dashehari' mango in relation to harvest period. Scientia Hort 19 : 263-269

Kapse MB, Rane DA, Kulkarni DM, Ingle UM (1977) Biochemical changes in 'Totapuri' mango during ripening and storage, South Indian Hort 25:119-120

Mann SS, Singh RN (1976) The cold storage life of 'Dashehari' mangoes. Scientia Hort 52:249-253

Mitchell GF (1985) Cooling horticultural commodities. In: Kader AA, Kasmire RF, Mitchell FG, Reid MS, Sommer NF, Thompson JF (eds), Post-harvest Technology of Horticultural Crops. Co-op Extension, University of California, Davis pp 35-44

Mukherjee PK (1972) Harvesting, storage and transport of mango. Acta Hort 24:251-258

Mukunda GK, Thilak KS (1990) 'Mallika' shreshtaa hybrid maavu. 'Prajavani' Dated Jan 20, 1990

Ranganna S (1977) Manual of Analysis of Fruit and Vegetable Products. Tata McGraw Hill Publishing Co. New Delhi

Ryall AL, Lipton WJ (1973) Handling Transportation and Storage of Fruits and Vegetables, Vol 2. AVI Publishing Co, West Port, Connecticut

Shukla HS, Bajpai PN (1979) Post-harvest physiological studies in mango (*Mangifera indica* L.) cv 'Dashehari'. Mango Working Meeting, Panaji, Goa, India

Singh K, Chauhan KS (1982) Effect of waxol and potassium permanganate with precooling on storage life of cv 'L - 49' guava. Haryana J Hort Sci 11 (3/4) : 192-198

Singh RN (1990) Mango - Indian Council of Agricultural Research, New Delhi

Subbaiah TK, Mukunda GK, Thimma Raju KR (1990) Performance of 'Mallika' mango under Bangalore conditions. International Seminar on New Frontiers in Horticulture. Bangalore pp 110-111

Thomas P, Oke MS (1983) Improvement in quality and storage of 'Alphonso' mangoes by cold adoption. Scientia Hort 19:257-262

Vazquez-Salinas C, Lakshminarayana S (1985) Compositional changes in mango fruit during ripening at different storage temperatures. J Food Sci 58:1646-1648

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A Kinetic Study on 5-Hydroxymethylfurfural Formation in Spanish UHT Milk Stored at Different Temperatures

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5-Hydroxymethylfurfural (HMF) formed at different storage temperatures (below 50°C) in commercial ultra high temperature (UHT) milk was measured both by colorimetric and RP-HPLC techniques. Lowest HMF amounts were noted in all samples by RP-HPLC method. HMF level was found to be related to temperature and time of storage and increased at higher temperature, although small losses were detected at 6°C. Two stages of HMF formation could be differenciated, i.e., at an early stage till first 60 days and an advanced one from 60 days until 90 days. Zero order kinetics were obtained for both stages, along with higher activation energy values for UGT-indirect samples.

Keywords: 5-Hydroxymethylfurfural, High performance liquid chromatography, Ultra high temperature, Stored milk, Browning, Spanish milk.

Consumption of ultra high temperature (UHT) milk in Spain is on the increase because a majority of people are not used to buy fresh or pasteurized milk daily. Raw milk of poor hygienic quality is subjected to severe heating in the dairy industries to ensure a safe product free from harmful microorganisms. Spain, being a warm country, atmospheric temperatures of above 30°C are common during a large part of the year (Morales and Jimenez-Perez 1991).

UHT process applied in Spain and in other countries, could be divided in a) UHT-direct (direct injection of steam) and b) UHT indirect (use of tabular heat exchangers). The limits of these treatments have been well defined in the Spanish law. Sometimes, overheating cases are detected. yielding a product of quality nearer to that from classical sterilization than of the UHT (Morales 1994). This implies higher levels of non-enzymatic browning reactions, isomerization and degradation of lactose, which are induced by heat (Olano and Martinez-Castro 1989).

The variations in milk components due to heat treatment have been widely reported in literature and include brown colour, defects in taste as well as flavour and diminished nutritional value (Burton 1984). In the study of thermal processes applied in the dairy industry, it is of considerable interest to evolve a compound, which may serve as an indicator of the heat treatment applied. In addition, a compound with these characteristics could be used to discriminate between different processing types as well as their development during storage. Among the many compounds formed in the milk during heat treatment, 5-hydroxymethyl-2-furfuraldehyde (HMF) has been earlier proposed as a suitable indicator of heat intensity applied to milk (Fink and Kessler 1986). Traditionally, total HMF content in milk has been determined by colorimetric measurement at 443 nm of complex, formed with thiobarbituric acid (TBA) (Keeney and Bassette 1959; Craig et al. 1961). Presence of variable amounts of HMF in crude milk makes the interpretation of the data from processed milk somewhat difficult (Burton 1984). Moreover, these colorimetric methods present a serious problem, as TBA is not a specific reagent for HMF. TBA is a general reactive of aldehyde groups, although TBA method is valid as a routine test. HMF values reported by several workers showed significant differences for apparently similar heat treatments (Zadow 1970; Klostermeyer et al. 1978; Horak and Kessler 1980). At present, reversed-phase HPLC techniques are also used to measure accurately HMF in milk (van Boekel and Rehman 1987; Morales et al. 1992; Berg 1993).

The objective of this work was to develop an improved assay for HMF in milk by RP-HPLC and study the kinetic behaviour of HMF in UHT-stored milk at controlled temperatures for comparing the results between colorimetric and HPLC methods.

Materials and Methods

Milk samples : UHT-treated samples that were heated indirectly (batch I) and directly (batch II) were obtained from commercial Spanish dairy companies. The samples were stored at 6, 20, 30, 40 and 50°C for 90 days and analysed after every

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15 days for HMF contents by colorimetric and RP-HPLC methods. All the reagents were of analytical grade and the solutions prepared were used on the same day.

Colorimetric analysis (TBA method) : HMF analysis by TBA method was carried out according to Keeney and Bassette (1959), with the modifications of Della Monica et al (1967). Milk (10 ml) was digested with 5 ml of 0.3 N oxalic acid solution for 1 h at 100°C in a water bath to measure total HMF (free-HMF + bound-HMF + precursors). After a rapid cooling in ice, the mixture was slowly deproteinized with 5 ml of TCA solution (40%, w/v) and filtered through Whatman No.42 filter paper. Filtrate (4 ml) was incubated with 1 ml of 0.05 M TBA solution at 40°C for 30 min. Absorbance at 433 nm was measured in spectrophotometer (Lambda 15 UV-VIS, Perkin Elmer) within 12 min. Distilled water was used to adjust the absorbance at zero. An average of triplicate samples was extrapolated to a regression curve made with pure HMF (up to 60 μmol l^{-1}) in Millipore water. (Recovery, % = 97.4±4.53, Reproducibility, c.v. % = 3.75).

RP-HPLC analysis : All colorimetric steps were followed, until filtrate was obtained. Filtrate was stored in eppendorf tubes at -20°C, until chromatographic analysis. For the analysis, sample was cooled and filtered through a 0.2 μm nylon filter. The HPLC conditions were according to Morales et al (1992). Sample (20 μl) was injected and total run time was 14 min. Average HMF retention time was 7.36 min at an isocratic elution (room temperature).

Chromatographic analysis : Sample was injected into Rheodyne 7125 injector and reversed-phase column Spherisorb C18 S5 ODS-2 (250 x 0.46 mm) of 5 μm particle size. Flow rate was set at 1 $mL \cdot min^{-1}$. Degassed and filtered mobile phase was made with sodium acetate buffer (0.08 M pH 3.6, adjusted with glacial acetic acid), used isocratically. To measure HMF, a spectrophotometer UV-VIS (Kontron Instruments Model 4322, Italy) at 2280 nm with 0.1 AUFS and 0.2 s of response time was used. The spectrophotometric signal was passed by interface RS-232 to personal computer (Compaq Deskpro 286) and integrate by means of the MT-450 software (Kontron Instruments, Italy). Calibrations were made using an external standard method. Standard curve of pure HMF (up to 60 $\mu mol \cdot l^{-1}$ in water was used to calculate the concentration of HMF in the sample. (Recovery, % = 99.8±1.28, Reproducibility, c.v. % = 3.81).

TABLE 1. GENERAL ANALYTICAL STUDY AND THERMAL PARAMETERS OF BATCHES I AND II BEFORE STORAGE

Parameters	I	II
Dry matter, %	10.88	10.61
Fat, %	3.40	3.20
Protein, %	3.00	2.98
Lactose, %	4.65	4.65
pH	6.62	6.76
HMF-C, μmol l^{-1}	11.20	4.26
HMF-H, μmol l^{-1}	9.20	3.73
Vit. B_1, mg l^{-1}	0.32	0.32
Lactose, mg 100 ml^{-1}	62.42	16.96
Sterilization temp, °C	141.50	146.00
Holding time, s	22.00	5.00
F_c factor, s	129.30	25.36

Results and Discussion

Milk samples were picked up from the industrial plant on the same day of their processing. In case of 1 day storage, a general analysis was made on the samples and no significant differences were found in lactose, protein and fat contents (Table 1). With regard to differences in initial pH values after thermal process, these could be related to different heating systems applied to each sample, direct or indirect. During heating of milk, the pH decreased, mainly due to formation of organic acids (e.g., formic acid). These organic acids are formed due to degradation of carbohydrates. Moreover, phosphate released from casein, its precipitation as calcium phosphate and subsequent release of H^+ are also responsible for the pH decrease (van Boekel et al. 1989).

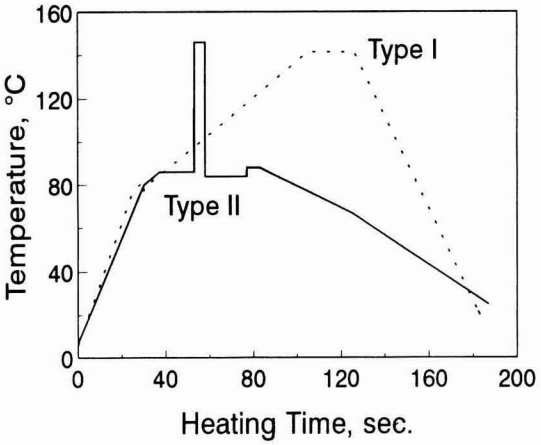

Fig. 1. Temperature (°C) vs. time (s) profiles of heat treatments of batch I (UHT-indirect) and batch II (UHT-direct) milk.

Fig.1 shows the heating profiles of each treatment applied for milk samples. To know the severity of heat damage, the sterilization factor (F) is of vital importance, for comparing or finding out a relationship between different industrial processes (Kessler 1988). Sterilization factor, F_c, is defined as the time in sec. at 127°C, where a thermal process is equivalent with the z value at 30°C (Reuter 1980). It represents the increase in temperature that causes a 110-fold increase in the reaction rate. Sterilization factor equation is as follows :

$$F_c = 10^{\frac{(T-T_B)}{z}} t_{res}$$

where,

T = temperature of the real process (°C)

T_B = temperature of the equivalent process (127°C)

t_{res} = time of sterilization temperature(s)

z = z factor (°C), fixed at 30°C.

Based on F_c values, it can be stated that a more severe heat treatment was applied in batch I than other batches, thereby leading to higher HMF after processing in batch I samples (Table 1).

In the present investigation, two different analytical procedures were used to measure HMF concentration in stored milk. Both methods measure the HMF, released in boiling oxalic acid, due to the dehydration of hexoses, free or linked to protein (e.g., amadori products), via 1,2 enolization and loss of three molecules of water, as well as free HMF (Gottschalk 1952). In the TBA method, HMF

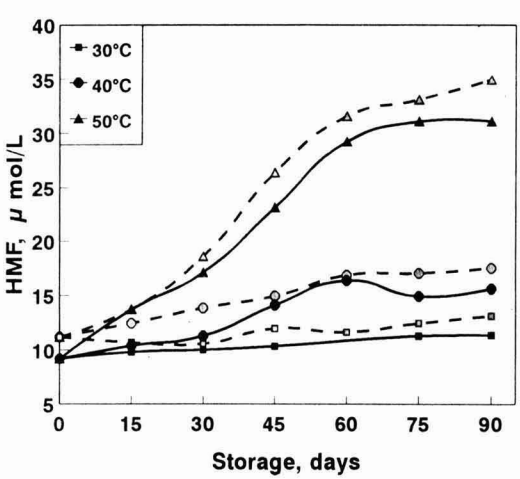

Fig. 2. Evolution of HMF content in sample (I) stored at 30, 40 and 50°C, as measured by RP-HPLC (solid line) and colorimetric method (dotted line)

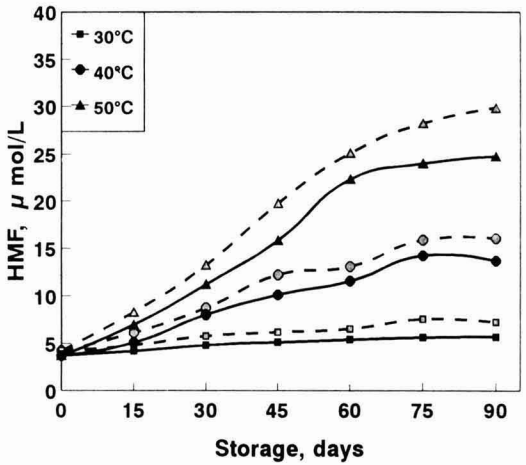

Fig. 3. Evolution of HMF content in sample (II) stored at 30, 40 and 50°C, as measured by RP-HPLC (solid line) and colorimetric method (dotted line)

is converted into a coloured complex, which can be measured by spectrophtometry at 443 nm. In the RP-HPLC method, formation of a complex with TBA is not necessary and HMF can be detected directly by its absorption at 280 nm after separation on a C_{18} reversed-phase silica column (Morales et al. 1992). Due to this reason, HMF detection by HPLC produce is more specific..

An average value of HMF in raw whole milk was subtracted from all samples. These values were 4.59±0.59 $\mu mol \cdot l^{-1}$ (3.62 to 6.12) by TBA method and 1.30±0.23 $\mu mol \cdot l^{-1}$(0.92 to 1.79) by RP-HPLC method. During storage at 6 and 20°C, no significant variations in HMF content were found, although small losses were detected at 6°C. HMF information, as measured by both techniques at 30, 40 and 50°C in batches I and II, are shown in Fig. 2 and 3.

HMF levels showed a linear increase with the temperature and storage time, but at 50 and 40°C, a loss linearity was observed after 60 days. HMF is an intermediate product of Maillard reaction and its relationship with the main inducing factor, the temperature, can be explained. At higher temperatures of storage, higher HMF levels could be expected in response to storing time. Moreover, HMF is known to be in a state of equilibrium between its destruction by oxidation and formation from precursors. Thsi equilibrium is moved to HMF formation at temperatures ≥30°C, as indicated by the present results. Linearity loss at storing times higher than 60 days could be due to protein precipitates in bottom portion and on the wall of

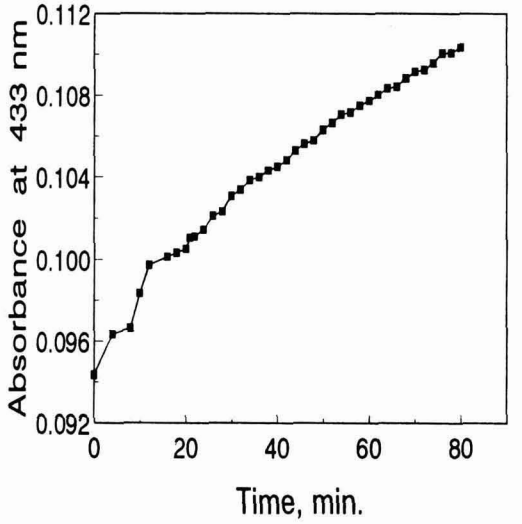

Fig. 4. Variation of chromophore HMF-TBA absorbance with time at 25°C

containers. When this happens, the precursors are separated in the reaction medium, the ε-NH_2 free residues of lysine, although samples were homogenized prior to analysis. High precipitation due to higher formation of HMF is most important at higher temperatures. On the other hand, at higher storage time, the differences were higher between HMF values in both techniques (5.24% of coefficient of variation (CV) in sample I and 9.81% (CV) in sample II at 50°C).

Values obtained from traditional colorimetric technique are always higher than those by RP-HPLC analysis, as shown in Fig. 2 and 3. Several authors have indicated that careful standardization of the assay is essential for obtaining reliable results in the colorimetric analysis with TBA. Some disadvantages of colorimetric method are low specificity, unstability of yellow complex and variable blank value (Kahlhofer 1982; Lechner 1982). The variation in the absorbance of HMF-TBA complex with the time at 25°C is shown in Fig. 4. Such problems are not encountered in the HPLC analysis, where it is not necessary to convert it into an intermediary coloured compound (complex HMF-TBA) for quantification. But, HPLC method presents, another drawback. Earlier report indicated an occasional interference with two unknown compounds that could get co-eluted with HMF peak, though chromatographic conditions were not well defined (Morales et al. 1992).

HMF formation in UHT-milk, stored at temperatures lower than 50°C, was adjusted at a zero order kinetic during the shelf-life of the product for 60 and 90 days. At refrigeration temperatures (5°C) and 20°C, net formation of HMF was not detected and hence HMF formation at these temperatures has been ignored in the kinetic study. In the zero order reaction, initial levels of precursors were not important in the reaction rate, if these were in higher amounts than the products. Lactose levels in milk are approximately 132.000 $\mu mol \cdot l^{-1}$ and lysine levels are 19.500 $\mu mol \cdot l^{-1}$ (Fink 1984). Following the zero reaction, formula used was either :

$$\frac{d[HMF]}{dt} = K_{(T)} \quad \text{or} \quad \frac{[HMF]_t}{[HMF]_o} = K_{(T)}$$

where,

$[HMF]_o$ = initial HMF concentration ($mol \cdot l^{-1}$) (t=0)

$[HMF]_t$ = HMF concentration at fixed storage time (t=days)

$K_{(T)}$ = reaction constant at fixed temperature (T)

Slopes of the lines of $[HMF]_o/[HMF]_t$ versus storage time (days) $K_{(T)}$ values were obtained for 30, 40 and 50°C. On the other hand, its logarithms are plotted for each sample in the Arrhenius plot (Log $K_{(T)}$ versus $1/T(°K)$ 10^3), the slope being $-E_a/R$ 2.303 (E_a activation energy of the process and R universal constant 8.341 J $mol^{-1} \cdot l^{-1}$). Kinetic values obtained for HMF formation in both procedures are given in Table 2.

TABLE 2. KINETIC PARAMETERS OF HMF EVOLUTION IN STORED SPANISH UHT MILK AT 60 AND 90 DAYS (ZERO ORDER KINETICS)

Sample	$K_{(30°C)}$ $mol \cdot l^{-1} \cdot s^{-1}$ x 10^2	$K_{(40°C)}$ $mol \cdot l^{-1} \cdot s^{-1}$ x 10^2	$K_{(50°C)}$ $mol \cdot l^{-1} \cdot s^{-1}$ x 10^2	E_a $KJ \cdot mol^{-1}$	A_o s^{-1}
I-H (60 d)	2.60 (0.948)	1.31 (0.956)	3.59 (0.987)	107.34 (0.987)	$7.90\ 10^{15}$
II-H (60 d)	0.76 (0.976)	3.70 (0.987)	8.23 (0.984)	97.78 (0.971)	$5.42\ 10^{14}$
I-H (90 d)	0.26 (0.979)	0.87 (0.845)	2.92 (0.952)	97.93 (0.999)	$1.74\ 10^{14}$
II-H (90 d)	0.59 (0.939)	3.30 (0.959)	6.92 (0.964)	100.73 (0.964)	$1.42\ 10^{15}$
I-C (60 d)	0.13 (0.320)	0.82 (0.992)	3.18 (0.973)	131.71 (0.994)	$5.79\ 10^{19}$
II-C (60 d)	0.92 (0.967)	3.72 (0.975)	8.32 (0.993)	90.27 (0.982)	$3.25\ 10^{13}$
I-C (90 d)	0.22 (0.736)	0.66 (0.961)	2.61 (0.957)	100.79 (0.993)	$4.34\ 10^{14}$
II-C (90 d)	0.85 (0.944)	3.31 (0.968)	7.19 (0.978)	87.55 (0.981)	$1.02\ 10^{13}$

H = HPLC, C = colorimetric analysis, Figures in parentheses indicate correlation index values.

In both samples, low HMF values were found by HPLC analysis, with low E_a values and zero order kinetics. From 60 to 90 days, the HMF formation was not linear. Partially, this behaviour may be attributed to some protein precipitation found at the bottom of the containers. Results in 60-90 days range are not in agreement with those reported by other authors, who found a linear response in the HMF formation in stored UHT milk at 50°C for 160 days, based on the colorimetric analytical method (Fink and Kessler 1986). Both treatments applied (with characteristics F_c values) can be differentiated also by their E_a values (0-60 days), where the indirect process had given higher values than direct method, independent of methodologies used for analysis.

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References

Berg HE (1993) Reactions of lactose during heat treatment of milk: A quantitative study. PhD. Thesis. Wageningen Agricultural University, The Netherlands

Burton H (1984) Reviews of the progress of dairy science: The bacteriological, chemical, biochemical and physical changes that can occur in milk at temperatures of 100-150°C. J Dairy Res 51:341-363

Craig JC, Aceto NC, Della Monica ES (1961) Occurrence of HMF in vacuum-foam-dried whole milk and its relation to processing and storage. J Dairy Sci 44:1827-1835

Della Monica ES Craig JC, Calhoum MJ (1967) Error in the analysis of HMF in processed milk. J Dairy Sci 51:352-355

Fink R, Kessler HG (1986) HMF values in heat treated and stored milk. Milchwiss 41:638-641

Fink R (1984) Uber lagenrungsbedingte Veraanderungen von UHT-Vollmilch und deren Reaktionskinestische. PhD. Thesis. Technische Universitat Munchen, Germany

Gottschalk A (1952) Some biochemically relevant properties of N-substitued fructosamines derivatives from N-glucosylamino-acids and N-arylglucosylamines. Biochem J 52:455-460

Horak PF, Kessler HG (1981) The influence of UHT heating sterilization on lysine in milk. Milchwiss 36:543-547

Kahlhofer H (1982) Untersuchungen zur Methode der HMF-Bestimmung in Milchpulver. Osterreichische Milchwirtschaft 37:1-7

Keeney M, Bassette R (1959) Detection of intermediate compounds in the early stages of browning reaction in milk products. J Dairy Sci 422:954-960

Kessler HG (1988) Lebensmittel und bioverfahrenstechnik Molkereitechnologie. Technische Universsitat, Munchen, Germany

Klostermeyer H, Herlitz E, Jurgens RH, Reimedes EH, Thomasow J (1978) Lactosehandling von Margermilchzur Herstellung lactosereduzierten Margermilchpulvers. Kieler Milchwirtschaft Forchungsber 30:295-340

Lechner E (1982) Analytische Abgrenzung: Pasteurisierte Milch, H-Milch, Sterilmilch. Deustch Milchwirtschaft 14:489-494

Morales FJ Romero C, Jimenez-Perez S (1992). An enhanced liquid chromatographic method for 5-hydroxymethylfurfural determination in UHT milk. Chromatographia 33:45-48

Morales FJ, Jimenez-Perez S (1991) Tratamientos UHT en productos lacteos. Alimentacion: Equipos y Tecnologia 7:61-71

Morales FJ (1994) Determinacion de 5-Hidroximetilfurfural en leche tratada termicamente y su correlacion con otros parametros de calentamiento. PhD Thesis. Universidad Autonoma de Madrid, Spain

Olano A, Martinez-Castro I (1989) Modification and interactions of lactose. IDF Bulletin 238:35-44

Reuter H (1980) Bewertung der Thermischen Wirksankeit von UHT -Anlagen. Deustche Molkerei-Zeitung 45:1701-1703

Van Boekel MAJS, Nieuwenhuijse JA, Walstra P (1989) The heat coagulation of milk. 1. Mechanisms. Neth Milk Dairy J 43:97-127

Van Boekel MAJS, Zia-Ur-Rehman (1987) Determination of HMF in heated milk by HPLC. Neth Milk Dairy J 41:297-306

Zadow JG (1970) Studies on the UHT of milk: II. Measurement of the products of browning reaction as influenced by processing and storage. Aust J Dairy Technol 9:123-126

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Stability, Rheology and Chemical Properties of Soymilk Concentrates Developed from Sprouted Soybeans

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Sterilized (121°C, 10 min) soymilk concentrates (20 and 30 % solids) were prepared from blanched and unblanched sprouted soybeans and their storage stability, rheological behaviour and chemical properties evaluated. Concentrates from blanched-sprouted soybeans were stable (uncoagulated) for 9 months in ambient tropical storage (26-32°C), while those from unblanched-sprouted soybeans (control) coagulated within 1 month storage. All samples, except the 30% solids control, were pseudoplastic liquids with flow behaviour index of 0.68 to 0.94. Upon sterilization, an average 1.1-fold increase in viscosity index of the 20% solids samples was observed. Viscosity index of the 30% solids treatment and control samples increased by 3- and 77-folds, as a result of sterilization. Total carbohydrates concentration was 83% greater in the control than treated sample. The control samples had lower pH, lower total protein concentration and higher polysaccharide index than the treated samples. Insoluble complex formation in sterilized stored soymilk concentrates is dependent on concentrate pH and polysaccharides-denatured proteins cross-links density.

Keywords: Soymilk concentrate, Storage stability, Sprouted soybeans, Rheology, Viscosity, Flow behaviour, Proximate analysis, Blanching-effect.

Storage instability of soymilk concentrate has constrained the widespread use of the beverage, particularly in tropical countries (Nsofor et al. 1993). Soymilk has been advocated for the sub-regions of the world, where cow's milk production is low and animal protein is in short supply (Nelson et al. 1976; Banigo et al. 1986; Nsofor 1996). Soymilk concentrate may have utility worldwide as a low-cost, cholestrol-free and lactose-free (INTSOY 1987) alternative to concentrated cow's milk (Nsofor 1996; Nsofor and Anyanwu 1992a). Indices of instability of stored soymilk include increase in viscosity, clot formation and consequent separation of the colloidal phase from whey. Earlier workers who conducted studies on concentrated soymilk emphasized the importance of viscosity reduction in the formulated beverage (Lo et al. 1968; Urbanski et al. 1982; Wei et al. 1985; Khan et al. 1989, 1990). Nsofor and Anyanwa (1992a) subsequently postulated that the high apparent viscosity and eventual coagulation of heat-processed soymilk concentrate was a result of cross-linking of denatured soybean proteins and their interactions with soybean polysaccharides. Sprouting induces the hydrolysis of soybean polypeptides and polysaccharides, limiting the cross-linking of these macromolecules during and after heat treatment, thereby delaying the coagulation of the soy extract (Nsofor and Maduako 1992). Nsofor et al (1995) established that the duration of sprouting and the effect of blanching significantly influenced soymilk storage stability. Nsofor et al (1995) reported that 48 h-sprouted and blanched soybeans yielded soymilk of low solids, (less than 10%), which remained stable (uncoagulated) for about 8 months in tropical storage conditions compared to less stable samples, prepared from unblanched-sprouted soybeans. Blanching of whole (unsprouted) soybeans has been correlated with early coagulation of soymilk concentrate during tropical storage (Nsofor et al. 1993). Che Man et al (1989, 1991) indicated that blanching insolubilized soy proteins and caused the reduction of total extractable solids from the cotyledons (Nsofor and Maduako 1992). Blanching is usually applied during soybean processing to inactivate lipoxygenase (Nelson et al. 1976), the enzyme that catalyzes peroxide formation from unsaturated soybean oil, resulting in the production of the objectionable grassy and beany odour-causing phenolic compounds (How and Morr 1982; Huang et al. 1981). It was, therefore, imperative to study the sprouting/blanching-induced variations in chemical properties and viscosity characteristics of soymilk concentrates together with their stability during ambient tropical storage.

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Materials and Methods

Soybean sprouting and blanching : Three 1kg lots of cleaned dry whole soybeans (c.v. 'TGM 579', Nigeria) were separately steeped in tapwater for 12 h, spread on jute sacs and allowed to sprout for 48 h in ambient tropical room condition (26-32°C) with sprinkling of tapwater once a day. One lot of sprouted bean was blanched for 10 min in 2 l boiling 0.5% $NaHCO_3$ solution (Nelson et al. 1976),

another in 2 l boiling tapwater for 30 min and the third (control) steeped in 2 l hot water (60°C for 30 min) (Nsofor and Maduako 1992). Each lot was then drained, rinsed and hand-dehulled. All the experiments in this study were repeated twice.

Processing and storage stability of soyconcentrates : Each lot of cotyledons above was milled in a kitchen blender as previously described (Nsofor and Anyanwu 1992a). The ratio of cotyledons to water was adjusted to yield 30% soy solids in the final soy extract (INTSOY 1987; Nsofor and Anyanwu 1992a), after filtering the slurry through gauze metal and calico cloth. Each extract was divided into two parts, one part was diluted by adding 1 part by volume of tap water to 2 parts by volume of the 30% solids soy concentrate (Nsofor and Anyanwu 1992b). The second part of the 30% solids soy extract was undiluted. Ten ml aliquots of the diluted (20% solids) and undilued (30% solids) soy concentrates were dispensed in test tubes, stoppered with rubber corks,sterilized at 121°C for 10 min, cooled and stored in ambient tropical room condition. Coagulation time (stability index) of the stored samples was determined by visual observation for clots on the inside wall of gently tilted test tube that contained the soy concentrate sample (Nsofor et al. 1993; Nsofor and Anyanwu 1992b; Nsofor and Maduako 1992). All determinations were made in replicates.

Rheological measurement : Apparent viscosity of the soy concentrates was determined with a Brookfield Synchrolectric LVF rotational viscometer (Brookfield Engineering Laboratories Inc., Stoughton, MA) in ambient room condition (29±0.5°C), using spindle number 1 at rotational speeds (shear rates) of 6, 12, 30 and 60 rpm. Spindle number 4 was used for samples with apparent viscosity above the measuring range of spindle number 1. Determinations were done on freshly prepared unsterilized and sterilized, but cooled (29°C) samples (80 ml) in a 100 ml beaker and acceptably stable readings were taken after about 1 min of spindle rotation. The apparent viscosity of a commercial brand of canned evaporated milk (30% solids) was also determined under similar conditions and the data served as reference. The viscometer dial readings were converted to centipoise, that is, mpa.s by using Brookfield conversion charts.

Chemical analysis : The pH of fresh soy concentrate was measured with a pH meter (Nsofor and Anyanwu 1992a). Starch concentration index of the soy concentrates was rapidly determined by the method of Nsofor and Maduako (1992), with slight modifications as follows:- two drops of standard iodine solution were added to 10 ml soymilk sample that was prepared by diluting each 30% total solids soy concentrate 500 times with distilled water (1 part concentrate: 499 parts water) and the absorbance was read in spectrophotometer at 620 nm wave length. A distilled water blank, containing 2 drops iodine, was adjusted to zero in the instrument.

Soluble protein indices of the soy concentrates were measured by modifying the methods of Ibiama and Griffiths (1987) and Nsofor et al (1995). One-half ml of each soy concentrate was added to 9 ml distilled water in a test tube, followed by the addition of 0.5 ml 3% trichloroacetic acid (TCA). The mixture was then incubated at 37°C for 10 min, centrifuged at 3000 x **g** for 30 min and the soluble fraction was decanted. One ml of the decantate was added to 9 ml distilled water and the absorbance of the mixture was read at 280 nm in the spectrophotometer. The blank was 9.5 ml distilled water to which was added 0.5 ml 3% TCA, incubated (37°C, 10 min) and centrifuged as described above.

Total solids yield index of the soy concentrates was estimated as the volume of water in litres needed to mill sprouted soybean cotyledons derived from 1 kg dry soybeans to produce 30% solids extract.

Soy concentrate powder was prepared by drying the 30% solids concentrate sample in a forced draft oven without vacuum at 55°C for 24 h in shallow aluminium dishes, crushing with porcelain mortar and pestle and sieving with fine mesh. Crude protein (N x 6.25) was estimated by Kjeldahl method, while ether extract, crude fibre, ash and moisture were measured by AOAC (1990) methods and carbohydrate was culculated by difference.

Data analysis : Linear regression of shear rate - apparent viscosity data in a modified Power-law equation $\mu app = k\gamma^{(n-1)}$ was done after log transformation as described by Sopade and Kassum (1992) and Khan et al (1989) to obtain flow behaviour index, viscosity (consistency) index and correlation coefficient.

Results and Discussion

Storage stability and chemical properties : The blanched-sprouted soybeans yielded soy concentrates with greater storage stability than the control (unblanched) samples (Table 1). Whilst the control

TABLE 1. STABILITY IN AMBIENT TROPICAL STORAGE, CHEMICAL PROPERTIES AND RHEOLOGICAL INDICES OF SOYMILK CONCENTRATES FROM SPROUTED SOYBEANS WITH DIFFERENT TREATMENTS

		Blanching treatment								
		Boiling in $NaHCO_3$			Boiling in H_2O			Unblanched Control		
Soy concentrate[1]	(20%)	>36			>36			2.5		
stability	(30%)	>36			>36			2.6		
pH	20	6.90			6.66			6.38		
	30	6.83			6.70			6.33		
Soy solids[2] yield index, l		1.35			1.25			1.65		
Starch absorbance	(620 nm)	0.19			0.23			0.32		
Soluble protein absorbance	(280 nm)	0.48			0.46			0.66		
Rheological indices[3]		k	n	r	k	n	r	k	n	r
Unsterilized	(20%)	16.0	0.88	0.80	15.5	0.87	0.98	25.3	0.86	0.98
soy concentrate	(30%)	40.6	0.94	0.93	46.9	0.82	0.99	45.3	1.03	0.62
Sterilized	20	19.6	0.81	0.99	16.7	0.85	0.99	25.7	0.90	0.96
soy concentrate	30	118.7	0.73	0.99	128.2	0.68	0.99	3482.8	0.52	0.99
Proximate analysis[4]										
Crude protein, %		42.9			41.7			36.5		
Fat, %		28.6			25.6			27.2		
Carbohydrates, %		11			18.2			20.1		
Crude fibre, %		15.3			12			13.7		
Ash, %		0.07			0.04			0.05		
Moisture, %		2.3			2.6			2.1		

[1] Soy concentrate (20 and 30% solids) stability = coagulation time in weeks

[2] Yield index (estimate) = volume (L) of water utilized to mill sprouted soybeans from 1 kg dry soybeans to yield 30% solids concentrate

[3] k = consistency (viscosity) index n = power law index r = correlation coefficient; indices for canned evaporated milk reference sample k = 53.8 n = 0.9 r = 1.0

[4] Proximate analysis of soy concentrate powder

coagulated in less than 3 weeks ambient storage, the treated samples remained uncoagulated beyond 9 months. No variations were observed in the stability of the 20 and 30% solids concentrates in the treated group. The effect of sprouted soybean blanching on pH of the resultant soy concentrates is also shown in Table 1. The $NaHCO_3$-blanched and the control samples showed the highest and the lowest pH, respectively. Early coagulation of the unblanched samples was partly related to their low pH. Nsofor and Maduako (1992) observed that the pH at coagulation of sterilized (121°C, 15 min) soymilk (22% solids) from unblanched-sprouted soybeans was 5.6. Coagulation pH was not measured in the present work, but it is known that the pH of sterilized soymilk decreases during storage (Nsofor et al. 1993) and limited solubility of a major soybean protein, glycinin, occurs at pH 6.0 (Kinsella 1985). Low pH favours soy protein precipitation (Nsofor et al. 1993). The pH of the unblanched samples in the present study was closer to 6.0 than that of the blanched and likely to drift to 6.0 in a shorter time than the blanched samples during storage. Visual perception of spoilage (storage instability) of soymilk occurs, when there is apparent increase in viscosity. Nsofor and Anyanwu (1992b) noted that significant correlations existed between viscosity, pH and coagulation time of stored soy beverage.

Blanching reduced soy solids yield estimate of the extracted concentrates (Table 1), indicating that blanching denatured and insolubilized soybean proteins (Che Man et al. 1989, 1991; Kinsella 1985), thereby limiting solids extractability from the blanched cotyledons (Nsofor and Maduako 1992). The blanched samples contained less soluble protein and less starch than the unblanched samples (Table 1). This observation is in line with Nsofor et al (1995). Slight differences in the concentration of extracted substances occurred between the $NaHCO_3$ - blanched and water-blanched samples. Since blanching denatures soy proteins and in turn, makes soy solids more inextractable, it follows that the unblanched cotyledons (control) released

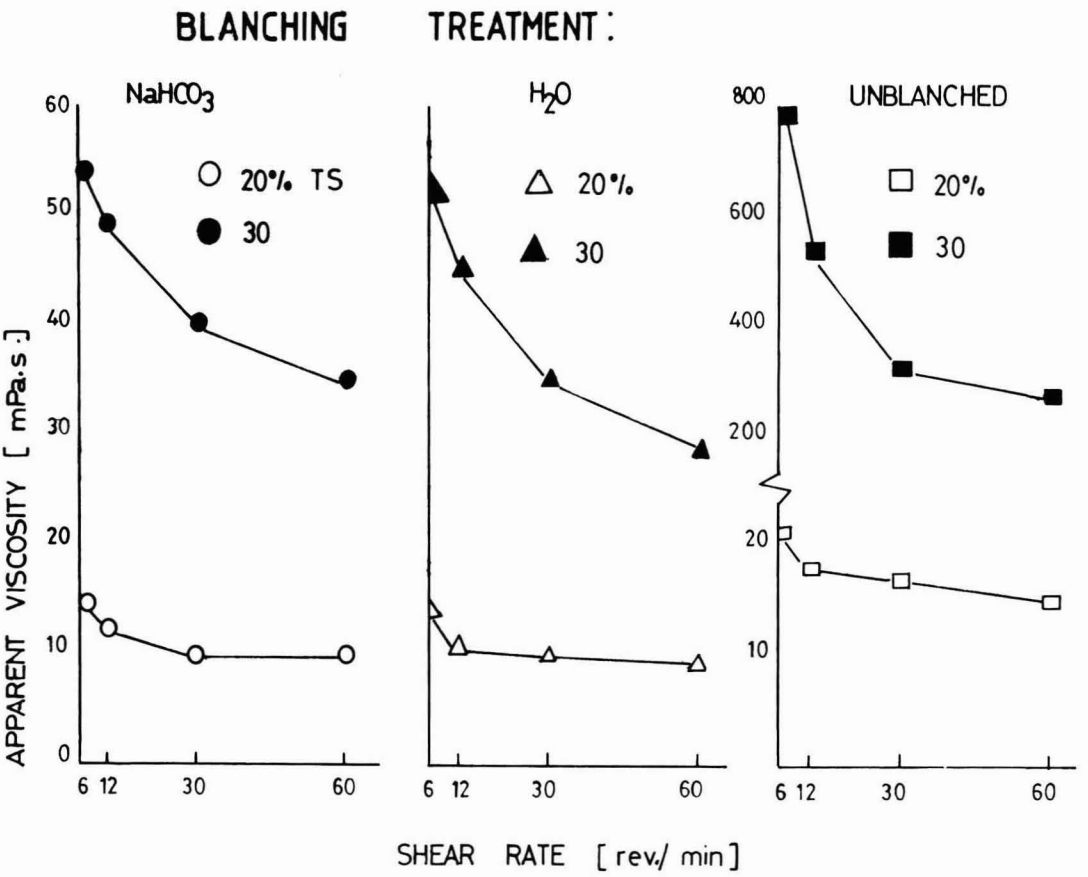

Fig. 1. Interactive effect of blanching and total solids concentration (20 and 30% TS) on mean apparent viscosity of unsterilized and sterilized soymilk from sprouted soybeans, measured at different shear rates

more soluble (hydrolyzed) protein.

More starch also was released by the unblanched cotyledons than the blanched ones. Thus, the relative instability of sterilized soy concentrate derived from unblanched-sprouted soybeans compared to that from the blanched ones could be partly attributed to the higher polysaccharide content of the former. Starch, whose hydrolysis was rapidly measured, was used as an index of other soybean polysaccharides, which were expected to undergo variable levels of hydrolysis during sprouting. Since soymilk stability increased as starch content decreased during a 0 h (control) to 48 h-sprouting interval, it follows that starch and possibly other soybean polysaccharides play an important role in storage stability of soymilk. The degree of involvement of soluble proteins in soymilk stability is not clear. Whilst unblanched samples had a higher concentration of soluble protein than the blanched, instability occurred in the unblanched quite early in storage (Table 1).

The work of Nsofor et al(1995) showed that as a major decline occurred in soymilk storage stability within the 48 h and 72 h - sprouting interval, a sharp decrease in soluble proteins occurred in the interval, whereas starch concentration did not show further decrease. Thus, relative instability of the 72 h-sprouted samples was attributed to cross-linking of the residual partially hydrolyzed soybean macromolecules (polysaccharides and proteins) at that sprouting time, since the growing sprouts at that time may have absorbed most of the fully hydrolyzed soluble components such as sugars and amino acids, leaving the insoluble (partially hydrolyzed macromolecules) in the cotyledons to cross-link themselves, following extraction and heat-sterilization. This observation agrees with the present findings, where early coagulation of the unblanched

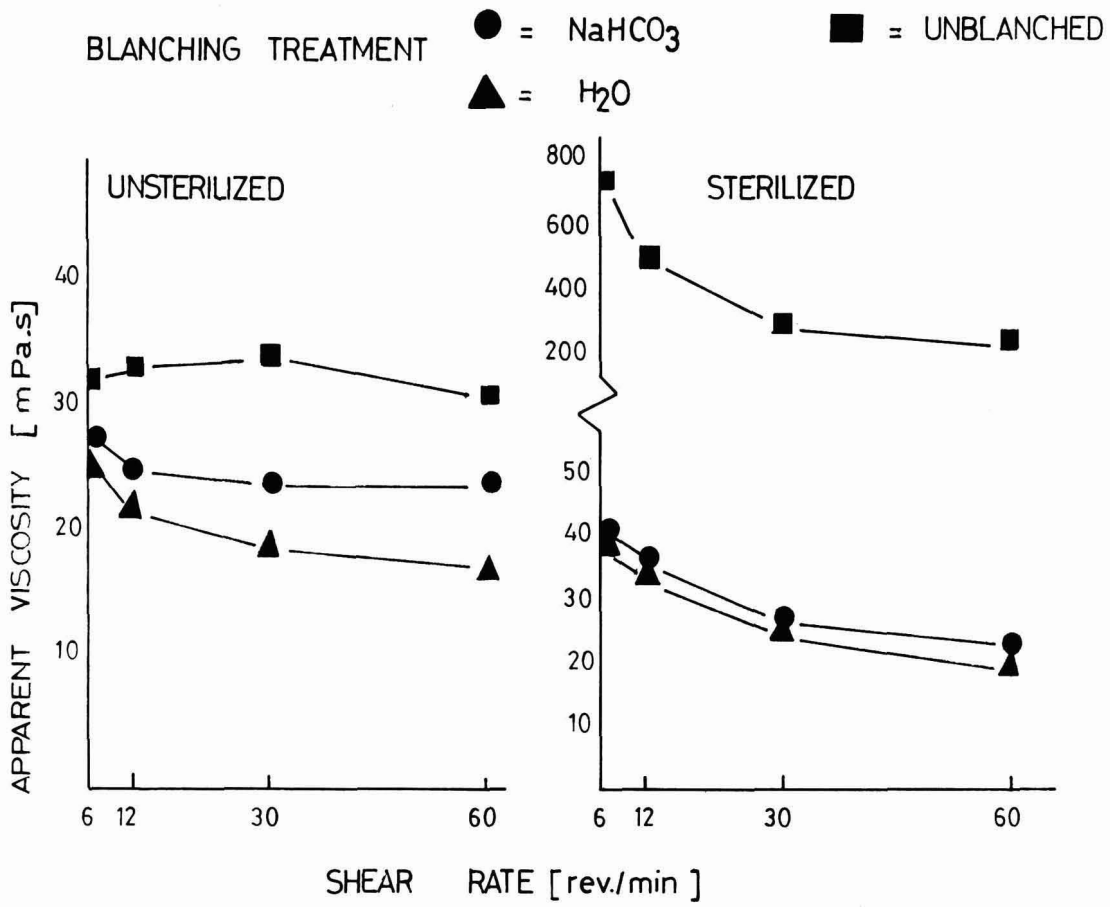

Fig. 2. Interactive effect of blanching and sterilization (unsterilized and sterilized on mean apparent viscosity of soymilk concentrates (20 and 30% total solids) from sprouted soybeans, measured at different shear rates

samples was most likely, consequent to cross-linking of higher concentration of extracted partially hydrolyzed polysaccharides with denatured proteins after heat processing. The contribution of low soymilk pH in causing insolubility of soy components and in turn, instability (Table 1) was significant.

Rheological properties : Soymilk concentrates from blanched-sprouted soybeans generally had lower apparent viscosity than unblanched (control) samples (Fig 1). Apparent viscosity of the 20% solids samples also was lower than that of 30% solids for each blanching treatment, whereas the 30% solids control sample exhibited the largest apparent viscosity. Overall, increase in shear rate caused decrease in apparent viscosity, indicating that soy concentrates from sprouted soybeans were non-Newtonian liquids, specifically, pseudoplastic liquids (Khan et al. 1989, 1990). Sopade and Kassum (1992) have noted that the inverse relationship that exists between viscosity and shear rate in pseudoplastic fluids is due to the increased alignment of the fluid molecules in the direction of flow of the liquid. This induces shear thinning and is characteristic of emulsions and dispersions (Howard 1991). Soymilk is a dispersion of soybean particles in water. It appears that the higher apparent viscosity of the unblanched samples relative to the blanched was due to the probable occurrence of a greater number of cross-links between the extracted soy solids in the unblanched samples.

Sterilization increased apparent viscosity and larger increases were observed in the unblanched samples, compared to the blanched ones (Fig. 2). The unsterilized 30% solids control exhibited shear thickening or dilatancy at low shear rates (Fig. 3),

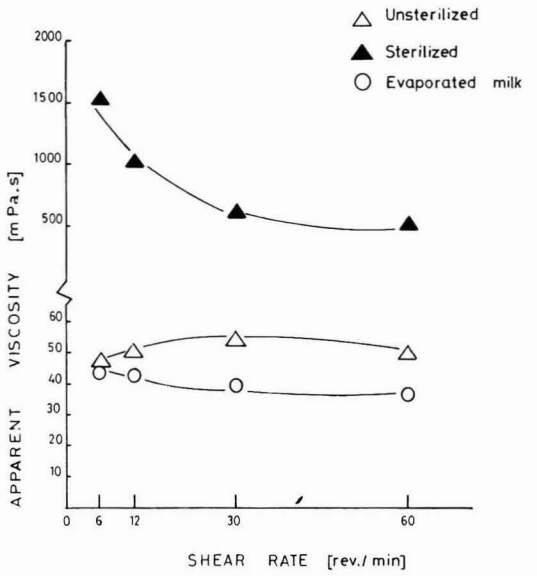

Fig. 3. Apparent viscosity at different shear rates for unsterilized and sterilized 30% solids soy concentrates from unblanched-sprouted soybeans and for a commercial brand of canned evaporated milk (31% solids)

which resulted in the concave nature of the curve for unsterilized-unblanched samples (Fig. 2). Dilatant fluids usually contain high concentrations of suspended solids and as shear rate increases, the dense packing of solids is no longer sufficiently lubricated by the liquid phase and the solids pack further together (Howard 1991). Sharp increase in apparent viscosity of 30% solids unblanched sample after sterilization (Fig. 3) was above the measuring range of spindle number 1 of the viscometer, which necessitated the use of spindle number 4. Shear rate-apparent viscosity curve for the canned sterilized evaporated milk is also shown in Fig. 3. At each total solids level, the viscosity index of the unblanched samples was generally greater than for the blanched samples (Table 1).

Sterilization also caused increase in the viscosity index of blanched and unblanched samples. Whilst the 20% solids samples only showed an average 1.1-fold increase, the 30% solid varieties exhibited large increases, about 3-fold for the blanched and 77-fold for the unblanched samples. The large viscosity index increase in the sterilized 30% solids control possibly was a result of intense association (aggregation) of its high concentrations of partially hydrolyzed polysaccharides and denatured proteins (soluble and insoluble), leading to the development of high density cross-links, which resisted shear by spindle number 1. The viscosity index for sterilized canned evaporated milk was remarkably lower than for sterilized 30% solids soy concentrates (Table 1). Since canned evaporated milk is known to be stable, even in ambient tropical storage, its rheological indices could serve as reference for sterilized soy concentrates. Khan et al (1990) observed a 640-fold difference in viscosity index of two soy beverage formulations that contained 10 and 20% soy solids plus varying concentrations of sucrose. They showed that high soy solids greatly increased viscosity, but the incorporation of sugar in the formulation reduced it. The present study shows that blanching of sprouted soybeans reduced soy beverage viscosity particularly at lower soy solids level. Less variation occurred in the flow behaviour index of the sterilized- blanched and unblanched 20% solids samples (0.81-0.90), compared to the wider range of 0.52-0.73 observed for the 30% solids variety.

Flow behaviour index of 1.03 calculated for the unsterilized-unblanched 30% solids sample suggests intermediate behaviour between Newtonian and dilatancy. For liquids that obey the power law, the power law index $n = 1$ for Newtonian behaviour, $n<1$ for pseudoplastic and $n>1$ for dilatant fluids (Lewis 1987). Shear rate-apparent viscosity data for the unsterilized-unblanched 30% solids sample (Fig. 3), however, showed mixed behaviour of dilatancy at shear rates of 6 to 30 rpm and pseudoplasticity at 60 rpm. The relatively low correlation coefficient of 0.62 (Table 1) for its linearly regressed data indicates that the 30% solids unsterilized control did not classically obey the power law. A correlation coefficient approximately equal to 1 indicates a classical power law fluid (Khan et al. 1989, 1990). Overall, the flow behaviour index for the 30% solids samples decreased after sterilization, with the largest decrease occurring in the unblanched samples. It should be noted that rheological indices of the soy concentrates obtained before storage (Table 1) did not clearly explain storage instability or predict storage stability.

Thus, while stored canned evaporated milk (30% solids and viscosity index of 53.8) was stable, 20% solids sample from unblanched-sprouted soybeans with lower viscosity index of 25.7 obtained before storage, was unstable. The most probable reason for the incongruity is that while further cross-linking (aggregation) of soybean macromolecules occurs during storage of the soy concentrates, minimal aggregation occurs most likely in stored canned evaporated milk. Thus,

viscosity index of stored soy concentrate is expected to increase beyond the initial value at the beginning of storage, thereby inducing storage coagulation. Viscosity index of stored evaporated milk may be an unequivocal reference for stored soy concentrates, if the viscosity index of the soy concentrate determined during storage and not before storage, is utilized for comparison.

Proximate composition of soy concentrate powders : The carbohydrates and proteins in soy concentrate powders derived from blanched and unblanched cotyledons showed wide variations in concentration (Table 1). An approximate 2-fold (83%) difference in total carbohydrates of $NaHCO_3$ - blanched and unblanched (control) samples was observed. The high carboyhydrate content of the control indicates high extractability of this substance from unblanched cotyledons. Cross-linking of partially hydrolyzed carbohydrates with proteins may have limited carbohydrates extractability from blanched cotyledons and in effect, reduced the viscosity of their extracts. These observations partly agree with Urbanski et al (1982), who have indicated that cell wall materials are the single greatest contributor of high viscosity in soy beverages. The major carbohydrates of soybeans are oligosaccharides, cellulose and hemicellulose, while starch is present in small quantities (Hodge and Osman 1976).

Sprouting may have caused greater hydrolysis of starch and oligosaccharides than cellulose and hemicellulose. Formation of complexes by the partially hydrolyzed cellulose and hemicellulose with denatured proteins after blanching probably reduced the extractability of carbohydrates from the blanched cotyledons. The unblanched cotyledons, conversely, may not have formed as much complexes as the blanched and therefore, yielded more carbohydrates and total solids in their extract (Table 1). The occurrence of cellulose-protein complexes in heat-treated soy extracts would probably confer thixotropic properties on the extracts. Khan et al (1989) also have noted that soymilk is mildly thixotropic. Howard (1991), has observed that cellulose derivatives are also generally thixotropic. Fluids, which exhibit thixotropy lose viscosity under constant shear, but when shearing has stopped, regain their original viscosity by taking little more time. Home-prepared soymilk, after few days of refrigerated storage, usually require sharp jerks (yield stress) to break its initial high viscosity to enable even flow from the storage bottle, a characteristic that is typical of tomato ketchup, a classical thixotropic liquid. Thus, viscosity control in stored soy beverages, particularly the concentrates, partly depends on inhibition of extensive formation of cross-links between cellulose derivatives, proteins and water after heat processing.

Total protein concentration in the $NaHCO_3$ - blanched sample was greater than the unblanched one, probably because of the expanded scales of other components, arising from the low carbohydrate content of the $NaHCO_3$ - blanched sample. Total proteins comprised soluble plus insoluble proteins. The insoluble proteins may have contributed more than the soluble to the formation of insoluble polysaccharides - denatured protein complexes in the unblanched samples after sterilization, leading to the development of high viscosity and early coagulation during storage. Crude fibre was generally high in all samples, but the highest value was observed in the $NaHCO_3$ - blanched sample. The high contents may be due to the low moisture content of the powders, which tilted the scales of other components to expand.

Since crude fibre comprises mainly cellulose and lignin (Hodge and Osman 1976), the combined total carbohydrates in the $NaHCO_3$ - blanched, H_2O - blanched and unblanched samples were 26.3, 30.2 and 33.8%, respectively, which fall within the expected range of values for carbohydrates in soybean flour-based products. The 'TGM 579' soybean variety utilized in this study had proximate composition (%) as follows : proteins 40.3, fat 22, carbohydrates 26.7, minerals 4 and moisture 7, respectively (Nsofor 1996). Ash content of the soymilk concentrate powder was unexpectedly very low. The extent of depletion of minerals from the cotyledons by the growing sprouts was unknown and the sprouts were excluded from the milled cotyledons. Confirmatory studies of ash content of similar samples are needed in future work.

Nutritional implication of using sprouted soybean for concentrate production : Soymilk concentrate developed from sprouted soybeans would be more digestible and nutritious than that from the unsprouted soybeans. Germination of seeds causes hydrolysis of macromoloecules, which facilitates digestion. It also increases the concentration of some vitamins (Vanderstoep 1981 ; Cruz and Park 1982; Borejszo and Khan 1992). Also, since sprouted soybean is tenderized faster than the unsprouted during blanchiing (Nsofor unpublished), less protein denaturation and insolubilization are expected to occur in sprouted soybeans blanched for a short duration.

References

AOAC (1990) Official Methods of Analysis, 15th edn, Association of Official Analytical Chemists, Washington DC

Banigo, EOI, Ihimoyan, KJ, Osai, GEA (1986) Development of soybeverage for Nigeria. Nigerian Food J 4:53-63

Borejszo Z, Khan K (1992) Reduction of flatulence - causing sugars by high temperature extrusion of pinto bean high starch fractions. J Food Sci 57:771-772

Che Man YB, Wei LS, Nelson AI (1989) Acid inactivation of soybean lipoxygenase with retention of protein solubility. J Food Sci 54:963-967

Che Man YB, Wei LS, Nelson AI (1991) Control of off-flavours of soybean extract by pH adjustment. Asean Food J 6:117-119

Cruz R, Park YK (1982) Production of fungal galactosidase and its application to the hydrolysis of galacto-oligosaccharides in soybean milk. J Food Sci. 47:1973-1975

Hodge JE, Osman EM (1976) Carbohydrates. In: Fennemaor (ed) Principles of Food Science, Part I: Food Chemistry, Marcel Dekker, New York, NY, pp 41-138

How JSL, Morr CV (1982) Removal of phenolic compounds from soyprotein extracts using activated carbon. J Food Sci 47:933-940

Howard DW (1991) A look at viscometry. Food Technol 45(7):82-84

Huang AS, Hsieh O AL, Chang SS (1981) Characterization of the non-volatile minor constituents responsible for the objectionable taste of defatted soybean flour. J Food Sci 47:19-23

Ibiama E, Griffiths MW (1987) Studies on a milk-coagulating enzyme, "Calotropain", obtained from sodom apple *(Calotropis procera)*. J Food Agric 1:157-162

INTSOY (1987) INTSOY develops new techniques for commercial soymilk processing. Inter. Soybean Prog. Newsletter No. 36, Univ. of Illinois, Urbana-Champaign

Khan R, Stehli D, Wei LS Steinberg MP (1989) Activity and mobility of water in sweetened whole soy concentrates and their rheological properties. J Food Sci 54:931-935

Khan R, Stehli D, Wei LS, Steinberg MP, Yamashita N (1990) Activity and mobility of water in sweetened concentrated desludged soybeverages and their rheological properties. J Food Sci 55:537-542

Kinsella JE (1985) Functional criteria for expanding utilization of soyprotein in foods. In: Shibles R (ed), World Soybean Research Conference III : Preceedings, Westview Press, Boulder and London, pp 152-157

Lewis MJ (1987) Viscosity. In: Physical Properties of Foods and Food Processing Systems. Ellis Horwood Publ., Chichester, England, pp 108-136

Lo WY, Steinkraus KH, Hand DB (1968) Concentration of soymilk, Food Technol 22:1028-1030

Nelson AI, Steinberg MP, Wei LS (1976) Illinois process for preparation of soymilk. J Food Sci 41:57-61

Nsofor LM (1996) Suitability of ultrafiltered soybean extract for developing evaporated cow milk analogue. J Food Sci Technol 33:322-325

Nsofor LM, Anyanwu KB (1992a) Development and evaluation of concentrated soymilk beverage. J Food Sci Technol 29:331-332

Nsofor LM, Anyanwu, KB (1992b) Effect of heat processing on refrigerated shelf-life of concentrated soymilk beverage. J Food Sci Technol 29:40-44

Nsofor LM, Maduako O (1992) Stabilized soymilk for ambient tropical storage : A preliminary report. Inter J Food Sci Technol 27:573-576

Nsofor LM, Uzuegbu DN, Chukwuma AK, Udechukwu A (1993) Storage stability of concentrated soymilk - Evaluation of cowmilk concentrate and salts addition and soybean acid-steeping. Inter J Food Sci Technol 28:499-504

Sopade PA, Kassum AL (1992) Rheological characterization of Nigerian liquid and semi-liquid foods : *kunun zaki* and *kunun gyada*. Nigerian Food J 10:23-33

Urbanski GE, Wei LS, Nelson AI, Steinberg MP (1982) Effect of solutes on rheology of soyflour and its components. J Food Sci 47:792-795

Vanderstoep J (1981) Effect of germination on the nutritive value of legumes. Food Technol 35(3):83-85

Wei LS, Urbanski GE, Steinberg MP, Nelson AI (1985) Feasibility of a shelf-stable soybean beverage. In : Shibles R (ed) World Soybean Research Conference III Proceedings, Westview Press, Boulder and London, pp 191-198

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Technology of Ready-to-Use Banana Milk Shake Powder

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Banana milk shake powder was prepared from cow milk blended with 'Musa cavendishii' variety of banana (5:1). The milk was standardized to 2.0% fat and condensed to one third its original volume. Peeled bananas cut into circular pieces were mixed with water (1.0-1.5%) and heated to 85-90°C for 5-10 min. This was added to the homogenized (100 bar) in batches and further homogenized at 50 bar. Carboxymethylcellulose (CMC) was incorporated at 0.015% to the milk before homogenization to improve the body and texture characteristics. The mix was spray-dried with an inlet air temperature of 160-180°C and outlet air temperature of 85-95°C. Ground sugar was blended with dried mix to obtain final sugar content of 42.5% in banana milk shake powder.

Keywords: Milk, Banana, Stabilizers, Homogenization, Spray drying.

Banana and milk are blended in many parts of the country to produce a relishing beverage, which is popularly called milk shake. The beverage, apart from its high nutritive value, is effective in the treatment of celiac disease, sprue and other forms of carbohydrate intolerance in children (Wealth of India 1962). The nutritive value of the product also adds to the demand of the product. Eventhough the milk shakes are popular and known for their nutritive value, the beverage is not available in convenient-to-use form. In order to fill this gap, the present project to standardize the production of an acceptable quality banana milk shake in convenient-to-use dry form has been initiated. A ready-to-use banana milk shake powder was prepared and evaluated organoleptically. The physico-chemical characteristics of the product were also studied and the results are reported in this paper.

Materials and Methods

Preparation of banana milk shake powder : Ripened 'Musa cavendishii' *(Pachabale)* and 'Musa Paradisica' *(Elaichibale)* varieties of bananas obtained from the market were peeled out manually. For each trial, about 5.0 kg of peeled fruit was taken and cut into circular pieces. Potable water (1.0-1.5% of peeled fruit) was added to the fruit pieces and the same was heated to 85-90°C/5-10 min, followed by cooling to 38-40°C. Twenty five litres of pasteurized milk standardized to the required composition was used for each trial. The milk was condensed to about one third its volume by using vaccum evaporator. The total solids (TS) of the concentrated milk varied from 32-36%. Calculated quantity (based on total solids level) of carboxymethylcellulose (CMC) was dissolved in hot water at 60°C and mixed with the condensed milk. The condensed milk was homogenized at 38-40°C with 100 bar pressure after the addition of CMC. Banana pulp was added in batches to the homogenized milk and was again passed through the homogenizer, initially without any pressure and finally with 50 bar pressure to get more uniform milk shake. The homogenisation improved the viscosity, which in turn, helped during the spray drying. The homogenized banana milk shake slurry was spray-dried by using centrifugal spinning disc atomiser. The TS of the shake varied from 30-32%. An inlet air temperature of 160-180°C and outlet air temperature of 85-95°C were maintained during drying. Moreover, to reduce heat damage during drying and to obtain desired moisture content, an outlet air temperature of 85-95°C was preferred. The powder (BMSP) was blended with calculated quantity of powdered sugar to obtain ready-to-use banana milk shake powder (RBMSP). The RBMSP was evaluated organoleptically by reconstituting with potable water (20% TS) at ambient temperature of about 25-30°C. The flow diagram for the manufacture of RBMSP is shown in Fig 1.

Analysis : Twenty g of RBMSP was reconstituted with 80 ml potable water. It was then evaluated organoleptically at ambient temperature (25-30°C) for different quality attributes i.e., appearance, colour, body, texture and flavour by a select panel of trained judges using a 9-point Hedonic scale. The same panel of trained judges evaluated all the samples.

The estimation of titrable acidity (% lactic acid) moisture, fat (Mojonnier method), protein, solubility and ash content of powder were carried out as per the methods described in ISI (1981). The bulk density and flowability of powder were determined as per the methods outlined by Hall and Hedrick (1975).

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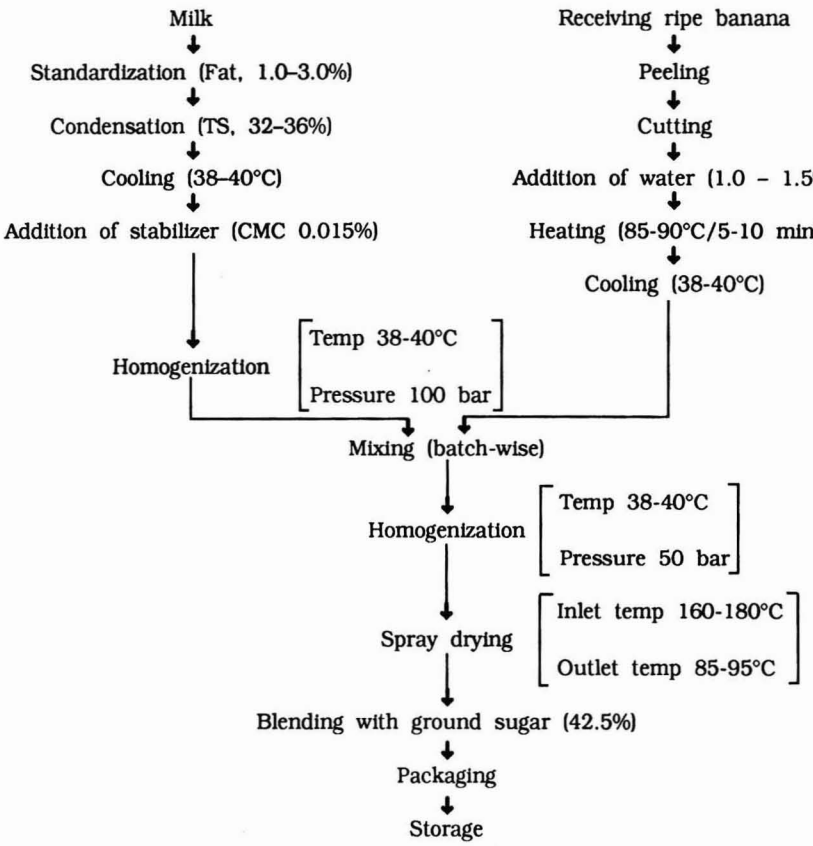

Fig. 1. Flow diagram for the manufacture of ready-to-use banana milk shake powder

Results and Discussion

Comparison of BMSP made from 'Musa cavendishii' *(Pachabale) and* 'Musa paradisica' *(Elaichibale) varieties of banana :* BMSP was prepared from two varieties of bananas. It was observed that the ripeness of *Elaichibale* banana was not uniform and stickiness was observed during cutting. It was difficult to get uniformly ripened *Elaichibale* bananas and for similar quantity of pulp, more quantities of bananas were required. About 2.0% more water was needed for cooking the *Elaichibale* banana compared to the *Pachabale*. The homogenization of the milk shake with *Elaichibale* was difficult compared to the milk shake with *Pachabale*. The stickiness of the *Elaichibale* could be ascribed to higher starch content of banana, which might not have been converted into sugars. The proximate composition (%) of *Pachabale* and *Elaichibale* banana pulp was moisture 75–78 and 66–68. TS 22–25 and 32–34, fat 0.11–0.14 and 0.05–0.10, protein 1.30–1.40 and 1.25–1.30, respectively.

The appearance and colour of the reconstituted shake prepared from two varieties of banana were almost similar (Table 1). However, the difference in the flavour score of the RBMSP, prepared from two banana varieties, was observed to be prominent. The powder made from *Elaichibale* was criticised as dusty, chalky and lacked typical banana flavour.

It was observed that there were no distinct differences in the moisture contents of powders

TABLE 1. SENSORY QUALITY OF RECONSTITUTED RBMSP MADE FROM TWO VARIETIES OF BANANA

Banana varieties	Sensory score		
	Appearance and colour	Flavour	Body and texture
Pachabale ("Musa cavendishii")	6.0 (5.0–8.0)	6.6 (6.0–7.0)	6.2 (6.0–7.0)
Elaichibale ("Musa paradisica")	5.5 (5.0–6.0)	5.5 (5.0–6.0)	5.8 (5.0–6.0)

The figures in parentheses indicate the range
Average of three trials

(BMSP), made from both the varieties of banana. The higher fat content could have contributed to the better flavour score of BMSP prepared with *Pachabale*. The protein content (18.49%) was more in BMSP prepared from *Pachabale* than in BMSP made from *Elaichibale* (16.11%). Lower fat and protein contents in BMSP prepared from *Elaichibale* may be due to the higher carbohydrate and TS contents of the fruit. The total ash contents of BMSP made from both the varieties of banana were found to be similar. The lower solubility in BMSP made from *Elaichibale* may be due to the higher starch content and lower conversion of starch into sugar in comparison to that of *Pachabale*. The lower solubility could also be ascribed to the insoluble starch present in *Elaichibale*, which did not tenderize even by heating the pulp to 85 - 90°C for 5–10 min. The average TS content ranged from 22–25% for *Pachabale* and 32–35% for *Elaichibale* banana. There was slight difference in the bulk density of both the BMSP, whereas the flowability was adjudged good for *Pachabale* and fair for *Elaichibale*. Hence, in all further investigations, *Pachabale* was used for the preparation of BMSP.

Optimization of the level of ingredients : After the standardization of manufacturing technique and the comparison of two varieties of banana, a detailed study was carried out to optimize the ingredient level, by using *Pachabale* variety of banana. This study included the effect of ratio of banana to milk and different levels of various ingredients like i) stabilizer ii) milk fat and iii) sugar.

Effect of banana to milk ratio on the quality of the product

The proportions of banana required for the manufacture of BMSP is an important step, as it contributes to the body, texture and flavour of the final product. Therefore, to determine the optimum level of banana to milk, 3 different proportions 1:6, 1:5 and 1:4 by weight were used. Twenty five litres of standardized milk with 3.0% fat was used for each batch. Equal quantity of stabilizer was used in all the trials.

Sensory properties : The mean sensory score of the reconstituted RBMSP made from 1:6, 1:5 and 1:4 ratio of banana to milk are presented in Table 2. The appearance and colour scores were best(7.4) in the product made from 1:6 ratio and lowest (5.9) in the RBMSP prepared from higher quantity of banana pulp (1:4). The flavour score was maximum (6.6) for the product with 1:4 ratio and was moderate (6.7) with 1:6 ratio. The body and texture were comparatively thinner in RBMSP made from 1:6, even though the TS of reconstituted products were similar. In all cases, 20 g was reconstituted. This may be due to the presence of lower banana solids, which have greater role on the viscosity of the reconstituted product. Though, the viscosity increased with the increase in banana solids, there was a decrease in the uniformity of the body and texture of the reconstituted product. The highest flavour score was observed in the reconstituted RBMSP made from 1:4 ratio, which may due to the presence of higher banana solids and the appearance and colour scores were lowest, which may be due to visible insoluble banana solids floating on the surface of the reconstituted product. These visible insoluble particles were due to the presence of more crude fibre in the banana pulp. Keeping in view the uniform scores for various attributes, the overall acceptability of the reconstituted RBMSP prepared in 1:5 ratio was rated as most satisfactory. Hence, in all further investigations this ratio of 1:5 was considered.

Physico-chemical properties : The BMSP was analyzed and the results are presented in Table 3. Eventhough, the pulp ratio was higher, moisture

TABLE 2. EFFECT OF BANANA TO MILK RATIO ON SENSORY QUALITY OF RECONSTITUTED RBMSP

Ratio of banana to milk by wt	Sensory score		
	Appearance and colour	Flavour	Body and texture
1 : 6	7.4 (7.0–8.0)	5.9 (5.0–7.0)	6.8 (6.0–8.0)
1 : 5	6.7 (5.5–8.0)	6.4 (6.0–8.0)	6.6 (5.0–8.0)
1 : 4	5.9 (5.5–6.0)	6.6 (6.0–7.0)	6.2 (6.0–7.0)

The figures in parentheses indicate the range
Average of four trials

TABLE 3. EFFECT OF BANANA TO MILK RATIO BY WEIGHT ON PHYSICO CHEMICAL PROPERTIES OF BMSP

Attributes, %	Banana : Milk (by weight)		
	1 : 6	1 : 5	1 :4
Moisture	3.38	3.11	2.75
Fat on DM	19.82	19.08	16.81
Protein on DM	19.60	19.19	16.05
Ash on DM	5.59	5.59	5.60
Carbohydrate on DM	54.99	56.14	61.53
Acidity	1.71	1.80	1.90
Solubility	92.00	90.00	88.04
Bulk density g/cc	0.318	0.290	0.289
Flowability	Good	Good	Fair

DM - Dry Matter : Average of four trials

content was lower in BMSP made from 1:4 ratio of banana to milk. The lowest fat (16.81%) was observed in BMSP made from 1:4 ratio of banana to milk. The highest fat (19.82%) was observed in BMSP made from 1:6 ratio, which could be due to the higher milk solids content. The protein content was also observed to have a distinct influence on the BMSP prepared with three different ratios of banana to milk. The lowest protein content in BMSP made from 1:4 ratio was due to the proportionately higher banana solids with lower protein content. The higher carbohydrate (61.53%) in BMSP made from 1:4 ratio was due to the presence of higher banana solids with higher carbohydrates. There was a slight increase in the acidity of the product, as the quantity of the banana solids increased. It was observed that as the quantity of pulp increased, the solubility decreased. This may be due to the increase in the crude fibre content of BMSP with higher banana solids, as observed during the organoleptic evaluation. There were no distinct differences in bulk densities among the three products. However, there was a marginal difference in the flowability characteristics.

Influence of stabilizer on the manufacture of BMSP

Incorporation of stabilizer to milk normally increases the stability, reduces the probability of coagulation and improves the body and texture of the dried product. Carboxymethylcellulose (CMC), a common food stabilizer is widely used in the preparation of various drinks and beverages. Therefore, CMC was used at different levels (0.000, 0.015 and 0.030%) to study its influence on the manufacture of BMSP. Calculated quantity of stabilizer was dissolved in hot water (100-150 ml) before adding to the condensed milk. The condensed milk with stabilizer was homogenized at 38-40°C with 100 bar pressure, followed by the addition of banana pulp in batches. The milk shake was, then, spray-dried and the powder was evaluated for its sensory quality and physico-chemical properties.

Sensory characteristics : It was observed that the reconstituted RBMSP made without the addition of CMC was brighter, compared to the reconstituted RBMSP made with added CMC. There were not much differences in flavour scores for reconstituted RBMSP made with 0.000 and 0.015% CMC, while lowest flavour score (6.4) was observed for the reconstituted BMSP made with 0.030% CMC (Table 4). However, difference in score was observed in the consistency of the reconstituted product made with and without CMC. The reconstituted product

TABLE 4. INFLUENCE OF STABILIZER LEVELS ON THE SENSORY QUALITY OF RECONSTITUTED RBMSP

Stabilizer levels, %	Sensory score		
	Appearance and colour	Flavour	Body and texture
0.000	7.4 (7.0-8.0)	6.8 (6.0-8.0)	6.4 (5.0-8.0)
0.015	6.8 (6.0-7.0)	6.8 (6.0-7.5)	6.8 (6.0-7.5)
0.030	6.7 (5.5-8.0)	6.4 (5.0-7.0)	6.6 (5.0-8.0)

Figures in parentheses indicate the range ; Average of 3 trials

with CMC was more viscous and uniform than the product without CMC. Further, it was observed that higher (0.030%) CMC did not show much difference in the body and texture score, compared to BMSP prepared with 0.015% CMC. Since there were not much differences observed in the sensory attributes except marginal improvement of consistency, CMC at 0.015% level was considered most suitable for the manufacture of RBMSP. A similar recommendation has also been made by Wheeler and Gillies (1973).

Physico-chemical properties : Moisture content increased as the CMC level increased (Table 5). The solubility decreased with increase in CMC level and the bulk density showed a decreasing trend due to the addition of CMC.

Optimization of fat level in milk for the preparation of BMSP

Milk (25 l) was standardized to the desired fat levels (1.0, 2.0 and 3.0%). The powder obtained was analyzed for its sensory and physico-chemical properties.

Sensory quality : The levels of fat in milk had a definite influence on flavour, body and texture of RBMSP (Table 6). The appearance and colour

TABLE 5. INFLUENCE OF STABILIZER LEVELS ON THE PHYSICO - CHEMICAL PROPERTIES OF BMSP

Attributes, %	Stablizer levels, %		
	0.000	0.015	0.030
Moisture	2.31	2.53	4.46
Fat on DM	17.85	17.10	16.85
Protein on DM	18.33	18.28	18.63
Ash on DM	5.37	5.18	5.12
Carbohydrates on DM	58.43	59.43	59.39
Acidity	1.80	1.85	1.89
Solubility	87.49	84.72	83.47
Bulk density g/cc	0.343	0.338	0.298
Flowability	Good	Good	Good

DM - Dry Matter : Average of 3 trials

TABLE 6. SENSORY QUALITY OF RECONSTITUTED RBMSP MADE FROM THREE DIFFERENT LEVELS OF FAT IN MILK

Fat level in milk, %	Sensory score		
	Appearance and colour	Flavour	Body and texture
1.0	7.2 (7.0–8.0)	7.6 (7.0–8.5)	7.5 (7.0–8.0)
2.0	7.8 (7.5–8.0)	7.3 (7.0–8.0)	7.4 (7.0–8.0)
3.0	6.5 (5.0–7.0)	6.6 (5.0–7.0)	6.6 (5.0–7.0)

Note : As in Table 4

were not appealing in the reconstituted RBMSP made from 3.0% milk fat. The brightness of the reconstituted product was also not good and some visible fat gloubles were noticed. The intensity of banana flavour was less in the powder containing higher milk fat, which may be due to the masking of banana flavour by the flavour of milk fat. Body and texture were better in the powder made from the milk with 2.0% fat compared to those made from 1.0 and 3.0% fat. Increasing the fat level beyond 3.0% did not pose any serious problem during the manufacture of the product, but it had a lower shelf-life due to its susceptibility for oxidation. However, only a minimum level of fat was maintained for drying operation so as to avoid the burning and sticking of the particles. This minimum (2.0%) fat also contributed to the improvement of taste and mouthfeel of the reconstituted product.

Physico-chemical properties : The fat contents of BMSP increased, while the protein contents decreased with the increase in milk fat content (Table 7). The total ash content was slightly more (6.18%) in BMSP made from 1.0% fat milk. The average acidity ranged from 1.85 to 1.90% as lactic acid. The higher fat in milk resulted in the formation of a layer on the surface of the reconstituted product, when kept aside undisturbed, resulting in poor solubility of the BMSP. There was slight decrease in bulk density of the BMSP, as the milk fat increased. The flowability was rated as good for the BMSP made from 1.0 and 2.0% milk fat.

Blending of sugar with BMSP

BMSP (100 g) was blended with 20, 40, 60 and 80 g of ground sugar separately. From each batch of ready-to-reconstitute BMSP, 20 g was reconstituted with 80 ml of potable water at ambient temperature. The sugar contents of the

TABLE 7. EFFECT OF DIFFERENT FAT LEVELS IN MILK ON PHYSICO-CHEMICAL PROPERTIES OF BMSP

Attributes, %	Fat levels in milk, %		
	1.0	2.0	3.0
Moisture	2.61	2.95	3.11
Fat on DM	8.53	12.00	17.26
Protein on DM	20.18	18.82	18.67
Ash on DM	6.18	6.07	5.67
Carbohydrates on DM	65.11	63.11	58.41
Acidity	1.85	1.89	1.90
Solubility	93.59	88.93	84.72
Bulk density g/cc	0.362	0.327	0.318
Flowability	Good	Good	Fair

DM - Dry Matter : Average of 4 trials

reconstituted milk shake were 3.0, 6.0, 7.5 and 9.0% for the BMSP (100 g), containing 20, 40, 60 and 80 g sugar, respectively. However, 3.0 and 6.0% levels of sugar in the reconstituted BMSP were found to be lower. As it was difficult to distinguish the difference between the sugar levels of 7.5 and 9.0% in the reconstituted BMSP, an arbitrary level of 8.5% sugar was selected and found to be highly acceptable in the reconstituted product. Finally, to obtain 8.5% sugar in the reconstituted drinks. 42.5% ground sugar was blended with banana milk shake powder to get ready-to-reconstitute banana milk shake powder (RBMSP).

The proximate composition (%) of ready-to-reconstitute BMSP made with 1.5 ratio of banana to milk with 2.0% fat using 0.015% CMC and blended with 42.5% ground sugar was moisture 2.60, fat 6.95, protein 14.08, ash 3.15 and carbohydrate 75.86 on dry matter basis. The acidity was 1.05%, while solubility was 90.15%. The final bulk density of RBMSP was 0.44 g/per cc. The RBMSP was reconstituted with potable water (20% TS) and compared with the freshly prepared control, having the similar total solids content. There was no marked difference between the shakes.

References

Hall CW, Hedrick TI (1975) Drying of Milk and Milk Products, 2nd edn. The AVI Publishing Co Inc. Westport, Connecticut, USA

ISI (1981) Handbook of Food Analysis, IS:SP:18 (Part XI) Dairy Products. Bureau of Indian Standards, New Delhi

Wealth of India (1962), Vol VI, CSIR Publication, Council of Scientific and Industrial Research, New Delhi, pp 460-470

Wheeler RJ, Gillies AJ (1973) Banana milk - A milk fruit food, Australian J Dairy Technol 28(3):96-99

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Optimization of Process Parameters for the Production of *Rasogolla* from Cow Milk

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Optimum combination of fat and solids non-fat(SNF) contents of milk, acidity of milk-acid mixture and moisture content of *chhana* for production of *rasogolla* of desired hardness was studied. Hardness of *rasogolla* was mainly influenced by the fat content of milk, followed by acidity of milk-acid mixture, SNF of milk and moisture content of *chhana*. Both fat content of the milk and acidity of milk-acid mixture should be increased for obtaining low hardness in *rasogolla*. The analysis of a prediction model had shown that *rosogolla* of desired hardness could be obtained from milk with 3.3% fat and 8.0% SNF, coagulated at 0.40% lactic acid level of milk-acid mixture and the resulting *chhana* had 58% moisture content. Material balance studies for the *rasogolla* preparation at the optimized values of process parameters showed that 1 kg milk would yield 0.313 kg *rasogolla*, having 0.06 kg sugar and 0.066 kg milk solids.

Keywords: Hardness of *rasogolla*, Optimizaiton, Milk fat, Milk solids non-fat, Acidity of milk-acid mixture, Moisture content of *chhana*.

Cow milk *chhana* is preferred for *rasogolla* preparation, as it produces *rasogolla* of good quality with soft, smooth and spongy characteristics, while that from buffalo milk yields a hard, brittle, chewy and coarse product (Bhattacharya and Des Raj 1980). The reason for the difference may be lower hydration capacity and higher calcium content of buffalo milk casein (Sidhu 1995). Many workers (Bhattacharya and Des Raj 1980; Sen 1988; Tarafdar et al. 1988; Ten Hove and Das 1995) have described the preparation of *rasogolla*. They have used milk at different fat and solid non-fat (SNF) levels, ranging from 3.0–4.5% and 8.5–8.9%, respectively in the experiments. These studies, however, did not provide the specific amounts of fat and SNF of milk needed for the preparation of *rasogolla*. Since the cost of *rasogolla* is decided, based on the cost of fat and SNF of milk, optimization of fat and SNF levels in milk is essential for its preparation.

The other important factors, which influence the mouthfeel quality of *rasogolla*, are the texture of *chhana*, which depends upon its moisture content and the acidity of milk-acid mixture from which *chhana* is obtained. Ten Hove and Das (1995) reported that 0.38% acidity of milk-acid mixture gave good textured *chhana*, suitable for *rasogolla* preparation. At higher acidities, the *chhana* obtained was granular and did not suit for *rasogolla* preparation. Bhattacharya and Des Raj (1980) reported that about 55 to 58% moisture content in *chhana* was optimum for good quality *rasogolla*, with round shape, soft body and spongy structure. However, they did not vary the moisture content of *chhana*, along with the fat and SNF levels of milk as well as the acidity of milk-acid mixture at the time of coagulation.

The present investigation was undertaken to study the effect of fat and SNF levels of milk, acidity of milk-acid mixture at the time of milk coagulation and moisture content of *chhana*, on hardness and organoleptic quality of *rasogolla* and to find out the optimum level of the independent variables.

Materials and Methods

Milk from one particular cow was collected in the evening and stored overnight in a refrigerator. The refrigerated milk was heated to 40°C and the cream and skim milk were separated by using a cream separator. The fat contents of milk and cream were determined by Gerber method (ISI 1977). The titratable acidity of milk was determined by the method recommended by AOAC (1975). The moisture contents of milk, cream, skim milk and *chhana* were determined by Mettler LP16 infrared moisture analyzer at 105°C.

From the fat and SNF contents in the skim milk and cream, standardization was done to obtain desired composition of milk, by mixing required quantities of skim milk, cream and fresh water. Three combinations of fat (2.0, 3.25 and 4.5%) and SNF (8.0, 8.5 and 9.0%) levels were tried.

Three levels of acidity of milk-acid mixture viz., 0.40, 0.48 and 0.56% of lactic acid were considered during the experiments. The concentration (b) required for the citric acid solution for coagulating milk was determined using the following equation (Jonkman and Das 1993).

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$$b = \frac{X_3 (W_m + W_a) - C_m W_m}{(W_1 / M_a) W_a} \quad - - - \quad (1)$$

Where, b = strength of citric acid solution used for coagulation (%); C_m = titratable acidity of fresh milk (% lactic acid); W_m = weight of milk used (kg), M_1 = molecular weight of lactic acid (90 g/mole), M_a = equivalent weight of the acid used for coagulation (64 g/mole for citric acid), W_a = weight of acid solution used (kg) and X_3 = acidity of milk-acid mixture (% lactic acid).

Fig. 1 shows the procedure used for the preparation of *chhana* and *rasogolla* under optimised conditions. The acidity of milk-acid mixture was varied by varying the concentration of 0.253 kg citric acid solution. The required experimental moisture content of *chhana* (55, 58 and 61%) was obtained by adding calculated amount of water to the gravity separated *chhana*.

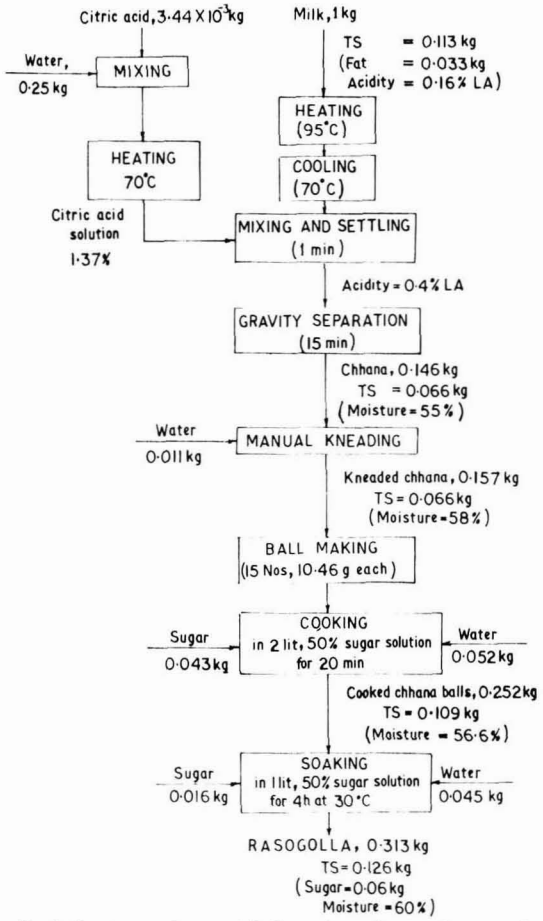

Fig. 1. Process and material flow chart for production of *rasogolla*

A survey of local sweet shops in and around Kharagpur revealed that 48 to 50% sugar syrup was used for cooking *chhana* balls to produce good quality *rasogolla*. Hence, in the present experiments, the concentration of cooking sugar syrup was maintained at 49±1%. A steel vessel was used for cooking the *chhana* balls and the container was partially closed to reduce water evaporation from the vessel. Water was added to the vessel during cooking in order to compensate for the water, lost by evaporation. A 20 min cooking time was used as recommended by Ten Hove and Das (1995). After cooking, the cooked *chhana* balls were dipped for 4 h into a 50% sugar syrup solution at room temperature. Cylinder (1.3 cm dia and 1 cm height), cut out from the *rasogolla* samples, was placed under the crosshead of Stevens LFRA (Textural Technologies Corpn., USA). A 0.5 mm/s crosshead speed and 2 mm compression depth were used. The maximum force developed at the end of the compression was taken as the hardness of *rasogolla*.

The values of the independent variables, viz., fat content of milk (X_1), SNF of milk (X_2), acidity of milk-acid mixture (X_3) and moisture content of *chhana* (X_4) were normalized within +1 and −1. The relation between normalized and real values were: $X'_1 = (X_1 - 3.25)/1.25$; $X'_2 = (X_2 - 8.5)/0.5$; $X'_3 = (X_3 - 0.48)/0.8$ and $X'_4 = (X'_4 - 58)/3$. Linear and second order regression equations between hardness values of *rasogolla*, as obtained from the textural analyser and the normalized values of X_1, X_2, X_3 and X_4 were developed (Myers 1971).

Results and Discussion

The fat and SNF contents of fresh milk were 4.6±0.1% and 9.3±0.1%, respectively. The acidity of fresh raw milk was 0.16±0.01% as lactic acid.

The effect of process variables, viz., fat and SNF levels in milk, acidity of milk-acid mixture and moisture content of *chhana*, on the hardness and shape of *rasogolla*, is given in Table 1. Maximum and minimum values for the hardness of *rasogolla* were 48 and 16 g, respectively. The hardness of market *rasogolla* was 24±1 g. The 24 g hardness level of market *rasogolla* was considered as the basis for comparing the experimental *rasogolla* quality.

The linear relationship between hardness of *rasogolla* (Y) and the normalized values of X_1, X_2, X_3 and X_4 was

$$Y = 29.461 - 10.407\ X'_1 + 2.037\ X'_2 + 2.704\ X'_3 - 1.574\ X'_4 \quad ....(2)$$

Correlation coefficient R = 0.98

TABLE 1. EFFECT OF MILK FAT, SOLIDS NON FAT (SNF), ACIDITY OF MILK-ACID MIXTURE AND MOISTURE CONTENT OF *CHHANA* ON HARDNESS AND SHAPE OF *RASOGOLLA*

Fat, (X_1), %	SNF, (X_2), %	Acidity of milk-acid mixture, %	Moisture content of *chhana* (X_4), %	Hardness of *rasogolla*, g: Actual	Hardness of *rasogolla*, g: Predicted (Y)	Shape of *rasogolla*
2.0	8-9	0.4-0.56	55	38-48	37.8-48.6	Round
3.2	8-9	0.4-0.56	55	25-34	24.7-34.2	Round
4.5	8-9	0.4-0.56	55	18-26	17.7-25.9	Round
2.0	8-9	0.4-0.56	58	36-47	36.0-46.7	Round
3.2	8-9	0.4-0.56	58	22-33	23.2-32.6	Round
4.5	8-9	0.4-0.56	58	17-24	16.4-24.7	Flat
2.0	8-9	0.4-0.56	61	35-45	34.1-44.9	Oval
3.2	8-9	0.4-0.56	61	21-32	21.6-31.1	Oval
4.5	8-9	0.4-0.56	61	16-23	15.2-23.4	Flat and broken
Four market samples				23-25	-	Round

Looking into the coefficients of the variables in eqn (2), it may be inferred that increase in fat content of milk (X_1) and increase in moisture content of *chhana* (X_4) would decrease the hardness of *rasogolla*. The same would be effected by decreasing the acidity of milk-acid mixture (X_3) and SNF levels of milk (X_2). It is further evident from the values of the coefficients of X_1, X_2, X_3 and X_4 in eqn (2) that the hardness of the *rasogolla* was influenced maximum by the fat content of the milk, followed by the acidity of the milk-acid mixture, SNF of milk and the moisture content of *chhana*.

A second order regression equation developed between the hardness of *rasogolla* and the normalised values of X_1, X_2, X_3 and X_4 was :

$$Y = 26.37 - 10.407^{***}X'_1 + 2.037^{***}X'_2 + 2.704^{***}X'_3 + 1.574^{***}X'_4 + 3.037^{***}X'^2_1 - 0.250^{*}X'_1X'_2 - 0.389^{**}X'_1X'_3 + 2.778^{*}X'_1X'_4 + 0.482^{*}X'^2_2 + 0.926^{***}X'^2_3 + 0.204^{*}X'^2_4 \quad ...(3)$$

Correlation coefficient R = 0.993

** Coefficients which were significant at 1% level of significance; * Coefficients which were significant at 5% level of significance; *** Coefficients which were significant at less than 5% level of significance

Higher value of correlation coefficient for the eqn (3), in comparison to eqn (2), indicates that the experimental data were well represented by the former. The predicted values of hardness of *rasogolla* (Y) using eqn (3) are shown in Table 1. This equation was analyzed to find out the optimum values of the independent parameters for obtaining the desirable hardness (24 g) of *rasogolla*.

It may be observed from Table 1, that the hardness of *rasogolla* decreased with the increase in moisture content of *chhana*. When the moisture content of *chhana* was 61% and fat content of milk ranged between 2.0-3.25%, the *chhana* balls became oval during cooking in sugar syrup. When the fat content of milk was 4.5% and moisture content of *chhana* was 61%, it was difficult to prepare *chhana* balls. Also, the *chhana* balls broke during cooking and there was fat loss to the sugar syrup. *Rasogolla* obtained with 58% moisture content of *chhana* was spherical in shape and had lesser hardness than those prepared from *chhana* having 55% moisture content. Hence, the optimum moisture

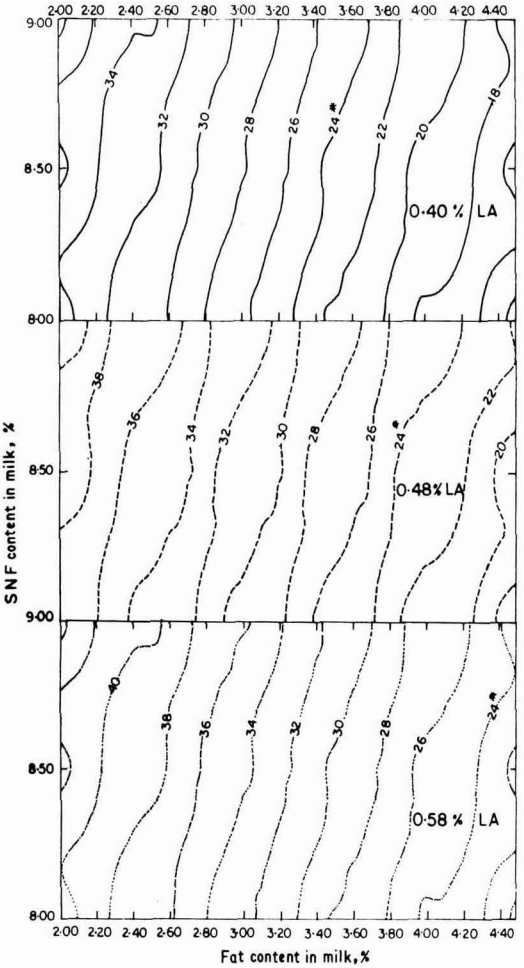

Fig. 2. Effect of fat and SNF levels of milk on hardness of *rasogolla* at 58% moisture content of *chhana* and 0.4% (—), 0.48% (----) and 0.56% (····) lactic acid levels of the acidity of milk-acid mixture.

TABLE 2. MINIMUM MILK FAT AND SNF CONTENTS REQUIRED FOR THE PREPARATION OF *RASOGOLLA* HAVING 24 g HARDNESS FROM *'CHHANA'* WITH 58% MOISTURE CONTENT AT VARYING LEVELS OF ACIDITY OF MILK-ACID MIXTURE

Acidity of milk-acid mixture, 5% lactic acid	Minimum fat content in milk, %	Minimum SNF content in milk, %
0.40	3.3	8.0
0.46	3.7	8.0
0.56	3.9	8.0

content of *chhana* was fixed at 58%.

Fig. 2 represents hardness contours of *rasogolla* with the variation in fat (2–4.5%) and SNF (8–9%) levels of milk at three different levels of acidity of milk-acid mixture (0.4%, 0.48% and 0.56%) and 58% moisture content of *chhana*. It may be observed that lesser hardness contours have resulted at higher fat contents of milk. Similarly, 24 g hardness contour lies between 3.3–3.7% fat for 0.4% acidity, whereas these are laid between 3.7–4.2% fat at 0.48% acidity and 3.95–4.40% fat at 0.56% acidity (Fig. 2). Therefore, as the acidity of the milk-acid mixture is increased, the fat content of milk should be increased for the same hardness of *rasogolla*. Table 2 shows the minimum fat and SNF levels of milk at different acidities of milk-acid mixtures to obtain 24 g hardness *rasogolla*.

Since a low fat and SNF level in milk is necessary from the point of view of having low-cost *rasogolla*, the desirable hardness of *rasogolla* could be obtained, when the acidity of milk-acid mixture was low (Table 2). At 0.4% acidity, the fat and SNF contents of milk are 3.3% and 8%, respectively. The optimized values of the parameters for *rasogolla* preparation would be, therefore, 3.3% fat, 8% SNF, 0.4% acidity of milk-acid mixture at the time of coagulation of milk and 58% moisture content of *chhana* at the time of ball making. The yield of *rasogolla* will be 0.313 kg/kg milk. The total solids in *rasogolla* will be 40% and the sugar required for the preparation of 1 kg *rasogolla* will be 0.19 kg.

References

AOAC (1975) Official Methods of Analysis, 12th edn. Association of Official Analytical Chemists, Washington DC

Bhattacharya DC, Des Raj (1980) Studies on the production of *rasogolla*. Part I. Traditional Method. Indian J Dairy Sci 33:237-243

ISI (1977) Determination of Fat in Whole Milk, Evaporated Milk, Milk, Skim Milk, Butter Milk and Cream by Gerber Method, Indian Standard 1223-Part I. Indian Standards Institution, New Delhi

Jonkman MJ, Das H (1993) Optimisation of process parameters for production of *chhana* from low fat cow milk. J Food Sci Technol 30:417-421

Myers RH (1971) Response Surface Methodology, Allyn and Bacon Inc., Boston

Sen DC (1988) *Rasogolla*, a classical Indian milk sweetmeat. Indian Dairyman 41:145-150

Sidhu JS (1995) The inherent advantages and problems encountred during processing of buffalo milk. Indian Dairyman 47(6):26-30

Tarafdar HN, Das H, Sitaram Prasad (1988) Mechanical kneading of *chhana* and quality of *rasogolla*. J Food Sci Technol 25:223-227

Ten Hove K, Das H (1995) Evaluation of yield, texture and cooking time of *rasogolla*. J Food Sci Technol 32:109-114

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Effect of Processing on the Nutritional Quality of Pearl Millet

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Effect of processing treatments viz., grinding, soaking, debranning, dry heat treatment and germination was assesed on the nutritional quality of pearl millet. Debranning and soaking reduced the crude protein, true protein and non-protein nitrogen. Autoclaving increased the non-protein content, thus reducing the true protein. Fat content was reduced on debranning and starch was reduced on giving various treatments. Total soluble sugars and reducing sugars increased on germination and autoclaving, whereas non-reducing sugars decreased after processing. *In vitro* digestibilities increased after processing treatments, of which germination proved to be the best.

Keywords: Pearl millet, Processing, Nutritive value, *In vitro* digestibility.

In the recent years, millets are recognised as important substitutes for major cereal crops to cope up with worldwide food shortage and to meet the demands of increasing population of both developing and developed countries (Rachie 1975). The nutritive value of millets is comparable to other cereals with regard to protein, fat and mineral contents (Gopalan et al. 1989). But their utilisation is limited due to the presence of various antinutrients, poor digestibility of proteins and carbohydrates and low palatability. However, various processing treatments are known to affect the chemical composition and improve nutritive value of foods. The present study was carried out to improve the nutritional value and availability of nutrients in pearl millet by giving various processing treatments.

Pearl millet grains procured from Directorate of Farms of University, were cleaned manually of broken seeds, dust and other extraneous material and given the following processing treatments.

Grinding: Grains were ground to fine and coarse sized powder in an electric grinder to a mesh size of 0.5 and 1.5 mm, respectively.

Soaking: Pearl millet grains were soaked in water for 12 h at 30°C with a grain to water ratio of 1:10(w/v)

Debranning: Cleaned grains were tempered to attain 16% moisture level and hand-pounded to separate the bran. Debranned grains and bran after drying were separately powdered.

Dry heat treatment : Fine powder of pearl millet was taken in a conical flask, properly plugged and autoclaved at 1.05 kg/cm^2 pressure for 10 min.

Germination : Soaked seeds were kept in trays lined with wet filter paper and allowed to germinate at 30°C for 48 h. Ungerminated seeds were separated and germinated ones dried at 60°C.

Autoclaving : All the treated samples, except those, with dry heat treatment were autoclaved by adding water at 1.05 kg/cm^2 pressure for 10 min. The autoclaved samples were dried, ground and stored.

Chemical analysis : The total nitrogen and crude fat were estimated by the standard methods (AOAC 1980). True protein was determined by subtracting non-protein nitrogen from total nitrogen and then multiplying with the factor of 6.25.

Total soluble sugars other than starch were extracted according to the procedure of Cerning and Guilbot (1973) and estimated by the method of Yemm and Willis (1954). Reducing sugars was estimated by the method of Somogyi (1945). The amount of non-reducing sugars was calculated as the difference between total soluble sugars and reducing sugars. Starch from free pellet, obtained after centrifugation in extraction procedure for total soluble sugars, was estimated by the method of Clegg (1956).

In vitro digestibility of protein was carried out by the method of Akeson and Stahmann (1964), as modified by Singh and Jambunathan (1981) and that of starch by the method of Singh et al (1982) by employing pancreatic amylase.

Statistical analysis: Data were subjected to analysis of variance according to Snedecor and Cochran (1967).

Crude protein content of the control sample was 11.1% (Table 1). Soaking, debranning and germination caused a significant reduction in the

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amount of crude protein. On autoclaving, changes were observed in debranned grains only. Reduction in crude protein on soaking might be due to leaching out of low molecular weight nitrogen compounds into water (Chavan and Kadam 1989). Changes similar to that caused by debranning in this study have been reported by Agarwal (1992).

On the other hand, debranning caused significant reduction in the non-protein nitrogen (NPN) content (Table 1). Bran had a higher level of NPN (105 mg/100 g). Reduction in concentration of NPN- in debranned sample is due to removal of NPN rich bran fraction from the sample. The decrease in NPN on soaking and germination may be due to leaching out of low molecular weight nitrogen compounds during these treatments. Autoclaving of control (finely ground) and treated samples resulted in a significant increase in NPN concentration, as compared to non-autoclaved samples. This increase in NPN content on autoclaving may be due to breakdown of protein into peptides and other lower molecular units.

Autoclaving led to a significant decrease in true protein content in debranned and dry autoclaved samples (Table 1). Reduction in true protein on milling and soaking has also been observed in pearl millet by earlier workers (Agarwal 1992; Chowdhury 1993).

Of all the processing treatments, only debranning reduced the fat content significantly (Table 1), which might be due to removal of fat-rich germ along with bran.

In vitro *protein digestibility* : All the treatments except coarse grinding increased the protein digestibility significantly (Table 1). Autoclaving of the treated sample further improved the protein digestibility and the maximum effect was observed on autoclaving of germinated seeds. Bran had the lowest value for protein digestibility (30.8±0.8%).

Increased protein digestibility on soaking may be due to leaching of phytic acid and polyphenols in water. Polyphenols can form complex with dietary proteins, reducing their digestibility and hence protein quality. Soaking might have led to activation of certain enzymes, resulting in degradation of high molecular weight proteins to lower units. Improved protein digestibility on debranning may be due to removal of antinutrients, which hinder the protein digestibility with bran. Activation of phytase and proteolytic enzymes during germination may be responsible for increased protein digestibility. The improved protein digestibility on autoclaving may be due to breakdown/reduction of antinutrients, particularly phytate and slight alteration and degradation of high molecular weight protein are due to activation of enzymes.

Debranning caused a significant increase in starch (Table 2). On the contrary, all other treatments except coarse grinding led to a reduction of starch content. Autoclaving of the treated samples caused a further decrease in starch content and the lowest amount (41.9%) was observed in germinated autoclaved samples. Autoclaved samples also differed significantly among themselves with regard to starch. The increase in starch on debranning is due to removal of bran, which had small amount of starch (6.8%). Reduction of starch content caused by soaking and germination may be due to activation of amylase during these treatments, resulting in the hydrolysis of starch. Also, during autoclaving, there is starch breakdown.

Coarse grinding, soaking and debranning did not affect the total soluble sugars and reducing sugars significantly, whereas non-reducing sugars decreased (Table 2). On the other hand, germination caused a significant elevation in these sugars. Autoclaving of treated samples resulted in improvement of total sugars and their components with a minimum increase in dry autoclaved and maximum in germinated autoclaved samples. Non-reducing sugars decreased after autoclaving of

TABLE 1. EFFECT OF PROCESSING ON CRUDE PROTEIN, NPN, TRUE PROTEIN, FAT AND PROTEIN DIGESTIBILITY OF PEARL MILLET (ON DRY MATTER BASIS)

Treatments	Crude protein, %	NPN, mg/ 100 g	True protein, %	Protein digestibility, %	Fat, %
Finely ground	11.1±0.2	51±2	10.7±0.2	52.6±0.4	6.2±0.3
Coarsely ground	10.9±0.2	52±2	10.6±0.1	51.7±0.7	6.2±0.1
Soaked	10.8±0.1	49±3	10.5±0.2	59.6±1.2	5.9±0.4
Debranned	10.6±0.1	43±3	10.4±0.1	63.0±0.9	4.2±0.3
Germinated	10.9±0.1	49±2	10.6±0.1	78.1±0.8	6.3±0.1
Fine autoclaved	11.2±0.2	57±1	10.8±0.2	71.0±0.4	6.3±0.2
Coarse autoclaved	11.0±0.1	56±1	10.6±0.1	71.9±1.4	5.9±0.2
Soaked autoclaved	10.7±0.1	59±4	10.4±0.1	75.9±0.6	5.8±0.1
Debranned autoclaved	10.0±0.1	56±2	9.7±0.1	78.7±0.5	4.3±0.2
Dry autoclaved	10.9±0.1	54±2	10.4±0.1	54.6±0.8	6.0±0.3
Germinated autoclaved	11.0±0.1	63±3	10.5±0.1	85.9±0.7	6.1±0.0
Bran	14.0±0.1	105±1	13.3±0.1	30.8±0.8	12.3±0.3
SEM ±	0.06	1.5	0.1	0.4	0.1
CD(P<0.05)	0.20	5.0	0.2	1.4	0.4

Values are mean ± SD of 4 replications

TABLE 2. EFFECT OF PROCESSING ON STARCH, TOTAL SOLUBLE SUGARS, REDUCING SUGARS, NON-REDUCING SUGARS, STARCH DIGESTIBILITY OF PEARL MILLET (ON DRY MATTER BASIS)

Treatments	Starch, %	Total soluble sugars, %	Reducing sugars, %	Non-reducing sugars, %	Starch digestibility, mg maltose/g
Finely ground	63.8±1.7	1.99±0.45	0.41±0.02	1.58±0.02	13.0±0.5
Coarsely ground	63.5±0.8	1.92±0.46	0.41±0.03	1.50±0.03	12.5±0.6
Soaked	59.4±2.1	1.65±0.38	0.36±0.04	1.28±0.04	18.9±1.1
Debranned	72.9±0.4	1.90±0.11	0.39±0.04	1.51±0.04	18.3±1.1
Germinated	46.0±1.1	12.78±0.39	0.59±0.04	12.18±0.04	35.4±1.9
Fine autoclaved	54.1±2.2	4.50±0.36	1.86±0.09	2.63±0.09	24.3±1.3
Coarse autoclaved	54.7±2.7	4.46±0.31	1.88±0.03	2.58±0.03	23.7±0.8
Soaked autoclaved	44.9±1.2	5.13±0.31	2.12±0.05	3.00±0.05	31.3±1.3
Debranned autoclaved	51.9±1.6	4.92±0.15	1.87±0.01	3.05±0.01	33.7±1.2
Dry autoclaved	57.9±2.3	2.60±0.42	0.72±0.07	1.88±0.07	13.7±1.5
Germinated autoclaved	41.9±1.3	15.17±0.52	8.91±0.04	6.25±0.04	53.8±1.8
Bran	6.8±1.0	2.01±0.42	0.42±0.04	1.58±0.04	2.8±0.3
SEM ±	0.09	0.20	0.02	0.02	0.6
CD(P<0.05)	2.8	0.66	0.08	0.08	2.1

Values are mean ± SD of 4 determinations

germinated sample, but increased in all the other treatments. Significant increases in sugars on germination can be attributed to activation of amylase enzyme, which hydrolyses the starch and increases the concentration of different sugars. Further improvement in the contents of sugars on autoclaving may be due to heat degradation of starch and release of sugars. Lower values in dry autoclaved samples may be due to lesser hydrolysis/degradation of starch for want of water. These findings are in confirmity with those of earlier workers (Khetarpaul and Chauhan 1991; Agarwal 1992).

In vitro *starch digestibility* : In general, the starch digestibility was very low in all the treatments except coarse grinding increased in significantly (Table 2). Autoclaving of the treated samples improved the starch digestibility significantly. Dry autoclaved sample had almost the same starch digestibility as that of control, indicating that dry heat is not effective in increasing the starch digestibility.

Higher values of starch digestibility on soaking may be due to leaching of antinutrients like phytic acid and polyphenols, which inhibit α-amylase enzymas. Similarly, debranning removes the antinutrients with bran and hence improves the starch digestibility. Enhanced digestibility on germination can be due to activation of amylase, which accelerates the hydrolysis of starch. Boralkar and Reddy (1985) have also reported that activation of amylases is responsible for improvement of starch digestibility during germination. Further improvement in starch digestibility on autoclaving may be due to rupturing of starch granules, which facilitate the amylolytic hydrolysis and thus increase starch digestibility.

References

Agarwal AJ (1992) Processing of pearl millet for its more effective utilization. PhD Thesis, CCSHAU, Hisar, India

Akeson WE, Stahmann MA (1964) The pepsin-pancreatin digest index of protein quality evaluation. J Nutr 83:257-259

AOAC (1980) Official Methods of Analysis.13th edn., Association of Official Analytical Chemists, Washington, DC

Boralkar M, Reddy SH (1985) Effect of roasting, germination and fermentation on the digestibility of starch and protein present in soybean. Nutr Rep Int 31:833-835

Cerning J, Guilbot J (1973) Changes in carbodydrate composition during maturation of wheat and barley kernel. Cereal Chem 50:220-232

Chavan JK, Kadam SS (1989) Nutritional improvement of cereals by sprouting. CRC Crit Rev Food Sci Technol 28(5) : 401-437

Chowdhury S (1993) Preparation and nutritional evaluation of some traditional foods from pearl millet. M.Sc. Thesis, CCSHAU, Hisar, India

Clegg KM (1956) The application of anthrone reagent to the estimation of starch in cereals. J Sci Food Agric 7:40-44

Gopalan C, Ramasastri BV, Balasubramanian SC (1989) Nutritive Value of Indian Foods. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad

Khetarpaul N, Chauhan BM (1991) Sequential fermentation of pearl millet by yeasts and lactobacilli: Changes in available carbohydrate content. Food Chem 40:235-240

Rachie K (1975) The Millet : Importance, Utilisation and Outlook. International Crops Research Institute for Semi-Arid Tropics, Hyderabad, India

Singh U, Jambunathan R (1981) Studies on, 'Desi' and 'Kabuli' chickpea (*Cicer arietinum* L.) cultivars : Levels of protease inhibitors, levels of polyphenolic compounds and *in vitro* protein digestibility. J Food Sci 46:1364-1367

Singh U, Kherkar MS, Jambunathan R (1982) Studies on 'Desi' and 'Kabuli' chickpea cultivars. The levels of amylase inhibitors, levels of oligosaccharides and *in vitro* starch digestibility. J Food Sci 47:510-512

Snedecor GW, Cochran WG (1967) Statistical Methods. Oxford IBH Publishing Co. New Delhi, India

Somogyi M (1945) A new reagent for the determination of sugars. J Biol Chem 160:61-63

Yemm EW, Willis AJ (1954) The estimation of carbodydrates in plant extracts by anthrone. Biochem J 57:508-514

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Frying in Fats - Nature of Fats after Use and Fats Absorbed

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Acid value and peroxide value of *desi ghee, vanaspati,* sunflower, mustard and groundnut oils before and after making *purees* were determined. These values both for residual fats and extracted fats were within the acceptable range. After frying *purees*, high peroxide values were found in sunflower oil and high acid values in *desi ghee* and *vanaspati.*

Keywords: Acid value, Peroxide value, Wheat flour, *Bengal*gram *dhal,* Fats/oils.

Fats/oils used for cooking undergo certain undesirable changes. Sebedio and Grandigiard (1989) reported that on cooking or frying, polyunsaturated fatty acids underwent transformations such as oxidation, polymerization and cyclization. Kotwal et al (1993) showed increases in acid value and peroxide value of groundnut oil on heating. Heated oils are poorly absorbed and can produce tumours (Artman 1969). Thus, severe decomposition of frying oils not only adversely affects the nutritional quality of the fried food products, but could also pose a potential hazard to human health (Huang et al. 1988). It is, therefore, of interest to study the quality of various heated fats/oils and the products prepared after frying in oils.

In the present study, five fats/oils viz., sunflower oil, mustard oil, groundnut oil. *vanaspati* and *desi ghee* were procured from the local market and used for preparing commonly consumed products from wheat flour and *Bengal*gram *dhal.* Three products were prepared from wheat flour namely *chapati, puree* and *parantha, Chapatis* were made from a soft dough of wheat flour on a hot iron plate without using any fat. *Puree* and *parantha* were prepared from wheat flour using all five fats/oils. *Purees* were deep-fried in a pan after rolling-whereas *paranthas* were shallow-fried on a hot iron plate. Three products were prepared from *Bengal*gram *dhal* i.e., boiled *dhal,* boiled and sauteed *dhal* and deep-fried *dhal.* Boiled *dhal* was prepared by boiling in water till done. For sauteing, each of the five oils/fats were used to fry finely chopped onions, tomatoes and cumin seeds and this fried mass was then added to the boiled *dhal.* For the preparation of deep fried *dhal,* raw *Bengal*gram *dhal* was soaked in water for 1 h, excess water drained off, the *dhal* dried in air at room temperature for 10 min and deep-fried in each of the oils/fats.

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The various products prepared from wheat flour and *Bengal*gram *dhal* were dried at 60±1°C, finely ground and sieved through a 60 mesh. Total lipids were extracted in chloroform : methanol: 2:1, (Folch et al. 1957). Peroxide value and acid value of extracted lipids were estimated, following AOAC (1980) methods. Leftover oils/fats before and after making 15 *purees* were also analyzed for the above parameters. All samples were analyzed in triplicate. The results for the two wheat products and for the two *dhal* products, were statistically analyzed, using the t-test (Walter 1955). The data on acid value and peroxide value of various oils used before and after cooking and of the oils extracted from various raw and cooked foods are presented in Table 1. The acid values of oils/fats employed ranged between 0.28-0.95mg/g with the highest value for groundnut oil. The acid value of all the fats increased after frying and was maximum for *desi ghee* (1.79 mg/g), followed by *vanaspati* (1.5 mg/g), a 3- to 5- fold increase. In the other three fats, the increase in acid value was less than 1.5 times. However, the acid values of all these fats before and even after cooking were within the acceptable range of 0.8-6.0 mg/g, as reported by Weiss (1983). Similar findings were reported by Kotwal et al (1993) for groundnut and *mahua* oils on heating and frying.

Peroxide value of heated oils/fats increased significantly ($P<0.05$) and was maximum for sunflower oil both before and after heating. Kotwal et al (1993) also noted an increase in the peroxide value of groundnut oil after making a commercial snack.

The fats present were extracted from raw wheat flour, *chapati* and raw and boiled *Bengal*gram *dhal.* None of these fats showed any acid value or peroxide value. The acid value of fats extracted from *purees* (1.12-1.70 mg/g) fried in different oils was

TABLE 1. ACID VALUE AND PEROXIDE VALUE OF DIFFERENT OILS/FATS AND PRODUCTS OF WHEAT FLOUR AND *BENGALGRAM DHAL* PREPARED IN THEM

Fats/oils	Oils/fats employed		Oils extracted from wheat flour products		Oils extracted from *Bengal*gram *dhal* products	
	Acid value, mg/g	Peroxide value, meq/100g	Acid value, mg/g	Peroxide value, meq/100g	Acid value, mg/g	Peroxide value, meq/100g
	Before frying		*Purees*		Boiled and sauteed *dhal*	
Sunflower oil	0.28	0.25	1.68	0.50	0.84	0.15
Mustard oil	0.39	0.05	1.12	0.40	1.12	0.10
Groundnut oil	0.95	0.05	1.40	0.45	1.12	0.20
Vanaspati	0.28	0.05	1.70	0.40	1.12	0.05
Desi ghee	0.56	0.10	1.24	0.20	1.12	0.10
	After frying		*Parantha*		Deep-fried *dhal*	
Sunflower oil	0.39	0.42	2.13	0.90	1.12	0.55
Mustard oil	0.50	0.10	1.40	0.50	1.14	0.45
Groundnut oil	1.40	0.18	1.68	0.50	1.40	0.35
Vanaspati	1.51	0.15	2.17	0.50	1.60	0.30
Desi ghee	1.79	0.25	1.78	0.30	1.60	0.20
t-value	4.10**	2.40*	2.29*	1.60^{NS}	2.81*	4.61**

In wheat flour, raw *Bengal*gram *dhal* and boiled *Bengal*gram *dhal*, no acid value or peroxide value was detected.

Each value is a mean of triplicate analysis

*Significant at P<0.05, **Significant at P<0.01 and NS Non-significant differences between treatments

lower than that of *parantha* (1.40-2.70 mg/g), while the acid value of fats absorbed by sauteed *dhal* (0.84-1.12 mg/g) was lower (P<0.05) than those present in deep-fried *dhal* (1.12-1.60 mg/g). The acid value of fats absorbed by *puree, parantha*, sauteed and fried *dhal* was maximum, when made in *vanaspati* and *desi ghee*. Least acid value was observed, when made with mustard oil for the two wheat preparations and with sunflower oil for the two *dhal* products. All the values were within the acceptable range of 0.8-6.0, as reported by Weiss (1983). Similar results were reported by Kotwal et al (1993), where the acid values of raw, heated and fried groundnut oil were 1.02, 7.04 and 5.72, and those of *mahua* oil were 7.10, 15.83 and 12.0. Thus, the acid value of an oil used for frying is lower than that of heated oil.

The peroxide value of the fats extracted from *puree* and *parantha* ranged from 0.2-0.5 and 0.3-0.9 meq/100g, respectively, indicating higher values of the fats in *parantha* compared to *puree* prepared in the same oil. Similarly, the peroxide value of the fats in fried *dhal* (0.20-0.55 meq/100g) was higher than that of the sauteed *dhal* (0.05 – 0.20 meq/100g). Highest peroxide value was observed in sunflower oil preparations followed by groundnut oil. Least value was observed, when prepared in *desi ghee*. Kotwal et al (1993) reported that peroxide values of raw, heated and fried *mahua* oil were 0.25, 0.77 and 0.69 meq/100 g, indicating that peroxide value of fried oil was less than that for heated oil.

To conclude, while the peroxide value and acid value of the fats extracted from wheat flour and *Bengal*gram *dhal* products had increased considerably, when prepared in various oils and fats, they were still within the acceptable range. The values for left over oil used for frying at household level were also within the acceptable limits, but there is a possibility of crossing these limits on prolonged cooking.

References

AOAC (1980) Official Methods of Analysis. Association of Official Analytical Chemists, 13th edn, Washington, DC

Artman NR (1969) The chemical and biological properties of heated and oxidised fats. Adv Lipid Res 7:245-330

Folch J, Lee M, Sloonestanely GH (1957) A simple method for isolation and purification of total lipid from animal tissues. J Biol Chem 226:497-509

Huang CJ, Chung NS, Lu VR (1988) Effects of deteriorated frying oils and dietary protein levels of liver microsomal enzymes in rats. J Am Oil Chem Soc 65:1976-1803

Kotwal DS, Vali SA, Shastri NV (1993) Physico-chemical and biological properties of raw and used *mahua* oil. J Food Sci Technol 30:100-104

Sebedio JL, Grandigiard A (1989) Cyclic fatty acids: Natural sources, formation during heat treatment, synthesis and biological properties. Progr Lipid Res 28:303-336

Walter TF (1955) Experimental design. Theory and Application. Oxford, and IBM Publishing Co, New Delhi

Weiss EA (1983) Oilseed Crops, 3rd edn. Longman Group Ltd, New York

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Genotypic Differences in Nutritional Quality of Sprouted Sorghum (*Sorghum bicolor*) Flour

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The effect of two variables viz., genotypic differences and degree of sprouting on the nutritional quality of sprouted sorghum flour was investigated. The three genotypes viz. 'CSH-5', 'SPV-881' and 'CSV-13' registered significant differences in dry matter, proximate composition, calcium, iron, thiamine and riboflavin. The sprouted sorghum flour of all three genotypes showed significantly ($P<0.05$) lower dry matter, crude protein, crude fat, crude fibre and total ash than control. Changes in crude fat during sprouting did not exhibit any definite trend. Calcium, iron and thiamine contents of the genotypes decreased, while riboflavin and ascorbic acid increased significantly with the increase in sprouting period.

Keywords : Nutrient composition, Sorghum, Sprouting, Genotypic differences.

Grain sorghum (*Sorghum bicolor* (L.) Moench) is a crop with poor nutritional quality. Sprouting of cereals and millets has been suggested as a way to improve their nutritional quality. Studies on sprouted sorghum have shown improvement in protein quality owing to changes in amino acids and decrease in tannins on sprouting (Chavan et al. 1979, 1981; Wu and Wall 1980). Reports on mineral and vitamin contents of sprouted sorghum are also available, but some of them show contradictory findings (Aucamp et al. 1961; Malleshi and Desikachar 1986). The nutrient composition and dry matter losses during sprouting are affected by several factors including conditions during sprouting and degree of sprouting. The present study, therefore, was undertaken to study the effect of two variables viz., genotypic differences and degree of sprouting on proximate composition, minerals and vitamins of sprouted sorghum flour.

Three sorghum genotypes viz., 'CSH-5', 'CSV-13' and 'SPV-881' grown during kharif season under the similar agroclimatic conditions were obtained from the Department of Plant Breeding, College of Agriculture of the University. The grains after soaking in water for 20 h at 25±2°C were sprouted for varying periods, viz., 0, 24, 48 and 72 h. The samples were washed in running tap water thrice a day to prevent mould growth (Taur et al. 1984). The whole sprouted seedlings were dried at 50° C for 16-18 h in an air oven and brushed to remove rootlets. The seedlings were ground to 60 mesh and stored at 4°C. Whole grain samples ground to 60 mesh were taken as control. The samples were analyzed for proximate composition (AACC 1962), dry matter loss (Bhise et al. 1988), minerals viz., calcium and iron (AOAC 1975) and vitamins viz., thiamine (AOAC 1976) riboflavin and ascorbic acid (AACC 1962) in three replicates each. The data collected were analyzed statistically by two way ANOVA (Snedecor and Cochran 1967).

The results indicate that all three genotypes viz., 'CSH-5', 'SPV-881' and 'CSV-13' differed significantly ($P<0.05$) with regard to dry matter loss. The dry matter loss increased with the increase in sprouting period due to increased metabolic activity (Chavan and Kadam 1989). The notable findings of proximate composition are significant differences in moisture content, crude protein, crude fibre, crude fat and total ash contents between control (raw) and sprouted sorghum flour (Table 1). The ash contents of all three genotypes decreased significantly after steeping for 20 h and then increased significantly on sprouting for 72 h. An increase in ash content is considered to be apparently caused by the loss of starch, while a decrease can be attributed to leaching losses during soaking and rinsing (Chavan and Kadam 1989; Wu and Wall 1980). The mean crude fibre of sprouted grain flour of 'CSV-13' was significantly higher than 'CSH-5' and 'SPV-881,' though all three genotypes showed significant decreases on sprouting. Similar results have been reported by other workers (Bhise et al. 1988; Wu and Wall 1980). Cell wall degradation during sprouting lowers crude fibre content (Glennie 1984). The trend for change in crude fat content of sprouted grain flour in all three genotypes differed significantly from each other. But, the total crude fat in sprouted sorghum flour was significantly lower than control in all three genotypes. Wu and Wall (1980) could not find a definite trend in change of lipids during sprouting of

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TABLE 1. DRY MATTER LOSS AND PROXIMATE COMPOSITION OF STEEPED AND SPROUTED SORGHUM FLOUR OF THREE GENOTYPES

Characteristic	Genotype	Control	Steeping period, h 20	Sprouting period, h 24	48	72
Dry matter loss, %	'CSH-5'			6.19	8.24	13.43
	'SPV-881'			6.14	7.61	13.50
	'CSV-13'			4.74	7.73	13.55
Moisture**, %	'CSH-5'	10.50	5.40	5.98	6.16	7.05
	'SPV-881'	10.38	5.35	5.76	6.21	7.21
	'CSV-13'	10.18	5.45	5.81	6.05	6.91
Total ash***, %	'CSH-5'	2.60	1.38	1.44	1.47	1.49
	'SPV-881'	2.14	1.23	1.47	1.45	1.43
	'CSV-13'	2.11	1.24	1.42	1.43	1.37
Crude fibre****, %	'CSH-5'	1.67	1.59	1.48	1.41	1.17
	'SPV-881'	1.69	1.60	1.42	1.40	1.27
	'CSV-13'	1.93	1.89	1.75	1.68	1.63
Crude fat*****, %	'CSH-5'	4.08	2.94	3.48	2.87	3.33
	'SPV-881'	4.83	3.59	3.75	3.70	3.44
	'CSV-13'	4.03	3.77	3.86	3.33	3.00
Crude protein******, %	'CSH-5'	11.60	10.54	10.85	10.53	10.33
	'SPV-881'	11.21	10.12	10.60	10.32	10.23
	'CSV-13'	10.90	9.97	10.33	10.20	10.18

CD_1 between genotypes, CD_2 between treatments

* CD_1 0.13, CD_2 0.13

** CD_1 0.17, CD_2 0.22

*** CD_1 0.01 CD_2 0.02

**** CD_1 0.04, CD_2 0.05

***** CD_1 0.15, CD_2 0.20

****** CD_1 0.08 CD_2 0.11

sorghum grains. Steeping of grains for 20 h caused significant decrease in crude protein from control and then subsequent sprouting for 24 h caused significant increase followed by decrease upto 72h in crude protein in all three genotypes. Loss in dry weight (carbohydrates) during sprouting may show apparent increase in protein, while loss of low molecular weight nitrogenous compounds during soaking and rinsing of grains causes decrease in crude protein on sprouting (Chavan and Kadam 1989).

The data on minerals and vitamins presented in Table 2 show that calcium and iron contents of 'CSH-5', 'SPV-881' and 'CSV-13' differed significantly from each other initially and on sprouting after 24 h. The significant decrease in

TABLE 2. MINERAL AND VITAMIN CONTENTS OF STEEPED AND SPROUTED SORGHUM FLOUR OF THREE GENOTYPES

Nutrient, mg/100g	Genotype	Control	Steeping period, h 20	Sprouting period, h 24	48	72
Calcium*	'CSH-5'	46.54	46.63	45.14	38.77	37.17
	'SPV-881'	44.21	45.42	42.70	38.75	37.11
	'CSV-13'	38.31	39.07	37.66	35.06	32.26
Iron**	'CSH-5'	9.25	8.29	7.72	6.55	5.29
	'SPV-881'	8.67	7.72	5.69	4.66	3.97
	'CSV-13'	8.18	5.42	4.78	4.11	3.41
Thiamine***	'CSH-5'	0.59	0.58	0.56	0.50	0.46
	'SPV-881'	0.45	0.37	0.32	0.28	0.25
	'CSV-13'	0.37	0.26	0.18	0.16	0.14
Riboflavin****	'CSH-5'	0.09	0.14	0.20	0.25	0.37
	'SPV-881'	0.08	0.09	0.13	0.21	0.33
	'CSV-13'	0.12	0.13	0.19	0.24	0.35
Ascorbic acid*****	'CSH-5'	0.00	0.80	2.13	4.20	5.20
	'SPV-881'	0.00	0.80	2.46	4.20	4.60
	'CSV-13'	0.00	1.60	3.53	4.00	5.00

CD_1 between genotypes, CD_2 between treatments

* CD_1 1.46, CD_2 1.89

** CD_1 0.17, CD_2 0.21

*** CD_1 0.01, CD_2 0.02

**** CD_1 0.01, CD_2 0.02

***** CD_1 0.36 CD_2 0.47

calcium and iron observed with corresponding increase in sprouting period is attributed to leaching losses (Chavan and Kadam 1989).

The notable findings regarding vitamin content of sprouted sorghum flour are: significant decrease in thiamine, significant increases in riboflavin and ascorbic acid contents. Thiamine contents in all three genotypes in control as well as in sprouted samples differed significantly from each other. The reason for the observed decrease appears to be the partial destruction of thiamine on drying of the sprouted grains at 50°C for 18 h. Malleshi and Desikachar (1986) have also observed lower thiamine in germinated sorghum than ungerminated grains. The highest increase in riboflavin has been observed in 'CSH-5'. Riboflavin contents of steeped and sprouted flours of 'CSH-5' and 'CSV-13' did not differ significantly, while 'SPV-881' differed significantly. Increase in riboflavin of sorghum has been observed by Aucamp et al (1961). The ascorbic acid has been found to increase continuously and significantly with progressive sprouting of grains in all three genotypes. The present study indicates that genotypic differences significantly affect the nutritional quality of sprouted sorghum flour. Sprouting of grains for different periods also showed variations in nutritional quality.

References

AACC (1962) Approved Methods, American Association of Cereal Chemists, St. Paul, Minnesota

AOAC (1975) Official Methods of Analysis, 12th edn. Association of Official Analytical Chemists, Washington, DC

AOAC (1976) Official Methods of Analysis, 13th edn. Association of Official Analytical Chemists, Washington, DC

Aucamp MC, Grieff JT, Novelli L, Papedick B, Schwartz HM, Steer AG (1961) Kaffir corn malting and brewing studies, VIII. Nutritive value of some kaffir corn products. J Sci Food Agric 12:449-456

Bhise VJ, Chavan JK, Kadam SS (1988) Effects of malting on proximate composition and *in vitro* protein and starch digestibilities of grain sorghum. J Food Sci Technol 25:327-329

Chavan JK, Ghonsikar CP, Kadam SS, Salunkhe DK (1979) Protein, tannin and starch changes in developing seeds of low and high tannins cultivars of sorghum. J Food Biochem 3:13-20

Chavan JK, Kadam SS (1989) Nutritional improvement of cereals by sprouting. Crit Rev Food Sci Nutr 28:401-437

Chavan JK, Kadam SS, Salunkhe DK (1981) Changes in tannin, free amino acids, reducing sugars and starch during seed germination of low and high tannin cultivars of sorghum. J Food Sci 48:638-639

Glennie W (1984) Endosperm cell wall modification in sorghum grain during germination, Cereal Chem 61:285-289

Malleshi NG, Desikachar HSR (1986) Nutritive value of malted millet flours. Qual Plant Foods Hum Nutr 36:191-193

Snedecor GW, Cochran WG (1967) Statistical Methods. Oxford and IBH Publishing Co, pp 299-334

Taur AT, Pawar VD, Ingle UM (1984) Nutritional improvement of grain sorghum (*Sorghum bicolor* (L.) Moench) by germination. Indian J Nutr Dietet 21:168-173

Wu YV, Wall JS (1980) Lysine content of protein increased by germination of normal and high lysine sorghum. J Agric Food Chem 28:455-458

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Proximate Composition of Edible Blue Crab *Callinectus sapidus*

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The proximate composition of edible blue crab *Callinectus sapidus* was evaluated. The results revealed that blue crab was high in moisture content (78.60g/100g wet weight). Crude protein, crude fat, ash, crude fibre and carbohydrate contents of carapace were 54.20, 5.40, 25.06, 8.80 for edible portion and 27.82, 3.80, 50.20, 15.36 and 2.82g/ dry matter, respectively. Elemental analysis showed that blue crab was rich in calcium, phosphorus, magnesium, sodium, potassium, manganese, zinc and iron. The potential of *C. sapidus* as a cheap source of animal nutrients is discussed.

Keywords : *Callinectus sapidus*, Proximate composition, Nutritive value, Animal proteins, Minerals.

Seafoods are known to be potential sources of calories, proteins, fats and oils, essential amino acids, minerals and small amounts of carbohydrates. Crab meat is classified as a speciality food that adds variety to the diets and is always very high in proteins.

Callinectus sapidus (Efik: *Isobo*, Class: Malacostrata, Family: Portunidae) is the common edible blue crab of the Atlantic Coast and many rivers of the world. It is used as food by both rural and urban dwellers in the Atlantic Coast of West Africa. They are charaterized by short, flattened and broad body covered with exoskeleton (carapace) of about 14 cm by width and 15-18 cm in length. This communication describes the nutritive value and mineral content of edible portion and carapace of *C. sapidus*.

Live samples of *C sapidus* were bought from James Town beach in Mbo Local Government Area of Akwa Ibom State. The samples were steeped in hot distilled water at a temperature of 60° C for 5min to remove all dirt. They were dried in an air-drought oven (Gallen Kamp) at 60°C for 72 h.

The dried samples were then separated into two portions (the edible portion and carapace) and were milled separately into homgeneous fine powder, passed through a 300 mesh sieve and stored in air-tight containers in a refrigerator, until used for analysis.

Proximate composition was determined by the standard methods (AOAC 1980). A know amount of the dry powdered sample was ashed at 600°C in a muffle furnace for 4h. The ash was dissolved in 6M HCl solution and used for the determinaton of mineral elements and toxic substances. Phosphorus was determined by the molybdovanadate colorimetric method of Vogel (1969). Sodium and potassium were determined with a flame photometer (Jenway PF7 flame photometer, Essex, UK), while other mineral elements were determined using an atomic absorption spectrophotometer (AAS) Unicam Analytical System, model 919 Cambridge, UK) (AOAC 1980). All analyses were done in triplicate and the mean values are presented.

Table I shows the proximate composition of *C. sapidus*. The protein content was higher in the edible portion of *C. sapidus*. The crude protein value (54.20g/100g dry matter) was comparable with the values obtained for snail (*Vivapara quadrata*) 63.3g/100g dry matter (DM), periwinkle (*Pachymelania byronensis*) (55.0g/100g DM), crayfish (*Paramonetes varians*) (69.4g/100g DM), whole smoked fish (*Chrysichthys* spp) (70.4g/100g DM), (Mba 1980), *Limicolaria aurora* (51.4g/100g

TABLE 1. PROXIMATE AND MINERAL COMPOSITION (g/100g DM)OF *C. SAPIDUS*

Constituent	Edible portion	Carapace
Moisture (wet weight)	48.80±0.001	29.20±0.04
Crude fat	5.40±0.05	3.80±0.15
Crude proteins	54.20±0.04	27.82±0.01
Crude fibre	8.80±0.04	15.36±0.03
Ash	25.06±0.01	50.36±0.04
Carbohydrates	6.60±0.14	2.82±0.23
Minerals		
Calcium	1.500	10.648
Magnesium	0.630	0.710
Sodium	1.616	0.640
Potassium	0.790	0.330
Iron	0.066	0.060
Zinc	0.013	0.005
Copper	0.003	0.001
Manganese	0.033	0.029
Phosphorus	1.899	2.300
Calorific value (Kcal/100g)	291.80	171.88

DM) (Udoh et al. 1995), hen's egg (50.0g/100g DM) (Paul et al. 1976), clam (*Egreria radiata*) 60.1g/100g DM (Ifon and Umoh 1987) and those of other seafoods (Umoh and Bassir 1977). The use of blue crab in soups and other diets may provide a satisfactory supply of animal protein for growing children, pregnant and lactating women. The crude fat content (5.40g/100g DM) was higher than correpsonding values for *V quadrata* (2.66g/100g DM), *P. byronensis* (1.3g/100g DM) and *P. varians* spp (10.1g/100g DM) and hen's egg (36.8g/100g DM) (Mba 1980). Diets rich in crab may be recommended for patients with atheroslerosis, coronary attacks, nortic artheroma disease because of its low fat content (Briggs and Calloway 1979). The crude fibre content of the carapace was higher than the edible portion. When compared with other seafoods, it was higher than those reported for *V. quadrata* (0.14g/100g DM), *P. byronensis* (0.21g/100g DM), *P. varians* (4.72g/100g DM), *Chrysichthys* spp (0.21g/100g DM), hen's egg (0.28g/ DM) (Mba 1980). Dietary fibre is protective against bowel cancer (Robinson and Lawler 1977) and maintains an intestinal distension for normal peristaltic movement in the intestinal tract (Davidson et al. 1975). High fibre contents reduce the rate of glucose and fat absorption (Mottram 1979).

The carbohydrate content and calorie values were generally low and comparable with the values reported for fish (Thompson 1966). The ash content (25.06g/100g DM) of the edible portion was higher than (11.8g/100 DM) for *P. varians*, 17.9g/100g DM for *Chrysichthys spp* and 5.00g/100g DM for *V. quadrata* (Mba 1980). The high ash content indicates the high mineral contents of crabs compared with other seafoods studied (Mba 1980; Ifon and Umoh 1987).

Mineral composition of *C. sapidus* is shown in Table 2. The levels (mg/100g DM) of sodium (1616), potassium (790), calcium (1500), magnesium (630) and phosphorus (1899) present in the edible portion of *C sapidus* were much higher than those found in *Littorina littorea* (Mba 1980) and *Vicapara quadrata* (Umoh and Bassir 1977). It is, therefore, concluded that *C sapidus*, if consumed in adequate quantities, may help in alleviating nutrient deficiency prevalent in many developing countries.

References

AOAC (1980) Official Methods of Analysis, 13th edn, Association of Official Analytical Methods, Washington, DC

Briggs GM, Calloway DH (1979) Bogerts Nutrition and Physical Fitness, W.B. Sanders Co, Philadelphia Pa, pp 155-205

Davidson S, Passmore R, Brock JF, Transwell A.S., (1975) Human Nutrition and Dieteties 10th Edn,. Churchill, Livingstone, Edinburgh, pp 270-436

Ifon, ET, Umoh IB (1987) Biochemical and nutritional evaluation of *Egreria radiata* (Clam). A delicacy of some riverine peasant population in Nigeria. Food Chem 24:21-27

Mba AU (1980) Chemical composition of some local sources of protein foods for man. Nig J Nutr Sci 1(2):142-147

Mottram, RF (1979) Human Nutrition, 3rd edn, Edward Arnold Publishers Ltd, Great Britain, pp 58-59, 159

Paul AA, Southgate DAT, Russel J (1976) First Supplement to McCance and Widdowson's Composition of Foods. Her Majesty's Stationery Office, London, UK, p16

Robinson CH, Lawler MR (1977) Normal and Therapeutic Nutrition, 15th edn, MacMillan Publishing Co. Inc. New York, pp 1-15

Thompson MH (1966) Proximate Composition of Gulf of Mexico Industrial fish, US Fish White Serv. Fishland Res, pp 3,29-39

Udoh AP, Akpanyung EO, Igiran IE (1995) Nutrients and antinutrients in small snails (*Limicolaria aurora*) Food Chem 52 (In Press)

Umoh IB, Bassir O (1977) Lesser known sources of protein in some Nigerian peasant diets. Food Chem 2:315-321

Vogel AI (1969) A Textbook of Qualitative Inorganic Analysis. 3rd edn. Longman, London

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Detection of Polychlorinated Biphenyls in Fats

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A thin layer chromatographic method of separation and detection of polychlorinated biphenyls (PCB) was developed, using petroleum ether as developing solvent and 1% orthotolidine in acetone as spray reagent. As low as 0.1 µg of the PCB (1254, 1242, 1260 and 1268) could be extracted by petroleum ether and cleaned up by sulphuric acid method. DDT, alpha, gamma, beta and delta HCH did not interfere in the TLC separation and detection of PCBs from oils and fats. As low as 0.4 ppm could be detected from oils and fats by using this method.

Keywords : Fats, Polychlorinated biphenyls, Detection.

Polychlorinated biphenyls (PCB) have emerged as potential contaminants in foods, as they are present in considerable amounts in the samples of fish, butter, margarines, vegetable oils, eggs, beef, lamb, chicken, bread, biscuits and baby foods. (Westoo and Noren 1970; Westoo et al. 1971; Mes et al. 1974). PCBs were found to migrate into foods from the packaging material (Westoo et al. 1971). As a consequence of their chemical stability and lipid solubility, PCBs are ubiquitous contaminants which accumulate in food chain (Widmark 1967). Therefore, the detection and determination of PCB in food commodities have attained importance.

Detection of PCB by thinlayer chromatographic method, using Fisetin reagent and oxidative reagents were reported earlier (Mallet and Frei 1971; Mulhern et al. 1971). These methods were cumbersome and the colour is not as stable as the orthotolidine method described in this communication. Several GLC and HPLC methods were also reported for the determination of PCBs, which were not cost effective and time consuming and could not be utilized in the large scale, screening of food materials for the presence of PCBs in the regulatory analysis (Schulte and Acker 1974; Berg et al. 1972; Zitkov et al. 1971; Hajslova et al. 1993; Ahling and Jensen 1970; Brinkman et al. 1976).

Silica gel G plates of 0.25 mm thickness were prepared, activated at 100°C for 30 min and allowed to cool to room temperature. Stock solution (10 ppm) of individual PCBs (1254, 1242, 1260 and 1268) were prepared in petroleum ether and aliquots containing 0.05, 0.1, 0.5, 1.0, 2.5, 5.0, 7.5 and 10 µg were spotted on TLC plates. The plates were developed in petroleum ether upto 15 cm height, air-dried and sprayed with 1% orthotolidine in acetone and exposed to sunlight for 5 min. Another experiment was conducted to find out the interference of PCBs with DDT and HCH isomers. PCBs (1254, 1242, 1260, 1268) were spotted at 0.1µg level on TLC plate along with 5 µg each of pp DDT, op DDT, alpha, gamma, beta and delta HCH and mixtures of PCBs with DDT and HCH. The plate was developed and sprayed as mentioned earlier.

Groundnut oil and *ghee* samples were spiked with PCBs at 1 to 5 ppm levels (PCB 1254, 1242, 1260 and 1268). Samples (5g) of oil and *ghee* containing 1 to 5 µg/g of PCBs were taken in separate beakers (representing 1 to 5 µg of PCB in oil and fat) and dissolved in 40 ml petroleum ether. The petroleum either extracts of PCBs were transferred to glass columns of 30 cm length and 2.5 cm dia and cleaned up by sulphuric acid as described by Kapoor et al (1981). The cleaned up extract was concentrated in a vacuum evaporator to 1 ml and transferred to 10 ml beakers. The extracts were further concentrated to 20-30 µl and spotted on TLC plates along with PCB, DDT and HCH standards. The plate was developed in petroleum ether and sprayed with orthotolidine.

PCBs at levels of 0.1µg and above developed dark blue coloured spots. While DDT and HCH isomers developed blue spots. The Rf values of PCBs op–DDT, pp DDT, and alpha, gamma, beta, delta isomers of HCH were 0.97, 0.92, 0.86, 0.4, 0.25, 0.18 and 0.06, respectively. PCBs at 2 µg/ 5 g oil and *ghee* samples spiked with PCBs (2 µg/ 5 g) showed blue coloured spots at 0.4 ppm level.

The TLC described above for the detection of PCBs from oils and *ghee* showed that DDT and HCH did not interfere in the separation and detection of PCBs. All the PCBs (1254, 1242, 1260 and 1268) moved along with the solvent front and gave a single spot. Although this TLC method cannot be used for the separation of individual PCBs, the method could be tried for the rapid screening of fat samples for the

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presence of PCBs and other organochlorine insecticides indicated above (DDT, BHC). This method could detect as low as 0.1µg of PCB in technical grade materials and 0.4 ppm residue in oils and fats. As the detection limit of PCBs from this TLC method is below the tolerance limit of FAO/WHO (1.5 ppm) for dairy products, the method is useful in rapid screening of samples under regulatory analysis. The samples, which are positive to this test, should be subjected to quantitative determination by the standard GLC or HPLC methods. This method helps in quickly screening the samples for the presence of PCBs.

References

Ahling B, Jensen S (1970) Reversed liquid-liquid partition in determination of polychlorinated biphenyls (PCB) and chlorinated pesticides in water. Anal Chem 42:1483-1486

Berg OW, Diosady PL, Rees GAV (1972) Column chromatographic separation of polychlorinated biphenyls from chlorinated hydrocarbon pesticides and their subsequent gas chromatographic quantitation in terms of derivatives. Bull Environ Contam Toxicol 7:338-347

Brinkman UAT, Seetz JWEL, Reymer HGM (1976) High speed liquid chromatography of polychlorinated biphenyls and related compounds. J Chromatogr 116:353-363

Hajslova J, Holadova K, Kocourek V, Poustka J, Cuhra P, Raverdeno V (1993) Determination of PCBs in tissues by means of several detection techniques. Seitschrift fur Lbenasmittel-Unter-Suchung-Forschung 197 (6): 562-569

Kapoor SK, Chawla RP, Kalra RL (1981) Modified method for estimation of DDT and hexachlorocyclohexane residues in milk. J Assoc Off Anal Chem 64(1):14-15

Mes J, Coffen DE, Campbell D (1974) Polychlorinated biphenyl and organochlorine pesticide residues in Canadian chicken eggs. Pestic Monit J 8:8-11

Mallet VI, Frei RW (1971) An investigation on flavones as fluorogenic spray reagents for organic compounds on a cellulose matric. Part II. Detection of pesticides J Chromatogr 56:69-77

Mulhern BM, Cromartie E, Reichal WL, Belisle AA (1971) Semiquantitative determination of polychlorinated bihenyls in tissue samples by thin layer chromatography. J Assoc Off Agric Chem 54:548-550

Schulte E, Acker L (1974) Gas chromatographic unit glascapillaran bei temperaturan bis zu 320°C. S Anal Chem 268:261-267

Westoo G, Noren K (1970) Levels of organochlorine pesticides and polychlorinated biphenyls in fish caught in Swedish water areas or kept for sale in Sweden 1967-1970. Var Foda 3:93-146

Westoo G, Noren K, Anderson M (1971) Levels of organochlorine pesticides and polychlorinated biphenyls in some cereal products. Var Foda 10:341-360

Widmark, GJ (1967) Possible interference by chlorinated biphenyls. J Assoc Off Anal Chem 50:1069

Zitkov S, Hutzinger O, Safe S (1971) Retention times and electron capture detector responses of some individual chlorobiphenyls. Bull Environ Contam Toxicol 6:160-163

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Development of β-carotene-rich Extruded Maize Product

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Extrusion technology was used to develop an extruded product with maize. β-carotene-rich vegetables like carrot, and curry leaves were dehydrated to powders and incorporated at various levels in the extruded product. Red palm oil, another rich natural β-carotene source was also incorporated by blending groundnut oil at different ratios. In the sensory evaluation tests conducted, the products prepared with 30% curry leaf powder and 30% carrot powder scored high. The extruded maize product prepared with 30:70 oil blend of red palm oil: and groundnut oil were better accepted than 50:50 of the respective blend. The chemical analysis of the experimental products at 30% incorporation of curry leaf powder and 30% incorporation of carrot powder showed energy (Kcal), protein (Nx6.25g) fat (g), β-carotene (mg) contents of 474, 12.7, 10.7, 5.7 and 483, 11.9, 10.2, 9.8 per 100g product, respectively. Similary, products prepared with 30:70 oil blend of red palm oil and groundnut oil with 30% curry leaf powder incorporation and 30:70 oil blend of red palm oil and groundnut oil with 30% carrot powder incorporation showed energy (Kcal), protein (Nx6.25g), fat (g) β-carotene (mg) 469, 13, 10.9, 7.7 and 481, 11.2, 10.2, 11.0, respectively. The experimental products were stored in high density polyethylene bags for 4 weeks at a temperature of 38.2 °C and relative humidity of 56%. The stability of the experimental products in terms of proximates and β-carotene showed a decreasing trend. The mean % storage losses of calories, proteins, fat and β-carotene were 4.7, 17.6, 4.2 and 15.6. Overall, the extruded maize product incorporated with curry leaves and carrots (30%) and red palm oil blend with groundnut oil (30:70) were organoleptically acceptable and the retention of proximates and β-carotene was found satisfactory.

Keywords : β-carotene, Extrusion cooking, Curry leaf, Carrot, Red palm oil, Supplementation.

Increasing number of studies have revealed the protective role of β-carotene against cancers and coronary heart diseases (Cindy et al. 1992). β-carotene is an important precursor of vitamin A. Low level of consumption of vitamin A has been shown to be the primary cause of night blindness. Pre-school children are more prone to vitamin A deficiency symptoms, as the rate of consumption of vitamin A or β-carotene-rich foods in their diet is low (Vitamin A report 1989). Besides, this vitamin is subjected to destruction during processing. The processing losses of this vitamin are estimated to be as high as 75% (Onayami and Badifu 1987). The disadvantage in processing of carotene-rich foods can be eliminated by application of extrusion method (Ulrich 1994). Recent studies indicated the use of carrots (Lilian et al. 1992) and red palm oil (Manorama 1992) as a source of β-carotene. Curry leaf is also a rich source of carotene, but has not been exploited for its β-carotene content till now. Attempts have been made to develop an extruded maize product, using these β-carotene sources and evaluate its nutrient contents, shelf life and the sensory quality. The results are presented in this communication.

Procurement and processing of raw materials: Samples of maize procured from local markets were cleaned, washed and milled to semolina to pass through a BS 30 sieve (500 μ). Curry leaves and carrots also purchased from local market were washed, shade-dried for 6-7 days and powdered to pass through a BS 60 sieve (250 μ). Crude red palm oil was obtained from Central Plantation Crops Research Institute, Palade, Thiruvananthapuram. Standard brands of double-refined groundnut oil, pepper and salt were procured from a local departmental store.

Extrusion process: The extrusion processing was done according to standard methods (Asp and Bjorck 1983). Maize grits were moistened, using water at a level of 4 ml per 100 g and mixed homogenously. The mix was passed through a collet extruder, having internal temperature and pressure of 160-180°C and 20-40 atmospheres, respectively. The final product obtained was long and oval-shaped. The extrudate was passed into a mixing chamber, wherein a seasoning mix, comprising curry leaf powder (30 g) or carrot powder (30 g), pepper (0.05 g), salt (0.15 g) were added per 100g product. Oil spraying was done at a rate of 8 ml per 100g of product and thoroughly mixed to ensure proper coating of the seasoning on products. The products were then passed through a heating chamber. The warm temperature (40-45°C) of the heating chamber aided in removing the remaining moisture in the products and thus made the product crisp. The product was then packed in high density polyethylene bags and

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TABLE 1. SCORE CARD FOR THE EXTRUDED MAIZE PRODUCT

Score	Determinant
	Taste
5	Balanced and highly acceptable
4	Slightly pungent
3	Too spicy
2	Pungent
1	Bland
	Flavour
5	Balanced and acceptable
4	Good
3	Slightly strong
2	Strong
1	Bland
	Texture
5	Highly crisp
4	Slightly crisp
3	Slightly hard
2	Slightly soft
1	Hard/soft
	Colour and appearance
5	Attractive
4	Satisfactory
3	Dull/light
2	Patchy
1	Dark
	Overall acceptability
5	Highly acceptable
4	Moderately acceptable
3	Acceptable
2	Slightly acceptable
1	Not acceptable

sealed. These bags were stored at room temperature and humidity for 4 weeks. The fresh and stored experi-mental products were judged organoleptically by a panel consisting of 10 members. The attributes were ranked on a 5-point Hedonic scale (Table 1). The fresh products, which obtained the highest total score, when served to panel, were given *ad libitum* to children of 2 1/2-3 years age for general acceptance of the product as a snack item.

Chemical analysis: Fresh and stored samples were estimated for energy, protein and fat contents as per standard procedures (AOAC 1975). Analysis of β-carotene was carried out by HPLC (Shimadzu, model 6A) on a C 15 bondapak column using UV-detector as per the methodology, described by Tan et al (1976).

Sensory attributes such as taste, flavour, texture, colour and appearance and overall acceptability were tested, using analysis of variance between fresh and stored products.

Products with supplementation (30%) of curry leaf powder (CLP) and carrot powder (CP) were accepted highly by the sensory panel as well as pre-school children. The proximate composition of the control (no supplementation) and supplemented products with curry leaf powder (CLP) and carrot powder (CP) at 30% level is given in Table 2. Data revealed that the energy content of the products (387-483 Kcal/100g) would fulfil one-third of the recommended daily allowance (RDA) for pre-school children of β-carotene and can partially contribute towards the maintenance level of protein (ICMR 1992) of the pre-school children.

Carotenoid content: Analysis of the products for carotenoid content (Table 2) revealed that these products would provide nearly two-thirds of the RDA of β-carotene for pre-school children (ICMR 1992). The average β-carotene content in the

TABLE 2. COMPOSITION OF THE FRESH AND STORED MAIZE PRODUCT (PER 100 g ON FRESH WEIGHT BASIS)

		C	C-CLP	C-CP	R	R-CLP	R-CP
Energy,	Fresh	387.1	474.0	483.0	386.3	469.9	481.4
Kcal	Stored	380.1	473.3	482.8	387.1	468.0	480.0
Protein, g	Fresh	9.0	12.7	11.9	9.2	13.0	11.2
Nx6.25	Stored	8.9	10.5	10.0	9.0	12.8	9.5
Fat, g	Fresh	9.8	10.7	10.2	10.0	10.9	10.2
	Stored	9.5	10.0	9.8	9.2	10.1	9.1
β-carotene, mg	Fresh	ND	5.7	9.8	2.7	7.7	11.0
	Stored	ND	5.5	9.0	2.0	7.0	12.1

CLP - Curry leaf powder; CP- Carrot powder
C - Control product (without incorporation of CLP or CP)
C-CLP - Curry leaf powder incorporated at 30% level in control
C-CP - Carrot powder incorporated at 30% level in control
R - Product prepared using 30:70 oil blend of red palm oil and groundnut oil
R-CLP - 30:70 oil blend and CLP at 30% incorporation
R-CP - 30:70 oil blend and CP at 30% incorporation

TABLE 3. PERCENTAGE LOSSES OF PROXIMATES DURING PROCESSING AND STORAGE

	Energy, Kcal		Protein, g (Nx6.25)		Fat, g		β-carotene, mg	
Sample	P	S	P	S	P	S	P	S
Control	5.26	1.81	18.18	1.11	3.92	3.06	–	–
Control + curry leaf supp	4.41	0.15	21.12	17.32	3.60	6.54	9.95	3.51
Control + carrot supp	3.78	0.41	7.75	15.97	4.67	3.92	15.66	8.27
Red palm oil supp	5.49	0.21	21.37	2.17	1.96	0.04	10.10	25.28
Red palm oil + curry leaf supp	5.47	0.40	23.08	1.54	3.54	7.34	17.42	8.98
Red palm oil + carrot supp	4.03	0.29	13.85	15.18	7.27	10.78	24.81	7.84

P - Processed S - Stored

TABLE 4. SENSORY QUALITY OF FRESH AND STORED PRODUCTS

		Mean scores				
Attribute	Sample	Control	CLP	CP	R-CLP	R-CP
Taste	Fresh	4.9	4.7	4.8	3.6	4.2
	Stored	4.7	4.5	4.7	3.4	4.1
Flavour	Fresh	4.8	4.6	4.9	3.8	4.3
	Stored	4.3*	3.2	4.1	3.4	3.2
Texture	Fresh	4.8	4.7	4.9	4.4	4.4
	Stored	4.7	3.6	3.7	4.2	4.1
Colour and	Fresh	4.8	4.7	4.9	4.0	4.2
appearance	Stored	4.7	4.6	4.8	3.9	3.9
Overall acceptability	Fresh	4.9	4.5	4.9	4.4	4.3
	Stored	4.6	4.3	4.7	4.1	3.5

* Significantly different ($P<0.05$)

CLP – Curry leaf powder incorporated at 30% level in control
CP – Carrot powder incorporated at 30% level in control
Control – Product without incorporation of CLP or CP
R-CLP – 30:70 oil blend and CLP at 30% incorporation
R-CP – 30:70 oil blend and CP at 30% incorporation

supplemented samples ranged from 5.5 to 12.1 mg%. Analysis showed that products made with red palm oil-carrot powder had higher β-carotene, while the product made with red palm oil-curry leaf powder had low values, but these values were significantly higher than the control (products without ingredients).

In addition to the higher β-carotene content, the supplemented maize products had a desirable colour, spicy flavour and taste compared to the control. This induced the children to accept the product, better than the conventional foods being distributed under supplementary feeding programmes.

Processing losses: Extrusion processing resulted only slightly but significant losses ($P<0.05\%$ level) of energy, protein, fat, and β-carotene (Table3).

Storage stability and sensory quality : Organoleptic evaluation revealed that the products stored for 4 weeks were not significantly different from fresh samples, except for flavour (Table 4). There was no significant change observed in proximates after storage. The loss in β-carotene on storage was 10.2% (Table 3). The retention of the nutrients can be increased by proper packaging before storage.

The products developed are useful as good sources of β-carotene and hence are ideal as supplementary foods for pre-school children. Consumption of 30g of product made with carrot powder-red palm oil combination can provide one-third of a child's RDA of vitamin A at a rate lower (Rs. 0.46) than conventional supplementary foods supplied by government agencies (Beaton et al. 1993).

References

AOAC (1975) Official Methods of Analysis, 12th edn. Association of Official Analytical Chemists, Washington, DC

Asp NG, Bjorck I (1983) Nutritional properties of extruded foods in extrusion cooking In: Mercier C, Linkoe P, Harger JM (eds) American Association of Cereal Chemists St. Paul, MN, USA, pp 399-434

Beaton GH, Martorell R, Abbe B, Edmonston CR., Ross AC, Harvey B (1993) Effectiveness of vitamin A supplementation in the control of young child morbidity and mortality in developing countries. A summary report presented at ACC/SCN 20th Session, SCN News 9

Cindy JF, Harold F, Adrianne B, Roberts P, Daphne AR (1992) Effect of β-carotene supplementation on photosuppression of delayed type hypersensitivity in normal young men. Am J Clin Nutr 56:684-690

ICMR (1992) Nutrient Requirements and Recommended Dietary Allowances for Indians. Indian Council of Medical Research Ansari Nagar, New Delhi

Lilian P, Julieta Q, Louise C, Thomas J, Noel WS (1992) Carrots and dietary vitamin A adequacy. Food Nutr Bull 14(2)

Manorama R (1992) Studies on red palm oil (*Elaeis guinensis*) Nutritional, Biochemical and Biological Aspects. PhD. Thesis, Osmania University, Hyderabad, India

Onayami C, Badifu GEO (1987) Effect of blanching and drying methods on the nutritional and sensory quality of leafy vegetables. Plant Foods Hum Nutr 37:291-298

Tan B, Grady CM, Gawienowski AM (1976) Hydrocarbon carotenoid profiles of palm oil processed fractions. Modified from the Method of Davien BH Chemistry and Biochemistry of Plant Pigments. In: Goodwin TW (ed), Academic Press of New York, pp 54-165

Ulrich K (1994) Vitamin retention in extrusion cooking. Food Chem 49(2):149-155

Vitamin A (1989)- A report by the Subcommittee on vitamin A deficiency prevention and control. Research priorities for investigation of the influence of vitamin A supplementation on morbidity, Food Nutr Bull 11(3)

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Antioxygenic Activity of Turmeric (*Curcuma longa*) in Sunflower Oil and *Ghee*

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The anti-or pro-oxygenic activity of turmeric, its fractions extracted using various solvents, volatile oil and curcumin were determined in refined sunflower oil and *ghee* at 37°C. The ground spice and water-soluble fraction of the spice showed antioxygenic activity. On the other hand, curcumin, water insoluble fraction, acetone soluble, ethanol soluble and insoluble fractions of turmeric showed moderate pro-oxidant activity. Volatile oil of turmeric also exhibited slight antioxygenic activity. α-tocopherol exhibited marginal antioxygenic effect in *ghee*, but a combination of α - tocopherol and curcumin, showed moderate pro-oxygenic activity.

Keywords: Turmeric, Anti-or pro-oxygenic activity, Solvent/water fractions, Curcumin, Volatile oil, α-tocopherol, Sunflower oil, *Ghee*, Peroxide value, Thiobarbituric acid value.

Rancidity resulting from lipid autoxidation is the major cause of spoilage during storage of dehydrated convenience foods. A number of synthetic antioxidants like butylated hydroxy anisole (BHA), butylated hydroxy toluene, propylgallate and tertiary butylated hydroxy quinone are allowed in foods for extending the shelf life of fatty products. However, in recent years, their use in foods has come under severe criticism. Therefore, the search is on for natural products that can act as antioxidants either alone or synergistically with other additives, to limit the usage of synthetic antioxidants.

Turmeric (*Curcuma longa*) is widely used as a colouring and flavouring material in Indian culinary and it has been found to exert antioxygenic action in dehydrated rice (Semwal and Arya 1992) lard (Chipault et al. 1956), sardine oil (Revankar and Sen 1975), oil-in-water emulsions (Chipault et al. 1955) and biological systems (Leela et al. 1992). Antioxygenic activity of turmeric is generally believed to be due to curcumin, a major phenolic constituent of turmeric. However, there is no systematic study on the antioxygenic activity of various fractions of turmeric or of curcumin in any oil or food product. Also, it has been reported that the antioxygenic activity of turmeric varies considerably on the nature of substrate and source of spice (Chipault et al. 1956). In the present study, the relative antioxygenic potency of various fractions of turmeric powder *vis-a-vis* curcumin in refined sunflower oil and *ghee* is reported.

Materials: Refined sunflower oil and turmeric tubers were procured from local market. *Ghee* was obtained from Mysore Milk Dairy. Ethyl alcohol was distilled before use. All other chemicals used were of analytical grade. Turmeric tubers were ground in an ultra centrifugal mill (Model Retsch RI, Haan, Germany), using 1 mm sieve.

Preparation of curcumin: Curcumin was isolated from turmeric powder according to the method of Janaki and Bose (1967). It was further purified by thin layer chromatography on silica gel G plate, using 5% methanol in dichloromethane as developing solvent (Akiko et al. 1992). Curcumin band was scraped and extracted with acetone. Solvent was evaporated, using a rotary vacuum evaporator (Model Superfit PBU-8, Continental Instrument Co. Bombay) and the residue was recrystallized in hot alcohol. The purified curcumin melted at 182°C and its IR and NMR spectra matched with that of pure curcumin. Commercially available curcumin was also purified by the same procedure.

Fractionation of turmeric powder: Turmeric powder (15 g) was extracted with hot distilled water (1500 ml) as per the method of Leela et al (1992). After centrifugation, the aqueous extract was decolorised with washed and activated charcoal, filtered and evaporated to dryness in a rotary vacuum evaporator. The insoluble residue was spread in a petri dish and the moisture was allowed to evaporate at 50°C. The dried residue was powdered in a glass mortar and 10 g sample was packed in a glass column (2.5 x 30 cm) and sequentially eluted with 500 ml each of petroleum ether (40-60°C, boiling range), acetone and ethanol. Each eluent fraction was separately evaporated, using rotary vacuum evaporator and preserved at 5°C till used.

Preparation of turmeric volatile oil: Turmeric powder (50 g) was steam-distilled and the distillate (1000 ml) was transferred to a separating funnel. Aqueous layer was discarded and upper volatile oil layer was dried over anhydrous sodium sulphate.

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TABLE 1. EFFECT OF TURMERIC (0.25%), ITS FRACTIONS*, VOLATILE OIL AND CURCUMIN ON PEROXIDE VALUE (PV) AND THIOBABITURIC ACID VALUE (TBA) OF SUNFLOWER OIL STORED AT 37±1 °C

Spice and its fractions	PV** (meq O_2/kg fat) after indicated storage period, days			TBA** (mg malonaldehyde/kg) after indicated storage period, days		
	10	20	30	10	20	30
Control	25.2	43.1	66.8	0.23	0.32	0.44
Turmeric	20.6	32.6	54.7	0.18	0.24	0.35
Water-soluble extract (decolorised)	20.9	33.6	55.8	0.19	0.26	0.36
Water insoluble residue	24.7	49.9	69.2	0.23	0.33	0.46
Petroleum ether soluble extract	24.8	42.7	65.8	0.23	0.31	0.45
Petroleum ether insoluble extract	25.8	43.7	65.4	0.23	0.32	0.45
Acetone soluble extract	27.5	57.4	77.5	0.27	0.39	0.54
Acetone insoluble residue	25.2	42.7	66.2	0.23	0.32	0.45
Ethanol soluble extract	26.2	44.9	68.5	0.24	0.33	0.46
Ethanol insoluble residue	26.6	44.2	66.7	0.23	0.32	0.45
Commercial curcumin (200 ppm)	27.9	47.1	68.7	0.28	0.35	0.49
Purified curcumin (200 ppm)	26.9	45.1	67.4	0.27	0.34	0.47
Volatile oil (200 ppm)	22.7	39.3	59.4	0.21	0.29	0.41
Volatile oil (1000 ppm)	22.5	39.3	59.1	0.21	0.28	0.40

* Spice fractions at 0.25% ground spice equivalent

** The values are mean of two replicate experiments

Initial peroxide and TBA values were 4.5 and 0.10, respectively

Evaluation of antioxygenic activity: Antioxygenic activity of turmeric powder and its fractions were evaluated in refined sunflower oil and *ghee*. Samples (100 g each) of sunflower oil and *ghee* with and without 0.25 g of turmeric powder or with an equivalent amount of various turmeric fractions or 200 ppm of curcumin or volatile oil (200 or 1000 ppm) were incubated in 250 ml glass beakers at 37±1°C. Samples (20g) were removed at regular intervals of 10 or 15 days and analyzed for peroxide value and thiobarbituric acid value, as per methods reported earlier (Semwal and Arya 1990).

Antioxygenic activity of turmeric and its fractions: Effect of turmeric powder and its various fractions on the rates of peroxide formation in sunflower oil is given in Table 1 and the means of the ratios of the peroxide value of the control sample to those of treated samples (antioxygenic activity) after 10, 20 and 30 days are given in Table 2. It is interesting to observe that both turmeric powder and its decolorised water-soluble fraction exhibited strong antioxygenic activity. Both peroxide and TBA values increased at much slower rate in sunflower oil samples containing turmeric powder and its water soluble fraction than the ones containing other turmeric fractions (Table 1). On the other hand, curcumin and water insoluble fraction of turmeric as well as acetone-soluble and insoluble fractions and ethanol-soluble and insoluble fractions were practically devoid of antioxygenic activity in refined sunflower oil. Surprisingly, acetone-soluble fraction, which contained curcumin as major constituent as well as pure curcumin, exhibited a slight pro-oxidant activity. In order to confirm this observation, the antioxygenic activity of recrystallised curcumin and also that extracted from turmeric powder was evaluated in sunflower oil (Table 1). It is of interest to note that

TABLE 2. ANTIOXYGENIC ACTIVITY+ OF TURMERIC (0.25%) ITS FRACTIONS*, VOLATILE OIL AND CURCUMIN IN REFINED SUNFLOWER OIL STORED AT 37±1 °C

Spice and spice extractives	Sunflower oil** Mean±SD
Turmeric	1.25±0.06
Water-soluble extract (decolorised)	1.23±0.05
Water insoluble residue	0.96±0.08
Petroleum ether soluble extract	1.01±0.06
Petroleum ether insoluble residue	1.00±0.02
Acetone soluble extract	0.84±0.09
Acetone insoluble residue	1.00±0.04
Ethanol soluble extract	0.97±0.01
Ethanol insoluble residue	0.97±0.03
Commercial curcumin (200 ppm)	0.93±0.04
Purified curcumin (200 ppm)	0.96±0.03
Volatile oil (200 ppm)	1.10±0.02
Volatile oil (1000 ppm)	1.12±0.02

\+ Values >1 indicate antioxygenic activity and < 1 indicate pro-oxygenic activity

* Fractions equivalent to 0.25% of ground spice

** Mean of 3 values after 10, 20 and 30 days

TABLE 3. EFFECT OF TURMERIC (0.25%), ITS EXTRACT*, CURCUMIN AND α-TOCOPHEROL ON THE PEROXIDE VALUE (PV) AND THIOBARBITURIC ACID VALUE (TBA) IN *GHEE* STORED AT 37±1°C

	PV**, meq O_2/kg fat after indicated storage period, days				TBA**, mg malonaldehyde/kg after indicated storage period, days			
	15	30	45	60	15	30	45	60
Control	1.6	3.2	3.6	4.3	0.36	0.38	0.41	0.45
Turmeric	1.1	2.4	2.8	3.1	0.30	0.33	0.35	0.38
Curcumin (200 ppm)	2.0	4.6	5.9	7.1	0.43	0.47	0.51	0.72
α - Tocopherol (500 ppm)	1.2	2.9	3.2	3.4	0.32	0.35	0.39	0.41
α - Tocopherol (500 ppm) + curcumin (200 ppm)	2.0	4.9	7.1	11.4	0.50	0.58	0.65	1.30
Water extract	1.2	2.8	3.1	3.4	0.31	0.35	0.36	0.41

* Extractives equivalent to 0.25% ground spice

** Values are mean of two replicate experiments

Initial peroxide values and thiobabituric acid values were 1.0 and 0.29, respectively

both these components exhibited slight pro-exidant activity in refined sunflower oil. Turmeric volatile oil, on the other hand, exhibited slight antioxygenic activity at 200 ppm and this activity remained at same level even at 1000 ppm (Tables 1 and 2).

Because of this unexpected behaviour of curcumin and other turmeric fractions, their effect was evaluated in *ghee* also. Similar to that observed in sunflower oil, turmeric powder and its water-soluble fraction exhibited antioxygenic activity, while curcumin exhibited a slight pro-oxidant activity in *ghee* as well (Table 3). It is interesting to note that though α-tocopherol exhibited slight antioxygenic activity in *ghee*, in combination with curcumin, it exhibited mild pro-oxygenic activity (Table 3). This further confirms the observed effect of curcumin in sunflower oil. These results reveal that curcumin does not exert any antioxygenic activity in sunflower oil and *ghee* and antioxygenic activity of turmeric powder is mainly due to its water-soluble fraction. This is also substantiated from the fact that when an equivalent amount of water soluble fraction as present in 0.25 g of turmeric powder was incorporated in sunflower oil, their antioxygenic indices were practically same (Table 2). Leela et al (1992) have reported that water-soluble fraction of turmeric contains mainly polypeptide, turmerins, which exert strong antioxidant effect in model systems of phosphatidylcholine vesicles, liposomes and human erythrocyte ghosts, in comparison with BHA and curcumin. In their study curcumin was also found to exert antioxidant effect, but in the present study, antioxygenic activity of turmeric in sunflower oil and *ghee* was mainly due to water-soluble fraction only. Curcumin, on the other hand, exerted slight pro-oxidant activity.

References

Akiko J, Toshiya M, Tengah IGP, Suprapta D, Gara IW, Nobuji N (1992) Antioxidant activity of tropical ginger extracts and analysis of curcuminoids. J Agric Food Chem 40:1337-1340

Chipault JR, Mizuno GR, Lundberg WO (1955) Antioxidant properties of spices in oil in water emulsions. Food Res 20:443-448

Chipault JR, Mizuno GR, Lundberg WO (1956) The antioxidant properties of spices in foods. Food Technol 10:209-211

Janaki N, Bose JL (1967) An improved method for the isolation of curcumin from turmeric (*Curcuma longa*). J Ind Chem Soc 44:985-987

Leela S, Shalini VK, Shylaja M (1992) Turmerins, a water soluble antioxidant peptide from turmeric (*Curcuma longa*). Arch Biochem Biophys 2:617-623

Revankar GD, Sen DB (1975) Spices on the stabilisation of sardine oil. J Oil Technologists' Association of India 7:88-91

Semwal AD, Arya SS (1990) Effect of vegetable oils on the stability of carotenoids in fried *Bengal*gram *dhal*. J Food Sci Technol 27:58-59

Semwal AD, Arya SS (1992) Effect of spices and salt on the storage stability of precooked dehydrated rice. J Food Sci Technol 29:210-213

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Post-harvest Loss Assessment of 'Totapuri' and 'Alphonso' Mangoes

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Survey to assess post-harvest losses of 'Totapuri' ('Bangalora') and 'Alphonso' ('Badami') mangoes in Karnataka showed a total post-harvest loss of 17.9% (3.5% orchard/field, 4.9% transportation, 4.1% storage and 5.4% retail level) and 14.4% (1.9% orchard/field, 3.7% transportation 3.5% storage and 5.3% retail level) and 14.4% (1.9% orchard/field, 3.7% transportation 3.5% storage and 5.3% retail level), respectively. The major causes of losses in the order of their occurrence were mechanical injuries, spoilage, either over mature/shrivelling, or immature/unmarketable sizes, pilferage, damage by birds/hailstorm.

Keywords : Loss assessment, Loss location, Mango, Harvesting, Storage, Marketing, Transportation.

Mango (*Mangifera indica* L.) is the most popular tropical fruit in the world and has been rightly described as king of fruits (Singh 1990). It is relished for its succulence, exotic flavour and delicious taste (Jain 1961). It is also a good source of pro-vitamin A and vitamin C. India is the leading mango growing country in the world (Singh 1990), the production being 65% of the world's production (Anon 1992). In India, at present, mango occupies 42.6% of the total area under fruit crops, comprising 9.4 lakh hectares with a total production of 92 lakh tonnes (Anon 1992). Mango has considerable export potential both in its processed and raw forms.

The post-harvest losses of fruits and vegetables in developing countries have been reported to vary between 15 and 50%, with an estimated minimum of 20% at different stages of marketing (Subramanyam 1986). Extent of losses of mangoes during post-harvest handling is not known. Hence, the present investigation was carried out on 'Totapuri' and 'Alphonso' varieties of mango.

A survey was conducted in Srinivasapur taluk of Kolar district, one of the important mango growing taluks in Karnataka State, India (Anon 1993). It is located at a distance of 104 km from Bangalore and 30 km North of Kolar, bordering Andhra Pradesh on North-East. The study was carried out at three stages, i.e., (a) immediately after harvest at the farm itself (b) during transit to the markets both at Srinivasapur and Bangalore and (c) at the wholesale and retail markets. The nature and extent of loss due to damage, spoilage and loss in value associated with these losses were quantified by drawing samples and also based on perception of the marketing functionaries. Packing, mode of transportation and type of harvesting were also evaluated by drawing samples at each stage to identify possible reasons for the spoilage and damage of fruits.

A multistage sampling technique was employed and 50 mango growing farmers were interviewed. Fifty lots (the sizes of these lots varied from 100 kg to 10,000 kg) were examined, at Srinivasapur and Bangalore wholesale markets individually, for periods extending from time of loading in the market upto 4-5 days (till it was sold). Randomly selected 20 retailers from Bangalore were interviewed. Data were collected using standard questionnaire. Simple tabular analysis was employed to quantify the extent and value of losses at these three stages..

The assessment at all the three stages indicated an overall loss of 17.9% (3.5% orchard/field, 4.9% transportation, 4.1% storage and 5.4% retail level) in 'Totapuri' (Table 1). On the basis of 100 tonne fruits harvested, the overall post-harvest losses worked out to the extent of about 16,765 kg, valued at Rs. 77,337. The losses estimated are comparative to those reported in similar studies on fruits and vegetables. For example, Jamaludin and Tandon (1976) reported losses to the extent of 15 to 20% for tomatoes in Maharashtra and 4 to 10% in Uttar Pradesh. Similarly, Harvey (1978) quoted an estimated post-harvest loss of 11.7% for lettuce, 14.2% for tomatoes and 12.6% for peaches. In another study, Madan (1988) reported about 9-15% loss of banana and 20.8% of 'Banganapally' mangoes.

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TABLE 1. OVERALL LOSS AND VALUE DURING VARIOUS STAGES OF MARKETING OF 'TOTAPURI' AND 'ALPHONSO' MANGOES

Stages of loss	'Totapuri', kg	Loss, %	Value, Rs	'Alphonso', kg	Loss%	Value, Rs.
			Harvesting			
Quantity harvested	1000000.00	0.00	300000.00	100000.00	0.00	700000.00
Mechanical damage	735.0	0.73	2205.0	779.0	0.80	5493.0
Spoilage	1414.0	1.41	4242.0	685.0	0.68	4795.0
Damage by birds	199.0	0.20	597.0	261.0	0.26	1827.0
Over-ripening	686.0	0.69	2058.0	133.0	0.13	931.0
Pilferage	211.0	0.21	633.0	0.0	0.00	0.0
Hailstorm	279.0	0.28	837.0	35.0	0.03	245.0
Total loss	**3524.0**	**3.52**	**10572.0**	**1913.0**	**1.90**	**13391.0**
			Wholesale market including transportation			
Quantity transported	96476.00	0.00	434142.00	98087.00	0.00	980870.0
Breakage	1204.98	1.24	5422.41	1608.62	1.63	16086.2
Spoilage	744.80	0.77	3351.6	1294.74	1.31	12947.4
Over-mature	1031.32	1.07	4640.94	510.05	0.51	5100.5
Immature and unmarketable size	1707.62	1.77	7684.29	176.55	0.17	1765.5
Total loss	**4688.28**	**4.85**	**21099.24**	**3589.96**	**3.62**	**35899.6**
			Storage			
Quantity stored	91787.28	-	413042.76	94497.04	-	944970.4
Over-mature and shrivelling	1540.20	1.67	6930.90	1322.95	1.39	13229.5
Spoilage	2223.08	2.43	10003.86	2003.33	2.11	20033.3
Total loss	**3763.28**	**4.10**	**16934.76**	**3326.28**	**3.50**	**33262.8**
			Retail level			
Quantity purchased	88024.00	-	528144.00	91170.76	-	1185219.90
Over-mature and shrivelling	1830.90	2.08	10985.40	3081.56	3.37	40060.28
Spoilage	2271.00	2.57	13626.00	1230.80	1.34	16000.40
Pilferage	686.58	0.78	4119.48	537.90	0.58	6992.70
Total loss	**4788.48**	**5.43**	**28730.88**	**4850.26**	**5.39**	**63053.38**
Overall loss	**16764.48**	**17.92**	**77336.88**	**13679.51**	**14.37**	**145606.78**

In case of 'Alphonso' variety of mangoes, the overall loss amounted to 14.4% (1.9% field/orchard, 3.7% transportation, 3.5% storage and 5.3% retail level). On the basis of 100 tonne fruits harvested, the overall post-harvest losses worked out to the extent of about 13,680 kg. valued at Rs. 1,45,607. At the orchard/field, the losses were low, when compared to other stages of marketing. However, the retail level losses were higher. In case of 'Totapuri', the losses were more, when compared to 'Alphonso' in physical terms, but loss in monetary value was more in case of 'Alphonso', because of its high price. During the study period, the price in case of 'Totapuri' was ruling at the rates of Rs. 3, 4.5 and 6 per kg and in case of 'Alphonso', the rates were Rs. 7,10 and 13 per kg at orchard, wholesale market and retail levels, respectively. Even the loss in quantity was also low in case of 'Alphonso', because more care was taken at the time of harvesting and handling of the fruits, when compared to 'Totapuri'.

In general, the fruits were harvested mostly by hand except the fruits at a higher level, which were harvested with a long bamboo stick to which a cloth bag was tied at the top end along with a knife. Since labourers handled the fruit roughly, there were more chances of damage to the fruit. Most of the farmers followed traditional methods of harvesting, using the minimum mechanical aid. They were also unaware of the right stage of maturity at which the fruits were to be harvested to get good post-harvest quality. The major loss was due to mechanical or physical damage, spoilage, either overmature or immature and unmarketable sizes. The predominent spoilage diseases identified are Blackmold rot (*Aspergillus niger*), Anthracnose (*Botryodiplodia theobromae*) and softrot (*Rhizopus oryzae*). Usually, farmers transport their produce either in a truck or in a tempo. If the quantity was less than one tonne, these were transported by bullock carts. While transporting the fruits, the fruits were dumped into lorries without packing,

which increased the risk of physical damage to the fruits.

The results of this investigation may be useful in planning the improvements in the post-harvest handling methods for mango to reduce their post-harvest losses.

References

Anon (1992) Annual Report. National Horticulture Board. Ministry of Agriculture, Government of India, New Delhi, p 8

Anon (1993) Annual Report. State Department of Horticulture, Government of Karnataka, Bangalore

Harvey JM (1978) Reduction of losses in fresh fruits and vegetables. Ann Rev Phytopath 16:321-341

Jain NL (1961) Chemistry and Technology of Mango. Rev Food Technol 3:31-36

Jamaluddin KA, Tandon MP (1976) Some new market diseases of fruits and vegetables. Indian Phytopath 29:74-75

Madan MS (1988) Economic assessment of harvest and post-harvest losses in horticultural crops. Annual Report, Indian Institute of Horticultural Research, Bangalore, pp 93-95

Singh RN (1990) Mango, Indian Council of Agricultural Research, New Delhi

Subramanyam KV (1986) Post-harvest losses in horticultural crops. An appraisal, Agriculture Situation in India 41:339-349

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Characterisation of Chemical Constituents of Indian Long Pepper (*Piper longum* L.)

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Studies were carried out on the chemical composition of long pepper and the results showed that long pepper contained about 1% volatile oil, 1.25% piperine and 40% starch. As compared to black pepper, long pepper was poor in essential oil and piperine and the volatile oil was dextrorotatory, while that of black pepper was levorotatory. The GC-MS analysis of the essential oil showed the presence of 48 components, out of which 44 were identified for the first time. The three major components of the oil, identified were β-caryophyllene (17%), pentadecane (17.8%) and β-bisabolene (11.16%).

Keywords : Long pepper, *Piper longum*, Chemical composition, Essential oil, GC-MS analysis.

Long pepper (*Piper longum* L.) is a slender aromatic climber with perennial woody roots occurring naturally in Himalayas, Assam hills, and Western ghats. The dried spikes are 1-3 cm long and 4-6 mm in dia and are greyish to dark in colour (Wealth of India 1969). The fruits/spikes are pungent and have pepper-like flavour. Although the flavour resembles black pepper, it is less agreeable. Long pepper is used as a spice, and also in pickles and preserves. Though long pepper is similar in proximate composition to black pepper (*Piper nigrum* L.), it is commercially less expensive, and sometimes used as an adulterant of ground black pepper (Govindrajan 1977).

Two types of long pepper are well known, the 'Indian long pepper' (*Piper longum* L) and 'Javanese long pepper' (*Piper retrofractum* and *Piper officinarum*). The Indian long pepper contains about 1% volatile oil and it is not produced commercially. The volatile oil was investigated and n-octadecane, n-nonadecane, n-eicosane, zingiberene, dihydrocarveol and two monocyclic sesquiterpenes were identified as the major components of the oil (Handa et al. 1963). Some work on the proximate composition of long pepper has been reported (Birch and Lindley 1986). However, information is scanty on the composition of the volatile oil of long pepper. This communication presents the data on proximate composition of long pepper and chemical composition of its volatile oil.

Sample (500g) was powdered in a spice mill (Buhler-Miag) to 500 micron size, sieved and the sample was thoroughly mixed and stored in an air-tight bottle. The moisture content was determined by the toluene distillation method and the volatile/essential oil by both Clevenger (hydrodistillation) and steam-distillation methods (ASTA 1985). The distilled oil was made moisture free by storing over anhydrous sodium sulphate. The total ash, acid insoluble ash, cold alcohol, and water extracts crude fibre and starch contents were determined by the methods of ISI (1982). Solvent extracts were obtained by the Soxhlet method. Nitrogen and crude proteins were determined by the semimicro-kjeldhal method (ISI 1980). Total reducing sugars (before inversion) were determined by Lane and Eynon's method (David Pearson 1970). The mucilage content was determined by the method given by Datta (1961). The oleoresin content was determined by removing the volatile oil by steam-distillation first and then extracting the spent powder with acetone, using a glass column. After desolventization, the resinous material obtained was mixed with the corresponding volatile oil. The values of proximate analysis (on moisture-free

TABLE 1. PROXIMATE COMPOSITION OF LONG PEPPER*

Characteristic	Value %,
Moisture	7.52
Volatile oil (Clevenger method)	0.95
Volatile oil (steam distillation)	0.40
Total ash	5.20
Acid insoluble ash	0.85
Crude fibre	6.80
Crude starch	40.50
Crude protein	11.94
Reducing sugars	5.07
Mucilage	2.08
Piperine	1.25
Acetone extract	9.95
Non-volatile ether extract (NVEE)	6.53
Oleoresin yield	7.84

* Values on moisture-free basis and average of duplicates

* Corresponding Author

TABLE 2. PHYSICO-CHEMICAL CONSTANTS OF LONG PEPPER OIL AT 27°C

Property	Value
Colour	Colourless
Odour	Peppery
Specific gravity	0.8451
Refractive index	1.4670
Optical rotation (25°C)	+6.90
Acid value	0.975
Ester value	6.967
Aldehydes, as C_{10}%	0.763
Solubility in 90 % alcohol, vols	1 in 15
Evaporation residue, %	20.58

basis) are given in Table 1. The results of the present studies agree with the literature values (Birch and Lindley 1986) to a large extent. The steam-distilled volatile oil was analyzed for its physico-chemical constants like optical rotation, refractive index etc. as per the methods given by Nigam (1966). The analytical values are given in Table 2.

Steam-distilled volatile oil of long pepper was analyzed, using Hewlett Packard 5995 GC-MS (Quardrapole) instrument. The oil sample was diluted 10-fold with acetone and 0.5 µl was injected into the GC. The following two columns were used with the conditions: Column (1) HP 101-fused silica capillary column: 0.32 mm (i.d.) x 25m coated with methyl silicone (0.3 µm film thickness); carrier gas helium with a flow rate of 5 ml/min; injection port temperature 150°C; ion source temperature 170°C; temperature programme: 70(6)°C-200 (6)°C at 2°C/ min; Column (2) H.P. 20 M-fused silica capillary column 0.53 mm (i.d.) x 30 m coated with carbowax-20 M (0.3 µm film thickness); carrier gas helium with a flow rate of 5ml/min; injection port temperature 200°C; ion source temperature 180°C, temperature programme: 70(6)-200(6)°C at 2°C/ min.

GC-MS analysis of volatile oil of long pepper carried out for the first time and a total of 48 constituents were identified with the help of mass spectral analysis and Kovat's indices (Table 3). These constituents were quantified with the help of peak areas and 44 of these were reported for the first time. The ratio of monoterpenes to sesquiterpenes was found to be 1:13. Oxygenated compounds constituted 8 to 10% of the volatile oil, but the straight chain hydrocarbons (i.e. alkanes and alkenes) were present to the extent of 35-40%. The major constituents of the oil were: pentadecane (17.8%), β-caryophyllene (17%), β-bisabolene (11.2%),

TABLE 3. CHEMICAL COMPOSITION OF VOLATILE OIL BY GC-MS ANALYSIS

Retention time, min	Compound identified	Peak Area, %	Kovats indices
5.5	α-Pinene	Trace	956
6.8	β-Pinene	Trace	981
7.4	Myrcene	Trace	991
7.9	α-Phellandrene	0.116	999
8.5	P-Cymene	0.100	1011
9.1	1,8-Cineole	0.400	1023
9.1	Limonene	0.444	1024
9.8	Acetophenone	0.502	1038
10.1	γ-Terpinene	0.600	1045
12.6	Linalool	0.061	1087
13.4	Undecane	0.119	1100
14.1	Camphor	Trace	1112
16.3	Naphthalene	Trace	1149
16.8	Terpinen-4-ol	0.069	1155
17.5	α-Terpineol	0.066	1166
23.3	Cumin aldehyde	0.072	1249
24.1	Isopulegyl acetate	0.504	1260
24.6	Undecanone	0.539	1268
25.5	Tridecene	0.918	1279
27.1	Tridecane	6.780	1300
28.2	δ-Elemene	0.103	1317
29.0	α-Cubebene	0.076	1330
30.1	α-Ylangene	0.125	1348
30.6	α-Copaene	1.575	1355
31.6	β-Bourbonene	0.377	1370
31.8	β--Elemene	0.536	1374
34.4	β-Caryophyllene	17.044	1410
34.9	cis-β-Farnesene	3.682	1419
35.3	α-Gurjunene	0.779	1426
35.8	α-Humulene	1.946	1434
36.5	α-Zingiberene	5.014	1445
37.5	γ-Muurolene	Trace	1460
37.7	Germacrene-D	4.933	1465
38.4	Germacrene-B	1.829	1473
-	β-Selinene*	Trace	-
38.8	Pentadecene	1.797	1479
40.0	β-Bisabolene	11.158	1508
-	Calamenene*	Trace	-
41.2	Pentadecane	17.778	1508
42.3	γ-Elemene	0.772	1538
43.1	Globulol	2.624	1549
43.6	Spathulenol	2.956	1559
46.6	Cubenol	0.095	1610
47.0	δ-Cadinol	0.273	1618
50.7	Heptadecene	2.331	1685
52.1	Heptadecane	5.656	1701
60.7	Nonadecene	0.080	1874
62.1	Nonadecane	0.217	1901

* Identified with the help of carbowax-H.P.-20M column

tridecane (6.8%), heptadecane (5.7%), α-zingiberene (5%), germacrene-D (4.9%), Cis-β-farnesene (3.7%), spathulenol (3%), globulol (2.6%), and heptadecane (2.3%). β-caryophyllene and limonene are the major constituents of the black pepper oil (Govindarajan 1977), whereas β-caryophyllenes pentadecane and β-bisabolene are the major constituents of long pepper oil.

Long pepper powder is reported to be an adulterant for ground black pepper due to their similarity in colour and flavour. Therefore, these analytical values of long pepper may help in quality control of black pepper powder. Black pepper contains about 3.5% volatile oil, 3% piperine and 15% starch, whereas long pepper contains about 1% volatile oil, 1.25% piperine and 40% starch. Also, the volatile oil of black pepper is levorotatory (Govindarajan 1977), while the volatile oil of long pepper is dextrorotatory (Table 2). Further, there is considerable variation in the chemical composition of volatile oils of black pepper and long pepper. These differences may help in the detection of long pepper powder in black pepper powder or long pepper oil in black pepper oil.

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References

ASTA (1985) Official Analytical Methods. The American Spice Trade Association, New York, pp 1-55

Birch GG, Lindley MG (1986) Developments in Food Flavours. Elsevier Applied Science Pub, New York, pp 190-195

Datta AB (1961) A chemical method for distinguishing cinnamon from cassia. J Assoc Off Anal Chem 44:639-640

David Pearson (1970) The Chemical Analysis of Foods. 6th edn. J and A Churchill, London, pp 26-158

Govindarajan VS (1977) Pepper-Chemistry, technology and quality evaluation. Crit Rev Food Sci Nutr 9:115-225

ISI (1980) Hand Book of Food Analysis Part I. General Methods. India Standards Institution, New Delhi pp 1-14

ISI (1982) Hand Book of Food Analysis Part-VII. Spices and Condiments. Indian Standards Institution, New Delhi, pp 111-149

Handa KL, Sharma ML, Nigam MC (1963). The essential oils of piper longum. Characterization of the constituents and isolation. Perfuem Kosmet 44:233-236

Nigam IC (1966) Analysis of volatile oils, In: Pharmaceutical Chemistry. Marcel Dekker Inc. New York pp 440-476

Wealth of India (1969) Raw Materials. Vol.8, CSIR, New Delhi, pp 96-98

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Ferric Chloride Induced Degradation of Cyanoglucosides in Fresh Cassava

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Levels of reduction attained in total and free cyanides consequent to enzyme catalyzed degradation of cyanoglucoside in fresh cassava roots were examined in water and 0.1M phosphate buffer of pH 6.0. Presence of ferric chloride in the reaction medium augmented cyanide reduction. The effect of ferric chloride in degrading total cyanide was more pronounced in phosphate buffer than in water, when used as the solution phase.

Keywords : Cassava, Linamarin, Cyanide, Cyanoglucoside, Detoxification, Ferric chloride.

Attempts to detoxify fresh cassava (*Manihot esculenta* Crantz) have been made, using various techniques. Among the traditional techniques, soaking in water, sun-drying, soak-dry-soak method, boiling, steaming etc., are quite popular (Conrsey 1973; Cooke and Maduagur 1978; Jansz et al. 1974). The above techniques, however, enable greater reduction of free cyanides than bound ones. Fermentation of cassava in presence of exogenously added linamarase is reported to be very effective for detoxification by virtue of degradation of fairly high percentage of total cyanides (Ikediobi and Onyke 1982). In the present study, influence of an inorganic salt such as ferric chloride, which can behave as Lewis acid in inducing enzyme-catalyzed degradation of cyanoglucoside at ambient temperature, has been examined.

Freshly harvested cassava roots of cv 'H_{165}' having a moisture level of 60-63% and total cyanide content in the range of 668-700 ppm were sampled to pieces of 1.5 cm^3 size and used for the experiments. Linamarase enzyme was extracted from the rind of fresh cassava of cv 'M4' and purified, using 50% cold acetone essentially based on the method of Wood (1966). The enzyme was finally taken in 0.1m phosphate buffer of pH 6.0 and the activity was determined spectrophotometrically, using standard linamarin (Sigma Chemicals, USA) and appropriately modifying the procedure of Cooke and Cruz (1982). The unit activity is expressed as µg HCN released per min per ml enzyme.

For detoxification studies, samples weighing in the range of 14.15-14.72 g, at 60-63% moisture level, were transferred to 250 ml conical flasks, containing 100 ml of water or 0.1M sodium phosphate buffer of pH 6.0, having 0.25, 0.50 and 1.0% (w/v) of ferric chloride. Control samples devoid of ferric chloride were also kept simultaneously. After adding 0.1 ml of enzyme, the flask was stoppered and the reaction was allowed to proceed for 22 h with shaking at 28-30°C for 22h. After completion of the stipulated reaction time, the solution was filtered and the residue left behind was partially dried under the folds of filter paper. Moisture content in the sample was determined by standard air-oven method (AOAC 1984), while total and free cyanides in the residue were assayed spectrophotometrically (Obrien et al. 1991), using chloramine T and barbituric acid-pyridine reagents.

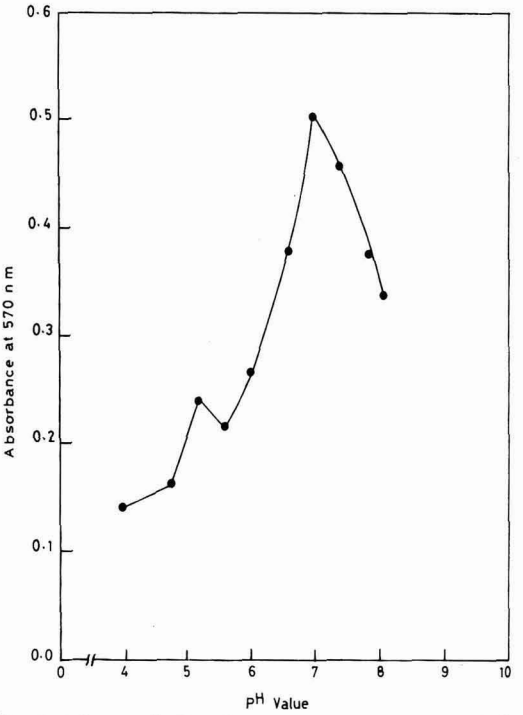

Fig. 1. Influence of pH on linamarase activity using standard linamarin as substrate at 30°C

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TABLE 1. RESIDUAL CYANIDE* IN CASSAVA SAMPLE AFTER REACTION AT 28-30°C FOR 22 h

	Cyanide content, g/g dry tissue	
	Total	Free
Fresh sample	700.0 ppm	137.0
Control in 100 ml water	157.1	93.3
100 ml water + 0.5% $FeCl_3$	99.6	76.0
100 ml water + 0.50% $FeCl_3$	99.6	57.1
100 ml water + 1.00% $FeCl_3$	85.4	47.6
0.1 M phosphate buffer pH 6.0		
Control in 100 ml buffer	185.6	102.9
100 ml buffer + 0.25% $FeCl_3$	83.9	87.2
100 ml buffer + 0.50% $FeCl_3$	67.9	63.5
100 ml buffer + 1.00% $FeCl_3$	50.7	45.2

instead of chloramine T-pyridine/pyazolone reagents. From the absorbance measured at 570 nm, HCN content was quantified with the help of a standard graph calibrated for potassium cyanide.

Linamarase enzyme extracted and partially purified showed an activity of 2.41 units. The pH versus enzyme activity pofile (Fig.1) reflected that enzyme had optimal pH of 7.0 and to a minor extent pH 5.5, possibly suggesting the presence of two enzymes, linamarase A and B. Pieris and Jansz (1976) have reported existence of both linamarase A and B, both of which are capable of hydrolyzing linamarin.

Results of the present series of experiments are given in Table 1. The study suggested that presence of ferric chloride in the medium positively influences reduction in total and free cyanides. Compared to control samples, the effect was more pronounced in phosphate buffer than in distilled water. At 1.0% (w/v) level, % reduction in total and free cyanides observed in samples in phosphate buffer were 92 and 67%, respectively. Samples placed in water showed a corresponding reduction of 88 and 65% in total and free cyanides. The above values were appreciably higher than the corresponding % reduction obtained in the control samples devoid of ferric chloride. Cooke and Cruz (1982) have reported that rate of loss of cyanide is influenced by the proportion of total and nonglycosidic cyanide viz., cyanohydrin present in the medium. As ferric chloride can ionise to Fe^{+++} ions and it behaves as a Lewis acid, it could form a highly unstable complex of $[Fe(CN)_6]$, having an instability constant of $1x10^{-31}$ (Alexeyev 1969). This possibly explains relatively higher reduction of cyanide observed in phosphate buffer than in water as in the latter, Fe^{+++} ions can form a stable $(Fe(OH)_3$ and this, in turn, restricts complexation with cyanide ions.

Studies are being pursued to optimise the reaction system in order to maximise the cyanide reduction from fresh samples of cassava without subjecting the material to drastic thermal processing.

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References

Alexeyev V (1969) Quantitative Analysis. MIR Publishers, Moscow

AOAC (1984) Official Methods of Analysis 14th edn. Association of Official Analytical Chemists, Washington DC

Cooke RD, Cruz DeLa EM (1982) An evaluation of enzymic and autolytic assays for cyanides in cassava (*Manihot esculenta* Crantz). J Sci Food Agric 33:1001-1009

Cooke RD, Madhuagur EN (1978) The effect of simple processing on the cyanide content of cassava. J Food Tech 13:299-306

Conrsey DG (1973) Cassava as Food in: Nestel B, Macintyra R (eds). Toxicity and Technology, Proceedings of Interdisciplinary Workshop, London pp 27-36

Ikediobi CO, Onyike E (1982) Linamarase activity and detoxification of cassava (*Manihot esculenta*. Crantz) during fermentation for 'gari' production. Agric Biol Chem 46:1667-1669

Jansz ER, Pieris N, Jeya Raj EE, Abeyaratne DJ (1974) Cyanogenic glucoside content of manioc II detoxification of manioc chips and flour. J Natn Sci Coun Sri Lanka 2:129-134.

Obrien GM, Taylor AJ, Paulter NH (1991) Improved enzymic assay for cyanogens in fresh and processed cassava. J Sci Food Agric 56:227-287

Pieris N, Jansz ER (1976) Cyanide liberation from linamarin. II. Purification and some properties of the cyanide liberating enzyme of manioc rind. J Natn Sci Coun Sri Lanka 4:29-47

Wood T (1966) The isolation, properties and enzymic breakdown of linamarin from cassava. J Sci Food Agric 17:85-90

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Physico-chemical Characteristics of Twelve Plum Cultivars of Himachal Pradesh

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A study on the physico-chemical characteristics of 12 plum cultivars and accessions showed marked variations. The variety "Frontier" was found to have fruits with maximum fruit weight, length, breadth and comparatively smaller stone size. The pulp/stone ratio was also maximum with desirable chemical characteristics found in this cultivar.

Keywords : Plum, Cultivars, Physico-chemical characteristics, Variation.

Plum is a widely cultivated and best known stone fruit of the temperate region. The areas ranging from 900 to 1600 m above mean sea level are ideally suited for growing plums. Himachal Pradesh, thus provides excellent and congenial conditions for plum cultivation. In this State, Santa Rosa is the lone commercial cultivar of plum, but it has a major drawback of being sour around the stone. Moreover, monoculture is not always a desirable proposition for sustained productivity. Because of this, a large collection of the plum germ plasm was made in the experimental orchard of the Fruit Breeding Department. The present studies were planned to select a suitable cultivar, having desirable quality parameters so that the same could be recommended for cultivation in the State.

Twelve cultivars were selected for the study from the plum block of the Department of Fruit Breeding. Solan, located at a height of about 1225 meters above mean sea level, having a mild temperate climate. Three replications, comprising 25 randomly selected fruits from all directions of the trees in each were taken up in each cultivar to record data on physico-chemical characters. Titratable acidity was determined in terms of malic acid. The sugars were estimated by Lane and Eynon's volumetric method (AOAC 1970).

Physical characters of the fruit: The fruit weight ranged from 17.61 to 61.62 g; length from 2.97 to 4.55 cm and breadth from 3.10 to 4.48 cm in the different cultivars (Table 1). These variations among cultivars may be attributed to varietal differences, since the environmental and management conditions are the same, although they also have an important role. Monin (1988) reported similar variations in fruit characters of European plum cultivars.

TABLE 1. PHYSICAL CHARACTERISTICS OF FRUIT AND STONE OF SOME PLUM CULTIVARS

Cultivar	Fruit weight, g	Fruit size, cm		Stone size, cm			Stone weight, g	Stone weight as% age of fruit weight	Pulp stone ratio
		Length	Breadth	Length	Breadth	Thickness			
"Alu Bokhara"	20.12	2.97	3.22	1.76	1.24	0.83	0.86	4.27	22.40
"Beauty"	39.00	3.99	4.02	2.12	1.61	0.82	1.85	4.74	20.08
"Black Chamba"	53.38	3.90	4.36	2.20	1.75	0.92	1.52	1.87	34.12
"Fazli Manani"	48.24	3.72	3.83	1.97	1.23	0.80	1.34	2.78	35.00
"Frontier"	61.62	4.55	4.48	1.73	1.35	0.79	1.10	1.76	55.02
"Santa Rosa"	50.42	3.97	4.05	2.09	1.56	0.82	1.15	2.28	42.84
"Starking Delicious"	41.22	4.03	4.05	2.02	1.63	0.81	1.29	3.13	30.95
"Accession No.1"	21.27	3.04	3.10	1.69	1.21	0.78	0.60	2.82	34.45
"Accession No.2"	32.01	3.46	3.32	1.83	1.17	0.80	0.95	3.12	32.69
"Accession No.3"	51.15	4.02	4.34	2.15	1.82	0.88	1.38	2.70	36.07
"Accession No.4"	43.40	4.02	4.03	2.08	1.52	0.79	0.98	2.26	43.29
"Myrobalan"	17.61	3.07	3.19	1.68	1.29	0.80	0.67	3.80	21.01
C.D. at 5%	2.96	0.13	0.11	0.15	0.05	0.03	1.15	0.05	12.77

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TABLE 2. CHEMICAL CHARACTERISTICS OF SOME PLUM CULTIVARS

Cultivar	Acidity, %	TSS, °Brix	Sugars, %			Sugar/ acid ratio	TSS/Acid ratio
			Reducing	Non-reducing	Total		
"Alu Bokhara"	2.90	12.0	5.44	1.10	6.60	2.28	4.14
"Beauty"	2.15	12.5	5.28	1.41	6.76	3.14	5.81
"Black Chamba"	1.94	14.3	6.48	1.67	8.24	4.25	7.37
"Fazli Manani"	1.78	15.2	5.35	1.88	7.33	4.12	8.54
"Frontier"	1.41	14.2	6.68	2.17	8.96	6.35	10.07
"Santa Rosa"	1.53	14.2	5.68	1.48	7.24	4.73	9.28
"Starking Delicious"	1.74	12.5	4.24	1.73	6.16	3.54	7.18
"Accession No.1"	1.51	14.2	6.75	1.42	8.24	5.46	9.40
"Accession No.2"	2.52	13.0	5.96	1.71	7.76	3.08	5.16
"Accession No.3"	1.61	13.2	5.30	1.43	6.80	4.22	8.20
"Accession No.4"	1.88	13.9	5.32	1.44	6.84	3.64	7.39
"Myrobalan"	2.51	14.1	4.96	1.44	6.48	2.58	5.62
C.D. at 5%	0.19	0.77	0.06	0.06	0.02	0.10	0.11

Stone characters: The stone length varied from 1.76 to 2.20 cm; breadth from 1.17 to 1.82 cm and thickness from 0.78 to 0.92 cm in these cultivars, while the stone weight varied from 0.67 to 1.85g (Table 1). Earlier workers also have obtained variations in stone characters and considered it as a parameter for describing the variety (Beyer and Hubner 1988; Norton et al. 1990; Tehrani and Lay 1992; Ramming and Tanner 1993).

Pulp/stone ratio: The pulp/stone ratio has a great significance in determining the quality of the fruit. The high pulp/stone ratio is preferred. In the present studies, maximum pulp/stone ratio (55.02) was found in "Frontier" followed by "Santa Rosa", which had 42.84. The fruits with minimum (20.08) pulp/stone ratio were obtained in cv. "Beauty" (Table 1). Vasilev et al (1973) obtained variations in pulp/stone ratio in different cultivars of plums and found that stone accounted for 2.36 to 3.85% of the total weight of fruit in *Prunus cerasifera* and 5.79% in *P. domestica* cultivars.

Chemical characteristics: The data presented in Table 2 on the acidity, total soluble solids and sugars contents of the fruits indicate that the acid content of the fruits varied from 1.41 and 2.90%; total soluble solids from 12.0 to 15.2°Brix; reducing sugars from 4.24 and 6.75% and total sugars from 6.16 and 8.96%. The variation in sugar/acid ratio was between 2.28 and 6.35 and in TSS/acid ratio between 4.14 and 10.07 in the present cultivars. The wide variation between cultivars in respect of these chemical constituents may be due to differences in genotype. Polovyanov (1985) reported wide variations in the biochemical constituents within and between species.

These studies, indicate that "Frontier" may be a promising cultivar to replace "Santa Rosa" for cultivation in Himachal Pradesh.

References

AOAC (1970) Official Methods of Analysis. Benjamin Franklin Station, Washington DC

Beyer E, Hubner H (1988) A comparison of plum and prune cultivars. Obst und Garten 12:589-590

Monin A (1988) About Pomology. A Propos de Pomologie Fruit Belge 56(422):99-128

Norton JD, Boyhan GE, Smith DA, Abrahams BR (1990) Au-Amber plum. Hort Science 25(4):487-488

Polovyanov GG (1985) Using the chemical composition of the fruit in the phylogeny and taxonomy of stone fruit crops. Sbornile Nauchnykh Trudov PO Botanike Genetike i Selektsii 97:86-92

Ramming DW, Tanner O (1993) Fortune plum. Hort Science 12:679-681

Tehrani G, Lay W (1992) Victory plum. Hort Science 11:1232-1233

Vasilev VV, Tanev T, Bushev I (1973) Characterisation of some Afuska plum varieties. Ovoshcharstvo 52(3):32-35

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FUMONISINS IN FOOD., Edited by L.S. Jackson, J.W. DeVries and L.B. Bullerman. Advances in Experimental Medicine and Biology. Vol 392, Plenum Press, New York and London pp 399, 1996, Price. US$ 110/-

Ever since the resurgence of interest in mycotoxins with the discovery of aflatoxins, almost half a century ago, several secondary metabolites of fungi have been recognized as a possible source of hazard to animal and human health. Among these, fumonisins, the water-soluble heat-stable, non-genotoxic carcinogenic mycotoxins capable of producing different toxic effects in different species of animals are the most important. Although the claim that the "concern which exceeds even that which occurred with the discovery of the aflatoxins in the 1960's" is exaggerated, it is undoubtedly next in importance to aflatoxins. The interest of the scientific community and regulatory authorities, besides food and feed companies in fumonisins, had grown in response to the reports of the incidence of disease in farm animals and increased awareness of potential human risk including that of carcinogenesis.

Maize is one of the most important agricultural commodities in the world. In the developing countries of the world including India, certain population groups depend on maize as a staple. Even in developed countries, it is revealing to know from the book that maize forms an important component of human food, being used for making bread, flakes, chips, meal, pops, pasta, maze, masa (tortila flour), bran, chips, grits, semolina, polenta, muffins, hominy and beer, canned sweet corns, frozen corns, corn puff, blue corn pancake and corn sugar. Maize, of course, forms an important item of animal feed, consumed daily throughout the life time of dairy cattle, pigs, poultry and horses. Because of the effect of fumonisins on the animal health as well as its possible residue in meat, milk, eggs, used as food by humans, besides the possible consumption of fumonisin through the various maize products by humans, it is not surprising that considerable interest has been generated on the problem of fumonisins, specially in the developed countries of the world.

The book 'Fumonisin in Food' is a fulfilment of expectation of the mycotoxin workers in the field. It contains 33 articles, most of them contributed by leading scientists mostly from North America. It includes current information on occurrence, analysis, microbiology, metabolism and toxicity, effect of processing and regulatory aspects of fumonisins. Almost all the articles except two contain references of the South African group, which pioneered the work on fumonisin and it is a tribute to vision and persistent effort of the multisubject team of Dr. Wally Marasas of Tygerberg. The book also contains little known facts like the simultaneous discovery of fumonisin by the French group led by Laurent in 1988, as macrofusine. Discussion on a chemically related mycotoxin AAL toxin produced by *Alternaria alternata* f.sp. lycoperscici, which has similar toxicological mechanism of action on inhibition of ceramide synthase in animal cells as well as inducing cell death in tomato tissues and protoplast has been included.

Fumonisin is reported to occur wordwide in only maize and now in India in both sorghum and maize. However, the fungus *Fusarium moniliforme*, the predominant fumonisin producing fungus has been isolated from sorghum, wheat, rice, oats, bean, cotton, groundnut, pecan, banana, sugar beet, green pepper, cotton flex, soya, fig, stone fruit, sugarcane, besides maize. Why then fumonisins have not been reported in these foods? Why sorghum isolates produce less FB_1, if they are put back to maize? Pigs on the fumonisin diet upto 24 days consume 25% more diet than control pigs, but after 6 th week show dramatic drop in performance in relation to control. What is the reason for such rapid mainfestation of toxicity?

The reader of the book encounters these types of provocative questions, while going through the book, which is a stimulation for further work. The book also provides candid admissions like "It is such risk assessments, coupled with economic and political realities, which form the basis for the setting of regulatory levels" and "If tolerance levels are too low, the economic consequences may be disastrous e.g., levels <1000 ng/g may result in 34.5% commercial corn products for human consumption in the USA being declared illegal". Although some articles in the volume like 'Regulatory aspects of Fumonisins' in the United States do not provide much information pertaining to fumonisins, they reflect fully the lack of data and compulsions of uncertainities in the risk analysis process.

Some articles in the volume are reviews on fumonisins, while others are communications of original research. Being a symposium volume, such a mix was perhaps unavoidable, but they do, nevetheless, provide the latest up-to-date information on the subject.

The book is singularly free of editorial errors and include almost all the references on 'Fumonisins' published till 1995. The highly specialized book is more useful to workers interested in the field of mycotoxins.

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MICROBIAL FOOD POISONING (2nd Edition)- Edited by Adrian R. Eley, Published by Chapman and Hall, 2-6, Boundary Row, London SE1 8 HN, U.K, 1996, pp 211, Price UK £ 21.99/-

Food poisoning due to microbial sources is a problem of universal concern. This is particularly true in tropical countries where the favourable climatic conditions for microbial proliferation and poor hygiene compound the problem. Any case of food poisoning first appears at the doctor's clinic or in emergency rooms of the hospitals. It is amazing how little ready information is available to help doctors read up on the subject. Ready and concise information on food poisoning due to microorganisms is required by both students and teachers alike in the subject of food science and food microbiology. Moreover, the subject of the recently emerging pathogens and foodborne viruses is still shrouded in vagueness as far as the class rooms are concerned.

This small book of about 200 pages by Dr. A.R. Eley has a wealth of distilled information condensed into 11 chapters. They cover a wide variety of topics, which include food poisoning due to bacterial, fungal, viral and protozoan origin and epidemiological aspects. General aspects of control, food hygiene and legislation in UK are described. The brief chapter on laboratory diagnosis is significant in that though no procedural details are given (they are not necessary in this type of book), enough guidance is available to proceed with the analysis of any suspect sample from a food poisoning case. Newer methods of analysis are mentioned for those, who are interested sufficiently to do any follow up studies. Under each chapter, the information is presented in an organised manner. Recommendations for further reading are indicated in the end.

As public awareness slowly develops, the demand for microbiologically safe food is expected to increase. From food caterers to food manufacturers and from medical personnel to regulatory agencies will need to become more knowledgeable about control and safety measures, diagnosis and identification, and about analysis and legislation.

I believe this book provides sufficient information to work with and the Indian readers will find a very useful addition to their current range of specific literature on food poisoning. I can strongly recommend this book by Dr. Eley to public health people, food scientists, food and medical microbiologists and those involved in food catering. The language is simple and the style of writing is easy to read. The book makes good reading and some of us will surely reach for it more frequently than for other such books.

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MYSORE-570 011

USING THE BIOLOGICAL LITERATURE-A PRACTICAL GUIDE - Edited by Elisabeth B. Davis and Diane Schmidt, Published by Marcel Dekker Inc., 270 Madison Avenue, New York 10016, 1995; pp 422; Price not mentioned.

This is the second revised and expanded edition of the earlier publication with the same title. The aim of this publication, as mentioned in the Preface is to acquaint the undergraduates and graduate biology students with the biology literature covering important primary and secondary sources of the field. The publication covers all main fields of the biological sciences except applied areas such as medicine, clinical psychology, veterinary medicine, agriculture, horticulture, nutrition and teaching of biology.

The guidebook is arranged by broad subject chapters, which are sub-divided by form of materials. The 13 chapters covered in the publication include: an introduction to biological literature; subject access to biological information; general sources; abstracts and indices; biochemistry and biophysics; molecular and cellular biology; genetics; microbiology and immunology; ecology; evolution and animal behaviour; plant biology; anatomy and physiology; entomology and zoology. The first four chapters deal with general sources of information, which is followed by specific subject areas. Under each chapter, the source materials are sub-divided into abstracts and indices; databases; dictionaries and encyclopaedias; directories; guides to internet resources; guides to the literature; handbooks; histories of the literature; societies; textbooks and bibliography, thus covering all types of source materials in biology. The bibliographical details of each publication are appended with a small annotation, indicating the nature and usefulness of

each publication. This is very helpful to the students in biology in decision making.

This updated guide provides a comprehensive and exhaustive survey of printed and computerized reference sources, useful for biologists and biology students with an emphasize on current materials available in English language. Another feature observed in this second edition is the addition of information on the greatly expanded universe of electronic resources for the biological sciences, which include on-line databases, CD-ROMs, and most notably Internet accessible resources.

This publication will be of great use to all the academic libraries, where biology forms one of the subjects and to some extent to research libraries as well.

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CSIR RURAL TECHNOLOGIES - A COMPENDIUM
Published by Information Directorate, Dr. K.S. Krishnan Marg, New Delhi-110 012, 1995, pp 164, Price not mentioned.

This book is an excellent compendium of 350 rural technologies developed at various laboratories affiliated to CSIR. Through the knowledge of these technologies, material resources available in the rural area can be exploited and processed in small units right there to generate income and provide employment, especially in non-farm sub-sector. It has rightly pointed out that non-farm sub-sector of rural sector has not been benefitted much by the Green Revolution, the poorest of the rural poor continues to be there in this sub-sector. Dissemination of these appropriate rural technologies shall bring rural industrialization, which will help the non-farm sub-sector as well as the entrepreneurs through value addition and better use of rural resources.

The technologies have been documented under 9 heads and each chapter has been further described under various sub-heads. The first chapter on food and agro-based technologies summarizes the technologies related to cereals and pulses, fruits and vegetables, beverages, spices and plantation crops, oilseeds, additives and improvers, poultry, fish and meat, infestation control and farming. Simple technologies have been described, which are easy and convenient to use, not very expensive and can be utilised to set up small scale cottage industris in rural sector near the source of materials such as cereals, pulses, fruits, vegetables, oilseeds, spices, fish, meat, poultry etc. Technologies mentioned in this chapter also provide adequate information regarding know-how of the storage and preservation of food resources and their processing to develop nutritious as well as value-added products such as fruit bars, jams and jellies, tutti fruity, jams, squashes osmo-air dried fruits, improved methods for ripening of fruits, dehydrated vegetables, anardana, instant pickles, tomato products, ready-to-serve fruit beverages, lactic beverages, supplementary foods for toddlers, multipurpose food, *paushtik atta*, ready mixes for sweets and savouries, jowar flakes, rice flakes, production of *spirulina* as food etc.

The advantages of using improved huller systems for rice milling, manual/power operated thresher, paddy thresher cum winnower, their schematic diagram along with coloured illustrations, their cost, capacity, flow diagram for their operation have been incorporated in the first chapter in a very systematic manner. Information regarding the mechanism of action, various components, output, cost etc. with respect to mini rice mill, simple wheat mill, mini maize mill, grain mill, mini *dhal* mill, homescale oil expeller cum paddy dehusker, most of them developed at CFTRI, can be obtained after going through this chapter. The knowledge regarding the appropriate processing method i.e., improvised dry heat and hot soak method of parboiling the paddy to overcome production of foul smell due to fermentation and loss of dry matter, an accelerated process for curing the fresh paddy to improve its cooking quality and make stable lipase-free bran can be of great use to the students of food science and technology and entrepreneurs in non-farm sector. Technology package has also been developed for the production of *rhizobium* for mass propagation of nitrogen fixing bacteria, which can be taken up at a small scale level.

Our country is the largest producer of crops like ginger and turmeric, accounting for 60 and 76%, respectively of the global production. Simple cost-effective technologies related to preparation of dehydrated ginger, bleached dry ginger, ginger candy and preserve, garlic powder, saffron processing, dehydrated green pepper etc. have been highlighted along with coloured pictures of the products.

An integrated cost-effective process to obtain superior quality oil as well as meal has been developed for various oilseeds at CFTRI. A special filter pad, which can be manufactured at cottage

scale in rural areas, has been developed to remove aflatoxin and hence,detoxify the groundnut oil. Quick detection of butter yellow in mustard oil can be done by following a simple inexpensive method, using a spot colour detection strip.

Poultry farming is becoming an increasing popular venture. Small scale poultry processing plants can be established for hygienic dressings, packing and distribution of poultry meat. Gut of meat animals can be used as sausage casings and its processing can be made on cottage scale in rural areas. There is a great scope to develop a number of small units in the villages for the preparation of convenience meat and fish products, fish meal, cattle and poultry feeds etc., the standardized composition of which can be obtained from the concerned CSIR laboratory.

This chapter also consolidates the simple and safe methods such as use of mini fume tables, pest proofing of jute bags etc., of household disinfection of cereals and pulses to prevent nutritional and economic loss.

There is a great demand for natural plant materials for use in the manufacture of drugs, cosmetics, food flavours, perfumes and other industrial products. This requires systematic cultivation of these special crops. The cultivation cum processing of these agro crops can result in higher returns from the land. CSIR laboratories have developed high yielding strains, agro-technologies and post-harvest processing techniques for aromatic, medicinal and other economic plants. Information on planting material, agrotechnologies, supervision and guidance on post-harvest handling, processing, packaging etc., has been incorporated in chapter 2 of this compendium.

In chapter 3, the appropriate technologies developed by the Central Leather Institute, Madras, for tanning, curing, preservation of hides and skins, carcass utilization, enzymatic dehairing etc., of skin, special leathers, preparation of value-added products from animal residues and improved tools for artisans etc., have been outlined in brief, along with illustrations.

Under "Building materials, components and systems" in chapter 4, a brief description has been given, regarding the development of innovation construction materials such as production of various types of bricks, cement, cementitious binders, tiles, composite/particle boards, lime etc., building components and systems, low cost shelters etc., which are not only cost-effective and acceptable, but also are appropriate to the climate of the region. The main focus of these technologies is to develop material of superior quality, replace the scarce material and utilize waste. There is no doubt that fabrication of such materials in rural areas has a vast potential to promote local enterprise, utilizing available skills and raw materials.

Chapter 5 details the appropriate technology to economically construct a large number of rural roads. Models have been developed for rural roads network to connect villages to market centres or to the existing main roads. Tractor-bound technology for road construction and low cost culverts for rural roads have been discussed to obtain quality as well economy.

There are still so many villages in our country, which do not get sufficient supply of potable water. For better quality and supply of water, some of the salient technologies related to water exploration, purification, quality assessment and storage have been highlighted along with sketches and photographs in chapter 6.

One of the main reasons for unhygienic and unsanitary conditions in rural areas is the waste water flowing in the rural streets. Hence, waste water disposal is very important. After going through chapter 7, one can get the know-how of various technologies, pertaining to waste water disposal using brick system, soakpit system etc., disposal of human waste by constructing low cost latrines, hand flush water seal pit latrines, rotating biological rope contractor plants to treat biodegradable liquid wastes, septic tanks and manufacturing of vitreous sanitary ware.

Chapter 8 details some good technologies, which the rural artisans can foloow to upgrade their skills in floral crafts, brass metal crafts, pottery craft, terracota figurine, etc. and produce new crafts to generate more income.

The last and the 9th chapter incorporates technologies, related to mechanized making of leaf cups and plates, manufacturing of crystal glass articles by use of indigenous raw material and equipment at small scale bone china porcelain, decorated black and stoneware crockery, blackboard synthetic kiln, low dust chalk, wind pumps, liquid deodorant cleaner, multifuel cook stoves, electronic display boards etc.

All the technologies have been outlined and mentioned in brief, as it was difficult to describe each and technology at great length. The purpose of this compendium is to bring information

regarding various technologies developed at CSIR laboratories at one place and create awareness and interest among the readers to utilize these to develop small scale industries, depending upon their potential, interest, skill, resources available and suitability. A list of CSIR establishments has been given in the Appendix for further detailed information.

The compendium has been nicely prepared, well printed and it fulfils the objective of introducing new technologies in different fields developed at various CSIR establishments to all those who are interested to get self employment or generate more income or to the extension workers, who can transfer these technologies to the rural areas. All the chapters are adequately illustrated. It will certainly be a useful and an important book to all concerned with processing and packaging of food products, food scientists and technologists, engineers, artisans and rural non a farm sub-sector.

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Sensory evaluation studies should report the data on physical and environmental factors (taste booth type, colour of walls/separator, extent of distraction from external sound/odour, room temperature, relative humidity, illumination specification etc. The equipment ad methods of sample preparation, testing temperature conditions, sample size, number of samples evaluated per session, nature of palate clearing agents used, time of evaluation, sequence of testing and data entry carriers should be reported. For affective test, the location of testing (stores, homes, central location etc.), the instructions given regarding sample preparation/processing and the questionnaire used for collection of data should be specified.

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Published papers/notes/reviews

a) Tairu AO, Omotosu RA, Bamiro FO (1991) Studies on oxidative stability of crude and processed yellow nutsedge tuber and almond seed oil. J Food Sci Technol 28:8-11

Books/approved methods

a) Hacking AJ (1986) Economic aspects of Biotechnology, Cambridge University Press, Cambridge.

b) AOAC (1984) Official Methods of Analysis, 14th edn. Association of Official Analytical Chemists, Washington, DC

Chapter in edited books/book series/papers in symposium proceedings/souvenir

a) Kurtzman CP, Phaff HJ, Meyer SA, (1983) Nucleic acid relatedness among yeasts. In: Spencer JFT, Spencer DM, Smith ARW (eds) Yeast Genetics, Fundamental and Applied Aspects. Springer-Verlag, New York, pp 139-166

b) Gross E (1975) Subtilin and nisin: The chemistry and biology of peptides with α-β-saturated amino acids. In: Walter R, Merenhoper J (eds) Peptides, Chemistry, Structure and Biology: Proceedings of the Fourth American Peptide Symposium, Ann Arbor, Michigan, USA. pp 31-42

c) Bhalerao SD, Mulmulay GV, Potty VH (1989) Effluent management in food industry. In: Souvenir, National Symposium on Impact of Pollution in and from Food Industries and its Management. Association of Food Scientists and Techniologists (India), Mysore, pp 1-31

Reports by specified authors/Institutions

a) Andress EL, Kuhn GD (1983) Critical Review of Home Preservation Literature and Current Research, Co-operative Agreement No. 12-05-300-553. USDA and Pennsylvania State University, Pennsylvania

b) USDA (1977) Home Canning of Fruits and Vegetables, Home and Garden Bulletin 18, United States Department of Agriculture, Washington, DC

Patents

a) Schmidt GR, Means WJ (1986) Process of preparing algin/calcium gel-structured meat products. US Patent 4 603 054

Thesis

a) Ramesh MV (1989) Production of heat stable alpha-amylase. Ph.D. Thesis, University of Mysore, Mysore, India

Papers presented at symposia

a) Stevens KA, Klapes NA, Sheldon BW, Klaenhammer TR (1991) Anti-microbial action of nisin against *Salmonella typhimurium* lipo-polysaccharide mutants. Paper 7-501 presented at 91st American Society for Microbiology, Annual Meeting, Dallas, Texas, USA, 5-9 May

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3.	2nd ICFoST-1981: Sensory analysis, Contaminants and Nutrition	40	18	15	7
4.	Symposium on recent developments in food packaging 1986	65	18	35	8
5.	Prof. V. Subrahmanyan Commemoration Issue 1980 (Part of Journal of Food Science & Technology) contains write-up on various aspects of Food Science & Technology	30	18	12	8
6.	Production & processing of meat & poultry products	100	18	45*	-
7.	IFCON-88, 2nd International Food Convention & Exhibition: Food Technology Overview	100	18	45*	-
8.	IFCON-88, 2nd International Food Convention & Exhibition: Abstracts of papers	100	18	45*	-
9.	Trends in Food Science & Technology: IFCON-88 Proceedings, 1988	300*	-	105* or £57*	-
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