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CONTENTS

INDEXED AND SELECTIVELY ABSTRACTED IN

* *Current Contents-Agriculture, Biology and Environmental Sciences*
* *Indian Food Industry*
* *NCI Current Contents*
* *Chemical Abstracts*
* *Biological Abstracts*
* *Food Science and Technology Abstracts*
* *Food Technology Abstracts*
* *Dairy Science Abstracts*
* *Nutrition Abstracts and Reviews-Series A-Human and Experimentals*
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* *Online PIRA Databases-Data-Star, Dialog, Orbit Search Service, PFDS Online and STN*
* *Fisheries Review*
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* *Food Adlibra Dialog File 79.*
* *Food Adlibra Alerting Bulletin*
* *Food Adlibra Current Awareness Supplements for Food Science and Seafood*
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Tamarind - Chemistry, Technology and Uses - A Critical Appraisal

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Tamarind (*Tamarindus indica L.*) is an economically important tree of India, which grows abundantly in the dry tracts of Central and South Indian States. Its life span is long and yields 150-500 kg fruits per tree. The pulpy portion of the fruits form the tamarind of commerce, which finds extensive use in culinary preparations. Indian production of tamarind is about 3 lakh tonnes per year. The country earns about Rs. 50 crores annually from the export of various tamarind products such as tamarind concentrate, tamarind powder, tamarind kernel powder (TKP) pickles and pastes. The fruit pulp is the richest natural source of tartaric acid (8-18%) and is the chief acidulant used in the preparation of foods in India. The major industrial use for the seeds is in the manufacture of tamarind kernel powder (TKP), which is an important sizing material for the jute and textiles. The seeds are gaining importance as a rich source of proteins and valuable amino acids. Also, the seed kernels have been used as food in times of scarcity either alone or mixed with cereal flours. This review covers the chemical, technological and usage aspects of tamarind.

Keywords : *Tamarindus indica*, Chemical composition, Technology, Utilization, Products.

Tamarind is an arboreal fruit of *Tamarindus indica* Linn., which belongs to the family Leguminosae or Caesalpiniaceae. The tree is indigenous to tropical Africa and probably also to India. It is found throughout the tropics and sub-tropics and has been naturalised at many places. The tree grows wild, though cultivated to a limited extent. The tree is particularly abundant in the Indian States of Madhya Pradesh, Bihar, Andhra Pradesh, Tamil Nadu and Karnataka.

Tamarind is a long living (80-120 years) large tree spreading and open, upto 30 m tall. The fruits are straight or curved, brown, 5-18 cm long and 1.25-2.50 cm wide. They are somewhat flattened, constricted at intervals, with a thin brittle shell, containing a soft brownish or red pulp. The pods contain 3-12 seeds, which are ovate-oblong (1.5 x 0.8 cm), glossy and smooth, flattened, brownish-ash in colour. The seeds are contained in loculi, enveloped by a tough, leathery membrane, the so called endocarp. Outside the endocarp is the light brownish, red, sweetish, acidic edible pulp, traversed by a number of branched ligneous strands. The outer most covering of the pod (shell) is fragile and easily separable (The Wealth of India 1976; Duke 1981). Generally, the tree begins to bear fruits at the age of 8-12 years and continues to yield abundant crops for more than 60 years. But the trees from grafts and budlings take only 5-6 years for bearing fruits. The trees flower during April-June and the pods ripen during the cold season (Dec.-Jan.). The pods (fruits) should be allowed to ripen on the tree, until the outer shell is dry and can be separated from the pulp without adherence. The pods are harvested by merely shaking the branches and should not be beaten with sticks. A good full-grown tree yields 150-500 kgs of fruits per season and the fruit weight varies from 15-30 g (The Wealth of India 1976; Duke 1981). There are only a few varieties of tamarind grown in India. Some are less acidic (sweetish) and some are more acidic to taste and the colour of the pulp is usually brownish-red in the common variety and reddish in the so-called red variety. The red variety is not economically important, as it is not produced on a commercial scale. But, the red variety fetches better price and is preferred for making preserves. Some of the improved varieties of tamarind in India are grown in Periyakulam, Cumbum, Urigon of Tamil Nadu and Pratisthan of Rajasthan. Tamarind is a highly cross-pollinated crop and hence wide variability is common in this species. Selection could improve the quality, yield and earliness of fruiting (Geetha 1995, Saideswara Rao 1995).

Tamarind is one of the important and common trees of India. Though every part of it is useful, the fruit is the most important part. It is the most acidic of all fruits and contains a rather uncommon plant acid, tartaric acid, whose metabolic origin is still unknown. The fruit pulp is the most important product, which is a common article of trade in India. India, perhaps, is the chief producer and consumer of tamarind in the world. It is estimated that India produces about 300000 MT of fruits and exports tamarind products worth about Rs 50 crores per annum. (Kannada Prabha, Supplement, dated 18.8.1996 p. 6).

A few reviews have appeared in literature on tamarind (Lefevre 1971; Lewis and Neelakantan 1964; Hasan and Ijaz 1972), but there is still a need for an updated version covering the details on the chemical, technological and usage aspects. The present review critically analyses these aspects.

Chemistry

Tamarind pulp : On an average, the pod is composed of shell, 15-25%, pulp (flesh) 45-55%, seeds 25-35% and fibre 10-15%. The seed contains testa (seed coat) 25-30% and kernel (endosperm) 70-75%. The ripe fruit contains 63-69% pulp due to the presence of high moisture in it and the pulp content comes down to 45-55% after removal of the shell and drying.

The fruit pulp contains mainly tartaric acid, reducing sugars, pectin, tannin, fibre and cellulosic material. The edible portion of the ripe pod, before harvest, contains moisture 63.3-68.6%; tartaric acid 8.4-12.4%, sugars 23-30% and shows a pH around 3.15. (Table 1). As the ripened pods are high in moisture content, it is necessary to allow them to dry up on the tree itself. The colour and flavour of the pulp of the ripened fruit are very attractive and the mature pulp of tamarind pod is probably one of the most acidic natural products (Duke 1981; Lewis and Neelakantan 1964).

The dried pulp of commerce contains moisture 15-30%, tartaric acid 8-18%, and reducing (invert) sugars 25-45%. Of the reducing sugars present, about 70% is glucose and 30% is fructose. Table 2 shows the proximate composition of the dried pulp of tamarind. Nearly 50% of the tartaric acid is in the combined form mainly as potassium bitartrate and to a small extent as calcium tartrate, which is insoluble in cold water. Therefore, cold water extract of the pulp contains only a part of the available tartaric acid and hence hot water is to be used to extract the total acids in the pulp. About 2% of other acids (malic, oxalic, succinic, citric and quinic) are also present in the pulp, malic acid being predominant (The Wealth of India 1976; Lewis and Neelakantan 1964).

TABLE 1. COMPOSITION OF EDIBLE PORTION OF RIPE FRUIT/ POD OF TAMARIND

Constituent	Percentage
Moisture	62.50 - 69.20
Proteins	1.40 - 3.30
Fat/oil	0.27 - 0.81
Sugars, total	21.40 - 30.85
Sucrose	0.10 - 0.80
Cellulose	1.80 - 3.20
Ash	1.20 - 1.72
Tartaric acid, total	8.40 - 12.40
Total acidity, as tartaric acid	17.10 - 18.40
pH	3.15
Pentoses	4.20 - 4.80

Source: Duke (1981)

TABLE 2. PROXIMATE COMPOSITION OF DRIED PULP OF TAMARIND FRUIT

Constituent	Percentage
Moisture	15.00 - 30.00
Proteins	2.00 - 8.79
Fat/oil/lipid, crude	0.50 - 2.53
Carbohydrates, total	56.70 - 70.70
Fibre, crude	2.20 - 18.30
Tartaric acid, total	8.00 - 18.00
Reducing sugars	25.00 - 45.00
Total ash	2.10 - 2.90
Pectin	2.00 - 4.00
Cellulosic residue	19.40
Albuminoids	3.00 - 4.00
Total available carbohydrates	41.77
Alcohol insoluble solids	22.70
Water insoluble solids	20.50
Non-reducing sugars	16.52
Total sugars	41.20
Starch	5.70
Tannin, mg	600.00
Ascorbic acid, mg	3.0 - 9.0
β-carotene equivalent, µg	10.00 - 60.00
Thiamine, mg	0.18 - 0.22
Riboflavin, mg	0.07 - 0.09
Niacin, mg	0.60

Source: Wealth of India (1966), Duke (1981), Meillon (1974), Ishola et al (1990)

The tender fruits contain most of the tartaric acid in free form (upto 16%), which can be easily extracted with water. The acid and sugar contents vary within a narrow range among the varieties. Unlike in other fruits, ripending in tamarind fruit is not accompanied by a decrease in acid content The formation and breakdown of starch in a short period during the process of ripening result in the accumulation of 30-40% reducing sugars in the harvested fruit, giving it a sweet taste (Lewis and Neelakantan 1964).

Tartaric acid is an unusual plant acid, which perhaps is formed from the primary carbohydrate products of photosynthesis and once formed cannot be used further in the plant because of the absence of necessary enzymes. The titrable acidity is low in young leaves, but increases with age and again comes down in old leaves. The total tartaric acid

content in leaves decreases from 28 to 12% from May to December and the free tartaric acid disappears after the first three months and the alkalinity of the ash increases rapidly due to absorption of calcium and potassium, which neutralises the acid. Simultaneously, there is a shift in the pH of the leaves' sap from 2.3 to 4.1% (Lewis and Neelakantan 1959, Lewis et al. 1957).

Since oxaloacetate is the only tricarboxylic acid cycle intermediate found to be slowly oxidised by young tamarind leaves in respiratory studies, Ramakrishnan and Joshi (1960) have suggested that sugar gets converted to oxaloacetate through the operation of the tricarboxylic acid cycle enzymes and that oxaloacetate gets converted to tartrate via dihydroxy fumarate. In old leaves, the rate of oxidation for all intermediates is low, which suggests a general slow down of metabolism. Both young and old fruits oxidise all the intermediates, suggesting that the site of tartaric acid formation is in the leaves and the acid gets translocated to the fruits. Tartaric dehydrogenase is active only towards l-tartaric acid and not dextro- and meso-forms. The tartaric racemase can convert the meso-form to dextro-form. The inability of dehydrogenase to attack dextro-tartaric acid is considered to be responsible for the accumulation of dextro-tartaric acid in fruits and leaves (Lewis and Neelakantan 1964).

The so-called red variety of tamarind is sweeter than the common brown variety, evidently because it has a lower content of free acid. In the red variety, the acid is present in the combined form mostly as potassium bitartrate and to a small extent as calcium tartrate. The common variety has high proportion of free acid and less pectin content as compared to the red variety. An analysis of the pulp from red and common varieties showed, respectively, the following values: moisture 20.1, 18.2; tartaric acid (free) 6.6, 9.8; tartaric acid (combined) 11.4, 6.7; invert sugars 36.4, 38.2 and pectin 4.4, 2.4% (The Wealth of India 1976).

Tartaric acid (2,3-dihydroxybutanedioic acid) $C_4H_6O_6$ is a dihydroxydicarboxylic acid with two chiral centres. It exists as the dextro-and levorotatory acid, the mesoform (which is inactive owing to internal compensation), and the racenic mixtures. Tartaric acid that is present in tamarind and grape fruits is the natural, dextrorotatory form L (+) tartaric acid, m.p 169-170°C mol.wt. 150.086; solubility 139 g/100g water at 20°C; solubility of acid potassium salt 0.84g/100g water at 25°C; solubility of calcium salt 0.02g/100g water and it has 4 molecules of water in hydrate of calcium salt. The estimated total worldwide market (1991) for tartaric acid was 58000 tonnes and potassium bitartrate (acid basis) was 20000 tonnes. The consumption pattern of tartaric acid is represented by beverages (alcoholic) 30%; emulsifiers 20%; pharmaceuticals 15%, foods 10%; textiles 10%; electro-chemicals 10%; and others 5%. Potassium bitartrate (cream of tartar) is primarily used in baking powders and mixes. The FDA has affirmed tartaric acid as a GRAS Food substance. Tartaric acid and tartrates are poorly absorbed from the intestine. The acid that is absorbed is excreted unchanged in the urine (Kirk-Othmer Encyclopedia 1995).

The tamarind pulp pectin chemically resembles apple-pectin. The pectin powders prepared from different samples of pulp contained : moisture 7.8-8.9%; ash 2.3-3.0%; calcium pectate 70.0-80.4%; methoxyl 7.9-9.9%; uronic acid 43.0-56.4% and jelly grade 130-180. The purified pectin analysed gave galacturonic acid 81.3%; galactose 2.0% and arabinose 6.8%. The tamarind pulp contains about 600 mg tannin per 100 g (Narasinga Rao and Prabhavati 1982; The Wealth of India 1976). About 3% crude protein (Nx6.25) is present in the pulp, and of the total introgen in the pulp, 55% is present as non-protein nitrogen and of this, 70% is free amino nitrogen. The chief amino acids present are proline and pipecolinic acid. (Lewis and Neelakantan 1964). The pulp is fairly rich in minerals especially calcium, potassium and phosphorus. (Table 3). The tamarind pulp does not contain any detectable amount of phytic acid, but the seed contains 47 mg per 100g, which should have a minimal effect on its nutritive value. Trypsin inhibitor activity is

TABLE 3. MINERAL CONTENTS OF TAMARIND PULP, SEED, KERNEL AND TESTA

Mineral, mg/100g	Pulp	Seed	Kernel	Testa
Calcium	81-466	9.3-786.0	120.0	100.0
Phosphorus	86-190	68.4-165.0	-	-
Magnesium	72.03	17.5-118.3	180.0	120.0
Potassium	62-570	272.8-610.0	1020.0	240.0
Sodium	3.0-76.7	19.2-28.8	210.0	240.0
Copper	21.83	1.60-19.0	-	-
Iron	1.3-10.9	6.5	80.0	80.0
Zinc	1.06	2.8	100.0	120.0
Nickel	0.52	-	-	-
Manganese	-	0.9	-	-

Source: Bhattacharya et al (1993); Ishola et al (1990); Marangoni et al (1988)

higher in the pulp than in the seed, but is heat-labile in both. Although the pulp is relatively poor in protein and fat, the seed is a good source of both (Ishola and Agbaji 1990). Small amounts of vitamins, carotene, thiamine and nicotinic acid are found in the pulp.

Colour of tamarind pulp : During storage, the brownish-red coloured pulp becomes darker and after about a year, is almost black. This is perhaps due to the onset of Maillard reaction, since free amino acids and reducing sugars are present in the pulp. The pulp also becomes soft and sticky as pectolytic degradation takes place and moisture is absorbed, especially in humid weather (Lewis and Neelakantan 1964; The Wealth of India 1967).

The anthocyanin pigment, chrysanthemin, is responsible for the colour of the pulp in the red variety of tamarind and the common variety contains leucocyanidin. The anthoxanthin pigments lutein and apigenin are present to the extent of about 2% in the tamarind leaves. The fruits have low anthoxanthin content, while the flowers contain only xanthophylls. The seed testa contains leucoanthocyanidin (Lewis et al. 1957; Lewis and Johar 1956; Lewis and Neelakantan 1962). The mineral contents of the pulp, seed, kernel and seed coat (hull) are given in Table 3. The pulp is rich in calcium and potassium, while the kernel is rich in magnesium, potassium, calcium and zinc.

Flavour of tamarind pulp: The chemical composition of tamarind pulp flavour depends on the method of extraction, raw pulp used and the method of analysis. This is the reason why different workers have given different versions of the flavour composition. These are summarized below.

The volatile constituents of the pulp were investigated by the combined technique of GLC-MS with 61 constituents identified and confirmed (Lee et al. 1975). Five additional compounds identified as artifacts appeared to orginate from the vacuum steam distillation apparatus during isolation of the volatiles. The results of this study suggested that the overall aroma of tamarind consisted of citrus notes and warm spice-like flavours with some roasted character. The major constituents identified were: hexanol, cis-3-hexen-l-ol, trans-2-hexen-l-ol, trans and cis-linalool oxides, 2-acetyl furan, benzaldehyde, linalool, 4-terpineol, phenylacetaldehyde, a-terpineol, 2-phenyl ethyl alcohol, dibutyl phthalate and geraniol. The volatile compounds of the pulp were extracted with pentane/diethyl ether (1:1), separated by column chromatography and analysed by GLC (Askar et al. 1987) and 35 volatile were identified, including 10 hydrocarbons and 25 polar compounds. Monoterpenes, furan derivatives, benzaldehyde derivatives and methyl pyrazines were the important constituents.

Zhang and Ho (1990) isolated the volatiles of tamarind pulp by simultaneous-steam distillation/solvent extraction and analysed by GC-MS. A total of 28 compounds were identified with furfural (123 ppm); 5-methyl-2 (3H) furanone (10.61 ppm), phenyl acetaldehyde (10.11 ppm) and 5-methyl furfural (8.60 ppm) accounting for 88.74% of the total volatiles.

Supercritical fluid extraction of the tamarind pulp followed by GC and GLC-MS analysis showed that 16 compounds accounted for 97.5% of the extract and the major compound was aroma-dendrone (90%) (Sagrero et al. 1994). The non-volatile flavour components in extract of tamarind pulp were analyzed by HPLC and the major components were glucose (37.5%) fructose (18.4%) and alanine (14.2%) (Khurana and Ho 1989).

Tamarind juice concentrate : The tamarind pulp/juice concentrate obtained by extracting the pulp with boiling water contains 65-70% soluble solids and all the invert sugars, acid and pectin present in the original pulp. The concentrate contains about 13% total tartaric acid, 50% invert sugars, 2% proteins, 2% pectin and 30% moisture (Table 4). The presence of seeds in the pulp used for extraction results in a highly astringent tasting concentrate. This is because of the testa of the seed also getting extracted by the boiling water. It is therefore, necessary that the pulp should be free of seeds. Storage studies indicated that corrosion of the tin containers due to high acidity of the concentrate (pH 2.3) was not so rapid, because of the solid nature of the product. However, even lacquered cans showed corrosion after long periods

TABLE 4. COMPOSITION OF TAMARIND JUICE CONCENTRATE AND TAMARIND PULP POWDER

Constituent	Tamarind juice concentrate (TJC)	Tamarind pulp powder (TPP)
Moisture, %	30.0	3.5 - 8.8
Tartaric acid, total, %	13.0	8.7 - 11.1
Invert sugars, %	50.0	15.8 - 25.0
Proteins, %	2.0	1.7 - 2.4
Starch, %	-	20.0 - 41.3
Ash, %	-	2.1 - 3.2
Crude fibre, %	2.0	-
Pectin, %	2.0	-

Source: Manjunath et al (1991); Nagaraja et al (1975)

of storage (12-15 months). It is, therefore, desirable that the concentrate be packed and stored in either glass or plastic containers with plastic lids (Lewis et al. 1970).

Using HPLC, Siliha and Askar (1987) determined the sugar composition of tamarind juice concentrate and found that tamarind concentrate contained low levels of sucrose compared to reducing sugars (0.63% sucrose; 9.98% glucose and 9.55% fructose and 3.58% xylose). Manohar et al (1991) studied some physical properties of tamarind juice concentrates. Boiling point elevation of tamarind juice was twice that of sucrose solution at 50% solids and the specific heat of tamarind juice was less than that of sucrose solutions at all concentrations. Molasses, because of their appearance, are convenient for adulterating tamarind juice concentrate. But they contain twice the total ash and three times the phosphorus and calcium as compared to tamarind juice concentrate. Measurement of total sugars and total acidity would provide additional evidence of adulteration (Chaudhuri et al. 1979). The chemical composition and organoleptic properties of commercial juice concentrates stored for 12 months were studied by Nagaraja et al (1975). No significant changes occurred during the storage period. The colour changed from light to dark brown, but the products remained acceptable.

Tamarind pulp powder : Tamarind powder is one of the convenience food products developed from tamarind pulp and is being produced on commercial scale by several manufacturers in the country. There is a wide variation in the physico-chemical characteristics from one brand to another (Table 4). Manjunath et al (1991) have analysed 16 commercial samples of tamarind powder for physico-chemical composition and reported that the water soluble solids ranged from 18.6 to 25.0% and the degree of browning in terms of absorbance at 440 nm ranged from 0.17 to 0.46%. The percentage acidity was in the range of 8.7 to 11.1 with an average value of 9.9% as tartaric acid. Moisture content ranged from 3.5 to 8.8% with an average of 6.5%. Among the minerals estimated, calcium and potassium were in higher amounts and ranged from 74 to 143 mg% and 23.8 to 27.7 mg%, respectively. With respect to the heavy metals. lead, cadmium and arsenic were absent in all the samples. Copper content ranged from 1.2 to 3.4 ppm. All the samples were free from fungal growth and insect infestation. Starch is the second major ingredient in tamarind powder and there was wide variation in the percentage of added starch content (23-41%) in different samples. Hence, it is very necessary to specify the maximum permissible limit for starch content in tamarind powders (Manjunath et al. 1991).

Tamarind seed : Tamarind seed is the raw material used in the manufacture of tamarind kernel powder (TKP), polysaccharide (jellose), adhesive and tannin. Also, the seed is gaining importance as an alternative source of proteins, rich in some essential amino acids. Hence, a lot of interest is shown by the chemists, technologists and nutritionists on the chemical aspects of tamarind seed.

The seeds form about 30% of the whole fruit and 30% of the seed is testa (seed coat) and 70% is endosperm or seed kernel. The chemical composition of whole seed, seed kernel (cotyledons), and hull (testa) is given in Table 5. The whole seed and the kernel are rich in proteins (13-20%) and the seed coat is rich in fibre (20%) and tannins (20-24%). The mineral contents of the seeds, kernels and testa are presented in Table 3. The kernel is rich in potassium and magnesium.

The tamarind kernel powder (TKP) develops rancid smell and turns brown on storage, whereas the deoiled meal (0.5% oil) remains white and odourless. This indicates the desirability of oil extraction of TKP to maintain its quality for use as sizing material and to recover the fatty oil that is going as waste. Solvent extraction of TKP removes oil, containing very long chain fatty acids.

TABLE 5. COMPOSITION OF TAMARIND SEED, KERNEL AND TESTA

Constituent	Wholeseed	Seed kernel (cotyledons)	Testa (seed coat)
Moisture, %	9.4 - 11.3	11.4 - 22.7	11.0
Proteins, %	13.3 - 26.9	15.0 - 20.9	-
Fat/oil, %	4.5 - 16.2	3.9 - 8.0	-
Crude fibre, %	7.4 - 8.8	2.5 - 8.2	21.6
Carbohydrates, %	50.0 - 57.0	65.1 - 72.2	-
Total ash, %	1.60 - 4.2	2.4 - 4.2	7.4
Nitrogen-free extract, %	59.0	-	-
Yield of TKP, %	50.0 - 60.0	-	-
Calories/100g	340.3	-	-
Total sugars, %	11.3 - 25.3	-	-
Reducing sugars, %	7.43	-	-
Starch, %	33.1	-	-
Tannin, %	-	-	20.2

Source: Wealth of India (1996),; Ishola et al (1990,); Bhattacharya et al (1993); Morad et al (1978)

(e.g. C_{22} to C_{24}). (Sivarama Reddy et al. 1979). The TKP contains a polysaccharide (jellose) 60%, proteins, fibre, fat, inorganic salts, some free sugars and tannins. The polysaccharide (jellose) consists of D-glucose, D-xylose, D-galactose and L-arabinose in the molar ratio of 8:4:2. The polysaccharide can be used as a substitute for starch and pectin, although it is structurally different from them (The Wealth of India 1976).

Albumins and globulins constitute the bulk of seed proteins. Linoleic acid followed by palmitic acid and oleic acid constitute the predominant fatty acids. The seeds are high in saturated fatty acids, constituting 65-75% of total lipids. They contain recommended levels of all essential amino acids except threonine and tryptophan. They contain only moderate amounts of antinutritional factors (tannins, phytic acid, hydrogen cyanide, trypsin inhibitor activity, phytohaemagglutinating activity). Therefore, they can be adopted as cheap, alternate protein source to alleviate protein malnutri-tion in developing countries (Siddaraju et al. 1995). The results of experiments on roasting have shown that the antitryptic activities of the seeds decrease by 83% and antichymotryptic activity was absent in the seed (Marickar and Pattabiraman 1988).

Reymond et al (1980) used a rapid potentiometric method for determining alkaline earth ions (calcium and magnesium) in solution of natural hydrocolloids (e.g., aqueous solutions of gum arabic and tamarind meal). A study of the fatty acids extracted with ether from the gums of guar, locust bean (carob) and tamarind was carried out to facilitate differentiation of their colloids using Walbeca's chromatographic method of isolating sterols (Artaud et al. 1977). Pasting and flow properties of cooked solutions of TKP, its carboxy methyl and hydroxy propyl derivatives were examined by Prabhajan and Zakiuddin Ali (1995) with respect to their application in the food industry.

Enzymatic degradation of tamarind kernel powder (TKP) was studied by Kooiman (1957) and Srivastava et al (1970). A method for purification of tamarind gum has been patented by Jones (1978). Air classification of finely ground crude tamarind gum provides a purified tamarind seed polysaccharide. The crude gum may also be admixed with finely divided siliceous matter or may be defatted prior to air classification to increase the degree of purification. A process for preparing tamarind oligosaccharides has been patented by Whistler and Barkalow (1995) and another process for separating polysaccharides from tamarind seeds has been patented by Teraoka (1990).

Marangoni et al (1988) evaluated the tamarind seeds as a potential source of food or food ingredients. Crude proteins and nitrogen-free extract (NFE) comprised 15.5% and 59% of the seed, respectively. The soluble sugars composition (Table 6) showed that mannose and glucose were the principal sugars. Inositol, the sugar alcohol, which is usually associated with phosphorus as phytate in seeds was present. The oligosaccharides, raffinose and stachyose were found in low levels. Pentoses constituted 20% of the total sugars (Table 6).

Marangoni et al (1988) found that seed oil (lipid) contained a relatively large proportion of unsaturated fatty acids (75%) with linoleic acid (56.10%) as the predominant fatty acid. Calcium, magnesium and potassium were low in comparison to cultivated legumes. Alkali extraction of the seeds showed that 70% of the proteins were extractable. The protein isolated was relatively high in lysine (406 mg/g N), phenylalanine and tyrosine (520 mg/g N) and leucine (496 mg/g N). The results of these studies showed that tamarind seeds could be potentially useful as a source of food proteins (Table 6). Protein qualities of tamarind and African locust bean seed meals were studied by Kapu et al (1990).

TABLE 6. AMINO ACIDS AND SOLUBLE SUGARS OF TAMARIND SEEDS

Amino acid	g/16gN	Soluble sugars	Per cent of total sugars
Aspartic acid	11.59 -11.82	Arabinose	1.54
Glutamic acid	16.91 -18.53	Ribose	10.89
Serine	4.78 - 7.71	Xylose	6.89
Glycine	4.62 - 9.12	Mannose	17.35
Histidine	2.01 - 2.68	Fructose	6.16
Arginine	4.20 - 9.18	Galactose	4.75
Proline	6.19 - 8.70	Glucose	11.80
Alanine	4.99 - 6.96	Inositol	7.27
Cystine+ Methionine	0.63 - 1.04	Sucrose	5.23
Threonine	3.78 - 3.90	Maltose	1.84
Tyrosine+ Phenylalanine	6.32 - 8.32	Raffinose	3.25
Valine	4.60 - 6.03	Unidentified	0.10
Isoleucine	4.12 - 4.19		
Leucine	7.93 - 8.12	Oligosacchaides	
		1) Raffinose	traces
		2) Stachyose	traces
Lysine	5.96 - 6.49		

Source: Lumen et al (1986); Marangoni et al (1988); Sone and Sato (1994)

According to Lumen-Bo-de et al (1986), however, tamarind seeds are rich in proteins (18%) and methionine and cysteine (3.5%) and the seeds have a very favourable amino acid balance. The functional and nutritional properties of tamarind kernel proteins are given by Bhattacharya et al (1994) and Bose et al (1954). The kernel proteins are rich in lysine, glycine, leucine, glutamic acid, aspartic acid, but deficient in sulphur containing amino acids. The mineral contents of the pulp, seed, kernel and the seed coat of tamarind are presented in Table 3. Calcium, magnesium and potassium are the major minerals in all the ingredients. Studies by Sano et al (1996) have shown that tamarind polysaccharides are neither toxic nor carcinogenic to either male or female mice with long term dietary exposure. Isolation, purification and fractionation of tamarind kernel polysaccharides was carried out by Chakravarti (1961). No significant changes were noticed in the behaviour, physiology and morphology of rats receiving tamarind seed polysaccharides (Iida et al. 1978).

Seed kernel oil : Oils from six samples of tamarind seeds were examined by Andriamantena et al (1983). The seed kernels were extracted with hexane and a mixture of chloroform and methanol and the yield of the oil was 6.0-6.4% and 7.4-9.0% respectively. Investigation by GLC revealed 15 fatty acids, mainly palmitic (14-20%), stearic (6-7%), oleic (15-27%), linoleic (36-49%), arachidic (2-4%), behenic (3-5%) and lignoceric (3-8%). Seven sterols were separated and quantitatively analysed by GLC. Main sterols were β-sitosterol (66-72%), campesterol (16-19%) and stigmasterol (11-14%).

According to Sivarama Reddy et al (1979), it is better to remove the oil of the seed kernels, as the deoiled meal will be rich in polysaccharides and remains white and bland on storage. Considering the low oil content (5-7%) in TKP, solvent extraction will be necessary to recover it. The acid value and saponification values of the crude TKP oil comes down on refining and bleaching and refining improves the quality of seed oil. But there will be a refining loss of about 20%.

Several workers have analysed the seed oil for their physico-chemical properties and chemical composition. These values are given in Tables 7 and 8. The wide variations in the analytical values, may be due to the variations in the quality of the seeds used, method of processing, oil extraction, analytical methods used etc. (Bhat 1966; Morad et al. 1978; Pitka et al. 1977).

TABLE 7. CHARACTERISTICS OF TAMARIND SEED KERNEL FATTY ACIDS

Characteristics	Value
Saponification value	183.4 - 192.0
Iodine value	99.1 - 140.0
Titre	45.8°C
Bellier's turbidity temp.	52°C
Specific gravity	0.9194 - 0.9324
Refractive Index	1.4510 - 1.4770
Acid value	0.10 - 12.70
Unsaponifiable matter, %	1.60 - 3.70
Ester value	164
Sterols	
β-Sitosterol	66-72% of total sterols
Campesterol	16-19% "
Stigmasterol	11-14fi "

Source: Wealth of India (1976); Sivaramareddy et al (1979); Adriamantena et al (1983)

TABLE 8. COMPOSITION OF FATTY ACIDS OF TAMARIND SEED

Fatty acid	(%)
Lauric (12:0)	Trace - 28.2
Myristic (14:0)	trace - 0.4
Palmitic (16:0)	8.7 - 20.0
Stearic (18.0)	trace - 7.0
Oleic (18:1)	15.0 - 27.0
Linoleic (18:2)	7.5 - 56.1
Linolenic (18.3)	1.1 - 5.6
Arachidic (20:0)	1.9 - 12.2
Behenic (22:0)	3.0 - 12.2
Decosenoic (22:1)	0.1
Decosa-tetraenoic (22:4)	5.6
Lignoceric (24:0)	3.0 - 22.3

Source: Sivarama Reddy et al (1979); Andriamantena et al (1983); Morad et al (1978); Bhatt (1966); Pitka et al (1977)

Seed testa : In the production of TKP or the jellose, large quantities of testa (seed coat) are left as a residual by-product. The hull (testa) and kernel weigh 28.6% and 71.4% of the whole seed weight, respectively. The testa contains 21.6% crude fibre and 7.4% ash (Table 5). The presence of tannin (20-24%) and other colouring matter in the testa makes the whole seed unsuitable for human consumption. The seed testa contains leucoanthocyanidin pigment. It contains 38-40% of water solubles of which 80% is a mixture of tannins and colouring matter. The mixture comprises 35% phlobatannins, 55% depside group of tannins and 10% an uncharacterized material (The Wealth of India 1976). Though the seed testa is very rich in tannins (20-24%), the tannins obtained will be black in colour and highly polymeric due to the roasting of seeds for the removal of testa (Sundara

Rao et al. 1977). Further, the tannins impart black colouring to the leather.

Antioxidative activity of tamarind seed coat extract: The tamarind seed coat extracts have been found to possess good antioxidative properties. The supercritical carbondioxide extract obtained with ethanol (30 Mpa, 80°C) strongly inhibited autooxidation of lard and linoleic acid (Tsuda et al. 1995). The extracts exhibited antioxidative activities in two edible oils, lard and corn oil. In lard, addition of citric acid with the extract resulted in a synergistic antioxidative activity, but not in corn oil. The ethyl acetate extract prepared from the seed coat had strong antioxidative activity. Results suggest that tamarind seed coat, a by-product of tamarind powder and gum industries, can be used as a safe and low cost source of antioxidant in lipid containing foods, oils and fats (Tsuda et al. 1994). The carotene, L-ascorbic acid, dihydro ascorbic acid and tocopherol contents of tamarind fruit are reported by Schmandke and Olivarez (1969).

Leaves and flowers : The tender leaves and flowers of tamarind are eaten as a vegetable. The leaves contain oxalic acid (196 mg/100g) and the tender leaves show a calcium/oxalate ratio of 1:1 at pH 4.5, indicating that the leaves are good sources of calcium, but the presence of oxalic acid may affect their nutritive value. Total tartaric acid in leaves decreases from 28 to 12% (on dry basis) from May to December. Free tartaric acid disappears after three months of leaf formation. Malic acid in the young leaves is negligible and the quantity will be 1.5% in the leaves during winter. The proximate composition of leaves and flowers is shown in Table 9. The leaves and flowers contain high amounts of moisture (70-80%) and rich in phosphorus and calcium (The Wealth of India 1976, Lewis and Neelakantan 1964).

TABLE 9. COMPOSITION OF TENDER LEAVES AND FLOWERS OF TAMARIND

Constituent	Tender leaves, %	Flowers, %
Moisture	70.5 - 78.0	80.0
Proteins	4.0 - 5.8	2.8
Fat/oil	1.2 - 2.1	1.5
Fibre	1.9 - 3.0	1.5
Carbohydrates, total	16.0 - 18.0	-
Ash/minerals	1.0 - 1.5	0.7
Calcium, mg	101 - 250	35.5
Magnesium, mg	71.0	-
Phosphorus, mg	140.0	45.6
Iron, mg	2.0 - 5.2	1.5
Copper, mg	2.0	-
Chlorine, mg	94.0	-
Sulphur, mg	63.0	-
Thiamine, mg	0.1 - 0.2	0.07
Riboflavin, mg	0.1 - 0.2	0.14
Niacin, mg	1.5 - 4.1	1.14
Vitamin C, mg	3.0 - 6.0	13.80
Carotenes, mg	-	0.31
Sodium, mg	8.0	-
Potassium, mg	270.0	-
β-carotenes, µg	2500	-
Calories, Kcal	75.0	-
Oxalic acid, mg	196.0	-

Source: The Wealth of India (1976); Lewis et al (1964); Duke (1981)

Technology

Pulp preservation: The pods (fruits) are gathered when fully ripe and the brittle and hard pod shell is separated either manually or mechanically. The fruit pulp is separated from the seeds and fibrous material and dried in the sun for a few days to reduce the moisture content. Then, the dried pulp is packed in leaf mats, polythene or jute bags or bamboo or wooden boxes and stored in a cool and dry place. In some places, the salted (10%) pulp is trodden into a mass and made into balls and exposed to the sun or steamed for a short time and then exposed to the sun and dew for about a week. (The Wealth of India 1976).

Various methods of prolonging the storage life of whole and pulped tamarind were investigated by Chumsai-Silvanich et al (1991). For whole tamarind, steaming for 5 min followed by drying in a hot air oven at 80°C for 2 h proved to be the most suitable method and the resultant fruits could be stored in plastic bags at room temperature for 4 months without affecting quality and acceptability. For pulped tamarind, after removal of peel, veins and any unwanted part, steaming for 20 min, followed by drying at 60°C for 2.5 h, cooling and packaging in clear plastic bags gave the best results. The product could be stored at room temperature for 3 months with satisfactory quality and acceptability.

An improved procedure for extracting and preserving tamarind pulp is outlined by Benero et al (1972). Tamarind pulp cannot be separated from the fruit by mechanical means alone, dilution being necessary. A 1:2 fruit:water ratio produced the highest yields of soluble and total solids. Pulps obtained at this dilution had about 13.2° Brix with excellent fruit flavour. The proportions of weights

of pulp, seeds and shells in ripe tamarind fruit for processing were found to be 30, 40 and 30%, respectively. This mechanical extraction method for unpeeled tamarind fruit produced high quality tamarind fruit pulps with prolonged shelf life. A water -alcohol extract of tamarind having a pH of 2.0-3.5 and 80% solids has replaced the whole, shelled fruit formerly shipped in 500 lb wooden barrels (Anon 1969).

Tamarind fruit can be processed successfully by drying. A small electric dehydrator is practical and convenient for processing the fruits grown in home gardens. Fruits can be dried successfully without any pre-treatment also. The dried fruits should be stored in a refrigerator or freezer, if they have to be kept for more than a few days with outside temperature and high RH. Drying is a good way to store and preserve small amounts of tamarind pulp (Camphell and Camphell 1983).

Experiments conducted at CFTRI, Mysore have shown that the freshly harvested tamarind fruit pulp could be preserved well (for 4-6 months) by packing in High Density Polythene (HDP) bags and storing below 10°C in a dry place. Mixing the shelled tamarind fruits with minimum amount of water and passing through a pulper removes residual seeds, fibre and cellulosic material. Drum-drying of this soft homogeneous pulp and compressing it in molds gives block-like cheese (Lewis and Neelakantan 1964). There is an Indian standard for the tamarind pulp (IS:6364:1993), which helps in getting good quality pulp for utilization in the industry.

Products

Tamarind fruit has been used as a raw material for the manufacture of several products like Tamarind Juice Concentrate (TJC), Tamarind Pulp Powder (TPP), Tamarind Kernel Powder (TKP), tartaric acid, pectin, tartrates and alcohol, the yields of which are presented in Table 10. The following sections will deal with technology of some of the important products.

TABLE 10. LIST OF PRODUCTS FROM TAMARIND FRUIT

Product	Yield, %
Tamarind juice concentrate (TJC)	75-80
Tamarind pulp powder (TPP)	80-85
Tamarind kernel powder (TKP)	55-65
Tartaric acid (TA)	8-10
Pectin	2.0-3.5
Tartrates	10-12
Alcohol	10-13

Source: The Wealth of India (1976); Lewis et al (1964)

Pectin, tartrates, tartaric acid and ethanol: Studies have been carried out for the isolation of tartaric acid and fermentation of sugars for useful by-products like ethanol, lactic acid and citric acid (Lewis et al. 1954). Since the pulp also contains pectin, an integrated process has been worked out for the production of pectin, tartrates and ethanol from it. The pulp is repeatedly extracted with boiling water and the filtered extract is cooled to separate potassium bitartrate. The supernatant is concentrated under vacuum and the pectin is separated by the addition of alcohol. The filtrate, after recovering alcohol, is treated with lime to precipitate calcium tartrate. The remaining sugars are fermented with yeast and alcohol is recovered. The recovery of about 2.5% pectin in addition to 12% tartaric acid and 12% alcohol from tamarind pulp makes the process attractive. For the isolation of tartaric acid, the use of unripe green pods has been suggested, as they contain most of the acid in the free form. Krishna (1995) patented a process for the extraction of tartrates with acidified ethanol and subsequent extraction of pectin. After removal of alcohol, the residual syrup can be used for edible purposes (Indian Patent No. 52, 1955).

Tamarind concentrate: The tamarind concentrate or tamarind juice concentrate (TJC) is a convenience product and it is easy to disperse and reconstitute well in hot water. The concentrate is hygienic and can be stored well for longer periods.

The process for the manufacture of tamarind concentrate has been developed by the Central Food Technological Research Institute, (CFTRI), Mysore and several firms are producing the concentrate on commercial scale based on this process (Anon 1982). For the preparation of concentrate, the cleaned pulp is extracted with boiling water using counter current principle, where dilute extracts are used for extracting fresh batches of the pulp, an extract containing about 20% soluble solids is then obtained. The extract is separated from the pulp, using suitable sieves and concentrated under vacuum in a forced - circulation evaporator. When the concentration of the soluble solids reaches 68%, the material is removed and directly filled in cans or bottles. It sets like a jam on cooling. The yield of the concentrate will be about 75% of the pulp used. For getting a good product, it is necessary to use freshly harvested fruit pulp (which is not older than 5-6 months), which is free from insect infestation and rodent contamination (Lewis

et al. 1970). An Indian Standard is available for tamarind concentrate (IS:5955:1993), which helps in maintaining the quality of the concentrate.

A process for extraction, concentration and preservation of sour principles from the fruits of tamarind was patented by Pillai (1973). The sour principle is extracted with hot water, filtered, clarified by bleaching with SO_2 and then evaporated in vacuum to required consistency and treated with vinegar or acetic acid (2%) to provide a storage stable extract.

Jaleel et al (1980) used fungal pectic enzyme for the production of tamarind concentrate. The pulp was extracted with hot water, followed by sqeezing through cloth. Pectin enzyme concentrate (PEC) was used for depectinising the pulp. After 15 h of reaction time, the juice was expressed. Treatment with PEC gave a clear juice, which on concentration, gave an acceptable non-viscous and free-flowing product. From 5 kg pulp, 3.46 kg of free-flowing concentrate was obtained with the following characteristics:Brix 75°, acidity 18.1% and pH 2.0.

Beverage : Formulae for preparing spiced sauces and beverages from the pulp have been reported by Girdhari Lal et al (1958). Tamarind extract as a replacement for phosphoric acid, citric acid and other acids added to soft drinks is described by Zablocki and Pecore (1995). Beverages containing the extract with a lower pH have improved shelf-life. Tamarind fruit can be used as a raw material for the preparation of wine-like beverages (Benk 1987; Latino and Vega 1986; Sanchez 1985).

The extraction and processing techniques for the preparation of canned tamarind pulp and the manufacture of tamarind (pulp) soft drinks have been reported by Bueso (1978). Process for making drinks, syrup, juice, liquor and solid extracts based on tamarind were developed by Meillon (1974). Wine and vinegar production from tamarind fruit is reported by Maldonado et al (1975). Studies were conducted on the preparation and shelf life of tamarind and soursop-tamarind soft drinks by Benero et al (1974). Tamarind drinks with 9-12% pulp concentration and 21.5° Brix and soursop-tamarind blended drinks at 10-14% and 15° Brix and 17° Brix were proposed. The drinks were pasteurized at 185-190°F, canned and stored at 85°F. Canned tamarind drinks hept well for 1 year and blended drinks for about 10 months, blended drinks of 17° Brix, being preferred in terms of acceptability. Alian et al (1983) have studied the bacteriostatic effect of tamarind extract. Ethanol extract from tamarind was the most effective inhibitor against all tested organisms in soft drinks.

Tamarind powder : Central Food Technological Research Institute, has developed a process for the preparation of tamarind powder, which is free flowing in nature and retains its original colour and flavour characteristics for periods up to 6 months. The product is much superior to the available market samples. A method for preparation of tamarind powder has been patented (Table 11).

The general characteristics of good quality tamarind powder are that (i) it will have flavouring characteristics of good tamarind pulp, when dissolved in water and will be free from burnt or any other undesirable flavour, (ii) it will have a good keeping quality and (iii) it will be free from fungal growth, live or dead insects and insect fragments (Manjunath et al (1991).

Tamarind kernel powder (TKP) : The tamarind seed powder, commonly known as tamarind kernel powder (TKP) finds extensive use as a sizing material in the jute and textile industry (Anon 1984). Some physical and engineering properties of tamarind seeds are given by Bhattacharya et al (1993). The rheological behaviour of TKP suspension was studied by Bhattacharya et al (1991). It can be used as a pectin substitute in food industries (Bhattacharya et al. 1983). The characteristics of some food products from tamarind were studied by Bhattacharya et al (1994a). The functional and nutrional properties of kernel proteins were studied by Bhattacharya et al (1994b).

Tamarind kernel powder (TKP) is prepared by decorticating the seed and pulverizing the creamy white kernels. The decorticated seed is ground to the required mesh size by machines to obtain a yield of 55-60%. The powder is liable to deteriorate on long storage particularly in humid conditions. Therefore, it should be stored in a dry place in moisture-proof containers. The powder may be mixed with 0.5% of sodium bisulfite before packing to prevent enzymic degradation. The storage stability and colour of TKP will be better, if it is defatted and kept (Sivarama Reddy et al. 1979). The sizing property of TKP is due to the presence of a polysaccharide (jellose) to the extent of 60%. A good sample of TKP should have a relative viscosity of 5.0 at 35°C in 0.5% solution, which is somewhat higher than 1.5% solution of corn starch. The TKP is much cheaper than corn starch and is required

in smaller quantities as compared to other common starches. According to CSIR Patent No. 130997 (1973), the preparation of TKP involves extraction of seed powder with an organic solvent e.g., acetone or alcohol and pulverization.

A clarified tamarind powder is obtained by treating TKP with a strong base, followed by neutralisation and isolation. The final product may be used as a thickener in foods for human consumption (Sanford 1984). Effect of minerals on lipid production by *Rhizopus nigricans* and *Penicillium nigricans* on TKP was studied by Jambhulkar and Shankhapal (1992). Magnesium, potassium, ferric and zinc ions had a positive effect on lipid production in cantrast to calcium ions, which had a negative effect.

Adhesive : Tamarind kernel powder, when boiled in water containing boric acid and phenol as preservative, gives a very good paper adhesive (The Wealth of India 1976). Also, a high grade adhesive from tamarind seed kernel can be prepared by roasting the seeds at 110°C for 15 min, dehulling, to remove the testa, powdering and passing through a 180 mesh sieve and making a porridge by boiling with water. It is then mixed with 200% hot water, 5% glucose, 4% formalin and 12% sodium bicarbonate. The adhesive will be ready for use (Devadas and Gothandapani 1993). Production, properties, applications and structure of tamarind gum are described by Whistler and Barkalow (1993). Xyloglucan of tamarind seed (tamarind gum) is commercially available as a food additive for improving the viscosity and texture of processed foods (Sone and Sato 1994). Prabhanjan (1989) studied the modified TKP by preparing and analysing the properties of sodium salt of carboxy methyl derivatives. Swelling power, solubility and tolerance to organic solvents of the derivatives increased with increasing carboxy methylation.

Polysaccharide (Jellose) : The polysaccharide in the TKP form gels with sugar concentrates as do fruit pectins. However, they do not contain galacturonic acid or methyl-uronate groups, and also, unlike fruit pectins, form gels over a wide range of pH. Therefore, it can not be termed true pectin and has been named 'jellose' (Rao 1948). For the preparation of jellose on a large scale, TKP is gradually added to 30-40 times its weight of boiling water, containing citric or tartaric acid at a concentration of 0.2% and the mixture is stirred vigorously and further boiled for 30-40 min. The resultant solution is kept overnight for setting and the supernatant liquid is siphoned off and concentrated under vacuum, passed through a filter press and then dried in a drum-drier. The resultant product is pulverized in a ball-mill. Jellose disperses easily in cold water, forming a viscous, mucilagenous solution even at low concentrations.

Jellose is an excellent substitute for fruit pectins in the manufacture of jams, jellies and marmalades. Treatment with citric acid decreases the undesirable toughness of the gel. Jellose forms the best gel, when its concentration is 0.7-0.9% of the weight of the final gel, whereas the required concentration of the fruit preparation is nearly double that amount. Jellose is also much used in confectionery (The Wealth of India 1976).

The relationship of some metal ions with citric acid production by *Aspergillus niger* using TKP as raw material was studied by Purohit and Daginawala (1996). Maximum citric acid production was observed, when the TKP- basal medium was supplemented with ferrocyanide after sterilization. A process for recovering an improved polysaccharide from tamarind seed kernels, involving sequential solvent extraction with a polar organic compound and water was patented by Gordon (1968). A range of derivatives of tamarind seed polysaccharide were prepared, characterized and selected solution properties were examined by Lang et al (1992). Carboxylated, sulphated and alkylaminated derivatives, the nature and the extent of substitution were characterized by potentiometric titration, IR and IH and 13C NMR spectroscopy.

Other products of tamarind : Tender green fruits of tamarind are used to prepare tamarind pickles, as they are very acidic. Tender fruits can be a raw material for the manufacture of natural tartaric acid. The ripened fruit pulp is used in the manufacture of mixed fruit jams, sauces and tamarind paste (Goce et al. 1993). The tamarind pulp is also canned for long use. The tamarind juice is concentrated after mixing with spices, sugar and salt and converted into a preserve. Tamarind juice extract is also used in certain confectionery products like tamarind candy (Sadasivam et al. 1979; Girdharilal et al. 1958; Gowramma et al. 1968). Indian standard specifications are available for various tamarind products IS:6364 (1993) for tamarind pulp; IS:5955 (1993) for concentrate; IS:9587 (1992) for kernel oil; IS:189 (1977) and IS: 511 (1962) for kernel powders and IS: 9004 (1978) for seed testa. The important products that can be obtained from the fruit of tamarind are given in Table 10.

Uses

Pulp : Tamarind pulp is the chief agent for souring food products like sauces, *chutneys*, *sambar*, *rasam* and some beverages throughout the greater part of India. The fruit pulp is the important raw material for the manufacture of tamarind pulp concentrate, pulp powder, paste, tartaric acid, tartrates, soft drinks etc. The pulp is made into preserve and syrup. 'Jugo' or 'Fresco' de Tamarindo is a favourite beverage in many Latin American countries. The pulp is also used as an auxiliary in dying and tanning and for polishing and cleaning metal ware. The pulp of the fruit is used extensively in the local confectionery industry in several developing countries. The pulp has been used in the Indian system of medicine as a refrigerant, carminative and laxative. The pulp is used as an antiscorbutic (The Wealth of India 1976; Lewis and Neelakantan 1964; Duke 1981).

Seed : Tamarind seeds have many uses. They are used as feeds for cattle and pigs, as a valuable remedy in diarrhoea and dysentry, as a base in cosmetics, in the pharmaceutical industry, as a curative against rheumatism and as a soil stabilizer (Anon 1955). The major industrial use, however, is in the form of tamarind kernel powder (TKP), as a sizing material in the textile and jute industries. By using 10% TKP as a binder, saw dust fuel briquettes can also be made. The polysaccharide (jellose) is a good substitute for fruit pectins in the manufacture of jams, jellies and marmalades. The polysaccharide of TKP is perhaps the most important constituent for industrial application. High grade adhesives can be prepared from tamarind seed kernel (The Wealth of India 1976). Bhattacharya et al (1983) have reported the use of TKP (particularly its carbohydrate fraction) in developing food products such as jelly and marmalades. Rao and Subramanian (1984) and Marangoni et al (1988) have attempted production of protein concentrates or meals and studied the functional properties of the kernel proteins.

The presence of tannins and other colouring matter in the testa makes the whole seed unsuitable for human consumption. The kernels are separated from the testa either by roasting or by soaking in water. The testa has to be completely removed before using the kernels for food purposes. Otherwise, some side effects such as depression, constipation and gastro-intestinal inflammation might result (The Wealth of India 1976).

The seed kernels have been used as food in times of scarcity either alone or mixed with cereal flours. The kernels are boiled or fried before they are eaten. They are sometimes dried and ground into flour for making pancakes or *chappatis* usually after admixture with other cereal flours. Certain hill tribes eat kernels mixed with flowers of mahua (*Madhuca latifolia*) (The Wealth of India 1976). A fish paste product is produced by grinding raw fish meat with a fraction of tamarind seed (Japanese patent 1968).

Research findings have shown that the seeds of tamarind contain high levels of methionine and cysteine, making them a good source for supplementation for other legume seeds, which are limiting in these essential amino acids (Lumen et al. 1986; Marangoni 1988). As the seeds contain recommended levels of all essential amino acids except threonine and tryptophan and do not have significant levels of antinutritional factors, they may be adopted as cheap, alternative protein source (Siddaraju et al. 1996). The tamarind seed polysaccharide is neither toxic nor carcinogenic to mice (Sano et al. 1996).

Other uses : The tender leaves, flowers and young seedlings are eaten as vegetables. The tender fruits are made into pickles, pastes and *chutneys*. The leaves yield reddish yellow dye, reported to be used locally in colouring woollen and silk fabrics. The bark contains about 7% tannins and is reported to be used in tanning industry. The diuretic properties of the leaf sap is well established. The seed testa is said to be astringent and is used in diarrhoea and dysentery. It is useful in the preparation of tannin, antioxidants, colouring matter etc. The oil of tamarind seed kernels is reported to be useful in the preparation of paints and varnishes and for burning in lamps (The Wealth of India 1976; Lewis and Neelakantan 1964; Duke 1981).

Tamarind-related patents : Eight patents were issued in India from 1974 to 1990 and four patent applications were filed in the last two years. In fact, most of the granted patents stand expired today. These eight patents relate to the preparation of TKP, use of TKP as sizing agent, as tannin material, preparation of gum, preparation of juice and health care application. The subject of the four applications concerns food items except one, which relates to recovery of tartaric acid. No patent or patent application directly aims at recovering polysaccharide

TABLE 11. PATENTS ON PROCESSES, PRODUCTS AND USES OF TAMARIND

Patents granted/ Application field	Assignee/ Applicant	Year
Patents granted (India)		
Method of preparation of tamarind powder	Chakrapani S and Chakrapani J	1974
A new process for the preparation of TKP	CSIR	1974
A simple process for obtaining a good tanning material from tamarind seed testa	CSIR	1978
Purification of tamarind gum by air classification	General Mills Chemicals Inc.	1979
An enzymatic process for the preparation of tamarind juice concentrate	CSIR	1985
Patents application filed (India)		
Process for making tamarind pickles	Dilip Shantharam Dahanukar	1995
A process for preparing tamarind extract in the form of paste/jam	Shoki Kobayashi	1996
A manufacturing process for tamarind paste and concentrate	Yelantinaga	1996
A new process for recovery of tataric acid and other products from tamarind pulp	CSIR	1996
Patents granted (USPTO)		
Purification of tamarind gum	General Mills Chemicals Inc., USA	1978
Use of TKP as an anti-migrant	Merck & Co. Inc., USA	1982
Clarified tamarind kernel powder	Merck & Co. Inc., USA	1984
Process for separating polysaccharides from tamarind seeds	Shikibo Ltd., Japan	1990
Method for preparing tamarind oligosaccharides	Lafayette Applied Chemistry Inc., USA	1995
Beverages using tamarind extract and methods of making such beverages	Nutra Sweet Co., USA	1995

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from the TKP or seeds and the application in health is also negligible. Thirty patents have been granted by the US Patent and Trade Mark Office (USPTO) between 1978 and 1997. Merck and Co owns eight of thirty patents issued by the USPTO and its focus has been mainly on the utilization of TKP as a gum and binding agent.

The patents scenario tends to support the production of value-added products from tamarind. It may be appreciated that increased number of tamarind-related patents indicate the possibility of using tamarind products in more number of ways than known hither to. It is difficult to include all the patents on tamarind fruit and its derivatives or products in the text. However, some of the important patents with respect to food science and technology are listed in Table 11.

Conclusions

Harvesting tamarind fruits from the trees is a laborious and time consuming job. The problems of mechanization of harvesting and primary processing of the fruits require urgent attention by scientists and technologists. Destruction of fruits by insects and fungi is a serious problem in storage and field, respectively. The brown red colour of the pulp starts deteriorating and becomes black in about a year. Therefore, proper processing and storage is essential. There is a need to find out better uses for the tamarind pulp and seeds, which are produced in large quantities in India. Storing the prepared pulp in air-tight containers in cool and dry places helps a lot in preserving its quality for a long time. The main acid present in the fruit pulp is tartaric acid and it has no nutritive value, but has taste value. The chief use for the seeds is in the manufacture of sizing powders, which are widely used in sizing jute and cotton yarns. Although many medicinal values are claimed for various preparations from the fruit, leaf, flower, bark etc. of tamarind tree, only the antiscorbutic properties of the pulp, laxative action of the fruit juice and diuretic properties of the leaf sap are well established.

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Improvement in the Quality of Frozen Ground Buffalo Meat by Pre-blending with Natural Antioxidants and Vacuum Packaging

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Pre-blended ground buffalo meat samples with 500 ppm sodium ascorbate, 10 ppm alpha-tocopherol acetate and 0.5% sodium tripolyphosphate were vacuum-packaged and stored at -18°C for 90 days. It was observed that the pre-blended samples had significantly ($P<0.05$) greater pH, WHC, salt extractable proteins, better sensory scores for meat colour and odour, higher LTCU-R, chroma and lower metmyoglobin content, TBARS number, tyrosine values as compared to control ones. Vacuum-packaged samples had slightly higher amounts of salt extractable proteins, colour and odour scores, LCTU-R, chroma and lower amounts of metmyoglobin, TBARS number. Treatment did not cause noticeable difference in the growth of various microorganisms present in the meat. Meat quality had decreased as the storage period increased. Significant correlations were observed among quality parameters. Pre-blending and vacuum-packaging extended the shelf-life of ground buffalo meat from 45 to 90 days under frozen storage at -18°C.

Keywords : Sodium ascorbate, Alpha-tocopherol acetate, Sodium tripolyphosphate, Vaccum packaging, Ground buffalo meat, Frozen storage.

Buffalo meat has gained importance in recent years, because of domestic need and its export potential. It contributes about 85% of total meat export from India. In India, buffalo meat is mainly produced from old and unproductive animal and so it is coarse and tough. Such tough meat can be profitably utilized for the production of a variety of convenience and value-added meat products (Kondaiah et al. 1988; Sahoo 1989; Anjaneyulu et al. 1990). But, grinding of meat leads to rapid formation of metmyoglobin and increases oxidative rancidity, thereby decreasing colour, odour and shelf life besides, causing accumulation of lipid peroxidation products, which are injurious to health. In recent years, there is no consumer demand of chemical antioxidants in fresh meat. It has been reported that pigment and lipid stability in ground beef could be improved by using vitamins C and E (Mitsumoto et al. 1991).

Use of vacuum-packaging to increase shelf life and to maintain quality of muscle foods has recently been reviewed (Sahoo and Anjaneyulu 1995). During frozen storage of meat, vacuum-packaging is most protective for various characters, viz., TBA value, visual colour, metmyoglobin, Hunter 'a' value etc. (Brewer and Wu 1993).

Information to extend shelf life of buffalo meat during frozen storage is scanty. The objective of the present study was to improve the quality of pre-blended ground buffalo meat under vacuum-packaging with natural antioxidants under frozen storage condition.

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Materials and Methods

Meat samples : The deboned meat chunks from round position of spent adult female 'Murrah' buffalo carcasses slaughtered according to traditional halal method at a buffalo slaughter house of Bareilly Municipal Corporation were collected, packed in low density polyethylene (LDPE) bags and conditioned for about 24 h at 4±1°C in the laboratory of Livestock Products Technology Division, Indian Veterinary Research Institute, Izatnagar.

Sample preparation : The meat chunks after conditioning were trimmed off separable fat and loose connective tissue, cut into small cubes and minced with Seydelmann meat grinder (Model WD 114, Germany), using 8 mm (coarse) and 3 mm (fine) plate simultaneously to obtain ground buffalo meat (GBM). Half of the 6.4 kg GBM was blended for a minute with freshly prepared 500 ppm sodium ascorbate, 10 ppm alpha-tocopherol acetate and 0.5% sodium tripolyphosphate in Hobart food mixer (Model N-50) and the remaining half was used as control without any additive. Aliquots of 200 g each were prepared for each experimental group, i.e. control aerobic-packaged (CAP), control vacuum-packaged (CVP), treated aerobic-packaged (TAP) and treated vacuum-packaged (TVP), using polyester/cast polypropylene (10/65) laminated plastic

bags procured from FLEX Industries, NOIDA, UP, India. The samples were kept at -18°C for 105 days.

Analytical methods : The quality of the meat samples was examined at frequent intervals of the storage period. The pH was determined by dipping combined glass electrode of a digital pH meter (Century, model CP 901) into the meat suspension (Trout et al. 1992) and water holding capacity (WHC) by centrifugation method (Wardlaw et al. 1973). Salt extractable protein (SEP) contents of the meat samples were determined by extracting with 0.6 M NaCl, centrifuging at 5500 rpm for 15 min and estimating the protein content of the supernatant fluid by Biuret method (Knipe et al. 1985). Total meat pigments and metmyoglobin per cent of the meat samples were estimated as per Arganosa and Henrickson (1969) and Trout (1989), respectively. Sensoy scores for meat colour and odour were determined by using a 5-point scale (Krishna 1988). Lovibond tintometer red colour units (LTCU 'R') and yellow colour units (LTCU 'Y') were recorded using a Lovibond tintometer (Model E,UK). The sample colour was matched by adjusting red (a) and yellow (b) units, while keeping the blue units fixed at 1.0. Hue and Chroma of meat were determined by using the formula $(\tan^{-1})^{b/a}$ and (a^2+b^2), respectively, where a=red units and b= yellow units (Little 1975; Froehlich et al. 1983). The distillation method described by Tarladgis et al (1960) was followed to know 2-thiobarbituric acid reacting substances (TBARS) number of the meat. For estimation of tyrosine value, the procedure laid down by Strange et al (1977) was followed.

Sodium dodecylsulphate polyacrylamide gel electrophoresis (SDS-PAGE) : Sample extract (Ishikawa et al. 1987) of GBM from semi-tendinosus muscle after 1 and 2 months frozen storage was subjected to SDS-PAGE (Laemmli 1970) with slight modification, using 1 mm slab gel in Genie electrophorrsis equipment.

Microbiological parameters : Enumeration of colony forming units belonging to various groups of microorganisms viz., aerobic mesophiles (AMC), psychrotrophs (PPC), total coliforms (TAC), *Staphylococcus aureus* (SAC), lactobacilli (LAC), total anaerobes (TAC), yeast and mould (YMC) was done, following the methods of APHA (1984) by using Hi-Media bacteriological culture such as plate count agar, violet red bile glucose agar (VRBGA), Baird-Parker agar, MRS agar, anaerobic agar, potato dextrose agar, respectively.

Statistical analysis : Three replications of the experiment were done. Observed data upto 90 days storage were statistically analysed, using randomized block design. The data were subjected to analysis of variance (Snedecor and Cochran 1994) and Duncan's new multiple range test (Steel and Torrie 1981) and correlation coefficients (r-value) between different quality parameters. Regression line was drawn to predict correlation of metmyoglobin per cent and TBARS number with the help of a statistical software package MICROSTAT.

Results and Discussion

pH, water holding capacity and salt extractable proteins : The pre-blended meat samples (TAP and TVP) showed significantly higher ($P<0.05$) pH, WHC % and SEP%, as compared to control batches (CAP and CVP) (Table 1). Increasing of meat pH by phosphate pre-blending during frozen storage was also reported by Knipe et al (1985) and Verma et al (1985). Vacuum-packaging did not influence significantly the above parameters. During the storage period, pH of meat did not show any significant change. Water holding capacity (WHC) behaved inconsistently upto 75 days, but significantly ($P<0.05$) decreased at 90 days. Anjaneyulu (1988) also concluded that WHC of buffalo meat did not change significantly upto 75 days of frozen storage. Salt extractable proteins remained unchanged upto 45 days and thereafter, it was found to decrease insignificantly. Water holding capacity in the present study had positive correlation ($r=0.80$) with pH and SEP with pH and WHC.

Visual and instrumental colour : Pre-blending of buffalo meat (TAP and TVP) resulted in significantly higher colour score, Lovibond tintometer red colour units (LTCU 'R') and chroma than the control (CAP and CVP) samples (Table 2). Vacuum-packaging was found to increase colour score, LTCU "R" and chroma both in control and treated samples with more significant change in control groups. The highest value for the above parameters was found in TVP meat whereas, the lowest quality was observed in CAP batch. There were no significant differences of hue among CVP, TAP and TVP meats, However, it was significantly higher in CAP meat. Chroma, the intensity of meat colour was lowest (10.02) in CAP and highest (13.35) in TVP samples. However, no difference of chroma was observed between TAP and TVP batches. LTCU 'R' and chroma remained almost unchanged throughout the storage period. Though colour score significantly decreased during the storage period as compared to 0 day, it was well acceptable even upto

TABLE 1. EFFECT OF PRE-BLENDING AND VACUUM-PACKAGING ON PHYSICO-CHEMICAL PROPERTIES OF GROUND BUFFALO MEAT DURING FROZEN STORAGE (-18°C)

Treatments (n=3)	Storage period, days							Treatment mean ±SE (n=21)
	0	15	30	45	60	75	90	
				pH				
Control aerobic-packaged	5.59	5.60	5.61	5.64	5.57	5.68	5.68	5.62^{b} ± 0.09
Control vacuum-packaged	5.62	5.61	5.62	5.59	5.56	5.68	5.69	5.62^{b} ± 0.10
Treated aerobic-packaged	5.96	5.91	5.91	5.96	5.98	5.92	5.94	5.94^{a} ± 0.10
Treated vacuum-packaged	5.99	5.95	5.96	5.98	5.99	5.89	5.94	5.96^{a} ± 0.10
Day mean ± SE	5.79	5.77	5.78	5.79	5.77	5.79	5.81	
	± 0.23	± 0.18	± 0.19	± 0.20	± 0.24	± 0.16	± 0.15	
				Water holding capacity, ml/100 g				
Control aerobic-packaged	24.17	15.83	27.92	22.50	16.67	25.83	11.67	20.65^{b} ± 7.28
Control vacuum-packaged	22.50	16.67	27.08	20.42	20.83	25.42	12.50	20.77^{b} ± 7.46
Treated aerobic-packaged	45.00	33.33	40.42	36.67	30.83	32.50	26.67	35.06^{a} ± 9.26
Treated vacuum-packaged	43.33	34.17	40.00	35.83	30.00	29.58	31.67	34.94^{a} ± 8.68
Day mean ± SE	33.75^{a}	25.00^{bcd}	33.85^{a}	28.85^{ab}	24.58^{bcd}	28.33^{ac}	20.63^{d}	
	± 12.1	± 10.34	± 11.61	± 10.16	± 8.45	± 8.26	± 9.60	
				Salt extractable proteins, %				
Control aerobic-packaged	6.07	6.94	8.14	7.65	6.70	6.97	6.61	7.01^{b} ± 0.88
Control vacuum-packaged	5.65	7.01	8.63	7.99	7.24	7.63	7.73	7.41^{b} ± 1.11
Treated aerobic-packaged	6.05	9.67	9.35	9.17	7.76	8.22	8.05	8.32^{a} ± 1.46
Treated vacuum-packaged	6.42	9.77	9.48	9.01	7.84	8.61	8.90	8.58^{a} ± 1.47
Day mean ± SE	6.05^{d}	8.35^{ab}	8.90^{a}	8.45^{ab}	7.39^{c}	7.86^{bc}	7.82^{bc}	
	± 0.96	± 1.69	± 0.89	± 1.40	± 0.90	± 0.79	± 1.01	
				TBARS number, mg malonaldehyde/kg meat				
Control aerobic-packaged	0.33	0.40	0.46	0.47	0.52	0.41	0.44	0.43^{a} ± 0.11
Control vacuum-packaged	0.30	0.36	0.43	0.41	0.37	0.34	0.42	0.38^{a} ± 0.10
Treated aerobic-packaged	0.29	0.29	0.31	0.30	0.21	0.25	0.27	0.28^{b} ± 0.09
Treated vacuum-packaged	0.26	0.23	0.23	0.24	0.19	0.22	0.22	0.23^{b} ± 0.07
Day mean ± SE	0.30	0.32	0.36	0.35	0.32	0.31	0.34	
	± 0.17	± 0.14	± 0.11	± 0.11	± 0.15	± 0.09	± 0.11	
				Tyrosine value, mg/g				
Control aerobic-packaged	0.38	0.35	0.41	0.47	0.53	0.47	0.49	0.44^{b} ± 0.09
Control vacuum-packaged	0.39	0.33	0.50	0.49	0.55	0.47	0.48	0.46^{b} ± 0.09
Treated aerobic-packaged	0.41	0.43	0.54	0.55	0.59	0.56	0.55	0.52^{a} ± 0.10
Treated vacuum-packaged	0.43	0.43	0.54	0.53	0.62	0.56	0.55	0.52^{a} ± 0.10
Day mean ± SE	0.41^{b}	0.38^{b}	0.50^{a}	0.51^{a}	0.57^{a}	0.52^{a}	0.52^{a}	
	± 0.07	± 0.10	± 0.11	± 0.06	± 0.05	± 0.10	± 0.06	

SE = Standard error ; $^{a-d}$ Means with different superscripts in a row or column are different ($P<0.05$)

90 days of storage. Furthermore, treated samples showed more visual appeal. Brewer and Wu (1993) also found vacuum-packaging of meat to be the most protective for visual colour, colour acceptability, Hunder 'a' value etc. during frozen storage. In the present study, visual colour of meat positively correlated with LTCU 'R' (r=0.62) and negatively with metmyoglobin (r=-0.01).

Total meat pigments and metmyoglobin per cent: There were no significant differences among CVP, TAP and TVP samples in respect of total meat pigments (TMP) per cent. However, the pre-blended samples showed significantly higher TMP % as compared to CAP batch (Table 3). Vacuum-packaging did not affect the TMP % of GBM in both control and pre-blended samples. During the frozen storage period, no significant change in the content of TMP was observed. The pre-blended samples had significantly lower metmyoglobin (MMb) than the CAP meat. TVP batch showed minimum pigment oxidation problem. Vacuum-packaging decreased MMb contents both in control and treated samples. Lowering of MMb content in the pre-blended GBM was due to the antioxidant effect of the additives

TABLE 2. EFFECT OF PRE-BLENDING AND VACUUM-PACKAGING ON ODOUR AND COLOUR CHARACTERISTICS OF GROUND BUFFALO MEAT DURING FROZEN STORAGE (-18°C)

Treatments (n=3)	Storage period, days							Treatment mean ±SE (n=21)
	0	15	30	45	60	75	90	
Odour score, 5 pt								
Control aerobic-packaged	4.80	4.03	3.63	2.77	2.40	2.40	2.17	$3.17^{b} \pm 1.02$
Control vacuum-packaged	4.80	4.40	4.07	3.13	2.60	2.57	2.43	$3.43^{b} \pm 1.01$
Treated aerobic-packaged	4.87	4.57	4.47	3.80	3.60	3.30	2.97	$3.94^{a} \pm 0.75$
Treated vacuum-packaged	4.93	4.70	4.50	4.03	3.77	3.53	3.20	$4.10^{a} \pm 0.71$
Day mean ± SE	4.85^{a}	4.43^{b}	4.17^{b}	3.43^{c}	3.09^{cd}	2.95^{de}	2.69^{e}	
	± 0.09	± 0.37	± 0.58	± 0.66	± 0.73	± 0.67	± 0.61	
Colour score, 5 pt								
Control aerobic-packaged	4.73	3.87	3.80	3.03	2.97	3.03	2.60	$3.43^{c} \pm 0.76$
Control vacuum-packaged	4.63	4.10	4.20	3.67	3.10	3.33	2.83	$3.70^{b} \pm 0.70$
Treated aerobic-packaged	4.90	4.57	4.50	4.13	3.97	4.00	3.43	$4.21^{a} \pm 0.52$
Treated vacuum-packaged	4.80	4.67	4.53	4.33	4.13	4.00	3.73	$4.31^{a} \pm 0.41$
Day mean ± SE	4.77^{a}	4.30^{b}	4.26^{b}	3.79^{c}	3.54^{c}	3.59^{c}	3.15^{d}	
	± 0.12	± 0.45	± 0.39	± 0.76	± 0.58	± 0.47	± 0.50	
Lovibond tintometer colour units, Red								
Control aerobic-packaged	9.97	10.10	8.90	8.23	7.17	7.57	5.90	$8.26^{c} \pm 1.88$
Control vacuum-packaged	10.00	10.33	9.07	10.10	10.00	10.10	10.07	$9.96^{b} \pm 1.31$
Treated aerobic-packaged	10.10	10.90	11.50	11.47	10.97	11.43	10.93	$11.04^{a} \pm 1.29$
Treated vacuum-packaged	10.33	11.57	12.30	12.97	11.37	11.03	11.83	$11.63^{a} \pm 1.11$
Day mean ± SE	10.10	10.73	10.44	10.69	9.88	10.04	9.68	
	± 0.47	± 1.44	± 1.74	± 2.28	± 1.97	± 2.28	± 2.58	
Lovibond tintometer colour units, Yellow								
Control aerobic-packaged	6.67	5.77	6.10	5.60	5.00	5.80	4.57	5.64 ± 1.23
Control vacuum-packaged	6.50	5.60	6.03	5.53	6.63	6.30	6.17	6.11 ± 1.02
Treated aerobic-packaged	6.27	5.73	6.13	6.03	6.73	7.07	6.87	6.40 ± 0.98
Treated vacuum-packaged	6.50	5.73	6.03	6.57	6.60	7.10	7.03	6.51 ± 0.91
Day mean ± SE	6.48	5.71	6.08	5.93	6.24	6.57	6.16	
	± 1.37	± 1.05	± 0.82	± 0.85	± 0.93	± 0.86	± 1.48	
Hue								
Control aerobic-packaged	33.38	29.49	34.52	33.91	34.93	37.65	37.77	$34.52^{a} \pm 0.85$
Control vacuum-packaged	32.70	28.31	33.61	29.28	33.48	31.95	31.18	$31.50^{b} \pm 0.79$
Treated aerobic-packaged	31.38	27.50	28.01	27.96	31.58	32.41	32.08	$30.13^{b} \pm 0.87$
Treated vacuum-packaged	31.96	26.28	26.01	26.91	30.30	32.84	30.59	$29.27^{b} \pm 0.85$
Day mean ± SE	32.35^{ab}	27.90^{c}	30.53^{abc}	29.51^{bc}	32.57^{a}	33.71^{a}	32.90^{a}	
	± 1.35	± 0.66	± 1.43	± 1.30	± 0.75	± 1.06	± 1.20	
Chroma								
Control aerobic-packaged	12.03	11.63	10.80	9.97	8.74	9.53	7.46	$10.02^{c} \pm 0.46$
Control vacuum-packaged	11.95	11.75	10.92	11.54	12.00	11.93	11.82	$11.70^{b} \pm 0.32$
Treated aerobic-packaged	11.93	12.33	13.04	12.97	12.86	13.48	12.93	$12.79^{b} \pm 0.29$
Treated vacuum-packaged	12.24	12.91	13.71	14.55	13.15	13.13	13.78	$13.35^{a} \pm 0.24$
Day mean ± SE	12.03	12.15	12.12	12.26	11.69	12.02	11.50	
	± 0.30	± 0.49	± 0.46	± 0.64	± 0.61	± 0.66	± 0.82	

SE = Standard error ; $^{a-d}$ Means with different superscripts in a row or column are different ($P<0.05$)

used. Mitsumoto et al (1991) also found that vitamins C and E minimized pigment oxidation in ground beef. Emphasizing the advantages of anaerobic storage under vacuum, N_2 or CO_2, Echevarne et al (1990) also observed that the metmyoglobin contents of bovine muscles fell to minimum as the storage period prolonged. MMb contents of meat samples in the present study did not show significant change upto 30 days of frozen storage, but thereafter, it increased.

TABLE 3. EFFECT OF PRE-BLENDING AND VACUUM-PACKAGING ON TOTAL MEAT PIGMENTS AND METMYOGLOBIN CONTENT OF GROUND BUFFALO MEAT DURING FROZEN STORAGE (-18°C)

Treatments (n=3)	Storage period, days							Treatment mean ±SE
	0	15	30	45	60	75	90	(n=21)
				Total meat pigments, %				
Control aerobic-packaged	0.29	0.29	0.29	0.31	0.30	0.28	0.35	0.30^{b} ± 0.04
Control vacuum-packaged	0.29	0.29	0.31	0.31	0.30	0.29	0.37	0.31^{ab} ± 0.05
Treated aerobic-packaged	0.31	0.32	0.36	0.34	0.32	0.33	0.35	0.33^{a} ± 0.04
Treated vacuum-packaged	0.31	0.33	0.37	0.34	0.34	0.32	0.35	0.34^{a} ± 0.04
Day mean ± SE	0.30 ± 0.03	0.31 ± 0.03	0.33 ± 0.06	0.32 ± 0.03	0.31 ± 0.03	0.30 ± 0.03	0.35 ± 0.07	
				Metmyoglobin, %				
Control aerobic-packaged	52.03	53.89	58.87	61.27	63.53	66.66	69.06	60.76^{a} ± 7.56
Control vacuum-packaged	53.77	52.41	55.50	58.00	62.10	63.52	65.37	58.67^{ab} ± 6.07
Treated aerobic-packaged	57.77	53.83	56.70	57.63	56.30	58.46	59.57	56.88^{bc} ± 3.57
Treated vacuum-packaged	52.03	50.83	54.00	55.53	54.83	56.41	58.65	54.61^{b} ± 4.30
Day mean ± SE	53.38^{d} ± 5.58	52.74^{d} ± 3.43	56.27^{cd} ± 3.80	58.11^{bc} ± 3.84	59.19^{bc} ± 5.25	61.26^{ab} ± 5.90	63.16^{a} ± 5.81	

SE = Standard error ; $^{a-d}$ Means with different superscripts in a row or column are different (P<0.05)

Odour score, TBARS number and tyrosine value: Both the treated aerobic and vacuum-packaged (TAP and TVP) samples showed significantly (P<0.05) higher odour score and tyrosine value and lower TBARS number as compared to control batches (CAP and CVP), but no significant difference was obtained either between TAP and TVP or between CAP and CVP samples (Tables 1 and 2). Vacuum-packaging could maintain the desirable odour of meat for 15 days more, when compared to aerobic packaged samples. Vacuum-packaging also maintained consistently lower TBARS number of meat samples during the storage period. The desirable meat odour significantly decreased, as the storage period increased. Barring the treatments, the storage day means of TBARS number showed no significant difference even at the end of 90 days

TABLE 4. CORRELATION COEFFICEINT (r-VALUE) OF pH, WHC, COLOUR, METMYOGLOBIN AND ODOUR WITH DIFFERENT QUALITY CHARACTERS OF PRE-BLENDED VACUUM-PACKAGED GROUND BUFFALO MEAT DURING FROZEN STORAGE (-18°C)

Characters	pH	Water holding capacity	Colour score	Metmyo-globin	Odour score
Water holding capacity	0.80**	-	-	-	-
Salt extractable proteins	0.50**	0.41*	-	-	-
Colour score	0.49**	-	-	-	-
Lovibond tintometer colour units (Red)	0.61**	-	0.62**	-	-
Lovibond tintometer colour units (Yellow)	0.45**	-	0.35	-	-
Metmyoglobin	-0.35	-	-0.91**	-	-
Odour score	0.36*	-	00.96**	-	-
TBARS number	-	-	-	0.55**	-0.49**
Aerobic mesophiles count	0.25	-	0.36	-	0.31
Psychrotrophs plate count	0.12	-	-	-	-
Lactobacillus count	0.40*	-	0.23	-	0.08
Total anerobes count	0.47**	-	-	-	-0.17

* P<0.05 ** P<0.01

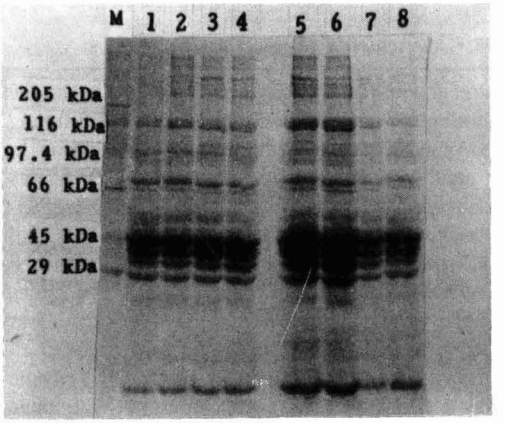

Fig. 1. SDS-PAGE of pre-blended vacuum-packaged ground buffalo semi-tendinosus muscle during frozen storage
M=molecular marker protein, Lane 1, 2, 3, 4= 30th day
Lane 5, 6, 7, 8 = 60th day
Control aerobic-packaged = Lane 1, 5
Control vacuum-packaged = Lane 2, 6
Treated aerobic-packaged = Lane 3, 7
Treated vacuum-packaged = Lane 4, 8

TABLE 5. EFFECT OF PRE-BLENDING AND VACUUM-PACKAGING ON THE MICROBIOLOGICAL QUALITY OF GROUND BUFFALO MEAT DURING FROZEN STORAGE (-18°C)

Treatments (n=3)	Storage period, days							Treatment mean ±SE (n=21)
	0	15	30	45	60	75	90	
	Aerobic mesophiles count, log_{10}/g							
Control aerobic-packaged	4.69	4.47	4.70	4.76	4.55	4.42	4.36	4.56 ± 0.66
Control vacuum-packaged	4.57	4.43	4.69	4.74	4.62	4.43	4.42	4.56 ± 0.56
Treated aerobic-packaged	4.59	4.49	4.86	4.74	4.66	4.38	4.49	4.60 ± 0.70
Treated vacuum-packaged	4.59	4.49	4.77	4.84	4.83	4.58	4.69	4.68 ± 0.65
Day mean ± SE	4.61	4.47	4.75	4.77	4.67	4.45	4.49	
	± 0.13	± 0.54	± 0.46	± 0.68	± 0.73	± 0.90	± 0.79	
	Psychrotrophs plate count, log_{10}/g							
Control aerobic-packaged	4.29	3.45	3.73	3.74	3.71	3.51	3.61	3.72 ± 1.17
Control vacuum-packaged	4.31	3.39	3.69	3.68	3.63	3.53	3.73	3.71 ± 1.11
Treated aerobic-packaged	4.30	3.21	3.93	3.89	3.87	3.63	4.13	3.85 ± 1.19
Treated vacuum-packaged	4.34	3.17	3.61	3.60	3.64	3.75	3.96	3.73 ± 1.19
Day mean ± SE	4.31	3.30	3.74	3.73	3.71	3.61	3.86	
	± 0.67	± 0.79	± 0.92	± 1.15	± 1.38	± 1.43	± 1.45	
	***Lactobacillus* count, log_{10}/g**							
Control aerobic-packaged	4.60	4.01	4.29	4.42	4.12	4.30	4.27	4.29 ± 0.84
Control vacuum-packaged	4.52	4.07	4.45	4.43	4.53	4.45	4.38	4.40 ± 0.82
Treated aerobic-packaged	4.51	4.19	4.51	4.57	4.74	4.82	4.46	4.54 ± 0.88
Treated vacuum-packaged	4.66	4.07	4.51	4.46	4.52	4.73	4.36	4.47 ± 0.86
Day mean ± SE	4.57	4.08	4.44	4.47	4.48	4.57	4.37	
	± 0.72	± 0.66	± 0.64	± 0.82	± 0.82	± 0.08	± 1.12	
	Total anaerobes count, log_{10}/g							
Control aerobic packaged	4.29	4.13	4.21	4.30	4.18	4.32	4.23	4.24 ± 0.66
Control vacuum packaged	4.25	4.16	4.32	4.62	4.38	4.43	4.46	4.37 ± 0.71
Treated aerobic packaged	4.35	4.34	4.34	4.73	4.44	4.41	4.48	4.44 ± 0.68
Treated vacuum packaged	4.23	4.28	4.37	4.71	4.48	4.61	4.73	4.49 ± 0.66
Day mean ± SE	4.28	4.23	4.31	4.59	4.37	4.44	4.47	
	± 0.80	± 0.21	± 0.36	± 0.41	± 0.70	± 0.96	± 0.96	

SE = Standard error

storage and the TBARS number was far below the minimum detectable levels (0.6 to 2.0 mg malonaldehyde/kg meat) for oxidized flavour in ground beef (Greene and Cumuze 1982). It was also observed that TBARS number was significantly correlated with MMb content (r=0.55) and odour score (r=-0.49) of meat samples. Further, a regression equation, Y=-0.297±0.011 X was established, where X=MMb% and Y= TBARS number (Table 4). Similar findings were also reported in ground veal by Faustman et al (1992). Tyrosine value (TV) increased significantly upto 30 days storage, but remained unchanged thereafter till the end of 90 days. It was comparable with the findings of Daly et al (1976), who reported that the TVs of minced beef were in the range of 0.26 to 0.85 mg/g meat. In the present study, pre-blended samples showed significantly higher TVs as compared to control batch. This might be due to availability of more salt extractable proteins for proteolysis in the former samples.

Sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-Page): The meat samples at 1 and 2 months of frozen storage were evaluated for changes in the protein profiles (Fig.1). No considerable change in the meat proteins of mol. wt. range 116-205 kDa and above was observed during 2 months of frozen storage. Some degradation in the protein molecules (66-97.4 kDa) occurred in the control samples of 2 months storage, when compared to 1 month sample. There was no marked change in the proteins of 29-45 kDa in different samples. All the samples at 2 months storage showed higher concentration of proteins in the molecular weight range of 45-66 kDa and less than 29 kDa. This showed that protein molecules could not sustain their molecular integrity *in toto* even in frozen storage temperature of -18°C. Further, pre-blending of meat

with the additives used were beneficial to some extent in maintaining protein quality.

Microbiological quality : The microbial loads at the end of 90 days of storage in respect of AMC, PPC and LAC (Table 5) were log 4.49, 3.86 and 4.37/g meat, which were lower than the initial load values of log 4.61, 4.31 and 4.57/g, respectively, indicating that some organisms died due to the effect of freezing (Ingram 1951) and the surviving organisms remained in their lag phase (Jay 1986). On the other hand, total anaerobes count of 3 months stored samples was log 4.47/g as compared to its initial load of log 4.28/g. It was due to increase in their number in the vacuum-packaged samples. A significant correlation of pH with LAC and TAC was observed.

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Microwave Blanching : Effect on Peroxidase Activity, Texture and Quality of Frozen Vegetables

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Carrot slices and French-fry style sweet potatoes were blanched for selected times (30-180 sec) in a microwave oven and a boiling water bath. Both blanched and unblanched samples were packaged and frozen-stored at -20°C. Samples were evaluated for peroxidase inactivation and texture degradation before and after blanching and after storage for 3.5 and 7 months. Microwave and thermal kinetics of peroxidase inactivation and texture softening were comparable and followed semi-logarithmic models. Larger size samples of both carrots and sweet potatoes indicated better inactivation of the enzyme, when heated in the microwave oven for mass-equivalent times. Although all frozen-stored samples, except those unblanched, were of acceptable quality at the end of the 7 month storage, samples blanched for intermediate periods were generally superior. Microwave-blanched samples were comparable to individually quick water-blanched samples, when the qualities of the frozen-stored samples were compared.

Keywords : Microwave, Blanching, Enzyme activity, Freezing, Vegetables, Carrots, Sweet potatoes.

In recent years, consumers have become increasingly conscious about the quality of foods, they consume. There has been a growing demand for minimally processed foods and the food industry for its part, has been focussing on technologies that offer potential for preserving the wholesomeness of foods. These minimal processes are generally based on low temperature processes such as freezing, which generally involves some prior mild heat-treatment such as blanching.

Blanching is a short heat treatment given to foods for inactivating naturally occurring oxidative enzymes such as catalase, peroxidase, polyphenol oxidase, lipoxygenase, etc., which would otherwise cause discoloration or off-flavour during frozen storage. Because of its thermal resistance, peroxidase is generally used as an indicator enzyme to determine the adequacy of blanching. Water and steam have been the most common commercial heating media for blanching of vegetables, although others such as hot air, flue gases and microwaves have also been studied as alternatives. The microwave blanching procedure has recently gained some recognition due to its rapid heating potential and possible additive non-thermal effects on enzyme inactivation (Henderson et al. 1975; Khalil and Villota 1988). Several studies on blanching, using microwaves either independently or in combination with steam/water heating have been reported (Collins and McCarty 1969; Dietrich et al. 1970; Huxsoll et al. 1970; Chen et al. 1971; Aref et al. 1972; Avisse and Varoquaux 1977). These studies generally show either a slight improvement or no difference in enzyme inactivation as well as colour and texture changes to be associated with microwave blanching, as compared with conventional steam or water blanching. Some studies suggest that microwave-blanched products do not have any positive effect on sensory quality (Glasscock et al. 1982; Gullet et al. 1984).

Traditionally, a blanching time to completely inactivate the peroxidase enzyme has been recommended to achieve good stability in the frozen products (Joslyn 1946). However, some studies have indicated that better quality frozen vegetables are obtained, when blanched to a residual peroxidase activity of 10-15% (Bottcher 1975 a,b; Ramaswamy and Ranganna 1989 a,b; Steinbuch 1991).

The objectives of this study were (1) to compare microwave and water blanching of vegetables (carrots and sweet potatoes) with respect to peroxidase inactivation and texture degradation and (2) to evaluate changes in peroxidase activity, texture and quality factors in blanched products, frozen-stored at -20°C for up to 7 months. Blanching times were chosen (30 to 180 sec depending on the sample size) to provide samples with varying residual peroxidase activities.

Materials and Methods

Sample preparation : Carrots and sweet potatoes were purchased from a local supermarket. Carrots were peeled and sliced (6 mm thick and 20 mm diameter). Sweet potatoes were peeled and cut in French-fries style (70 mm long, 8 mm wide and 8 mm thick). Three different sample sizes (50, 100 and 150 g) were used for microwave blanching,

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while water blanching was carried out only in 50 g batches.

Blanching : A household microwave oven (Eaton Electric Model EM-563 C:1 cubic foot, 700 W capacity; 2450 MHz) was used without a turn table. Samples were treated in a Pyrex dish, placed at the center of the oven. Full power heating was used for 30-60 sec with 50 g samples, 30-120 sec with 100 g samples and 30-180 sec with 150 g samples. Fifty gram samples of prepared carrots and sweet potatoes were also blanched for 30-180 sec in water in a kettle with water kept vigorously boiling, simulating conditions of individually quick blanching. Blanched samples were cooled immediately in running ice-cold water.

Sample temperatures were continuously monitored during both microwave and water blanching operations, using a Luxtron Model 1000A fluoroptic temperature sensor (Repron Scientific Instruments, Hamilton, ON). The probe was inserted into the microwave oven through a small hole drilled through the back of the oven.

Freezing and storage: Test samples blanched for various times in microwave as well as water were packaged in retort pouches (polyester/aluminium foil/polypropylene; A.C.F. Flexible Inc., Montreal; PQ), vacuum-sealed and frozen-stored at -20°C for 3.5 and 7 months. The unblanched samples of carrots and potatoes were also frozen-stored in a similar fashion for the same period of time for comparison.

Peroxidase activity : Peroxidase activity was evaluated before and after blanching, as well as after 3.5 and 7 months of frozen storage. A 50 g sample (fresh, blanched or frozen carrots or sweet potatoes) was blended at high speed in a 500 mL single speed Moulinex™ maxi-chopper with 200 ml of cold 2.0% NaCl solution. The mixture was strained through glass wool to remove coarse particles. Peroxidase activity was assayed within 30 min.

Peroxidase activity was estimated according to the AOAC titrimetric method (AOAC 1984), based on oxidation of ascorbic acid. The decrease in concentration of ascorbic acid, following a given reaction time, was determined by titration with indophenol and the activity was estimated, based on first order reaction rate kinetics. The logarithm of V_t/V_o (ratio of the volume of indophenol dye required at any given time, t, to that at time zero) was regressed against t and the reaction rate constant, k_1, was obtained as the negative slope. The activity was expressed as k_1/g of sample used.

Texture: Product texture was evaluated before and after blanching, and after 7 months of frozen storage. All frozen samples were thawed overnight in a refrigerator at 4°C. Texture was evaluated using an Instron Universal Testing machine calibrated to 10 kg full scale. A puncture probe (6 mm diameter) was used for carrots and a shear plate was used for sweet potatoes. The maximum force required to puncture carrots or shear potatoes was used to measure the sample texture. Observations on appearance, colour and flavour were noted and samples were qualitatively graded as good, fair or poor.

Results and Discussion

Blanching and peroxidase activity : Fig 1 shows typical first order plots for peroxidase activity in carrots and sweet potatoes before and after blanching. The steeper lines for sweet potatoes as compared with carrots and with unblanched samples as compared with blanched ones indicate their association with higher peroxidase activity. The activity on average was 0.32 k_1/g for unblanched carrots and 4.7 k_1/g for unblanched sweet potatoes. For the purpose of comparing the effect of blanching conditions, peroxidase activity for both carrots and sweet potatoes were expressed as

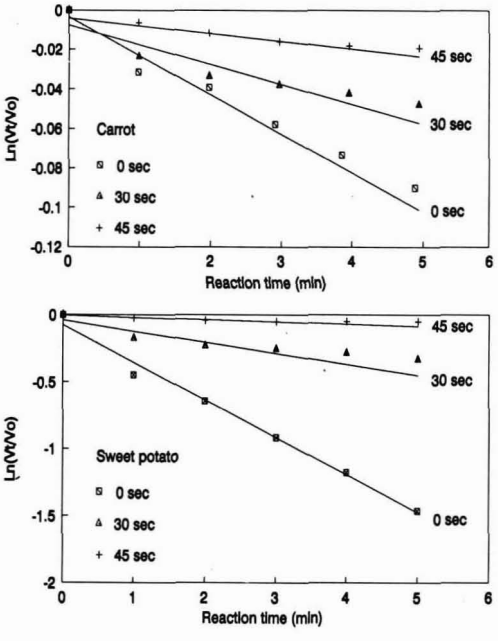

Fig 1. First order plots of peroxidase activity in carrots and sweet potatoes before and after microwave-blanching

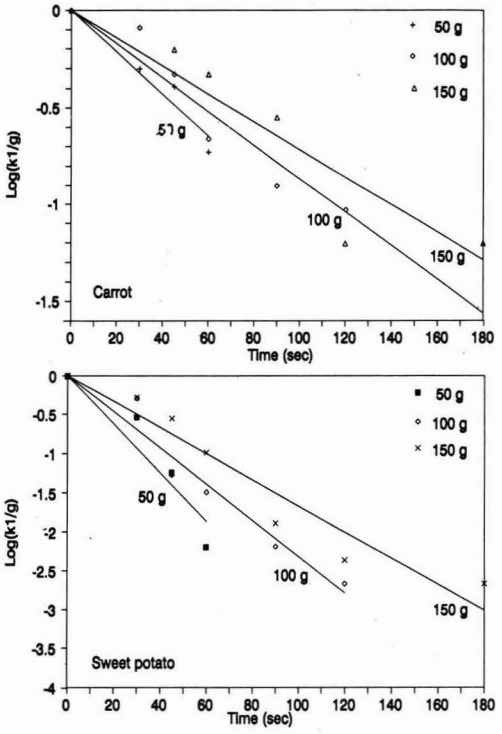

Fig 2. Residual peroxidase activity as a function of heating time for microwave-blanched carrots and sweet potatoes

residual activity, calculated as a fraction of the initial activity.

The residual peroxidase activities in carrots and sweet potatoes decreased logarithmically with heating time under both conventional and microwave blanching conditions (Fig 2). Enzyme inactivation under microwave blanching was faster for both carrots and sweet potatoes with the 50 g sample as compared with the 150 g sample. The decimal reduction time (time required to reduce the activity by 90% or one logarithmic cycle) under microwave heating conditions were approximately 90, 115 and 140 sec, respectively for the 50, 100 and 150 g samples. With sweet potatoes, the associated decimal reduction times were much smaller i.e., 30, 40 and 60 sec, respectively for the 50, 100 and 150 g samples. The decimal reduction times for water blanching were 110 sec for carrots and 50 sec for sweet potatoes. Consequently, water blanching curves were in between those for microwave blanching with 50 and 150 g samples, to the left of 100 g sample with carrots and to the right for sweet potatoes. Since decimal reduction times were not expected to depend on initial activity (Stumbo 1973), the higher stability of peroxidase in carrots and higher activity in sweet potatoes were considered to be product dependent.

The differences in D values observed above with respect to sample size during microwave blanching were not entirely expected. On one hand, since sample size was kept small (50-150 g), the heating rates were not expected to be limited by lack of availability of microwave energy. In which case, the D values should have been independent of the sample size, which was not true. On the other hand, the D values for samples of size 100 and 150 g should have been two and three times as high as that for the 50 g sample, because the absorbed microwave energy is proportional to the sample mass. Even this was not true. Additional tests revealed that while water loads $\geq$ 150 g almost fully absorbed the microwave energy, accounting for > 95% of the 700 W nominal power, test loads of 50 and 100 g resulted only in partial absorption of 50 and 85% of the total power. Time-temperature data from test samples also demonstrated similar results. Absorbed microwave energy to produce one decimal reduction in peroxidase activity (R) was calculated as $R=PE_mD/M$, where D is decimal reduction time in sec, P is the nominal microwave power in W, E is the mass related power absorption fraction (0.5 and 0.85 with samples of size 50 and 100 g, respectively, and 1.0 for samples of size 150g and higher) and M is the sample mass in kg. The calculated R value was 650 kJ/kg for carrots and 250 kJ/kg for sweet potatoes. Using this concept, D values for enzyme inactivation obtainable in a given microwave oven could be back-calculated, using the absorbed microwave power and sample size: D (sec)=RM/(PEm). In a 700 W microwave oven, the decimal reduction time for 200 g carrots will be 650 * 0.2/0.7 *1.0 or 185 sec, while for a 1000 g batch, it will be five times longer.

Temperatures in test samples under both microwave and water blanching conditions indicated that the enhanced enzyme inactivation associated with larger samples, as discussed above, could be related to higher product temperatures achieved in these samples under mass-equivalent heating conditions. Further analysis on peroxidase activity was, therefore, carried out with respect to sample temperatures achieved irrespective of the sample size.

Peroxidase activity in samples heated to various temperatures followed the Arrhenius-type relationship with the logarithm of residual activity being proportional to the reciprocal of absolute

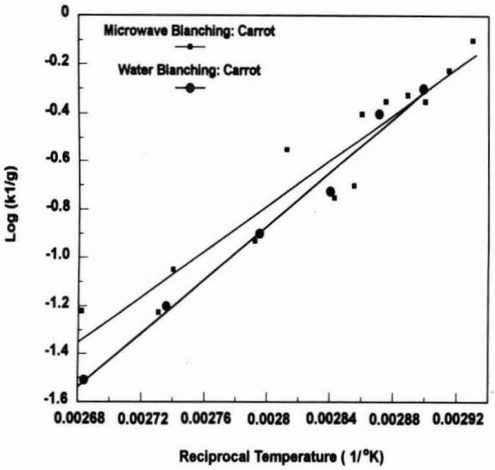

Fig 3. Arrhenius plots for peroxidase inactivation in microwave and water-blanched carrots

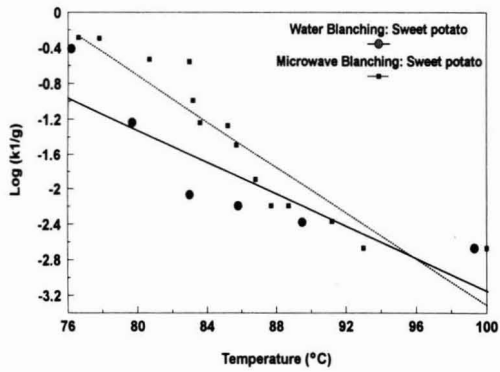

Fig 4. Thermal resistance curves for peroxidase in microwave and water-blanched sweet potatoes

temperature (Fig 3, shown only for carrots). The calculated activation energies (R^2=0.75-0.98) were 22 and 26 kcal/mole in microwave and water, respectively, for carrots and 56 and 52 kcal/mole, respectively, for sweet potatoes. Microwave and water blanching techniques were, therefore, considered comparable with respect to peroxidase inactivation. Residual peroxidase activity data gave an equally good fit with the traditional logarithmic order of inactivation (thermal resistance curve, Stumbo 1973) common to microorganisms (Fig 4, shown only for sweet potatoes). The calculated z values (temperature range which results in a ten-fold change in the activity; R^2=0.78-0.99) were 27 and 23°C in microwave and water, respectively for carrots and 10 and 11°C, for sweet potatoes. Again, the results showed similarities between microwave and water blanching techniques.

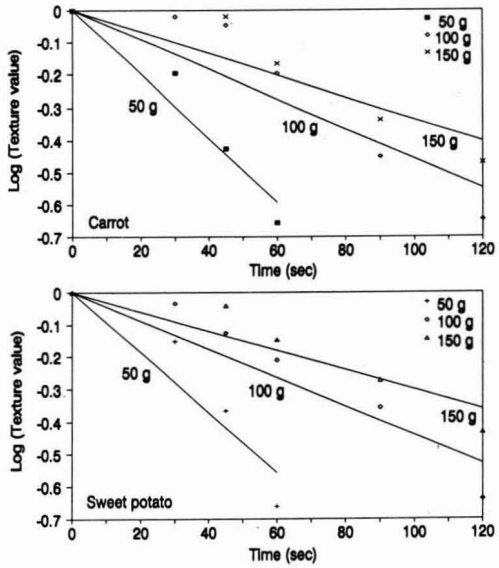

Fig 5. Texture softening in carrots and sweet potatoes after microwave-blanching

Blanching and texture: Thermal softening of carrots and sweet potatoes were evaluated, parallel to the peroxidase activity and they were generally comparable. The softening was reasonably described by first order kinetics (Fig. 5) with decimal reductions times of 110, 230 and 330 sec for microwave blanching (for 50, 100 and 150 g samples, respectively) and 170 sec for water blanching of carrots. For sweet potatoes, the values were 100, 220 and 300 sec for microwave blanching and 180 sec for water blanching. The order was, as before, smaller samples showing faster rate of softening and water blanched samples retaining slightly better texture than their microwave blanched counter parts.

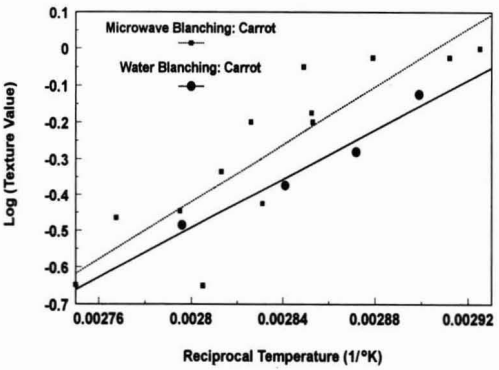

Fig 6. Arrhenius plots for textural quality of microwave and water-blanched carrots

With reference to the influence of temperature, rate constants could be related to temperature in either way: Arrhenius equation and TDT concept. The typical Arrhenius plot is shown in Fig. 6 for carrots. The calculated activation energies (from Arrhenius plots) were 18 and 15 kcal/mole in microwave and water, respectively for carrots and 16 and 23 kcal/mole, respectively for sweet potatoes. The calculated z values (from TDT plots) were 31 and 37°C in microwave and water, respectively for carrots, and 35 and 25°C, respectively for sweet potatoes.

Changes due to freezing and storage

Peroxidase activity: Peroxidase regeneration was evident during storage of all test samples as indicated in Table 1. In the short time blanched carrots (50 g samples heated for 30 sec, 100 g samples heated for 45 sec and 150 g samples heated for 60 sec), the peroxidase activity was reduced to below 50% following blanching. However, during storage, regeneration accounted for restoring the activity to more than 80% of the original level. To keep the regenerated peroxidase activity below 30%, it was necessary to microwave-blanch 50, 100 and 150 g samples for periods of 60, 120 and 180 sec, respectively. With sweet potatoes, the regeneration rates were relatively lower and in samples microwave-blanched as above, the regenerated peroxidase activity was well below 5% of the original level. For both carrots and sweet potatoes, regeneration of peroxidase activity decreased with blanching time and increased with the storage time. In contrast to microwave-blanched samples, water-blanched carrots and sweet potatoes showed lower levels of peroxidase activity regeneration.

Texture: The texture values of both carrots and sweet potatoes decreased with blanching time as indicated in Table 2. In consistence with the slightly lower peroxidase inactivation, water-blanched samples retained better texture. Freezing and storage of both carrots and sweet potatoes resulted in further lowering of texture values. Since texture was not evaluated immediately after freezing or after the 3.5 months storage, it was not possible to separate the influence of freezing and storage on the textural properties. In general, textural quality of water-blanched samples was either comparable or slightly superior to the microwave-blanched samples. It should be noted that small differences existing in texture values would normally disappear, when the product is cooked.

Overall quality: The overall quality based on colour, odor and texture of carrots and sweet potatoes as influenced by blanching and frozen storage were similar (Table 3). The poor quality of over-blanched samples were mainly due to texture softening, while that of unblanched samples was due to discoloration and off flavour development. Based on the quality assessment, carrots and sweet

TABLE 1. PEROXIDASE ACTIVITY FOR MICROWAVE AND WATER-BLANCHED CARROTS AND SWEET POTATOES BEFORE AND AFTER FREEZING

Blanching particulars	Time, sec	Peroxidase activity													
		$0_{(a)}$	$0_{(b)}$	$30_{(a)}$	$30_{(b)}$	$45_{(a)}$	$45_{(b)}$	$60_{(a)}$	$60_{(b)}$	$90_{(a)}$	$90_{(b)}$	$120_{(a)}$	$120_{(b)}$	$180_{(a)}$	$180_{(b)}$
Water-blanching (50 g)															
	After blanching	0.32	4.66	0.16	1.80	0.13	0.27	0.06	0.04	0.04	0.03	0.02	0.02	0.02	0.02
	After 3.5 month storage	0.33	3.77	0.17	1.87	0.16	0.26	0.09	0.04	0.06	0.02	0.02	0.02	0.02	0.01
	After 7.0 month storage	0.33	4.61	0.24	1.76	0.21	0.55	0.12	0.24	0.10	0.23	0.09	0.21	0.05	0.11
Microwave-blanching (50 g)															
	After blanching	0.32	4.66	0.16	1.37	0.13	0.27	0.06	0.03						
	After 3.5 month storage	0.33	3.77	0.23	2.17	0.19	0.27	0.05	0.06						
	After 7.0 month storage	0.33	4.61	0.28	2.08	0.21	0.45	0.12	0.28						
Microwave-blanching (100 g)															
	After blanching	0.32	4.66	0.26	2.37	0.15	0.25	0.07	0.15	0.04	0.03	0.03	0.01		
	After 3.5 month storage	0.33	3.77	0.29	2.47	0.24	0.37	0.10	0.13	0.06	0.10	0.03	0.02		
	After 7.0 month storage	0.33	4.61	0.32	4.51	0.28	0.75	0.14	0.26	0.08	0.18	0.05	0.04		
Microwave-blanching (150 g)															
	After blanching	0.32	4.66	0.32	2.42	0.20	1.29	0.15	0.48	0.09	0.06	0.02	0.02	0.02	0.01
	After 3.5 month storage	0.33	3.77	0.30	2.65	0.26	1.89	0.23	0.39	0.09	0.07	0.03	0.02	0.02	0.02
	After 7.0 month storage	0.33	4.61	0.33	4.60	0.29	2.69	0.27	1.17	0.16	0.19	0.06	0.06	0.05	0.04

a - Carrots
b - Sweet potatoes

TABLE 2. TEXTURE MEASUREMENTS FOR MICROWAVE AND WATER-BLANCHED CARROTS AND SWEET POTATOES BEFORE AND AFTER FREEZING

Blanching particulars	Time, sec	Texture value, kg													
		$0_{(a)}$	$0_{(b)}$	$30_{(a)}$	$30_{(b)}$	$45_{(a)}$	$45_{(b)}$	$60_{(a)}$	$60_{(b)}$	$90_{(a)}$	$90_{(b)}$	$120_{(a)}$	$120_{(b)}$	$180_{(a)}$	$180_{(b)}$
Water-blanching (50 g)															
After blanching		14.00	13.60	10.50	9.85	7.25	6.28	6.00	4.65	5.85	3.75	4.60	3.05	3.33	2.82
After 7.0 month storage		5.60	7.57	5.53	7.57	5.17	7.03	4.27	6.03	3.80	5.52	3.33	5.02	3.03	3.78
Microwave-blanching (50 g)															
After blanching		14.00	13.60	8.93	9.60	5.27	5.87	3.10	2.97						
After 7.0 month storage		5.60	7.57	4.47	5.33	2.40	4.43	2.03	3.63						
Microwave-blanching (100 g)															
After blanching		14.00	13.60	13.40	12.60	12.60	10.20	8.90	8.37	4.97	6.00	3.17	3.13		
After 7.0 month storage		5.60	7.57	5.57	5.23	5.23	5.43	4.70	4.17	4.10	3.37	2.90	2.83		
Microwave-blanching (150 g)															
After blanching		14.00	13.60	14.00	13.50	13.40	12.40	9.53	9.70	6.47	7.27	4.77	5.03	3.17	3.20
After 7.0 month storage		5.60	7.57	5.60	7.57	5.32	7.13	4.77	5.60	4.27	4.93	3.67	4.50	3.10	3.63

a - Carrots

b - Sweet potatoes

potatoes, microwave-blanched in 50 g size for 30 sec, 100 g size for 60 sec and 150 g size for 90 sec prior to freezing resulted in a better frozen product. Hence, it was observed that there was no direct relationship between the residual peroxidase activity and quality of the frozen vegetable. Water-blanching of carrots and sweet potatoes for 30-45 sec gave comparable results. During the frozen storage, the quality factors continued to change, but the above samples were acceptable after 7 months of frozen storage at -20°C.

Conclusion

The study with small size test samples (50-150 g) revealed that microwave-blanching was comparable to the conventional water-blanching with respect to peroxidase inactivation and texture degradation. Larger size samples of both carrots and sweet potatoes indicated better inactivation of the enzyme when heated in microwave for mass-equivalent times.

During the 7-month frozen storage at -20°C regeneration of peroxidase was observed, the extent

TABLE 3. OVERALL QUALITY OF MICROWAVE AND WATER-BLANCHED CARROTS AND SWEET POTATOES BEFORE AND AFTER FREEZING

Blanching particulars	Time, sec	Overall quality					
		30	45	60	90	120	180
Water-blanching (50 g)							
After blanching		Good	Good	Good	Fair	Fair	Poor
After 3.5 month storage		Good	Good	Good	Fair	Poor	Poor
After 7.0 month storage		Good	Good	Fair	Poor	Poor	Poor
Microwave-blanching (50 g)							
After blanching		Good	Good	Fair			
After 3.5 month storage		Good	Good	Poor			
After 7.0 month storage		Good	Fair	Poor			
Microwave-blanching (100 g)							
After blanching		Good	Good	Good	Good	Fair	
After 3.5 month storage		Fair	Fair	Good	Good	Fair	
After 7.0 month storage		Poor	Fair	Good	Fair	Poor	
Microwave-blanching (150 g)							
After blanching		Good	Good	Good	Good	Good	Fair
After 3.5 month storage		Poor	Poor	Fair	Good	Good	Fair
After 7.0 month storage		Poor	Poor	Fair	Fair	Good	Poor

being smaller in samples, blanched for longer times. Carrots microwave-blanched for 30 sec in small lots (50 g) had a regenerated peroxidase activity as high as 80%, but the frozen-stored product had good sensory qualities, while the larger lots (100-150 g) of sweet potatoes needed to be blanched to a residual/regenerated peroxidase activity below 10% (60-180 sec microwave heating) to have comparable keeping qualities. Microwave-blanching was comparable to individually quick water-blanching with respect to the quality of the frozen vegetables.

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Effect of Calcium Nitrate and Hydro-cooling on Cold Storage Life of Peach Cv. 'Shan-i-Punjab'

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Calcium nitrate at 1.0, 1.5, 2.0 and 2.5 % was sprayed thrice at weekly intervals before the anticipated date of harvest of peach Cv. 'Shan-i-Punjab'. The harvested fruits were hydro-cooled to 20°C and 15°C by dipping them in ice cold water. The fruits were packed in CFB cartons and stored at 3.3°C for 22 days. Pre-harvest sprays of calcium nitrate improved the colour of the fruits during storage. Minimum spoilage and loss in weight were observed in fruits, which were treated with 2.5% calcium nitrate. Hydro-cooling significantly reduced the spoilage and physiological loss in weight (PLW). However, 2.0% calcium nitrate spray combined with hydro-cooling at 15°C retained significantly the highest fruit firmness.

Keywords : Calcium nitrate, Hydro-cooling, Peach, 'Shan-i-Punjab' Pre-harvest, Cold storage.

The peach is adapted in temperature to sub-tropical zones. However, with the introduction of low chilling varieties during seventies, peach is successfully grown in North-West States of India. In Punjab, varieties like. 'Partap', 'Flordasun' and 'Shan-i-Punjab are being grown commercially. Due to its perishable nature, the post-harvest life of fruit is very short. This is further aggravated with the high temperature and low relative humidity, prevailing at the time of harvesting of fruit. Even the fruits kept in cold storage deteriorate in quality at a very fast rate. Calcium compounds, in general, and calcium nitrate, in particular, have been reported to extend the shelf-life of many fruits by maintaining their firmness and minimizing respiration rate, proteolysis and tissue breakdown (Gupta et al. 1980). It also acts as anti-senescent agent by preventing cellular disorganisation by maintaining protein and nucleic acid synthesis (Bengreth et al. 1972).

Generally, air-cooling, hydro-cooling and vaccum-cooling are used to remove the field heat (Chen 1988). Keeping these facts in view, the present studies were undertaken to judge the effect of pre-harvest sprays of calcium nitrate individually and in combination with post-harvest hydro-cooling on the storage life of "Shan-i-Punjab" peach.

Materials and Methods

The present investigations were conducted in the Department of Horticulture, Punjab Agricultural University, Ludhiana. Eight years old trees of 'Shan-i-Punjab' cv. of uniform vigour were selected. The plants received uniform cultural practices during the entire course of studies. Calcium nitrate at 1.0, 1.5, 2.0 and 2.5% levels and water was sprayed (control treatment) during second rapid development stage of fruits, using tween 80 as adhesive. The harvested fruits from trees treated with pre-harvest sprays of calcium nitrate were hydro-cooled by dipping them in ice cold water after the harvest, such as: Ho-control (No hydro-cooling), H_1-dipping the fruits in ice cold water to bring down the core temperature of the fruit to 20°C, while in H_2-the fruits were dipped in ice cold water to lower down the core temperature to 15°C.

The telescopic Corrugated Fibre Board (CFB) cartons of 25 x 20 x 60 cm size of 2 kg capacity punched for ventilation with two vents of 1 cm. diameter on each verticle side were used for packing the fruits. Paper was used for lining and paper cuttings were used as packing and cushioning material. Each treatment was replicated three times by using Randomized Block Design. The cartons were kept in commercial cold storage at 3 to 3.3°C with 85-90% relative humidity.

The physical changes in the fruits were recorded at harvest and at weekly intervals during cold storage. The colour of the fruit was observed with the help of Horticultural colour chart, prepared by Wilson Colour Ltd. in collaboration with the Royal Horticultural Society and British Council. For each colour group, there is a number, and in each number there are grades A-D, A-dark and D is light colour in that group. The per cent spoilage after each storage interval was calculated on the number basis by counting the fruits that had spoiled during the storage period. Loss in weight was calculated by substracting the final weight from the initial weight. The fruit firmness was measured with the help of fruit tester penetrometer after removing about one square centimeter of skin. The diameter of the top of the punch was 0.8 cm.

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The pressure readings were taken in kg/sq.m. The percentage of juice after extraction with Waring blender was calculated on volumes/weight basis.

Results and Discussion

Fruit colour: The colour of the fruit during storage improved from greenish yellow in control to yellowish green with increase in concentration of calcium nitrate sprays (Table 1). It was observed that the change in fruit colour was due to the increase in the anthocyanin pigment during storage. After 22 days of storage, calcium nitrate-treated fruits attained maximum colour development, which was noted as yellow orange (95%). The untreated fruits lagged behind in the colour development. Cheour et al (1990) also observed a linear correlation between colour and the rate of calcium nitrate applications. Such colour changes with pre-harvest sprays of calcium nitrate have also been reported in peach (Singh 1994).

Fruit spoilage: The pre-harvest sprays of calcium nitrate effectively reduced the spoilage of fruits upto 22 days of cold storage as compared to untreated fruits (Table 2). This might be due to absorption of calcium ions and it is known that calcium is essential for the maintenance of structural integrity of membrane and cell wall (Pooviah 1988). The importance of calcium for cell to cell adhesion is well recognised (Hanson 1983; Pooviah 1988). So, this integrity of cell wall reduces the penetration of fungi and bacteria causing soft rot, which reduced parenchymatous tissue to a watery mass. Calcium also provides resistance against pathogen infection in plants (Bangreth et al. 1972). The higher spoilage in untreated fruits was the result of lesser tissue strength and cellular disorganisation of the organelle. Such changes were also observed in "Flordasun" peaches (Bhullar et al. 1985). Similarly, decrease in spoilage in fruits receiving hydro-cooling might be due to reduced rate of respiration, thus maintaining structural integrity and preventing disorganisation of organella. Maximum spoilage was recorded after 22 days of storage. These findings are in agreement with those of Mangat (1989). Singh (1994) also studied the spoilage in storage of "Shan-i-Punjab" fruits and reported that pre-harvest sprays of calcium compounds reduced the decay losses during storage. Calcium is a major constituent of middle lamella of cell wall in the form of calcium pectate (Cleland 1960).

Physiological loss in weight (PLW) : The pre-harvest sprays of different concentrations of calcium nitrate decreased the loss of weight in fruits significantly as compared to water spray during cold storage (Table 2). The minimum loss was recorded in treated fruits over untreated ones. Singh et al (1982) and Gupta et al (1984) reported that foliar application of calcium nitrate effectively reduced the loss in weight of treated fruits, which might be due to the fact that calcium is known to prevent cellular disintegration by maintaining protein and nucleic acid synthesis, thus delaying senescence (Mason et al. 1975). Reduced PLW in hydro-cooled fruits could be due to reduced respiration and loss of moisture. Generally, the PLW increased gradually and progressively with the prolonged storage in all the treatments. This might be due to higher rate of respiration and moisture loss. Higher losses are expected, when respiration and transpiration processes continue for longer period.

Fruit firmness : The results presented in Table 3 indicate that the calcium nitrate sprays

TABLE 1. EFFECT OF CALCIUM NITRATE SPRAYS, HYDRO-COOLING AND STORAGE TIME ON COLOUR OF 'SHAN-I-PUNJAB' PEACH

Treatments	Storage period, days 0	7	15	22
Control + H_0	GYIB	Y9C	YO19A	YO16C
Control + H_1	GYIB	Y9C	YO19A	YO16C
Control + H_2	GYIB	Y9C	YO19A	YO16C
Ca $(NO_3)_2$ 1.0% + H_0	Y3B + R46A	Y11A + R46A	YO19A + R46A	YO16C + R45C
Ca $(NO_3)_2$ 1.0% + H_1	Y3B + R46A	Y12A + R46A	YO19A + R46A	YO16C + R45C
Ca $(NO_3)_2$ 1.0% + H_2	Y3B + R46A	Y12A + R46A	YO19A + R46A	YO16C + R45C
Ca $(NO_3)_2$ 2.0% + H_0	Y3B + R46A	Y12A + R46A	YO19A + R46A	YO21B + R45C
Ca $(NO_3)_2$ 2.0% + H_1	Y3B + R46A	Y12A + R46A	YO19A + R46A	YO21B + R45C
Ca $(NO_3)_2$ 1.0% + H_2	Y3B + R46A	Y12A + R46A	YO19A + R46A	YO21B + R45C
Ca $(NO_3)_2$ 2.5% + H_0	Y3B + R46A	Y12A + R46A	YO19A + R46A	YO21B + R45C
Ca $(NO_3)_2$ 2.5% + H_1	Y3B + R46A	Y12A + R46A	YO19A + R46A	YO21B + R45C
Ca $(NO_3)_2$ 2.5% + H_2	Y3B + R46A	Y12A + R46A	YO19A + R46A	YO21B + R45C

* GY = Greenish Yellow, Y= Yellow; YO = Yellow Orange; R = Red

Ho : No hydro-cooling, H_1 : Hydrocooling to 20°C H_2 : Hydrocooling to 15°C

A = Dark, C = Light

were quite effective in maintaining the fruit firmness as compared to control even after 22 days of storage. The maximum fruit firmness was obtained with 2.0% calcium nitrate treatment. The fruit firmness has direct relationship with pectin concentration, which was primarily due to higher calcium content of the treated fruits, as calcium is the major cation of middle lamella in cell walls and modifies cell wall strength (Dey and Brinson 1984), thereby increasing firmness of the fruits by thickness of the middle lamella of fruit cell well owing to increased formation and deposition of calcium pectate. Calcium, therefore, has an important bearing on the mechanical strength of the

TABLE 2. EFFECT OF CALCIUM NITRATE SPRAYS, HYDRO-COOLING AND STORAGE TIME ON PER CENT SPOILAGE AND PLW OF 'SHAN-I-PUNJAB' PEACH

Treatments	Hydro-cooling, 22 days				Spoilage		Storage period, days		
	H_0	H_1	H_2	Mean	0	7	15	22	Mean
Ca $(NO_3)_2$ 1.0%	3.44	3.22	3.18	3.28	0	0.00	5.05	8.08	3.28
Ca $(NO_3)_2$ 1.5%	1.15	0.80	0.76	0.90	0	0.00	0.00	3.61	0.90
Ca $(NO_3)_2$ 2.0%	0.55	0.44	0.38	0.46	0	0.00	0.00	1.84	0.46
Ca $(NO_3)_2$ 2.5%	0.43	0.34	0.31	0.36	0	0.00	0.00	1.45	0.36
Control	7.39	7.39	7.38	7.39	0	0.00	11.38	18.17	7.39
Mean	2.59	2.44	2.40	-	0	0.00	3.28	6.63	-
C.D. at 5%									
$Ca(NO_3)_2$	Concentration (a)			0.06			Concentration (a)		0.06
	Hydro-cooling (b)			0.05			Storage (c)		0.06
	Interaction (a x b)			0.12			Interaction (a x c)		0.13
				Physiological loss in weight (PLW)					
Ca $(NO_3)_2$ 1.0%	7.77	6.33	6.24	6.78		3.95	6.54	9.85	6.78
Ca $(NO_3)_2$ 1.5%	7.44	5.97	5.97	6.45		3.65	6.16	9.57	6.46
Ca $(NO_3)_2$ 2.0%	7.06	5.54	5.54	6.04		3.41	5.76	8.96	6.04
Ca $(NO_3)_2$ 2.5%	6.66	5.81	5.14	5.66		3.14	5.17	8.67	5.66
Control	8.88	7.64	7.42	7.98		4.96	7.67	11.31	7.98
Mean	7.56	6.13	6.06	-		3.82	6.26	9.67	-
C.D. at 5%									
$Ca(NO_3)_2$	Concentration (a)			0.07			Concentration (a)		0.07
	Hydro-cooling (b)			0.05			Storage (c)		0.05
	Interaction (a x b)			0.12			Interaction (a x c)		0.12

TABLE 3. EFFECT OF CALCIUM NITRATE SPRAYS, HYDRO-COOLING AND STORAGE TIME ON FIRMNESS AND JUICE CONTENT OF 'SHAN-I-PUNJAB' PEACH

Treatments	Hydro-cooling, 22 days				Fruit firmness, kg/sq/cm Storage period days				
	H_0	H_1	H_2	Mean	0	7	15	22	Mean
Ca $(NO_3)_2$ 1.0%	1.28	1.43	1.45	1.39	1.81	1.45	1.23	1.07	1.39
Ca $(NO_3)_2$ 1.5%	1.59	1.75	1.77	1.70	2.21	1.80	1.50	1.29	1.70
Ca $(NO_3)_2$ 2.0%	1.79	1.98	2.00	1.92	2.52	2.04	1.68	1.45	1.92
Ca $(NO_3)_2$ 2.5%	1.77	1.94	1.95	1.89	2.40	1.96	1.70	1.50	1.89
Control	0.93	1.13	1.18	1.08	1.60	1.17	0.88	0.66	1.08
Mean	1.47	1.65	1.67	-	2.11	1.68	1.40	1.19	-
C.D. at 5%									
$Ca(NO_3)_2$	Concentration (a)		0.03				Concentration (a)		0.03
	Hydro-cooling (b)		0.02				Storage (c)		0.02
	Interaction (a x b)		NS				Interaction (a x c)		0.06
				Juice content, % v/w					
Ca $(NO_3)_2$ 1.0%	43.36	43.83	43.89	43.69	45.00	44.39	43.53	41.86	43.69
Ca $(NO_3)_2$ 1.5%	44.00	44.47	44.53	44.33	45.59	45.00	44.18	42.57	44.33
Ca $(NO_3)_2$ 2.0%	44.66	45.13	45.17	44.99	46.19	45.63	44.84	43.28	44.99
Ca $(NO_3)_2$ 2.5%	45.92	46.39	46.44	46.25	47.36	46.88	46.13	44.64	46.25
Control	39.33	39.75	39.81	39.63	42.13	40.05	39.03	37.32	39.63
Mean	43.45	43.92	43.97	-	45.25	44.39	43.54	41.93	-
C.D. at 5%									
$Ca(NO_3)_2$	Concentration (a)		0.10				Concentration (a)		0.10
	Hydro-cooling (b)		0.79				Storage (c)		0.91
	Interaction (a x b)		N.S.				Interaction (a x c)		0.20

tissues and treated fruits, which had higher calcium recorded significantly higher firmness than low and untreated ones (Sofi 1983). A slow rate of softening in hydro-cooled fruits could be due to the additive effect of respiration and tissue breakdown. Firmness of fruits decreased during the entire period of storage. The decrease in firmness may be attributed to dissolution of insoluble pectin in cell wall and in middle lamela (Singh 1981). This insoluble pectin material of cell wall and middle lamella results in intercellular cementing and strength of cell wall, which is responsible for fruit firmness (Northcote 1958).

Juice content : The data in Table 3 reveal that both calcium nitrate as well as hydro-cooling treatments significantly affected the fruit juice percentage. The higher juice content in treated fruits may be attributed to the fact that calcium compounds are known to maintain the integration of cell organelles (Kumar and Chauhan 1990). The reduced loss in juice percentage after 22 days of storage in treated fruits may be due to reduced respiration rate. The calcium cations reduced respiration of cytoplasm and favoured the uptake of sorbitol earlier and thus non-involvement in reaction related to internal breakdown of cell organelles (Bengreth et al. 1972). Higher juice content in hydro-cooled fruits could be due to better moisture retention in hydro-cooled fruits as compared to non-hydro-cooled fruits. Moorthy et al (1962) reported higher juice percentage in pre-cooled sweet orange fruits at each interval of three days of storage. The juice content decreased with the increase of storage period. Significant decrease in juice percentage was observed during cold storage as reported in Kinnow mandarin (Kumar and Chauhan 1990) and in nectarines (Von Mollendorff et al. 1992). There may have been higher moisture loss due to prolonged transpiration, which reduced juice content. Brar et al (1996) reported improvement in the chemical constituent of calcium nitrate- treated fruits and attributed it to slow rate of respiration as compared to untreated ones during storage.

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Development of Soy-fortified Biscuits: III. Standardization of Baking Powder, Skim Milk Powder, Sodium Stearoyl-2-Lactylate and Glyceryl Mono Stearate Levels

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Soy biscuits were first standardized with baking powder (0.5, 0.8, 1.1 and 1.4%) and skim-milk powder (0.8, 1.6, 2.3 and 3.1%) levels, using the traditional creamery method. On the basis of good spread ratio and maximum overall acceptability score, baking powder at 0.8% level and skim milk powder (SMP) at 1.6% level were incorporated in the formulation of soy biscuits. Then optimum levels of Sodium Stearoyl-2-Lactylate (SSL) (0.3 or 0.5%) and Glyceryl Mono Stearate (GMS) (0.5, 0.75 or 1.0%) were incorporated in the formulation with three different levels of fat (20,25 and 30%). The spread ratio and overall acceptability increased, whereas hardness of the product decreased with increasing levels of SSL or GMS, irrespective of fat levels. Further, on the basis of maximum spread ratio and acceptability scores, SSL and GMS in soy biscuits were standardized at 0.5 and 1.0% levels, respectively. It was observed that both SSL and GMS could be used as shortening replacer in soy biscuits, since biscuits containing 25% fat with standardized levels of GMS and SSL had almost the same quality characteristics as those of biscuits containing 30% fat without emulsifiers.

Keywords : Soy-fortified biscuits, Glyceryl Mono Stearate, Sodium Stearoyl-2-Lactylate, Spread ratio, Baking powder, Skim milk powder, Overall acceptability.

Baking powder is the leavening agent produced by mixing of an acid reacting material and sodium bicarbonate with or without starch or flour. It yields not less than 12% of available carbon dioxide. Increase in total leavening brings about a gradual increase in the diameter or thickness, an opening of the grain and a more open and coarser cracking of the surface. Milk and milk derivatives are used in baked products for colour improvement, water absorption, spread-control properties and flavour. The dried products are preferred because of the convenience of use and their storage stability. In biscuits and crackers, casein assists in forming the porous structure and is regarded as a toughener. All the proteins of milk appear to be effective as flavour mellowers or blenders. They also participate in the browning reaction with reducing sugars.

Emulsifiers are surface-active agents promoting the formation and stabilization of emulsions. These products play many important roles in cookie and cracker's formulations. The unifying characteristics of emulsifiers are due to the presence of hydrophilic and lipopholic groups on the same molecule. The variability in performance of different emulsifiers is due to the relative potency of two kinds of regions, their spatial relationship, the size of the whole molecule and certain other factors (Matz 1968). The function of emulsifiers in cookies is well reported as a monitor of spread ratio and it also improves the texture (crispness) of cookies (Hutchinson et al. 1977).

Materials and Methods

Soy biscuits containing 20% defatted soy flour were prepared using the traditional creamery method as described earlier (Ranjana Singh et al. 1996). This recipe was then standardized for fat (refined groundnut oil, 30%) and sugar (43%) levels. Thereafter different levels of baking powder (0.5, 0.8, 1.1, and 1.4%) and skimmilk powder (0.8, 1.6, 2.3 and 3.1%) were tried to optimize their levels in the formulation of soy biscuits. Biscuits, thus, prepared were analyzed for physical (diameter, thickness, spread ratio, percent spread factor and hardness) and sensory characteristics (appearance, colour, texture, flavour and overall acceptability) as described earlier (Ranjana Singh et al. 1996). Results were analysed for statistical significance using the technique ANOVA (Snedecor and Cochran 1968). The levels of baking powder and skim milk powder, which produced a product of good spread and best sensory characteristics were standardized in the formulation. Thereafter, biscuits were prepared using two levels of SSL (0.3 and 0.5%) and/or with three levels of GMS (0.5, 0.75 and 1.0%) each at three levels of fat (20, 25 and 30%) in the formulation. At each fat level, one sample was prepared without emulsifier as a control for comparison. Biscuits, thus, prepared were analyzed for physical and sensory characteristics and the

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results were analyzed statistically for finding out the optimum levels of SSL and GMS.

Results and Discussion

The proximate composition of control and soy biscuits has been given earlier (Ranjana Singh et al. 1997).

Standardization of baking powder level : With increasing level of baking powder in the formulation, spread ratio of soy biscuits increased upto 0.8% level and thereafter decreased (Table 1). Changes in spread ratio of biscuits were, however, not significant (P>0.01). US Wheat Associates (1988) also reported that the main functions of leavening agents were to provide volume, to adjust the flavour, to control the spread and to give lightness to the product. There was no significant change in the hardness of soy biscuits, when the level of baking powder was increased from 0.5 to 0.8% in the formulation, but beyond this level, the hardness decreased significantly (Table 1). The decrease in hardness was due to leavening action of baking powder, which produced lightness and tenderness in biscuits. The sensory characteristics of soy biscuits did not show much variation with increasing level of baking powder in the formulation (Table 1). The scores for overall acceptability of soy biscuits first increased up to 0.8% baking powder level and thereafter decreased. The overall acceptability of soy biscuits was maximum at 0.8% baking powder level, but did not differ significantly from that of 0.5 and 1.1% baking powder level. On the basis of maximum spread ratio and overall acceptability scores, the level of baking powder for soy biscuits was standardized at 0.8%.

Standardization of skim milk powder (SMP) level: The results of effect of SMP incorporation in the recipe of biscuits are depicted in Table 2. With increasing level of SMP in formulation, spread ratio of soy biscuits decreased, whereas height of the product increased gradually. The spread ratio of soy biscuits containing different levels of SMP in formulation differed significantly (P<0.05) from one another. Tsen et al (1993) and US Wheat Associates (1988) reported that milk solids had a binding action on the flour proteins and when large percentage of milk solids was used, less spread was noted. Hardness of soy biscuits was found to increase significantly (P<0.05) with each increment of 0.8% SMP in the formulation. This was probably due to interaction of SMP with proteins, which made the products compact, thereby increasing their hardness. With increasing level of SMP in formulation, the scores of overall acceptability of soy biscuits increased up to 1.6% level and thereafter decreased (Table 2). Soy biscuits containing 0.8 and 1.6% SMP had the same acceptability statistically (P>0.05), whereas the acceptability differed at higher levels. On the basis of good spread ratio and maximum overall acceptability, SMP at 1.6% level was standardized in the formulation of soy biscuits.

TABLE 1. EFFECT OF DIFFERENT LEVELS OF BAKING POWDER** ON PHYSICAL AND SENSORY CHARACTERISTICS OF SOY BISCUITS

Parameters	Levels of baking powder,%			
	0.5	0.8	1.1	1.4
Spread ratio*	10.33[a]	10.38[a]	10.31[a]	10.23[a]
Hardness N*	25.30[a]	25.43[a]	22.60[b]	20.20[c]
OA*	6.35[a,b]	6.75[b]	6.25[a,b]	6.0[a]

OA : Overall acceptability

* Means followed by different letters differ significantly at 5% level (P<0.05)

** Quality : REX, Brown and Polson products

TABLE 2. EFFECT OF DIFFERENT LEVELS OF SMP** ON PHYSICAL AND SENSORY CHARACTERISTICS OF SOY BISCUITS

Parameters	Levels of SMP, %			
	0.8	1.6	2.3	3.1
Spread ratio*	10.91[a]	10.70[b]	10.62[c]	10.55[d]
Hardness N*	25.27[a]	26.10[b]	28.40[c]	29.30[d]
OA*	7.00[a,b]	7.30[a]	6.40[b]	5.90[c]

OA : Overall acceptability

* Means followed by different letters differ significantly at 5% level (P<0.05)

** Quality : Parag

Standardization of sodium stearoyl-2-lactylate (SSL) level : The results showing the effect of different levels of SSL with varying fat levels on physical characteristics of soy biscuits are shown in Table 3. The spread ratio of soy biscuits increased, whereas height decreased with increasing level of SSL in formulation, irrespective of fat level. Maximum spread ratio was obtained with 0.5% SSL and at all fat levels, spread ratio of soy biscuits containing different levels of SSL differed significantly (P<0.05) from one another. This finding is in accordance with that of Tsen et al (1973). Hardness of soy biscuits decreased significantly (P<0.05) with increasing levels of SSL, at all fat levels. Vecchio (1975) also reported similar observations. The overall acceptability of soy biscuits increased with increasing level of SSL irrespective of fat level and the effects were significantly different at 20 and 30% fat levels (Table 3), whereas at 25% fat level, the acceptabilities of soy biscuits

TABLE 3. EFFECT OF DIFFERENT LEVELS OF SSL WITH VARYING FAT LEVELS ON PHYSICAL AND SENSORY CHARACTERISTICS OF SOY BISCUITS

Parameters	Levels of fat, %								
	20			25			30		
	Level of SSL, %								
	0.0	0.3	0.5	0.00	0.3	0.5	0.0	0.3	0.5
Spread ratio*	9.21^{a}	9.53^{b}	10.02^{c}	9.36^{a}	9.75^{b}	10.25^{c}	10.20^{a}	10.60^{b}	11.38^{c}
Hardness N*	33.60^{a}	31.20^{b}	25.86^{c}	28.00^{a}	25.00^{b}	23.50^{a}	25.00^{a}	22.25^{b}	20.65^{c}
OA*	6.50^{a}	6.90^{b}	7.3^{c}	6.9^{a}	7.1^{ab}	7.4^{b}	7.2^{a}	7.6^{b}	8.0^{c}

OA : Overall acceptability

* Means followed by different letters differ significantly at 5% level (P<0.05)

without SSL and with 0.5% SSL differed significantly, but did not differ significantly (P<0.05) from those of biscuits with 0.3% SSL.

This study has indicated that by incorporation of SSL in the formulation, it would be possible to reduce the shortening level in biscuits without changing their quality. As was evident from the data, soy biscuits containing 25% fat and 0.3% SSL had almost the same quality characteristics (spread ratio, hardness and acceptability) as those of biscuits containing 30% fat without SSL. Similar observations were obtained for soy biscuits, when the fat level was reduced by 5% in the formulation (Tsen et al. 1973). Tsen et al (1973) and Tsen et al (1975) reported that surfactants like SSF and SSL delayed gelatinization of flour starch. The delaying action, although temporary, might reduce cookie dough viscosity (consistency) and allow the dough to spread before it firms or sets.

On the basis of maximum spread ratio and acceptability scores, the optimum level of SSL for soy biscuits was standardized at 0.5%. However, the overall acceptability of biscuits made with 30% fat and added 0.5% SSL was improved considerably.

Standardization of glyceryl mono stearate (GMS) level : The results showing the effect of different levels of GMS at different levels of fat on physical and sensory characteristics of soy biscuits are presented in Table 4. The spread ratio of soy biscuits increased, whereas height decreased with increasing level of GMS, at all fat levels (Table 4). Spread ratio of soy biscuits containing different levels of GMS differed significantly (P<0.05) from one another at each level of fat. Hardness of soy biscuits decreased significantly (P<0.05) with increasing level of GMS, at all fat levels (Table 4). The overall acceptability of soy biscuits increased as a result of addition of GMS in formulation at all fat levels and the maximum values were obtained with 1.0% GMS (Table 4). The overall acceptability of soy biscuits containing GMS differed significantly (P<0.05) from that of biscuits without GMS. At 20 and 30% fat levels, soy biscuits containing 0.5 and 1.0% GMS in formulation differed significantly (P<0.05) in acceptability, but did not differ significantly from the biscuits having 0.75% GMS, whereas at 25% fat level, the acceptability of soy biscuits containing different levels of GMS did not differ significantly (P>0.05) (Vecchio 1975).

On the basis of maximum spread ratio and acceptability scores, the level of GMS for soy biscuits was standardized at 1.0%. GMS could also be used as a shortening replacer in soy biscuits, since biscuits containing 25% fat with standardized level of GMS had almost same quality characteristics as those of biscuits containing 30% fat without GMS. Thus, 5% shortening could be

TABLE 4. EFFECT OF DIFFERENT LEVELS OF GMS WITH VARYING FAT LEVEL ON PHYSICAL AND SENSORY CHARACTERISTICS OF SOY BISCUITS

Parameters	Levels of fat, %											
	20				25				30			
	Level of GMS, %											
	0.00	0.30	0.75	1.00	0.00	0.50	0.75	1.00	0.00	0.50	0.75	1.00
Spread ratio*	9.47^{a}	10.05^{b}	10.66^{c}	10.93^{b}	10.66^{a}	10.86^{b}	11.32^{c}	11.47^{d}	11.44^{a}	11.94^{b}	42.14^{c}	12.40^{d}
Hardness N*	32.44^{a}	24.48^{b}	23.53^{c}	21.49^{b}	27.50^{a}	22.75^{b}	21.78^{c}	20.80^{d}	22.88^{a}	21.30^{b}	20.40^{c}	17.00^{d}
OA*	6.1^{a}	7.1^{b}	7.3^{b,c}	7.7^{a}	6.7^{a}	7.5^{b}	7.7^{b}	7.9^{b}	7.2^{a}	7.8^{b}	8.0^{b,c}	8.4^{c}

OA : Overall acceptability

* Means followed by different letters differ significantly at 5% level (P<0.05)

reduced in biscuits by the addition of GMS in formulation without affecting their quality.

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Effect of Processing Treatments on Guar Seed (*Cyamopsis tetragonoloba* Var. 'HG 75') Meal Proteins

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Guar meal was processed by various detoxification methods and their effect on its proteins was determined by various physico-chemical methods. The total proteins of defatted guar meal consisted of 4 fractions, two of high molecular weight and the other two low molecular weight proteins. Detoxification of guar meals by aqueous alcohols did not cause any significant changes in the proteins, while autoclaving or acidified water leaching resulted in drastic changes as indicated by the various physico-chemical techniques. Extraction of the autoclaved meal with acidified water or autoclaving alone resulted in the dissociation of the higher molecular weight proteins into lower molecular weight fractions. The values of $E^{1\%}_{1cm}$ at 280 nm of the proteins of these two samples were much higher than those of the defatted or aqueous alcohol-extracted meals. The fluorescence spectra of the proteins revealed that the fluorescence intensities of the aqueous alcohol-extracted meal proteins were higher than those of the defatted meal proteins at wavelength region of 300-400 nm. On the other hand, the fluorescence intensities of the autoclaved and acidified water-leached autoclaved guar meal proteins were lower than those of the defatted meal proteins.

Keywords: Guar meal proteins, Detoxification, Physico-chemical changes.

In recent years, the production of guar seed (*Cyamopsis tetragonoloba*) has increased considerably, since it is a main source of galactomannan gum. It has been known that the guar meal, left after extraction of gum, contains a high proportion of proteins (approx. 50%) and certain antinutritional factors (Subramanian and Parpia 1975; Tasneem and Subramanian 1986; Rajput et al. 1987). Ingestion of guar meal is reported to have caused anorexia, diarrhoea and decreased milk production in cattle (NDRI 1960). Defatted raw guar meal has been shown to be deleterious to the growth of rats and chicks (Kawatra et al. 1975; Mishra et al. 1984). Several studies have been carried out to detoxify guar meal for use in poultry feed as a source of protein (Patel et al. 1980; Nagra 1984). In this laboratory, successful attempts have been made to develop a feasible processing technique for detoxification of guar meal and to replace the groundnut cake protein completely by processed guar meal in poultry feed (Rajput et al. 1987). As a result of these detoxification procedures, the nutritive value of the treated meals (as indicated by chick growth) has been shown to have improved. It was of interest to know the physico-chemical changes that take place in the meal proteins as a result of the detoxification treatments. Hence, to monitor the effect of various detoxification treatments on the physico-chemical properties of guar proteins, a detailed study has been made. The techniques used were gel filtration, ultra-centrifugation, PAGE, UV-spectra and fluorescence spectra.

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Materials and Methods

Guar seed (variety "HG 75") was procured from Central India farm, Sirsa, Hisar, Haryana State, India. The seeds were processed to get gum-free meal according to the method of Rajput et al (1987). Detoxification treatments given to hexane defatted guar meal flakes were as follows:

A. No treatment (raw) B. 70% methanol extraction C. 80% ethanol extraction D. 80% isopropanol extraction E. Autoclaving at 1 kg/cm^2 steam pressure for 20 min. and F. Acidified water leaching of sample E.

The defatted guar meal raw as well as extracted meal were aerated and powdered to 60 mesh and stored in air tight glass bottles for further use.

Protein solutions: The proteins from variously processed meal samples were extracted with 1M NaCl, meal to solvent ratio being 1:10, at pH 8 for 1 h. The suspension was centrifuged at 6000 rpm for 20 min and the supernatant was dialysed extensively against 1M NaCl or phosphate buffer with several changes of the solvent. The dialysed sample was again centrifuged at 10,000 rpm for 20 min and then used for the experiments.

Protein concentration: The 1M NaCl extract of the meal proteins was diluted suitably with the

same solvent to have solutions of approximately 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50% protein concentration. The exact protein concentrations of these solutions were determined by micro-Kjeldahl method (AOAC 1980). A factor of 6.25 was used for converting nitrogen content to crude protein. The absorbance of these solutions at 280 nm in a cell of 1 cm path length was also determined. By plotting absorbance versus protein concentration, the absorbance of a 1% protein solution in 1 cm cell i.e., E at 280 nm was determined.

Gel filtration : The gel filtration of guar proteins was done with Sepharose 6B–100 packed into a column 1.9 x 85 cm equilibrated with 1M NaCl. The total 1M NaCl extract of guar meal (2ml) containing about 100 mg of protein was loaded on to a column and allowed to be absorbed. Buffer was carefully layered after complete absorption of the sample and eluted at a flow rate of 24 ml/h. Fractions of 3 ml were collected in an automatic fraction collector and the absorbance was measured at 280 nm in a Spectronic 21 UV spectrophotometer.

Ultracentrifugation : The ultracentrifugation experiments were performed with a Spinco-Model E-analytical ultracentrifuge equipped with RTIC unit and phase-plate Schlieren optics. Guar meal extracts in 0.02 M phosphate buffer containing 1 M NaCl, pH 7.5 and containing 1% protein were used. All experiments were performed at room temperature (about 27°C) and at 56,100 rpm. The sedimentation coefficients ($S_{20,w}$) of the protein fractions were calculated by the standard method (Schachman 1959).

Polyacrylamide gel electrophoresis (PAGE) : Electrophoresis of the proteins was carried out in 0.02 M phosphate buffer, pH 7.5, using a Shandon electrophoresis apparatus. Gels (7.5%) in the buffer were prepared by the standard procedure. Samples (50–100 µg protein/10 µl) containing 40% sucrose and 0.05% bromophenol blue (indicator dye) were loaded on to the pre-equilibrated gels and electrophoresis was carried out at a constant current of 3 mA/tube for 3 h.

Ultraviolet absorption spectrum : The ultraviolet absorption spectrum of the proteins in 1M NaCl solution was recorded in a Perkin-Elmer double beam recording spectrophotometer (Model 124) in the range of 240–350 nm.

Fluorescence spectrum : Fluorescence spectra of guar meal proteins were recorded in the range 300–400 nm after excitation at 280 nm, using a Perkin-Elmer fluorescence spectrophotometer (Model 203). A protein concentration corresponding to 0.1 absorbance at 280 nm was used. The fluorescence of blank (buffer) was measured and subtracted from that due to the protein.

Results and Discussion

Gel filtration : From the gel filtration patterns of the total proteins of guar meals, defatted meal proteins consisted of four peaks. The elution volumes of the four peaks were 88, 144, 175 and 193 ml, the void volume being 82 ml. The first fraction became turbid after 30 min of elution. This fraction gave a UV absorption spectrum with a maximum of 260 nm. Similar observations with the oilseed proteins were also made by many workers (Shetty and Narasinga Rao 1976; Rahma and Narasinga Rao 1979; Madhusudan 1985). The gel filtration pattern of the proteins of the processed meals showed the presence of only three fractions as compared to four in the defatted meal proteins. However, the area under the third fraction was increased considerably in all the aqueous alcohol-extracted meals. This might be due to either dissociation of the high molecular weight proteins or denaturation of this fraction by aqueous alcohols. A relative decrease in the solubility was reported (Wolf et al. 1963, 1964; Fukushima 1969). These data show that guar proteins undergo definite changes due to the treatment of the meal.

Ultracentrifugation: The sedimentation velocity pattern of guar meal proteins showed the presence of four peaks having $S_{20,w}$ values of 1.4, 7.0, 10.5 and 17.5S (Table 1). The relative proportions of these components were 48, 8, 42 and 2%, respectively. The sedimentation velocity patterns of proteins of the processed guar meals also showed the presence of 4 peaks except acidified water- leached guar meal protein, which showed the presence of only three peaks. The sedimentation coefficients ($S_{20,w}$) of the protein fractions corresponding to first, second, third and fourth peaks of these treated samples were in the range 1.4 to 2.4S, 3.5 to 7.5S, 10.5 to 11.7S and 14.7 to 16.2S, respectively. The proteins of autoclaved meal contained a high proportion (66%) of the low molecular weight fraction (1.9S). The proportion of the high molecular weight fraction (13.8S) was decreased to a great extent. The decrease to the high molecular weight proteins (13.8S) indicated that autoclaving dissociated the high molecular weight protein partially into low molecular weight fractions. The same trend was also observed in the case of acidified water-leached autoclaved meal, indicating the absence of

TABLE 1. $E^{1\%}_{1cm}$ ABSORPTION MAXIMUM AND ABSORPTION MINIMUM SEDIMENTATION COEFFICIENT (S20, W) AND THE PROPORTION OF THE PROTEIN FRACTIONS OF PROCESSED GUAR MEALS

Sample protein from	$E^{1\%}_{1cm}$ at 280 nm	Absorption, maximum nm	Absorption, minimum nm	$S_{20,w}$ (S)	Proportion, %
Defatted	8.2	277	254	1.4	48
guar meal				7.0	8
				10.5	42
				17.5	2
70% methanol-	7.8	278	254	2.3	64
extracted				5.8	3
guar meal				9.8	28
				16.2	5
80% ethanol-	7.9	278	254	1.4	52
extracted				3.5	4
guar meal				7.5	39
				14.7	5
80% isopro-	7.8	278	254	2.4	51
panol-extracted				7.5	5
guar meal				11.7	38
				16.0	6
Autoclaved	13.1	261	254	1.9	66
guar meal				9.8	27
				13.8	5
				18.0	2
Acidified	12.4	258	245	1.8	71
water-leached				10.3	25
autoclaved				15.9	4
meal				-	-

the high molecular weight fraction (18S), and a simultaneous increase in the low molecular weight fraction (1.8S) suggesting the dissociation of high molecular weight fraction to subunits. However, in the case of aqueous alcohol-extracted meals, the proportion of highest molecular weight fraction increased slightly, which could be due to aggregate formation induced by the treatment. It has been reported that organic solvents induce aggregate formation in the proteins (Nath et al. 1981; Navin Kumar 1982). The variations in the proportions of the fractions could also be due to the dissociation or aggregation of major proteins under experimental conditions (Schwenke et al. 1975).

Polyacrylamide gel electrophoresis (PAGE): The PAGE pattern of defatted guar meal proteins in 0.02M phosphate buffer (pH 7.5) consisted of four well defined bands, of which two were fast moving (Fig. 1). The fourth band appeared as a diffuse stained region and was characteristic of low molecular weight proteins. Khopkar (1976) also

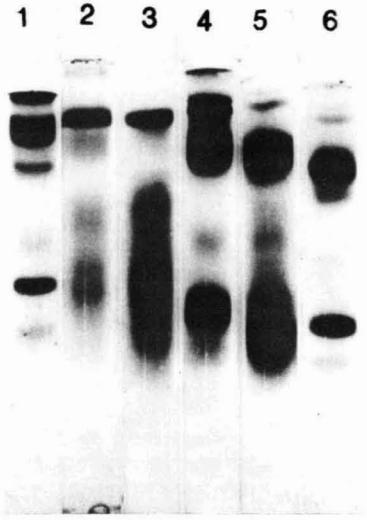

Fig. 1. Polyacrylamide gel electrophoresis patterns of the proteins from processed guar meals.
1. Defatted 2. Autoclaved 3. Acidified water leaching of autoclaved meal 4. 80% ethanol-extracted 5. 70% methanol-extracted 6. 80% Isopropanol-extracted

reported the presence of major bands and one minor band in the alkaline extract of guar meal at pH 8.3 by the method of Davis (1964). The PAGE pattern of the autoclaved meal and acidified water-leached autoclaved meal proteins exhibited one major band corresponding to high molecular weight protein and a continuous diffused band, a characteristic of low molecular weight fraction. This might be due to dissociation of high molecular weight proteins into low molecular weight fractions. The PAGE patterns of the proteins from the aqueous alcohol-extracted meal also showed the presence of 4 bands but the mobilities and the intensities of the bands, especially the two fast moving bands, showed variations.

Ultraviolet absorption spectrum : The UV absorption spectra of the defatted and detoxified guar meal proteins are given in Fig. 2. The defatted meal gave a typical protein spectrum with a maximum at 277-278 nm and a minimum at 254 nm. The autoclaved guar meal gave a different spectrum with a broad peak, the maximum had shifted to lower wavelength (261 nm) and a minimum occurred at 250 nm. Srikanta and Narasinga Rao (1974) have also observed that wet heating of groundnut proteins brought about changes in the UV absorption spectrum. Heating the guar proteins might also bring about the

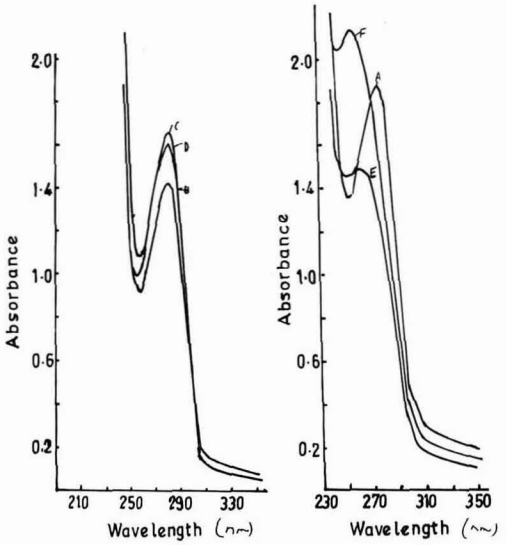

Fig. 2. UV absorption spectra of the proteins of processed guar meals.
A. Defatted, B. 70% methanol-extracted, C. 80% ethanol extracted, D. 80% Isopropanol-extracted, E. Autoclaved, F. Acidified water leaching of autoclaved meal

interaction of proteins with the other constituents present in the meal, notably carbohydrates, resulting in the formation of new complex products. Contribution of these products to the absorption spectrum of proteins might also be responsible for the observed changes in the UV spectra. The acidified water leaching of autoclaved guar meal further lowered its absorption maximum and minimum to 258 nm and 245 nm, respectively. Chemical and physical parameters such as pH, temperature, solvent composition and the presence of denaturing agents, which bring about changes in the secondary and tertiary structures of the proteins often result in alteration of their spectra which are manifested by shifts in wavelength and changes in intensity. The spectra, of the aqueous alcohol extracted guar meal proteins were similar to those of the defatted meal.

The values of $E^{1\%}_{1cm}$ at 280 nm of the proteins of the defatted and other detoxified guar meals are given in Table 1. $E^{1\%}_{1cm}$ at 280 nm of the proteins of the defatted guar meal was 8.2. The $E^{1\%}_{1cm}$ values of various detoxified guar meal proteins showed wide variations. The values for the autoclaved and acidified water-leached autoclaved guar meals were 13.1 and 12.4, respectively. In the case of the aqueous alcohol-extracted meals, the values ranged from 7.8 to 7.9. These variations in the values might be due to conformational/structural changes brought about by the various processing treatments. These changes in absorption might also be due to alteration of the micro-environment around the chromophores.

Fluorescence spectrum : As in the case of absorption spectrum, the fluorescence property i.e., the intensity and fluorescence maximum are dependent upon the environment of the fluorophores. Thus, fluorescence spectral measurements have been used to follow denaturation of proteins (Chen et al. 1969). Due to unfolding of the protein molecule, the fluorescence intensity generally decreases because of the exposed tyrosine and tryptophan residues (Teale 1960). The fluorescence emission intensity of the proteins was measured in the range 300–400 nm by exciting at 280 nm (Fig. 3). The concentration of the proteins in all the cases was the same 0.1%. The fluorescence intensities of the autoclaved and acidified water-leached autoclaved guar meal proteins were lower than those of the defatted meal proteins at all wavelengths in the region 300–400 nm. The fluorescence emission maximum of the defatted guar proteins occurred at 330 nm. However, the fluorescence intensities of the aqueous alcohol-extracted meal proteins were higher than those of the defatted meal proteins in the region 300–400 nm due to changes in environment around chromophores.

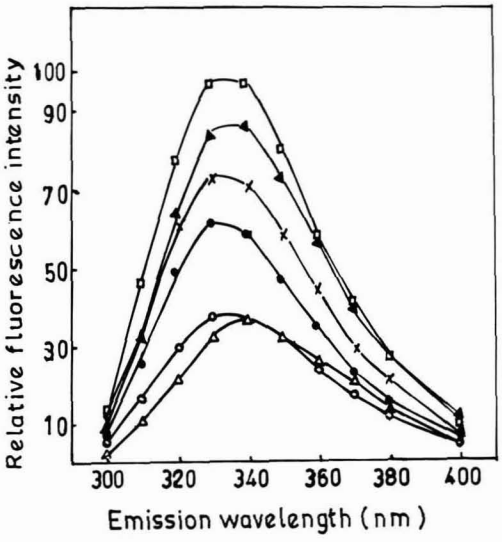

Fig. 3. Fluorescence emission spectra of the proteins of processed guar meals. (In 0.02M phosphate buffer, pH 7.5)
A. Defatted ---●--- B. 70% methanol extracted ---▲--- C. 80% ethanol-extracted ---□--- D. 80% Isopropanol-extracted ---x--- E. Autoclaved ---o--- F. Acidified water leaching of autoclaved meal ---Δ---

Summary

Evaluation of changes in protein quality of guar meal by *in vitro* techniques did not reveal any significant difference among the various detoxification treatments.

The total proteins of defatted guar meal consisted of 4 fractions, two of high molecular weight and the other two of low molecular weight proteins.

Detoxification of guar meal by the aqueous alcohols did not cause any significant changes to the proteins, while more autoclaving or acidified water leaching of autoclaved meal resulted in drastic changes, as indicated by the various physico-chemical techniques.

Extraction of the autoclaved meal with acidified water or more autoclaving resulted in the dissociation of the high molecular weight proteins into low molecular fractions.

The UV absorption maxima of the proteins of these two samples were shifted towards the lower wavelength regions. The values of $E^{1\%}_{1cm}$ (at 280 nm) of the proteins of these two samples were much higher than those of the defatted or aqueous alcohol-extracted meals.

The fluorescence spectra of the proteins revealed that the fluorescence intensities of the aqueous alcohol-extracted meal proteins were higher than those of the defatted meal proteins at all wavelengths in the region 300–400 nm. On the other hand, the fluorescence intensities of the autoclaved and acidified water-leached autoclaved guar proteins were lower than those of the defatted meal proteins.

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Water Activity Lowering Behaviour of Pumpkin Syrup Solids in the Intermediate Moisture Range

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Pumpkin syrup solids (PSS) were prepared by blanching the pieces of pumkin (*Cucurbita maxima*) fruit, hydrolysing pectin, using Pectinex Ulta SP-L, and partially dehydrating the clear juice by using a rotary evaporator. The honey-like concentrated syrup had 20.38% moisture, 79.62% total solids, 7.86% proteins, 0.80% fat, 8.22% ash and 63.74% total carbohydrates. The adsorption isotherms of PSS at 10, 25 and 40°C were determined and were fitted to the Caurie's equation. The equation describing the temperature dependence of Caurie's equation constants was established. The data were also fitted to the modified Norrish's equation. The water holding capacity of PSS was slightly less than that of glycerol but was better than sucrose, sorbitol and propylene glycol. Sensorily, the PSS had pleasant mild sweet flavour with relative sweetness of 0.19 as against 1 for sucrose. The viscosity of PSS at different total solids concentration was also determined. The lowering ability of PSS was tested in *khoa*, which was also found to be slightly lower than glycerol. Addition of PSS upto 16% did not considerably affect the sensory quality of *khoa*.

Keywords : Pumkin syrup solids, Water activity lowering behaviour, Intermediate moisture foods, Humectants.

Though a great deal of research has been done in the area of intermediate moisture foods (IMF) during the last three decades, there is still a dearth of humectants that are safe, effective, economical, relatively tasteless and colourless. All humectants so far used in the production of IMF fall short of the ideal requirements. The most popular humectants for food products are salt, sucrose and glycerol. The physiological implications of high salt intake and sweet taste imparted by sucrose limit their use in large quantities. Glycerol, which approaches the requirements of an ideal solute for IMF, also imparts unfamiliar taste (Ledward 1985). Moreover, feeding of high levels of dietary glycerol to rats has been shown to result in an accumulation of lipids in blood serum and the liver (Narayan et al. 1975, 1977). Attempts have been made to find other suitable humectants for use in IMF (Chirife et al. 1980; Chen and Karmaj 1980; Guilbert et al. 1981; Vallejo-cordoba et al. 1986). Glycine and protein hydrolysate seem promising, but their high cost and adverse effect of protein hydrolysate on flavour may restrict their use to lower concentrations only. Brimelow (1985) emphasised the need to investigate the water activity reducing properties of naturally occurring edible substances such as plant and fruit extracts. This work presents preparation of pumpkin (*Cucurbita maxima*) syrup solids (PSS) and its water activity reducing behaviour in the intermediate moisture range.

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Materials and Methods

Preparation of PSS : The fresh pumpkin fruit was peeled, seeds removed and cut into small pieces. It was then blanched with live steam for 3 min. The blanched pieces were then ground to a fine paste. The pulp (pH 6.25) was incubated for 4 h with 1% Pectinex Ultra SPL (Novo Ferment Ltd., Switzerland) at 35°C to hydrolyse pectin. After hydrolysis, the clear juice was separated from the unhydrolysed residue by filtration through four-fold muslin cloth. The average yield of the juice was 93%. The juice containing on an average 5.33% total solids, was concentrated in a rotary vacuum evaporator to obtain a honey-like syrup, which is designated hereafter as PSS.

Chemical analysis : The moisture and ash contents of PSS were determined as per methods described by Sienkiewcz and Riedel (1990) for cheese whey. Fat content was determined by a Mojonnier fat extraction method for cheese as described by MIF (1959). Total nitrogen was determined by using 150–200 mg PSS samples according to semi-micro-Kjeldhal methods outlined by Meneffee and Overman (1940) and multiplied by 6.25 to get the total protein content. Glucose was estimated according to the methods of Nelson (1944) and Somogyi (1945). Fructose was estimated as per the procedure described by Mann (1948) and sucrose estimation was carried as per the procedure of ISI (SP:18, Part XI- 1981).

Measurement of sorption equilibrium : The sorption apparatus used in equilibrium studies by Wolf et al (1985) was modified for use in the present

study. It consisted of sorption containers, support for weighing bottles and the weighing bottles in which the sample material was exposed to a humid atmosphere in the containers. Saturated salt solutions were used to give constant relative humidities in the intrermediate water activity range a_w = 0.67 - 0.98 (Greenspan 1977). PSS sample (1 g) was accurately weighed into the tared weighing bottles and placed on the support in the sorption containers containing saturated salt slurries. For temperature, control, the sorption containers were placed in chambers maintained at three different temperatures, viz., 10, 25 and 40±0.5°C.

To prevent mould growth, 5 mg potassium sorbate was added to each sample. The samples were weighed periodically until equilibrium. The equilibrium period ranged from about 1 month at 40°C to 4 month at 10°C. During this period, no apparent spoilage of samples was observed.

The sorption data were fitted to the Caurie's equation (Caurie 1981).

$$\frac{1}{W} = \frac{1}{Cw_m}\left(\frac{1-{}^{a}w\ 2c/w_m}{a_w}\right) \qquad \text{--------- (1)}$$

where W is the equilibrium moisture content, W_m the monolayer moisture content and C the value related to the density of the adsorbed moisture, The W_m and C values were calculated from the slope and the intercept of the equation. The accuracy of fit was checked by calculating the root mean square per cent error (RMS, %).

The numbers of monolayers of adsorbed moisture (N) were calculated from its relationship with slope (S) of the Caurie's plot:

$$S = 2/N \qquad \text{--------- (2)}$$

The nonfreezable or bound water was obtained by multiplying monolayer moisture content by N. The surface area of the adsorbant (A) was calculated according to the equation given by Caurie (1981).

$$A\ (m^2/g) = \frac{54.45}{S} \qquad \text{--------- (3)}$$

Measurement of water activity : The water activity of *khoa* PSS and *khoa*-glycerol blends were measured using a Rotronic Hygroskop (Rotronic AG, Zurich, Switzerland) at 25°C. The viscosities of aqueous solutions of PSS were determined at 25°C using a rotational viscometer (Rheomat 108/R, Mettler Toledo AG, Switzerland).

Sensory evaluation and relative sweetness : The overall flavour description analysis of PSS was done by a panel of 3 trained judges selected from the faculty. The aqueous solutions of PSS were served separately to the panelists at 25°C. The panelists were asked to describe the flavour profile of the samples. For evaluation of relative sweetness, the aqueous solution of PSS of known concentration was served to expert panelists and they were asked to rank it against a series of sucrose solutions as suggested by Wardip (1971).

The sensory evaluation of *khoa*-humectant blends was done using multiple sample difference test (ISI 1971), wherein panelists tasted sample and the control (*khoa* with no added humectant) on a 6-point scale, ranging from "No difference" (score 0) to "extremely large difference" (score 5).

Results and Discussion

Composition of PSS : The concentrated pumkin syrup was honey-like in appearance and consistency and contained 79.62% total solids, 7.86% proteins 0.80% fat, 7.22% ash, 20.14% glucose, 13.12% fructose, 25.49% sucrose and 4.70% other sugars.

Sorption characteristics : The adsorption of PSS measured at different temperatures are shown in the form of Caurie's plot in Fig. 1. The Caurie's equation was found to fit well to the data as is evident from the low % RMS values of 0.75, 4.89 and 2.83 at 10, 25 and 45°C, respectively. As can be seen from Fig. 1, the equilibrium moisture content (EMC) of PSS rose rapidly with increase in a_w, the increase being steeper with higher temperature. At lower water activity values, the

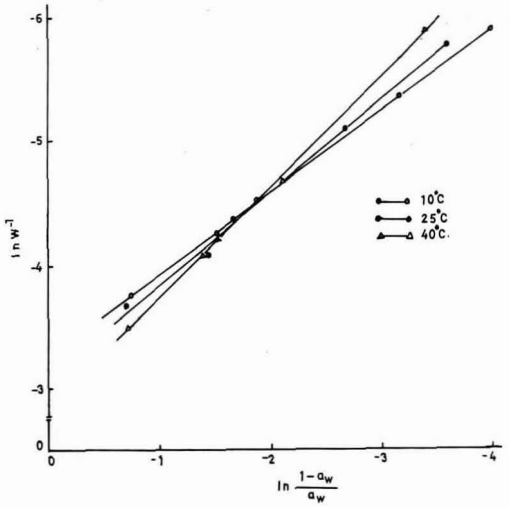

Fig. 1. Adsorption isotherms of pumpkin syrup solids at different temperatures in the form of Caurie's plot (0) 10°C, (●) 25°C, (Δ) 40°C

equilibrium moisture content was lower at higher temperature. The difference decreased with increasing water activity upto an a_w of 0.85, at which point, the temperature had almost no effect on the equilibrium moisture content. After water activity of 0.85, the trend reversed, showing higher EMC at higher temperature. In the region of lower a_w, the observed decrease in water-binding capacity of PSS at higher temperatures could be attributed to the protein content of PSS, since at low a_w proteins are known to be preferred sorption sites, which have greater water-binding capacity at a low temperature than at high temperature (Berlin et al. 1968). At higher a_w, however, the effect of protein is counteracted by carbohydrates and low molecular mass compounds, since the equilibrium moisture contents of these substances increase at higher temperatures and higher relative humidities because of increase in their solubilities (Ruegg 1985). The PSS contains 7.86% proteins, 0.80% fat and 63.74% carbohydrates and therefore, is primarily a carbohydrate-rich material. Table 1 shows similarity of PSS to sucrose with reference to adsorbed monolayer, N. However, the water activity lowering ability of PSS may be due to the joint action of all these soluble constituents.

The monolayer moisture content and other properties of adsorbed water on PSS and some other common humectants as calculated according to Caurie (1981) are presented in Table 1. The monolayer moisture content, number of adsorbed monolayers, non-freezable water and surface area of adsorbant decreased with increase in temperature. It can be observed from Table 1, that the monolayer moisture content of PSS was slightly lower than that of glycerol, but was higher than that of propylene glycol as calculated from the a_w values reported by Sloan and Labuza (1985). The density of sorbed water on PSS was also less than that of glycerol, but was more or less same as that of propylene glycol. The non-freezable water content of PSS was, however, same as that of glycerol. The number of adsorbed monolayer and surface area of the adsorbant was more in case of PSS than that of glycerol and propylene glycol (Sloan and Labuza 1985). The water holding capacities of PSS at 25°C were 30, 41, 62 and 113 g/100 g of solids at 0.6, 0.7, 0.8 and 0.9 water activities, respectively. On the basis of the water holding capacities of PSS and other humectants reported by Sloan and Labuza (1985), it can be concluded that PSS are better humectants than sucrose, sorbitol and propylene glycol, but are slightly inferior to glycerol.

Since constants of the Caurie's equation such as W_m and C were influenced greatly by temperature, their relationship with temperature was studied. It was found that both W_m and C were linearly related to the absolute temperature (T).

$$W_{m(T)} = 34.5665 - 0.0906\ T,\ r = 0.9971 \quad \text{---- (4)}$$

$$C_{(T)} = 4.5420 - 0.0057\ T,\ r = 0.9940 \quad \text{----(5)}$$

The $W_{m(T)}$ and $C_{(T)}$ calculated, using the above equations are presented in Table 1. Equations (4) and (5) together with equation (1) could be used to calculate accurately the equilibrium moisture contents, $W_{(T)}$ of PSS for any given a_w and temperature, as is evident from low % $RMS_{(T)}$ values of 1.16, 4.93 and 3.07 at 10, 25 and 40°C, respectively.

Prediction of a_w in aqueous solutions of PSS: The utilization of any solute for IMF formulation requires a precise knowledge of its water activity lowering ability, i.e., an equation for predicting the a_w of its aqueous solutions at various concentrations. Norrish (1966) proposed an equation for predicting a_w in binary solutions:

$$\log\frac{a_w}{X_1} = kX_2^2 \quad \text{--------- (6)}$$

where X_1 and X_2 are molar fractions of water and solute. This equation has been successfully applied to different non-electrolyte aqueous solutions of compounds relevant to IMF formulation, including

TABLE 1. MONOLAYER MOISTURE CONTENT, C-VALUE, NUMBER OF ADSORBED MONOLAYERS, NON-FREEZABLE WATER AND SURFACE AREA OF ADSORBANT FOR PSS

Temperature, °C	W_m (W_{mT}), $gH_2O/100g$ solids	C-value, C_T	Adsorbed monolayer, N	Non freezable- water, $gH_2O/100g$	Surface area of adsorbant, m^2/g
10	8.88	2.9339	3.03	26.87	82.38
	(8.93)	(2.9289)			
25	7.69	2.8651	2.68	20.63	73.05
	(7.57)	(2.8434)			
10	6.16	2.7640	2.23	13.73	60.67
	(6.21)	(2.7579)			

Figures in parenthesis are values calculated using Eqns 4 and 5

sugars, polyols, amino acids, amides and organic hydroxy acids (Chirife et al. 1980; Chirife and Ferro Fontan 1980 a, b). Norrish's equation, however, is suitable only for solutes having known molecular weights. Chuang and Toledo (1976) modified Norrish's equation for use with systems, containing complex molecules as follows:

$$\text{Log} \frac{a_w}{N} = kS_2^2 + b \quad \text{--------- (7)}$$

where N is moles of water/100 g solution: S_2 is g solute/100 g solution: k and b are constants, characteristic to that system.

The equation (7) was applied to the aqueous solutions of PSS. The water activities of PSS solutions at 25°C, are shown in Fig. 2. The plot did not give one single straight line, but gave 3 straight line regions at 10 and 25°C and 2 straight line regions at 40°C. The slope and intercept constants pertaining to different straight line regions are given in Table 2. These constants could be used not only to predict the water activity of PSS solution at any concentration but also, alongwith the general equation developed by Chuang and Toledo (1976), could be used to calculate the water activity of mixture of two solids i.e., mixture of PSS and any other solid.

Viscosity of PSS : Viscosity of the humectant is an important property, as it affects the texture of the resultant IMF. High concentration of low viscosity humectant such as glycerol has been

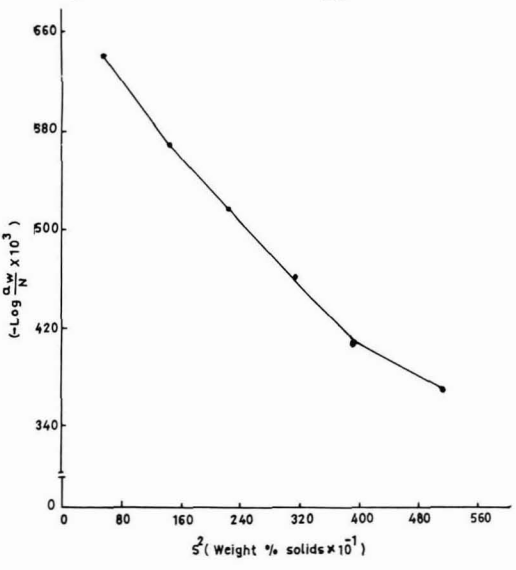

Fig. 2. Water activities of pumpkin syrup solids at 25°C plotted in the form of modified Norrish's equation

TABLE 2. CONSTANTS OF MODIFIED NORRISH'S EQUATION APPLIED TO AQUEOUS SOLUTIONS OF PSS

Temperature, °C	Concentration, wt. % solids	Slope K	Intercept b	Correlation coefficient, r
10	21.5-41.0	82.6751×10^{-6}	-68.3074×10^{-2}	0.9969
	41.0-58.6	56.7046×10^{-6}	-64.0880×10^{-2}	0.9993
	58.6-70.0	39.5232×10^{-6}	-58.2167×10^{-2}	0.9990
25	23.7-37.9	83.7369×10^{-6}	-68.5588×10^{-2}	0.9990
	37.9-62.8	62.8437×10^{-6}	-65.6198×10^{-2}	0.9994
	62.8-71.8	31.1547×10^{-6}	-53.0287×10^{-2}	0.9998
40	20.6-45.0	79.7038×10^{-6}	-68.8149×10^{-2}	0.9966
	45.0-75.1	59.7160×10^{-6}	-64.8680×10^{-2}	0.9996

shown to adversely affect the texture of *khoa* (Sawhney et al. 1974). The viscosities of PSS were found to vary from 7 to 12 m Pa. S for total solids range of 12 to 32.7%, respectively. The viscosity-total solids relationship was found to be curriinear:

$$\eta = 5.0525 \; e^{0.0262 \; TS_r} = 0.9991 \quad \text{-------(8)}$$

The observed values of viscosity of PSS were higher than those reported for corresponding solutions of sugar and corn syrup solids (Junk and Pancoast 1973), which is an added advantage of PSS over other humectants.

Sensory analysis of PSS : The 16% (w/w) solution of PSS was pleasant, very mildly sweet and had fruit-like odour. No inappropriate notes such as bitter, sour, green, metallic or burnt were detected. In relative sweetness test, the 16% solution of PSS matched in sweetness with 3% sucrose solution, indicating that the PSS is 5.3 times less sweet than sucrose, or taking sweetness value of sucrose as 1, the relative sweetness of PSS worked out to be 0.19. The relative sweetness of PSS, therefore, is less than that of lactose or dulciton (relative sweetness, 0.4) and 30 DE corn syrup (relative sweetness, 0.3) (Junk and Pancoast 1973), which is an added advantage of PSS over other humectants.

Water activity reducing ability and sensory analysis of PSS in khoa: The potential a_w reducing ability of PSS was tested by blending it with *khoa* (a heat-desiccated product from milk, total solids content of 62.5%). The *khoa*- glycerol blends with same *khoa*-humectant ratios were also made for comparison. The results on a_w reducing ability and sensory analysis of *khoa*-PSS and *khoa*-glycerol blends are given in Table 3. The a_w reducing ability of PSS was slightly lower than that of glycerol. The sensory quality of *khoa* was deteriorated with increasing levels of PSS and glycerol in the blends. The flavour of PSS-*khoa* blend was only moderately

TABLE 3. WATER ACTIVITIES AND SENSORY ANALYSIS OF DIFFERENT *KHOA* HUMECTANT BLENDS

Ratio of *khoa* solids: Humectant solids: Water	PSS				Glycerol			
	a_w	Sensory analysis			a_w	Sensory analysis		
		Flavour	Colour/ appearance	Texture		Flavour	Colour appearance	Texture
1:0.0	0.956	-	-	-	0.956	-	-	-
1.53:0.14:1 (5.38)	0.944	0.3	0.3	0	0.940	0.5	0	0
1.40:0.25:1 (10.17)	0.932	1.3	1.7	1.3	0.927	2.0	0	0
1.30:0.34:1 (14.76)	0.921	2.3	2.3	1.3	0.913	2.5	0.5	1
1.21:0.42:1 (19.11)	0.910	3.0	3.3	2.3	0.901	3.5	0.5	3
1.13:0.49:1 (23.15)	0.902	4.0	4.0	3.3	0.889	5.0	1.0	4

Figures in parentheses are per cent humectant of mixture

different at 19% PSS level. The texture of *khoa* was not much affected by addition of PSS. However, addition of glycerol increased the fluidity of the blend. The colour of *khoa*-PSS blend, however, was inferior to the corresponding *khoa*-glycerol blends.

Based on the results, it can be concluded that the PSS can be a very promising humectant for use in IMF, intended for human consumption, as it has water binding capacity close to glycerol, has pleasant flavour and relatively low-sweetness intensity. It can, thus, be added in large quantities (upto a maximum of 16%) without substantially influencing the flavour of the food. Moreover, it is manufactured from the widely consumed edible fruit and therefore, will have consumer acceptance.

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Studies on the Dehydration of Garlic

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Fresh garlic cloves (*Allium sativum* L.) were dehydrated by four methods viz.,i) sun-drying, ii) solar cabinet drying, iii) mechanical drying and iv) fluidized bed drying. The dried material was powdered and evaluated for drying characteristics and sensory qualities. Drying at 60°C for 4 h in a fluidized bed dryer gave good quality powder with a moisture content below 3%. The shelf life of the powder at 3 months of storage at ambient condition was found to be better in aluminum laminate and brown glass bottle. The product prepared from garlic powder was highly acceptable as determined by organoleptic evaluation.

Keywords: Garlic powder, Sun-drying, Solar cabinet drying, Mechanical drying, Fluidized bed drying, Quality characteristics, Shelf life.

Garlic, a native of middle Asia, is a semi-perishable spice. The moisture content of the bulb and surrounding relative humidity play an important role in maintaining its keeping quality. It has a tendency to lose its moisture on storage, which causes weight loss and shrivelling of cloves to an extent of 40–45% (Prakash et al. 1994). Due to lack of suitable storage and transport facilities, about 20% of the fresh crop is wasted by respiration, transpiration and microbiological spoilage (Pruthi et al. 1959). The total annual production of garlic is about 3,56,000 tonnes under an area of 89,700 hectares (AADF 1991). If the surplus crop could be conveniently and economically channelled into the production of garlic powder, a considerable amount of loss can be minimised.

Pruthi et al (1959) have reported that 8–10 h are needed to dry garlic in a mechanical tray dryer, whereas under multistage condition, it took nearly 11 h to obtain a safe moisture storage level of 5% (Sanjayakumar and Sandeep 1991).

The dehydration of garlic tried by earlier workers is time consuming. This has created the need to look for a better alternative to save extra energy in drying. Investigations were, therefore, taken up to standardize the conditions for producing garlic powder of good quality and to determine its storage stability and other related qualities.

Sample preparation : Freshly harvested market sample of the local variety called 'Malai Poondu' was used in this study. After loosening the cloves from the bulb by manual scrubbing and peeling, the cloves were cut into slices of 2.5 mm thickness, using stainless steel knife.

Drying technique : The garlic slices (150 g) were dried by four different methods as follows :- (i) The material was spread on aluminum tray of 30.5 x 25.5 x 2.5 cm size and dried by direct exposure to sunlight in the open yard to a final moisture content of nearly 2–3%. The temperature during sun-drying varied between 27° and 33°C. (ii) The material was dried in a solar cabinet dryer by spreading it on 30.5 x 25.5 x 2.5 cm size aluminium tray at varying temperatures of 40–61°C to a final moisture content of 2–3%. (iii) Drying was carried out in a mechanical dryer at a constant air flow rate of 0.075 m^3/min for different drying air temperatures of 40, 50, 60 and 65°C, respectively. The maximum temperature that could be availed in this type of dryer was only upto 65°C.(iv) Samples were dried in a fluidized bed dryer at 4 different temperatures of 40, 50, 60 and 70°C at an airflow rate of 3.81m^3/ mine to a final moisture content of 2–3% approximately. The product after drying was ground in an electrical blender to a fineness such that 90% of the powder passes through IS 500 micron sieve.

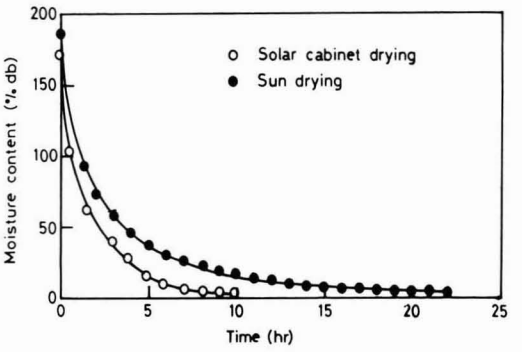

Fig. 1. Drying characteristics of garlic under solar cabinet drying and sun-drying

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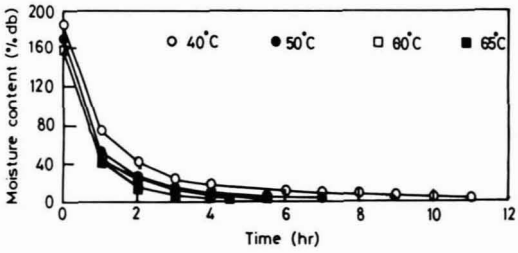

Fig. 2. Drying characteristics of garlic under thin layer drying at indicated temperature

Storage studies : Shelf life of the powder was evaluated by packing in polyethylene bags (300 gauge), aluminum foil laminates, brown and white glass bottles, for a period of 3 months at ambient conditions with the temperatures varying from 22 to 32°C and relative humidities from 50% to 80%. Samples were drawn at the end of storage period and analyzed.

Analytical methods : The moisture content was determined by distillation method (ISI 1983) and flavour strength by Chloramine-T method (Shankaranarayana et al. 1982). Total carbohydrates were estimated by Anthrone method, proteins by Lowry's method and ascorbic acid by volumetric method (Sadasivam and Manickam 1992). Colour was measured in terms of optical density at 440 nm using a colorimeter (Ranganna 1979).

Sensory evaluation : The organoleptic qualities like colour, flavour, texture, taste and overall acceptability were determined by a 12 member panel, using a 9-point Hedonic scale (Ranganna 1979). The quality test results were analysed statistically by completely randomised design (Cochran and Cox 1957). The best sample selected was confirmed for its acceptability by preparing *chutney*, following a standard recipe and evaluated by a composite scoring method (Ranganna 1979) by a 10 member panel.

The graphical representations of moisture reduction affected by different drying methods are

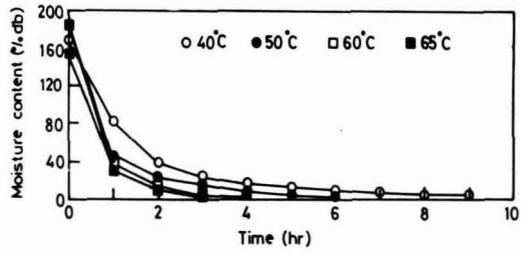

Fig. 3. Drying characteristics of garlic under fluidized bed drying at indicated temperature

TABLE 1. EFFECT OF DRYING METHODS AND TEMPERATURE ON THE QUALITY OF GARLIC

Method of drying	Temp, °C	Duration, h	Browning index, OD
Sun-drying	27-33	22	0.105
Solar cabinet drying	40-61	10	0.065
Mechanical drying	40	11	0.070
	50	7	0.062
	60	5.5	0.045
	65	4.5	0.050
Fluidized bed drying	40	9	0.068
	50	6	0.050
	60	4	0.025
	70	3	0.055

shown in Fig 1 to 3. Sun-drying took 22 h and solar cabinet drying took 10 h. It may be noted that both the methods were weather dependent (Fig. 1).

Mechanical drying took 4.5 to 11 h depending upon the temperatures, the shortest duration being 4.5 h at 65°C (Fig. 2). This is because, the product in contact with the drying surface dried quicker than that at the top. Drying was faster in fluidized bed drying due to the uniform exposure of the sample to the drying conditions. The shortest period of 3 h was observed at 70°C and the longest duration was 9 h at 40°C (Fig. 3).

The effect of temperature and drying method on the quality of garlic powder is presented in Table 1. The product's quality was evaluated by its colour in terms of browning index. The results showed that sun-drying, on long exposure to sun, resulted in poor quality with low organoleptic scores. Similar results were observed in solar cabinet drying. In the case of mechanical dryers, fluidized bed dryer encountered faster rate of drying.

The selection of best drying temperature was based on the browning index and scores of organoleptic evaluation. The results showed that drying of garlic at a temperature of 60°C for 4 h in fluidized bed dryer was found to be optimum for obtaining a desirable quality product.

TABLE 2. PROXIMATE COMPOSITION OF FRESH AND POWDERED GARLIC

Constituent	Fresh	Fluidized bed dried, (60°C 4h)	Sun-dried
Moisture, % (wb)	63.00	2.00	2.36
Carbohydrates, g/100g	28.60	67.40	54.00
Proteins, g/100g	6.40	15.00	13.75
Vitamin C, mg/100g	11.11	9.52	6.60
Flavour, volatile oil, %	0.07	0.20	0.034

TABLE 3. QUALITY CHANGES IN GARLIC POWDER DURING STORAGE

Constituents	Polythene bag		Al.foil laminate		Glass bottle			
					White		Brown	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Moisture, %	2.00	4.40	2.00	1.80	2.00	4.00	2.00	2.70
Carbohydrates, g/100g	67.40	64.60	67.40	64.60	67.40	64.60	67.40	64.60
Protein, g/100g	15.00	11.86	15.00	12.50	15.00	12.20	15.00	12.56
Vitamin C, mg/100g	9.52	6.95	9.52	7.94	9.52	7.94	9.52	8.73
Flavour, volatile oil %	0.20	0.18	0.20	0.19	0.20	0.18	0.20	0.19
Browning index, OD	0.03	0.05	0.03	0.03	0.03	0.04	0.03	0.04

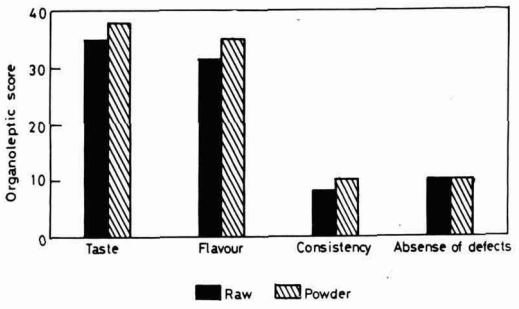

Fig. 4. Organoleptic evaluation of *chutney* prepared from garlic powder and raw garlic

Studies on the biochemical constituents of dehydrated garlic powder indicated that the maximum amounts of carbohydrate, proteins, vitamin C and flavour were retained in fluidized method of drying, when compared to sun drying (Table 2).

The dried products showed an increase in carbohydrate and protein contents due to concentration of solids because of less moisture content. Vitamin C, being heat labile, was reduced in sun-dried and as well as in fluidized method of drying. Reduction in flavour was observed in both the samples, which may be due to the enzymatic action initiated by cell wall collapse during slicing and the loss of volatile oil during drying.

To ascertain the acceptability of the powder for commercial use, comparison of the product prepared from dried garlic powder and raw garlic paste was conducted and the results showed that the qualities of taste, flavor and consistency were more in the case of garlic powder product than in raw garlic paste (Fig 4).

Storage over a period of 3 months in various packages showed insignificant changes in browning, carbohydrates, proteins, flavour strength and vitamin C (Table 3). But, the losses of nutrients were less in the case of aluminium foil laminates and brown glass bottles because of their barrier properties.

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Glycolipids Composition of Some Indian Linseed Varieties

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Composition of glycolipids from five varieties of linseed (*Linum usitatisium* Linn, Liliaceae) namely, 'C-429', R-552', RLC-4', RLC-6' and 'T-397' of Vidarbha region (Maharashtra) was investigated. The seeds were extracted with chloroform-methanol (2:1, v/v) to yield the total lipids (TL) (42.1-46.3%), which were separated into neutral lipids (NL) (87.8-89.6%), glycolipids (GL) (5.8-6.6%) and phospholipids (PL) (3.8-5.8%) by silicic acid column chromatography. Glycolipids were separated by TLC into individual components viz., monogalactosyldiacylglycerol (MGDG), digalactosyldiacylglycerol (DGDG), acylatedsterylgalactoside (ASG) and sterylgalactoside (SG). The fatty acid composition of total GL and its components as determined by GLC showed linolenic, oleic and linoleic acids, as the major fatty acids.

Keywords: Linseed varieties, Glycolipids, Components of glycolipids, Fatty acids, Chromatography.

Linseed is an important crop of the Vidarbha region, where its oil is used as a cooking medium by some sections of the local population. However, due to the presence of toxic cyanogenic compounds, linseed meal finds restricted use, which needs to be eliminated through breeding.

Lipids have important implications in post-harvest physiology as a matrix for the structure of the living cells and as integral components in biological oxidation. They have also been implicated in the blood clotting process (Gurr 1971). The role of the glycolipids is generally assumed to be to provide sugar molecules to cell for its functioning (Hanahan 1960). They also contribute to the aroma and flavour in fruits and berries (Tevini and Thaler 1977). Studies on lipids on the varieties of cottonseeds (Bhakare et al. 1992) oil palm (Kulkarni et al. 1991a) and other plant seeds from this region (Khotpal et al. 1992) have been reported. Bajpai et al (1985) reported on the component fatty acids and glycerides in the oils of different indian genetic varieties of linseed. This communication reports data on the glycolipids and fatty acid composition of 5 linseed varieties of the Vidarbha region.

Total lipids (TL) of the powdered seeds of the linseed varieties (obtained from PKV, Akola) were extracted with chloroform-methanol (2:1, v/v) according to the procedure of Folch et al (1957). The TLs were dried and separated into NLs, GLs and PLs by silicic acid column chromatography eluting successively by chloroform, acetone, and methanol (Rouser et al. 1970; Stahl 1962). The GLs, enclosed in the acetone elute, were quantified by total sugars estimation (Dubois et al. 1956). Separation of GLs into individual components such as MGDG, DGDG, ASG and SG was done by preparative TLC (Kates 1972). Glycerol was identified by the method of Malkin and Poole (1953). All the lipid materials were converted into their respective fatty acid methyl esters (FAME) by the method of Christie (1973). The FAMEs were analysed on a GLC unit consisting of a flame ionization detector (FID) at 280°C. The glass column used was packed with 15% EGSS-X on chromosorb-W (40-60 mesh size). The column and injection port temperatures were 200°C and 250°C, respectively. Nitrogen gas flow rate was 60 ml/min. and the chart speed was 60 cm/h. The fatty acids were quantified by the triangulation method (Kulkarni et al. 1991b) and by comparison with the standards, which were obtained from Analabs, USA.

The crushed seeds yielded TLs in 43.9, 46.3, 42.1, 43.5 and 45.2% respectively in the varieties. The TLs were separated into NLs (89.4, 90.1, 88.7, 87.8 and 89.6%), GLs (5.8, 5.9, 6.0, 6.4 and 6.6%) and PLs (4.8, 4.0, 5.3, 5.8 and 3.8%) by column chromatography. The GL fraction (Table 1) was resolved into MGDG, DGDG, ASG and SG. DGDG was the major component (40.5-43.1%) followed by MGDG (24.9-26.2%), ASG (15.4-16.5%) and SG (15.4-17.1%). This was in agreement with the earlier work on cottonseed varieties (Bhakare et al. 1992) and on rice bran varieties (Hemavathy and Prabhakar 1982). The fatty acid analysis of these fractions of GLs (Table 1) showed that linolenic acid was the predominent fatty acid in all the fractions, whereas oleic acid was present in good amounts in DGDG and ASG fractions. These observations agreed with the results on oils from palm varieties (Kulkarni et al. 1991).

On the basis of these results, it may be concluded that glycolipids of linseed varieties contain high amounts of unsaturated fatty acids mainly the

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TABLE 1. GLYCOLIPIDS OF VARIETIES OF LINSEED AND THEIR FATTY ACID COMPOSITION

Variety	Glyco-lipid compo-nents[a]	Weight, %	Fatty acids* Palmitic	Stearic	Oleic	Lino-leic	Lino-lenic
'C-429'	GL	5.8	10.5	2.5	25.8	25.8	35.4
	1	25.2	10.2	8.1	22.4	25.3	34.0
	2	42.2	5.9	2.5	35.8	19.5	36.3
	3	16.5	7.1	5.7	30.1	24.8	32.3
	4	16.1	-	-	-	-	-
'R-552'	GL	5.9	8.3	4.9	25.9	26.2	34.7
	1	26.2	9.8	7.8	23.5	26.4	32.5
	2	40.5	6.1	2.8	31.5	24.8	34.8
	3	16.2	7.5	4.5	29.2	25.3	33.5
	4	17.1	-	-	-	-	-
'RLC-4'	GL	6.0	9.6	2.8	24.8	23.9	38.9
	1	24.9	10.0	8.0	22.9	25.5	33.6
	2	43.1	5.7	2.7	31.3	26.5	33.8
	3	15.4	7.1	5.8	29.0	24.9	33.2
	4	16.6	-	-	-	-	-
'RLC-6'	GL	6.4	9.2	4.0	26.2	26.9	33.7
	1	25.0	9.9	8.4	24.8	24.8	35.0
	2	41.9	5.3	3.0	25.4	25.4	34.4
	3	16.0	7.5	6.5	24.5	24.5	34.7
	4	17.1	-	-	-	-	-
'T-397'	GL	6.6	10.2	4.8	24.2	24.0	36.8
	1	26.1	9.1	8.2	21.5	25.2	36.0
	2	42.8	6.5	2.9	31.0	26.0	33.6
	3	15.7	7.8	6.8	27.9	25.0	32.5
	4	15.4	-	-	-	-	-

* - means of triplicate analysis
[a] - GL - Total glycolipids
1-Monogalactosyldiacylglycerol 2-Digalactosyldiacylglycerol 3-Acylatedsterylgalactoside 4-Sterylgalactoside
Standard deviation value ± 0.0011

linolenic acid similar to the fatty acids present in the oil (Bajpai et al. 1985). The study also has shown that even though there are similarities in the types of fatty acids present in the oils originating from different varieties of linseed, significant quantitative dis-similarities in the concentration of individual acids can occur in the glycolipids of these varieties.

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Nutrient Composition and Amino Acid Contents of Malted Sorghum, Pearl Millet and Finger Millet and Their Milling Fractions

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The yields and composition of the milling fractions of milled sorghum, pearl millet and finger millet malts were determined. The yields of the refined flour from sorghum, pearl millet and finger millet were 86, 85 and 78%, respectively and their protein and crude fibre contents were 10.4, 15.5, 4.5% and 1.2, 1.0, and 1.8%, respectively. The lysine content of finger millet malt flour protein (3.4%) was higher than pearl millet malt (2.16%), sorghum (1.45%) malt flour protein. The bran fraction of pearl millet was a rich source of protein (23.1%) and fat (9.3%).

Keywords: Sorghum, Millets, Malting, Refined flour, Chemical composition, Amino acids.

Malting of sorghum and millets is traditionally practised for food and beverages in India and Africa (Venkatanarayana et al. 1979; Nout and Davies 1982; Elamalik et al. 1986; Palmer 1992). Besides brewing, sorghum and millet malts find use as a cereal base for low dietary bulk and calorie dense weaning foods, supplementary foods, health foods and also as amylase-rich food (Malleshi and Desikachar 1982; Gopaldas et al. 1986). Sorghum and millets contain about 10% coarse fibrous seed coat, which is concentrated with antinutritional factors such as phytate, pigments and polyphenols. Low fibre malt flour, free from antinutritional factors, is desirable for weaning and supplementary foods. Decortication or pearling of malted cereals is not feasible because the cereal malt is highly friable and it gets pulverised during decortication. However, moist-conditioning the malt and milling the same in roller mill are reported to be promising for the preparation of low fibre malt flour (Malleshi and Desikachar 1981). The nutrient composition and amino acid contents of malt flour and the bran obtained by milling malted sorghum and millets in the Quadrumat Jr. mill are reported in this communication.

Sorghum *(Sorghum bicolor)* 'SPV 473', white seeds and pearl millet *(Pennisetum americanum)* 'NW 305', blue seeds grown in the Fort Hays Agricultural Experiment Station, Hays Kansas, USA, and 'Indaf' variety of finger millet *(Eleusine coracana)*, brick red seeds, harvested at Naganahalli farm of the University of Agricultural Sciences, Bangalore, India, were used for the studies.

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The seeds were steeped for 16 h in water, germinated for 48 h at 25°C on muslin cloth, dried to about 10% moisture at 50°C and the rootlets were removed by gentle brushing to prepare malt (Malleshi and Desikachar 1982). The malt was sprayed with 5% additional water, tempered in rotating bins for 15 min and milled in the Quadrumat Jr. mill (M/s C.W. Brabender Instruments Inc., South Heckensack, NJ, Type: Quad mill No. 45), set to 0.1 and 0.2 mm clearances between the first and second rolls, respectively. The bran fraction from the first pass was sifted through a 60 mesh sieve and the +60 fraction was milled again and sieved through 60 mesh to extract the endosperm adhering to the bran. The -60 fractions were pooled and termed as malt flour, whereas the +60 fraction was designated as bran. The malted grains were pulverised in a Udy cyclone mill fitted with 0.5 mm screen to prepare the whole meal. The malt flour, bran and the whole meal were analysed for their proximate principles as per AACC (1983) methods. The sorghum and the millets malt samples and barley malt flour obtained from an industrial malt house were hydrolyzed by 2N *p*-toluenesulfonic acid and the hydrolysates were analyzed for amino acid contents except tryptophan, in a Deonex D-300 amino acid analyser (Jones 1983). The samples containing about 100 mg proteins were hydrolyzed in 5N NaOH at 110°C for 18 h in sealed tubes and the hydrolysates were processed for the determination of tryptophan colorimetrically as per Sastry and Tummuru (1985).

The yields of the refined malt flour from

TABLE 1. YIELD (%) AND COMPOSITION (g/100g) OF MILLING FRACTIONS FROM MALTED SORGHUM, PEARL MILLET AND FINGER MILLET

Sample	Yield	Proteins	Fat	Ash	Fibre
			Sorghum		
Whole meal	100.0	11.0	2.7	1.6	2.2
Flour	86.0	10.4	1.5	1.0	2.0
Bran	14.0	13.8	1.9	3.3	3.6
			Pearl millet		
Whole meal	100.0	16.9	5.1	1.5	1.6
Flour	84.8	15.5	3.8	1.1	1.0
Bran	15.2	23.1	9.3	3.4	4.8
			Finger millet		
Whole meal	100.0	6.0	1.4	2.3	3.8
Flour	77.5	4.6	1.2	1.8	1.8
Bran	22.5	11.2	2.5	4.5	10.4

Data on moisture-free basis

sorghum, pearl millet and finger millet were 86.0, 84.8 and 77.5% and the flours contained 10.4, 15.5 and 4.5% proteins and 2.0, 1.0 and 1.8% crude fibre, respectively (Table 1). Only finger millet malt flour contained about 25% less protein than its whole meal, whereas, the protein contents of sorghum and pearl millet malt flours were comparable to their whole meals. Malt flours from sorghum, pearl millet and finger millet contained 8.8, 36.0 and 51.5% less crude fibre than the whole meals. Malleshi and Desikachar (1981) had also reported 72% reduction in crude fibre and 45% reduction in protein contents on refining malted finger millet. About 20% reduction in protein on refining of sorghum has been reported by Pedersen and Eggum (1983). Since, the quality of the protein of refined flour is superior to that of bran, a small loss of protein on milling is compensated by the quality (Kurien and Desikachar 1966). The protein contents of the sorghum, pearl millet and finger millet bran fractions were 13.7, 23.1 and 11.2%, respectively and the bran fractions were rich in minerals. The pearl millet bran contained 9.3% fat.

The lysine content of finger millet malt flour was slightly higher than that of its whole meal, whereas sorghum and pearl millet malt flours contained slightly lower lysine than their respective whole meals (Table 2). The overall essential amino acid profile of finger millet was superior to sorghum and pearl millet. The bran fraction was slightly richer in essential amino acids as compared with the corresponding malt flour. Increases in lysine and tryptophan on germination of cereals have been reported (Wu and Wall 1980; Chavan and Kadam 1989). However, in a majority of the studies, the germination period was much longer than 2 days and the data were generally based on sprouts including the rootlets. The rootlets from sorghum and millet malt are reported to contain higher proportions of lysine (Malleshi 1992). The slightly lower values for lysine content of malt flour proteins as compared to the whole meal proteins observed in the present study could be due to removal of rootlets and bran.

TABLE 2. AMINO ACID CONTENTS OF MILLING FRACTIONS OF SORGHUM, FINGER MILLET, PEARL MILLET AND BARLEY MALT (g PER 100 g PROTEIN)

	Sorghum			Pearl millet			Finger millet			Barley malt
Amino acid	Whole meal	Flour	Bran	Whole meal	Flour	Bran	Whole meal	Flour	Bran	Flour
Aspartic acid	7.19	7.31	8.89	9.66	9.12	10.95	7.69	9.27	9.14	7.39
Threonine	3.28	3.20	3.91	4.20	4.00	4.57	4.38	4.16	4.58	3.73
Serine	4.67	4.64	5.19	5.41	5.27	5.47	5.30	5.30	5.56	4.90
Glutamic acid	21.49	22.25	18.61	19.90	21.11	16.78	17.13	16.63	17.14	22.07
Proline	9.15	8.91	7.73	5.54	5.80	5.43	6.26	5.98	6.37	12.13
Glycine	2.93	2.91	4.58	3.18	2.72	4.40	4.77	4.66	5.02	4.29
Alanine	8.69	8.66	8.08	8.61	8.66	8.43	7.42	7.39	7.47	5.01
Half cystine	2.05	2.08	2.07	1.35	1.46	1.43	1.63	1.83	1.44	1.61
Valine	3.67	3.66	3.95	4.93	4.88	4.93	5.36	5.52	5.35	4.17
Methionine	1.72	1.65	1.65	2.01	2.12	1.85	4.02	3.73	3.76	1.59
Isoleucine	2.90	2.85	2.96	3.77	4.04	3.59	3.66	3.90	3.65	2.99
Leucine	13.28	13.08	10.17	10.37	11.06	8.64	9.28	9.34	9.34	7.25
Tyrosine	4.42	4.32	4.42	3.86	3.74	3.95	4.53	4.57	4.69	3.69
Phenylalanine	5.44	5.24	5.03	5.38	5.53	4.86	6.07	6.19	5.91	5.66
Histidine	2.64	2.53	3.13	2.66	2.85	3.35	3.15	4.01	3.29	2.77
Lysine	1.53	1.45	3.12	2.66	2.16	3.93	2.01	3.41	3.03	3.76
Arginine	3.45	3.66	4.97	3.98	3.30	5.50	3.68	3.51	3.79	4.97
Tryptophan	1.05	1.16	2.31	1.51	1.98	2.75	1.35	1.62	2.63	1.62

The present study has revealed that, the low fibre malt flour from sorghum as well as millets are good sources of major nutrients and are generally comparable to barley malt flour with respect to the amino acid profile. The essential amino acid pattern of finger millet malt flour is superior to sorghum and pearl millet malt flours. The bran fraction is a rich source of proteins and minerals and may be useful in high fibre health foods and feed formulations.

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Development and Storage Stability of Cereal-based Papaya (*Carica papaya* L.) Powder

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Cereal-based powder was prepared using papaya and wheat flour. Physico-chemical, microbiological and organoleptic qualities were studied on storage for 0, 3, 6 and 9 months. Among the physico-chemical characteristics, no significant changes were observed in bulk density, total acids, pH, TSS, total ash, proteins and crude fibre. However, significant changes were observed in non-enzymatic browning, moisture, total sugars, reducing sugars, non-reducing sugars, vitamin C, total carotenes, β-carotene and fat. The non-enzymatic browning increased from 0.06 to 0.14 OD, while moisture increased from 1.05% to 11.9%, on 9 months storage. The losses of vitamin C (62%), total carotenes (55%) and β-carotene (51%) were high on 9 months storage. The microbiological counts such as viable bacteria, yeast and mould counts were observed on 6 months storage and increased slightly thereafter. Significant changes were not observed in organoleptic qualities.

Keywords: Papaya (*Carica papaya* L.), Physico-chemical changes, Storage studies, Sensory qualities, Microbiological counts.

India's papaya production accounts for about 7% of world's production. In Asia, papaya accounts for less than 1% of the total fruits produced (FAO 1991). Papaya is a tropical fruit and grows well in all soils except in rocky areas. India's climatic conditions are suitable for the growth of papaya. Papaya is a rich source of carotene, vitamin C and riboflavin, besides minerals (Giri et al. 1980; ICMR 1989). Carotene, which is the precursor of vitamin A, is present in adequate amounts in papaya.

Vitamin A deficiency results in corneal blindness. About half a million children in the world go blind every year as a result of vitamin A deficiency (WHO 1985). Carotenoids perform functions like precursors of vitamin A in photosynthetic tissue, protect the photosynthetic tissue against oxidation, antitumour agent and give colour to food. Therefore, a study on the development of a cereal-based papaya powder and its keeping quality was undertaken with the objective of promoting utilization of papaya in all seasons and by all age groups and the results are reported in this communication.

Preparation of the pulp : For the preparation of papaya pulp, evenly ripened fruit was procured in bulk from wholesale market. The fruit was washed thoroughly in water. The skin was peeled, papaya was cut into two halves and the seeds were removed. The pieces were put into the pulper and the pulp was passed through a 50 mesh sieve fixed in the pulper itself. The pulp contained total acidity 0.09%, total soluble solids (TSS) 12.9° Brix and showed a pH of 4.5. The pulp was heated to 85°C and filled into sterilized bottles and crown-corked. The prepared pulp was stored for a short period (not more than 5 days) and this was used for the preparation of the product.

Development of cereal-based papaya powder : Cereal-based powder was developed from papaya pulp. The product was prepared thrice and was presented to 20 trained panel members. Based on their recommendations, necessary modifications were made in cereal-based powder.

Standardization of cereal-based papaya powder: Since specifications for papaya powder are not available, the specifications of mango flakes (FPO 1991) were adopted, as the methodology and outcome were close. The details of the preparation of cereal-based papaya powder are given in Fig. 1.

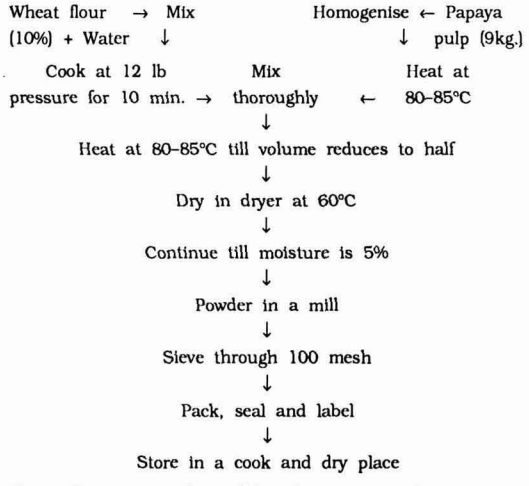

Fig. 1. Preparation of cereal-based papaya powder

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TABLE 1. PHYSICO-CHEMICAL CHARACTERISTICS AND ORGANOLEPTIC QUALITIES OF CEREAL-BASED PAPAYA POWDER (PER 100g PRODUCT)

Characteristics	Storage period, months				C.D. values
	0	3	6	9	
Physico-chemical					
Weight, g#	55.56	64.83	66.67	68.23	16.4730*
Volume, ml	82.70	94.45	98.54	100.68	27.7170*
Bulk density, g/ml#	0.67	0.69	0.68	0.68	NS
Total acids as citric acid, g	1.44	1.43	1.44	1.44	NS
pH#	4.84	4.83	4.84	4.84	NS
Acid insoluble ash, mg	0.04	0.04	0.04	0.04	NS
Non-enzymatic browning, OD#	0.06	0.09[a]	0.11[a]	0.14[abc]	0.0238***
TSS, °Brix#	58.67	57.67	57.33	57.67	NS
Moisture, g	1.65	10.04[a]	10.13[a]	11.90[a]	2.1894***
Total ash, g	2.45	2.46	2.47	2.49	NS
Total sugars, g	36.26	35.55[a]	35.14[ab]	34.95[ab]	0.3921***
Reducing sugars, g	21.40	21.12	20.71[a]	20.38[ab]	0.5660***
Non-reducing sugars, g	14.86	14.43	14.43	14.57	0.6627*
Vitamin C, mg	113.16	90.53[a]	72.42[ab]	43.45[abc]	1.5137***
Total carotenes, mg	5.28	4.33[a]	3.55[ab]	2.48[abc]	0.0777***
ß-carotene, mg	1.15	0.97[a]	0.80[ab]	0.56[abc]	0.0274***
Fat, g	0.40	0.41	0.41	0.40	NS
Proteins, g	7.39	7.33	7.34	7.33	NS
Crude fibre, g	2.73	2.76	2.76	2.80	NS
Organoleptic qualities					
Colour and appearance	4.63	4.50	4.50	3.88	NS
Texture	4.25	4.13	4.00	3.50	NS
Flavour	3.63	3.25	3.25	3.00	NS
Taste	3.75	3.25	3.25	3.13	NS
Overall quality	3.88	3.75	3.75	3.63	NS
Total	20.14	18.88	18.75	17.14	

Maximum scores for each parameter is 5-Excellent, 4-V. Good, 3-Good, 2-Fair, 1-Poor, 0-V.Poor

NS Not Significant
* Significant at 5% level
** Significant at 1% level
*** Significant at 0.1% level
C.D Critical difference 0.001 level
# Indicates product values

Superscripts of a, b and c indicate significant difference with that column of the same row

Storage studies : The prepared powder was packed in 150 gauze polyethylene covers and stored in stainless steel tins at room temperature for 9 months. Physico-chemical and microbiological properties as well as organoleptic evaluation were carried out intermittently at intervals of 0, 3, 6 and 9 months, during storage.

Physico-chemical characteristics : Since, chemical constituents present in papaya fruit influence the product outcome and its storage qualities, analysis of physico-chemical characteristics such as weight vs. volume (w/v) (Griswold 1962), pH, acid insoluble ash (AOAC 1965), non-enzymatic browning (Baloch et al. 1973), total acidity, sulphur dioxide, pectin (Ranganna 1986), TSS, moisture, total ash, crude fibre (AOAC 1984), total sugars, reducing sugars, non-reducing sugars (Lane and Eyon 1923), vitamin C (AVC 1966), total carotenes, ß-carotene (Zakaria et al. 1979; Nelis and DeLeenheer 1983), fat (AOCS 1981) and proteins (AOAC 1965) were carried out at the end of 0, 3, 6 and 9 months storage period. All the values were expressed for 100 g of the product (Table 1).

Microbiological counts : At the end of 0, 3, 6 and 9 months storage, viable yeast and mould and bacterial counts, were determined by pour-plate method (Cruickshank et al. 1975).

Organoleptic evaluation : Sensory qualities of developed products were evaluated with the help of descriptive test. A score card was developed and presented to the panel members (CFTRI 1986). The cereal-based powder was evaluated at 0, 3, 6 and 9 months of storage.

Incorporation into products : The developed powder was incorporated at 10, 20, 30 and 40% levels in ice cream, custard powder and weaning mixture. Acceptability of the products was tested by the panel members.

Statistical analysis : Different physico-chemical characteristics of cereal-based papaya powder were subjected to one way analysis of variance. The critical differences were also calculated (Snedecor and Cochran 1967).

Bulk density of the powder remained almost constant throughout the storage period due to proportionate changes in weight and volume. Total acid contents of the papaya powder remained constant throughout the storage period with negligible change. Changes were not observed, since necessary water was not provided in the powder (Dabhade and Khedkar 1980). Studies by Dabhade and Khedkar (1980) revealed that the acid content of the mango powder also did not increase on storage. This was supported by pH, which was constant throughout storage. Acid insoluble ash and total ash of the product showed negligible variation, indicating that no adulteration occurred after packing the product. The low values further indicated that the ingredients used in the preparation of the product were of good quality. The acid insoluble ash was low and below FPO (1991) recommendations.

Highly significant increase in non-enzymatic browning of cereal-based powder during storage can be explained as reactions between aldehydes, ketones and reducing sugars with amino acids, peptides and proteins (Maillard reaction), nitrogenous matter and organic acids themselves (Mahadeviah 1966).

Significant increase in moisture content was noticed at 3 months of storage, but after the initial rise, the change in moisture level was not considerable. It has been reported (Muralikrishna et al. 1969) that guava powder is hygroscopic in nature and moisture uptake is very high in natural conditions. The increase in moisture content of the product was to maintain equilibrium with atmospheric moisture. Hence, in the present study, the uptake of moisture was high during rainy season, due to high humidity in the atmosphere. Studies (Dabhade and Khedkar 1980) have also shown that moisture content increases considerably in mango powder, when kept in uncontrolled conditions i.e., at room temperature. In the present study, the increase in moisture content was high in papaya powder and this could be overcome by using better packaging material.

TSS also remained constant after an initial decline. This decline can be attributed to significant decrease in the total (34.95%), reducing (20.38%) and non-reducing sugars (14.57%). Total, reducing and non-reducing sugars probably decreased due to the inversion of sugars to monosaccharides by acid hydrolysis (Muralikrishna et al. 1969).

Vitamin C content of the product decreased significantly (62%) at 9 months storage. The greater loss of vitamin C may be due to heat, light sensitivity and greater area of the powder exposed to atmosphere. In an earlier study (Muralikrishna et al. 1969), a retention of 18 to 22% of vitamin C in storage of guava powder for 12 weeks at 37°C, was observed. Total carotenes and ß-carotene contents of the powder significantly decreased by the end of the storage period. Total carotene loss was 53%, while that of ß-carotene was 51%, at 9 months of storage. The decline can mainly be explained by the thermolabile and photosensitive nature, isomerisation and epoxide forming nature of carotenes (Land 1962; Eskin 1979; Mir and Nath 1993). Fat content remained the same during storage, while proteins decreased. Crude fibre showed an insignificant increase with storage.

Significant changes were not observed between storage periods, for bulk density, total acids, pH, acid insoluble ash, TSS, fat, proteins, crude fibre and total ash. Significant changes were observed in weight, volume and non-reducing sugars. Storage changes were highly significant for non-enzymatic browning, moisture, total sugars, reducing sugars, vitamin C, total carotenes and ß-carotene.

Microbiological qualities : Bacterial count was not observed up to 3 months of storage. Cereal-based powder had a moderate concentration of sugar and low level of moisture. At 9 months of storage, the count increased slightly due to increase in moisture content of the cereal-based powder and also due to increased environmental temperature. The organoleptic qualities of the products were acceptable to the panel members, at 9 months storage. The acceptability of the powder by the panel members confirmed that the minimal changes, which might have occurred due to bacterial, yeast and mould counts were within safe limits for human consumption.

Organoleptic qualities : Cereal-based papaya powder had good scores for colour, appearance and texture at initial, 3 and 6 months of storage, but

TABLE 2. ORGANOLEPTIC QUALITIES OF CEREAL-BASED PAPAYA POWDER INCORPORATED PRODUCTS

Product	Sensory qualities	% Incorporation			
		20	40	60	80
Ice cream	Colour and appearance	3.51	4.58	4.60	4.25
	Texture	4.55	4.50	4.45	4.45
	Flavour	4.25	4.60	4.55	4.40
	Taste	4.37	4.75	4.70	4.45
	Overall quality	4.15	4.80	4.62	4.17
	Total	**21.83**	**23.15**	**22.92**	**21.72**
Custard powder	Colour and appearance	3.25	3.75	4.50	4.01
	Texture	4.51	4.52	4.07	4.04
	Flavour	3.27	4.25	4.25	4.02
	Taste	4.15	4.57	4.55	4.19
	Overall quality	3.78	4.51	4.25	4.00
	Total	**18.96**	**21.60**	**21.62**	**20.26**
Weaning mixture	Colour and appearance	3.29	4.25	4.50	4.25
	Texture	3.75	4.54	4.74	4.56
	Flavour	3.45	4.58	4.75	4.25
	Taste	3.99	4.57	4.55	4.22
	Overall quality	3.51	4.55	4.70	4.25
	Total	**17.99**	**22.49**	**23.24**	**21.53**

Maximum score for each parameter is 5-Excellent, 4-V. Good, 3-Good, 2-Fair, 1-Poor, 0-V. Poor

the mean scores for these qualities declined to a great extent after 9 months of storage (Table 2). However, such variations were not noticed with respect to flavour and taste. The overall quality was also good with no major defects. Significant decrease was not noticed in all the sensory parameters. According to panel members, the product was starchy and had dominating cereal flavour. As the period of storage increased, the colour of the product decreased due to non-enzymatic browning. The product also acquired a bitter taste at the end of 9 months storage period.

Acceptability of cereal-based papaya powder incorporated products : Ice cream prepared by incorporating cereal-based papaya powder was acceptable and incorporation at 40% replacement was superior, followed by 60% replacement and 80% replacement was judged by the panel as inferior among all due to coarse texture. Custard powder prepared by incorporating cereal-based papaya powder was acceptable at 60% incorporation, followed by 40% replacement and 20% replacement was judged by the panel as inferior among all due to poor colour, flavour, taste and overall quality. Weaning mixture prepared by incorporating cereal-based papaya powder above 40%, was acceptable and at 60% was superior, followed by 40% and 20% replacement was judged by the panel as inferior.

Cost of cereal-based papaya powder : The cost of the product, was calculated as per existing prices at the time of the study. The cost included ingredients, labour, electricity etc., worked out to be Rs. 1500 per 10 kg cereal-based papaya powder. The cost of the cereal-based powder incorporated product, however, depends on the level of incorporation and cost of the other ingredients at the time of the preparation.

Conclusion

The cereal-based powder developed during the course of this study can be used only by incorporating it into recipes such as custard powder, ice cream powder, weaning mixture, processed products etc. The taste of this product was bland and hence can be easily incorporated into various preparations. Some changes in physico-chemical and organoleptic qualities were observed, while the losses of vitamins were high after 3 months of storage.

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Comparative Effects of Frozen Storage on Biochemical Changes in Pink Perch *(Nemipterus japonicus)* and Oil Sardine *(Sardinella longiceps)*

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Effects of frozen storage on biochemical changes in pink perch *(Nemipterus japonicus)* and oil sardine *(Sardinella longiceps)* were investigated. Significant ($P<0.05$) increases in peroxide value (PV), thiobarbituric acid (TBA) number and free fatty acids (FFA) were observed in pink perch and sardine during storage. While sardine showed a greater rate of lipid oxidation, hydrolysis of lipids to FFA was more pronounced in pink perch. Total volatile-base nitrogen (TVBN) and trimethylamine nitrogen (TMAN) increased in both fishes during storage. While non-protein nitrogen (NPN) declined, alpha-amino nitrogen (AAN) showed an ascending trend during storage. Salt-soluble proteins (SSP) reduced significantly ($P<0.05$), with the extent of reduction being more in sardine. SSP, in both species, showed significant negative correlations with PV, TBA and FFA. In pink perch, influence of lipid oxidation products on protein extractability was comparatively more than that of FFA. In sardine, lipid oxidised and hydrolysed products had an equally adverse impact on protein solubility.

Keywords: *Nemipterus japonicus, Sardinella longiceps*, Frozen storage, Lipid freshness parameters, Salt-soluble proteins, Non-protein nitrogen.

The most important aspect in the post-harvest technology of fish is to prevent and retard the deteriorative changes in fish muscle. Fresh fish is susceptible to rapid spoilage in tropical countries owing to the prevalence of high ambient temperature and therefore, requires immediate preservation. Freezing and frozen storage are important methods for preservation of fish and fishery products. However, in the best of conditions, chemical and other changes do occur, reflecting in a gradual decline of product quality. These changes are of great commercial importance, as they determine the storage life of frozen seafoods. The quality of frozen seafoods depends on inherent biological differences, initial freshness, temperature of holding, fish handling prior to processing and the care, the product receives during frozen storage.

Though reports on chemical changes in Indian marine fishes during frozen storage are umpteen, literature pertaining to the comparative influence of frozen storage on biochemical changes in lean and fatty fishes are meagre. Therefore, the aim of the present investigation was to study simultaneously the effect of frozen storage on biochemical changes in the lean demersal pink perch *(Nemipterus japonicus)* and the pelagic fatty oil sardine *(Sardinella longiceps)*.

Fresh pink perch *(Nemipterus japonicus)* and Indian oil sardine *(Sardinella longiceps)* procured from mechanised fishing crafts off Mangalore coast were iced on board in 1:1 ratio. After transporting to the processing laboratory in iced condition, the fishes were immediately dressed and washed in chilled water. Dressed fish (1.50 kg each) were packed in low density polyethylene (LDPE) covers (200 gauge), stacked in galvanised trays and immediately frozen in a coil freezer at - 28°C for 48 h. The frozen samples were glazed in chilled water, packed in a master carton and stored at - 18°C. Biochemical analyses were done immediately after freezing and at regular intervals. For thawing, the frozen samples were sealed in a polythene bag, kept in running water for 60-70 min and drained over a wire mesh for 10 min.

Moisture, proteins, lipid and non-protein nitrogen (NPN) were determined according to AOAC (1975). Salt-soluble protein (SSP) was extracted from fish muscle by the method of Dyer et al (1950) and the protein content of the extract was estimated by the Biuret method of Gornall et al (1949). Peroxide value (PV) and free fatty acids (FFA) were determined according to the procedures of Jacobs (1958) and Takagi et al (1984), respectively. The distillation method of Tarladgis et al (1960) was followed to estimate the thiobarbituric acid (TBA) number in fish muscle. Alpha-amino nitrogen (AAN) was determined according to Pope and Stevens (1939). Total volatile-base nitrogen (TVBN) and trimethylamine nitrogen (TMAN) were estimated by the Conway's microdiffusion method (Beatty and

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TABLE 1. BIOCHEMICAL CHARACTERISTICS OF FRESH PINK PERCH AND OIL SARDINE

Parameter	Pink perch	Oil sardine
	Mean ± SD	Mean ± SD
Moisture, %	80.15±0.74 (5)	74.43±0.42 (5)
Proteins, %	17.08±0.14 (3)	19.29±0.20 (3)
Lipids, %	2.14±0.01 (4)	3.99±0.10 (4)
PV, mM O_2/kg fat	6.16±1.24 (3)	6.55±0.71 (3)
FFA, as oleic acid %	4.34±0.22 (4)	3.11±0.16 (4)
TBA, mg malonaldehyde/ kg meat	0.47±0.12 (3)	0.93±0.18 (4)
TVBN, mg %	5.26±0.85 (3)	11.87±2.40 (3)
TMAN, mg %	ND	ND
AAN, mg %	17.54±2.43 (3)	18.66±2.40 (3)
NPN, mg %	109.65±1.24 (3)	72.94±1.20 (3)

Reported values are expressed on wet weight basis. Figures in parenthesis indicate number of observations.

ND : Not detected, PV : Peroxide value, FFA : Free fatty acid, TBA : Thiobarbituric acid, TVBN : Total volatile - base nitrogen, TMAN : Trimethylamine nitrogen, AAN : Alpha-amino nitrogen, NPN : Non-protein nitrogen

Gibbons 1937). Data from the biochemical analyses were subjected to one way ANOVA and Lsdt test to determine significant differences between experimental periods of storage. Correlations among the SSP and lipid freshness parameters (PV, TBA and FFA) were also established (Snedecor and Cochran 1962).

Biochemical characteristics of freshly caught pink perch and oil sardine are shown in Table 1. The tendencies of changes in lipid deteriorative indices during frozen storage are presented in Table 2. Peroxide value (PV) increased significantly ($P<0.05$) from 8.06 to 28.40 mM in pink perch and 9.29 to 37.76 millimoles of oxygen per kg lipid in oil sardine during 12 weeks of storage. Similar observations were recorded in marine catfish by Srikar et al (1989). Data also show a greater rate of increase in PV in sardine compared to pink perch. These results could be attributed to the presence in sardine of higher concentrations of unsaturated fatty acids, which are highly susceptible to oxidation.

Lipid oxidation, a common phenomenon during frozen storage, mainly depends upon the quantity, distribution and extent of unsaturation of lipids in the body of the fish, along with their possible exposure to atmospheric oxygen. Also, Shewfelt et al (1981) and Slabyj and Hultin (1982) showed that microsomes from both light and dark muscles of lean and fatty fish containing enzymes might also contribute to the oxidative deterioration of frozen fish. Kanner and Kinsella (1983) suggested that lipid deterioration in fish muscle might be initiated by myeloperoxidases from phagocytic leucocytes. Thus, enzymic hydroperoxidation of lipids in fish appears to affect the rate of oxidative deterioration during subsequent handling and frozen storage of fish.

Thiobarbituric acid (TBA) number increased significantly ($P<0.05$) in oil sardine, showing a greater rate of increase compared to pink perch (Table 2). This could be attributed to the higher

TABLE 2. CHANGES IN LIPID FRESHNESS PARAMETERS, SALT-SOLUBLE PROTEIN AND NON-PROTEIN NITROGENOUS COMPONENTS IN PINK PERCH AND OIL SARDINE DURING FROZEN STORAGE*

	Storage period, weeks									
	0		1		3		8		12	
	PP	OS	PP	OS	PP	OS	PP	OS	PP	OS
PV, mM O_2/kg fat	8.06^a ±1.55	9.29^a ±0.76	10.99^b ±2.15	11.25^b ±1.15	15.28^c ±1.65	19.00^c ±0.94	18.02^d ±1.96	26.08^d ±0.98	28.40^e ±2.59	37.76^e ±1.13
FFA, as oleic acid %	5.21^a ±0.36	3.64^a ±0.16	6.62^b ±0.28	4.06^b ±0.16	8.41^c ±0.77	6.89^c ±0.18	9.70^d ±0.30	7.90^d ±0.17	16.11^e ±0.46	11.13^e ±0.20
TBA, mg malonaldhyde/ kg meat	0.55^a ±0.04	1.07^a ±0.11	0.60^{ab} ±0.12	1.40^b ±0.08	0.71^{bc} ±0.15	2.05^c ±0.16	0.81^{cd} ±0.08	2.61^d ±0.18	0.85^d ±0.20	3.38^e ±0.16
SSP, g/100 g meat	8.87^a ±0.19	9.49^a ±0.17	8.55^b ±0.18	9.37^a ±0.21	8.24^c ±0.18	8.82^b ±0.19	7.75^d ±0.19	7.98^c ±0.31	7.25^e ±0.21	7.49^d ±0.19
TVBN, mg/100g meat	6.54^a ±1.62	12.30^a ±1.52	7.02^a ±1.52	13.15^a ±0.78	10.02^b ±1.58	15.94^b ±0.75	13.90^c ±2.05	18.30^c ±0.79	16.80^d ±0.79	21.03^d ±0.77
TMAN, mg/100 g meat	ND	ND	1.32^a ±0.65	1.36^a ±0.90	2.28^a ±0.79	3.01^b ±0.74	4.48^b ±1.55	3.66^{bc} ±0.79	6.31^c ±1.36	4.03^{bd} ±1.34
AAN, mg/100 g meat	20.55^a ±3.24	19.34^a ±3.05	26.33^b ±2.60	21.77^{ab} ±2.28	27.34^{bc} ±2.96	22.40^{ab} ±2.98	26.91^{bd} ±3.08	25.63^{bc} ±3.17	29.05^{be} ±3.14	26.85^c ±3.05
NPN, mg/100 g meat	108.36^a ±1.62	72.07^a ±1.52	100.07^{bc} ±2.63	65.32^b ±2.72	99.34^{cd} ±1.58	61.16^c ±1.49	96.88^d ±2.69	57.66^d ±2.74	87.16^e ±2.72	49.22^e ±1.55

* Reported values are average of triplicate determinations ± SD. Refer Table 1 for details of abbreviated parameters
a-e : Means followed by different superscripts within a row differ significantly ($P<0.05$). ND : Not detected

production of peroxides and hydroperoxides in sardines, which are the reactants for the formation of malonaldehyde in fish muscle. The results corroborate with those of Vidya Sagar Reddy et al (1992).

Free fatty acids (FFA) increased significantly ($P<0.05$) by a magnitude of 10.90% and 7.50% at the end of 12 weeks storage in pink perch and sardine, respectively (Table 2). Between the two species, pink perch showed a higher rate of increase in FFA. Also, the extent of lipid hydrolysis in both fishes was seen to be particularly more at the later stages of storage. The accumulation of FFA could be ascribed to the phospholipase activity in fish tissue. Various authors have reported that FFA originate from the phospholipid fractions, which are the major lipid constituents that undergo hydrolysis to FFA during frozen storage (Ohshima et al. 1983; Srikar et al. 1989).

Salt soluble proteins (SSP) decreased significantly ($P<0.05$) by 18% and 21% in pink perch and sardines, respectively (Table 2). These results are in good accordance with earlier reports (Srikar et al. 1989; Vidya Sagar Reddy et al. 1992). Reduced levels of SSP could be attributed to the aggregation, leading to the insolubilisation of the myofibrillar protein fractions and are dependent on the initial quality of the fish. Further, the rate of decrease in SSP was greater in sardine than in pink perch. These results could be ascribed to the higher production of peroxides and hydroperoxides in sardines, which interact with and insolubilise the salt soluble protein fraction. Besides, the FFA produced in sardine muscle may have accentuated the denaturation of the native proteins. Ohshima et al (1984) have observed that enzymically produced free fatty acids in cod flesh play an important role in the denaturation of proteins during frozen storage.

Generally, the quality of lean fish, when compared to fatty fish, suffers predominantly from severe alterations of proteins (Sikorski et al. 1976). Further, according to Colmenero and Borderias (1983), fatty fishes are generally less susceptible to protein denaturation, as a result of the protective effect of neutral lipids during frozen storage. In the present study, reduced solubility in sardines could be attributed to lipid hydrolysis, which resulted in the loss of protective effect of lipids on salt soluble proteins.

Protein denaturation is a major problem in frozen storage of fish. Various hypotheses exist concerning this process and the molecular events involved. Kuusi et al (1975) explained this phenomenon to the interaction of oxidized lipids with fish proteins such as cysteine – SH, the ε – NH_2 group of lysine and the N – terminal groups of aspartic acid, tyrosine, methionine and arginine. These reactions, as suggested by Kuusi et al (1975), increase hydrophobicity of the proteins, thus increasing aggregation. During frozen storage, a negative correlation between FFA formation and protein solubility was observed by Srikar et al (1989) and Sikorski et al (1976). Sikorski et al (1976) have suggested that free fatty acids attach themselves to the appropriate sites on protein surfaces, creating a hydrophobic environment, thus resulting in decreased protein extractability.

In the present study, SSP in pink perch correlated negatively and significantly with PV ($P<0.01$, $r = -0.9770$), TBA ($P<0.01$, $r = -0.9569$) and FFA ($P<0.05$, $r = -0.9757$). Similar negative correlations were observed in oil sardine among SSP and lipid freshness parameters such as PV ($P<0.01$, $r = -0.9853$), TBA ($P<0.01$, $r = -0.9880$) and FFA ($P<0.01$, $r = -0.9711$). The above correlations in sardine indicate that the influence of lipid oxidised and hydrolyzed products had an equally adverse impact on myofibrillar protein insolubilisation, as reflected by their similar level of significance. In pink perch, however, the influence of lipid oxidation products on protein solubility was predominant over lipid–hydrolyzed products as evident by its higher level of significance.

Total volatile–base nitrogen (TVBN) increased from 6.54 to 16.80 mg % and 12.30 to 21.03 mg % at the end of 12 weeks storage in pink perch and sardine, respectively (Table 2). This represents a 1.70 – 2.60 fold rise in TVBN levels in the two fishes studied. Trimethylamine nitrogen (TMAN), which was undetectable in both the fishes immediately after freezing, showed on overall significant ($P<0.05$) increase during storage. The overall magnitude of TVBN and TMAN production was greater in pink perch than in sardine during storage. Increases in volatile bases in frozen–stored fish were reported by Vidya Sagar Reddy et al (1992).

Non–protein nitrogen (NPN) showed an overall significant ($P<0.05$) decline, the extent of reduction being almost of a similar magnitude i.e., 21–22%, both in pink perch and sardines (Table 2). Decrease in NPN may be due to drip loss, through which considerable amount of NPN is lost, resulting in a decrease in NPN values in fish muscle.

Fazal (1985) reported an increasing trend in alpha amino nitrogen (AAN) content from 33.96 to 58.00 mg% and from 19.02 to 30.00 mg % during frozen storage of seerfish and pomfrets, respectively. In the present study also, AAN increased significantly ($P<0.05$) by a magnitude of 8.50 mg % and 7.50 mg % after 12 weeks in pink perch and sardine, respectively (Table 2). Formation of free amino acids is mainly attributed to the autolytic activity and bacterial action on proteins. Changes in the dynamic balance between the production and breakdown of free amino acids by the associated muscle enzymes may also lead to free amino acid production. Results of the present study could be ascribed to the release of free amino acids, as a result of autolytic changes and possible microbial preteolysis.

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Effect of Syruping and Drying Methods on Quality of Ber Candy

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Studies on effect of method of syruping (cold and hot) and drying (shed, sun, solar cabinet and tray) on organoleptic properties and chemical composition of ber (variety : 'Umran') candy were conducted. The results showed that the method of syruping had significantly affected the quality of ber candy. The overall acceptability of cold syruping candy (8.2) was higher than the hot syruping candy (6.7). The candy dried by solar cabinet dryer gave a better quality product.

Keywords: Ber candy, Destoning, Pricking, Sulphuring, Syruping, Drying.

India ranks third in fruit production, producing about 26.5 million tonnes from cultivated area of 294 million hectares (Kulkarni and Dhurdeo 1994). Ber (*Zizyphus mauritiana* Lamk) is one of the most ancient fruits of India. It is mainly grown in the States of Madhya Pradesh. Bihar, Uttar Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Maharashtra and Andhra Pradesh (Pareek 1983). The area under cultivation in Maharashtra is about 9,636 hectares with an annual production of about 76,030 tonnes (Anon 1994). The predominant cutlivars that are being grown in Maharashtra are 'Umran', 'Kadaka', 'Sanur-3', 'Sanur-6' and 'Popular Gola'. Conventionally, ber is considered as poor man's apple. It is valued for its nutritional and medicinal properties (Singh and Singh 1973; Bakshi and Singh 1974; Dhingra et al. 1973; Nijjar 1975; Bhandari 1969; Kirtikar and Basu 1975). With increased production of particular fruit in a season, there is a glut in the market and the farmer is at loss due to low market price for his produce. This is true in case of ber also. Besides this, the post-harvest losses in our country are upto 30%, which reduces per capita availability (Subrahmanyam 1986). It is therefore, necessary to develop suitable technology for processing of fruits. Among the different processes, candy making has been proved to be more viable and appropriate. Many farmers have adopted this technology and have started commercial production of ber candy. But to prepare ber candy, much longer time is required. Therefore, it is necessary to minimise the time of candy making process. This could be done (i) by reducing time of syruping and (ii) by minimising the time of drying without affecting the quality of ber candy. The present study was undertaken to investigate the effect of syruping and drying methods on the quality of ber candy.

Sample preparation, syruping and drying : Fully matured, golden yellow coloured, 'Umran' variety ber fruits were used for the preparation of candy. The light weight, infested fruits and impurities were removed by dipping them in water. The fruits were then graded, destoned and pricked manually. The samples were blanched in boiling water at 98±2°C for 2-3 min. Then, sulphuring of blanched samples was carried out by burning 2 g sulphur powder per kg of ber fruits for 2 h (Kadam et al. 1991; Patil 1992). The pre-treated samples were then kept for syruping. For cold and hot syruping, the methods standardised by Kadam et al (1991) and Jadhav (1996), respectively were used. Cold syruping method involved dipping of pre-treated ber fruit in 40, 50 and 60% sugar solutions with 1% citric acid for 24 h each, respectively, followed by dipping in 70% sugar solution with 1% citric acid for 7 to 8 days. Hot syruping was done by dipping pre-treated ber fruit in 70% sugar solution with 1% citric acid at 60°C for 54 h. In both the methods, the fruit to syrup ratio was kept at 1:1. After syruping, drying of candy was done using four methods viz., shed, sun, solar-cabinet and tray-drying. The drying air temperature varied from 22° to 26°, 28° to 34°, 32° to 65°C and 55±2°C for shed, sun, solar-cabinet and tray-drying, respectively. The candy was dried to a moisture content of about 17.5 to 18.5%.

Analytical methods : The moisture content of the sample was determined by standard air oven method recommended by American Association of Cereal Chemists (AACC 1962). Residual peroxidase activity after blanching was measured by peroxidase test, while the total soluble solids, TSS was measured with the help of Erma hand refractometer (Ranganna 1986).

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TABLE 1. CHEMICAL COMPOSITION OF BER CANDY

Pre-treatments	Method of drying			
	Shed	Sun	Solar-cabinet	Tray
Acidity % of ber candy (0.24)				
Cold syruping candy	0.70	0.72	0.75	0.73
Hot syruping candy	0.66	0.66	0.72	0.69
Ascorbic acid, mg per 100 g pulp (110.2)				
Cold syruping candy	28.00	26.40	24.10	25.60
Hot syruping candy	23.32	21.60	18.24	20.00
Reducing sugar content, % (4.7)				
Cold syruping candy	32.42	28.37	27.89	29.62
Hot syruping candy	26.99	25.00	21.11	23.14
Total sugar content, % (10.2)				
Cold syruping candy	79.21	79.64	71.14	74.44
Hot syruping candy	71.14	70.22	68.83	69.91
Non-reducing sugar content, % (5.5)				
Cold syruping candy	44.45	45.85	40.14	42.50
Hot syruping candy	41.94	42.96	45.33	44.43

Figures in parenthesis indicate values for fresh fruits

Sensory evaluation : Sensory evaluation was carried out by a panel of 10 judges of different eating habits. The attributes viz., colour, texture, taste and overall acceptability were rated on a 9-point Hedonic scale (BIS 1972), ranging from 1 (most undesirable) to 9 (most desirable). The data were subjected to statistical analysis (Snedecor and Cochran 1968; Nigam and Gupta 1979).

Chemical composition : Acidity of the pulp was determined by titration with 0.01 sodium hydroxide (Ranganna 1986). The percentage acidity was expressed in terms of anhydrous citric acid. Ascorbic acid was determined by using 2, 6 - dichlorophenol indophenol dye (AOAC 1975). The reducing and total sugars were estimated by the method of Lane and Eynon (Ranganna 1986).

The effect of method of syruping, method of drying and their interaction on colour, texture, taste and overall acceptability was studied.

Chemical composition : From Table 1, it is seen that among all the drying methods, the acidity of ber candy increased significantly both for cold syruping (0.70 to 0.75%) and hot syruping (0.66 to 0.72%) as compared to fresh ber fruit (0.24%). This is because of reduction in moisture content of ber candy. The ascorbic acid (vitamin C) decreased significantly for both cold syruping (24.1 to 28.0 mg per 100 g pulp) and hot syruping candy (18.42 to 23.32 mg per 100 g pulp) as compared to fresh ber fruit (100.2 mg per 100 g pulp). This may be due to leaching in blanching medium and/or heat of drying. The reducing sugar contents were higher for both cold syruping (27.89 to 32.42%) and hot syruping candies (21.11 to 26.99%) as compared to fresh ber fruit (4.7%). It may be due to conversion of sucrose into reducing sugars under acidic medium. The total sugar contents also increased for both cold syruping (71.14 to 79.21%) and hot syruping candy (68.83 to 71.14%) as compared to fresh ber fruit (10.2%). This is due to reduction in moisture content and sugar uptake during syruping.

Effect on colour, texture and taste : The average scores for colour ranged from 7.9 to 8.3 and 6.1 to 6.9 in case of cold and hot syruping candy, respectively. This shows that the colour of cold syruping candy is significantly better than hot syruping candy. The texture of cold syruping candy (8.3) was superior to hot syruping candy (6.3 to 7.2). The average scores for taste ranged from 8.2 to 8.4 and 6.5 to 7.1 in case of cold and hot syruping candy, respectively. The taste of cold syruping candy was found better than hot syruping candy. The statistical analysis has shown that method of syruping was statistically significant, while the interaction between syruping and drying was non-significant at 5% level of significance (Table 2).

Effect on overall acceptability : The arithmetic

TABLE 2. MEAN VALUES AND CRITICAL DIFFERENCES OF QUALITY ATTRIBUTES OF BER CANDY

Treatments	Sensory score			
	Colour	Texture	Taste	Overall acceptability
Cold syruping candy				
Shed	8.3	8.3	8.4	8.3
Sun	7.9	8.3	8.2	8.1
Solar-cabinet	8.0	8.3	8.4	8.2
Tray	8.0	8.3	8.2	8.2
Hot syruping candy				
Shed	6.9	7.2	7.1	7.1
Sun	6.1	6.3	6.5	6.3
Solar-cabinet	6.8	6.7	6.6	6.7
Tray	6.4	6.5	7.0	6.6
Effect of method of syruping				
Cold syruping	8.05	8.30	8.30	8.21
Hot syruping	6.55	6.67	6.80	6.67
CD (5%)	0.076	0.056	0.050	0.044
SE	0.027	0.020	0.018	0.015
Effect of method of drying				
Shed	7.60	7.75	7.75	7.69
Sun	7.00	7.30	7.35	7.21
Solar-cabinet	7.40	7.50	7.50	7.46
Tray	7.20	7.40	7.60	7.39
CD (5%)	NS	NS	NS	NS
SE	0.038	0.028	0.025	0.022

mean of colour, texture and taste was taken as overall acceptability. The average scores varied from 8.1 to 8.3 and 6.3 to 7.1 in case of cold and hot syruping candy, respectively. It revealed that the overall acceptability was higher for cold syruping candy than hot syruping candy. The test of significance showed that the method of syruping was statistically significant, while the interaction between syruping and drying was non-significant at 5% level.

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Changes in the Trace Elements Content During Pulping of Fruits in Different Mixies

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Grape, apple, pineapple and tomato were pulped in 9 brands of popular mixies and the quantum of Fe, Ni, Zn and Cr picked up by the juices was estimated. The increases in Fe, Ni and Zn contents of the fruit juices varied differently, when pulped in different mixies. Chromium was not found either in the control juice or in the juices after pulping in different mixies. The Fe uptake by the fruit juices was positively correlated with increasing acidity, whereas, in case of Ni and Zn, the uptake was negatively correlated with acidity.

Keywords: Mixies, Trace elements, Fruit Juice, Pulping, Acidity.

Fruit juices are rich in minerals and vitamins and are easily digested and utilized in the body. Hence, they are considered as nourishing foods from infancy to old age for all people including invalids. Now-a-days, the fruits are commonly pulped by using mixies, whose containers and blades are predominantly made of stainless steel and also from different types of metals and their alloys. The acidic nature of the fruits can act upon the metal during pulping and leach out trace metals from the mixies.

In the present study, 9 popular brands of mixies were selected from different households and their descriptions are given in Table 1. The fruits commonly used for preparing fresh juices viz., grape, apple, tomato and pineapple were pulped in them for 45 sec. without the addition of extra water except for apple. In the case of apple, a little amount of distilled water (50 ml for 200 g fruit) was added for easy pulping and pulped for 90 sec. The pulped fruit juices were passed through the stainless steel hand pulper (as practised in local fruit juice centres) to remove the debris. The strained fruit juices were made upto a known volume with distilled water. An aliquot was wet-digested as per the method described by Jackson (1973). The wet-digested samples were analysed for the trace elements viz., Fe, Ni, Zn and Cr by using Atomic Absorption Spectrophotometer (Perkin Elmer Model-380, USA). The results were expressed as mg/100 g of fruit juice on dry basis.

The physico-chemical characteristics of fruit juices such as TSS, pH and acidity were determined and the results are given in Table 2. The acidity of the pulped fruit juices ranged from 0.31 to 1.17 g/100 g and the pH from 3.1 to 3.9. Among fruit juices, grape juice had the highest TSS (16° Brix) followed by pineapple (14° Brix), apple (9° Brix) and tomato (5° Brix).

TABLE 1. DESCRIPTION OF THE MIXIES USED IN THE STUDY

Mixies * (Brands)	Metal	Jar particulars: Height, cm	Jar particulars: Diameter, cm	Blade particulars: No. of S.S. blades	Blade particulars: Length, cm (one side)
M_1	SS	15.0	13.5	6	3.0
M_2	SS	20.5	11.5	4	2.0
M_3	Plastic (unbreakble)	18.0	12.0	4	2.0
M_4	SS	19.0	12.0	6	3.0
M_5	SS	19.0	12.0	6	4.0
M_6	SS	15.0	13.5	6	2.5
M_7	SS	15.5	13.0	4	4.0
M_8	SS	18.5	12.0	6	4.0
M_9	SS	15.0	16.0	4	2.5

SS - Stainless steel
* Brand names of mixies withheld

A general trend of increases in Fe, Ni and Zn contents was observed in all the fruit juices after pulping in different brands of mixies selected for the study over the respective controls. The values obtained are presented in Table 3.

Iron : The mean Fe content of the fruit juices pulped in different mixies ranged from 1.03 (T_1M_3)

TABLE 2. PHYSICO-CHEMICAL CHARACTERISTICS OF FRUIT JUICES

Fruit juices	Characteristics: °Brix	Characteristics: pH	Characteristics: Acidity, citric acid g/100 g
Grape	16.0	3.3	0.65
Apple	9.0	3.9	0.31
Tomato	5.0	3.9	0.31
Pineapple	14.0	3.1	1.17

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TABLE 3. CHANGES IN THE IRON, NICKEL AND ZINC CONTENTS OF FRUIT JUICES PULPED IN MIXIES OF DIFFERENT BRANDS (mg/100 g ON DRY WEIGHT BASIS)

Mixies	Iron				Nickel				Zinc			
(Brands)	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
M_0	0.95	2.22	4.92	0.99	0.74	1.44	1.37	1.09	0.66	1.42	1.04	1.03
M_1	1.71	4.71	5.27	2.63	0.92	2.44	1.58	1.98	1.09	2.00	1.88	1.24
M_2	1.98	5.10	5.29	2.34	0.80	2.51	1.45	1.14	0.72	1.75	1.09	1.45
M_3	1.03	2.85	5.20	1.40	0.76	1.92	1.43	1.28	0.68	1.46	1.12	1.13
M_4	1.78	3.65	5.05	2.82	0.77	2.12	1.53	1.12	0.73	1.48	1.38	1.05
M_5	1.77	2.60	4.95	3.01	0.82	2.92	1.62	1.20	0.73	1.45	1.27	1.06
M_6	1.72	4.73	7.39	3.16	0.85	2.65	1.75	1.19	1.00	2.67	1.73	1.08
M_7	2.11	3.65	7.63	2.92	0.88	1.83	1.53	1.37	0.88	2.50	1.81	1.42
M_8	2.03	3.80	6.62	4.53	0.84	2.11	1.54	1.29	0.86	2.29	1.70	1.52
M_9	2.39	3.90	5.17	4.82	0.80	2.02	1.58	1.17	1.10	1.91	1.52	1.05
Source		SE(D)	CD			SE(D)	CD			SE(D)	CD	
M		0.0685	0.1387			0.0497	0.1006			0.0134	0.0271	
T		0.0433	0.0877			0.0314	0.0636			0.0085	0.0171	
MT		0.1371	0.2774			0.0994	0.2012			0.0268	0.0543	

* T_1 – Grape, T_2 – Apple, T_3 – Tomato and T_4 – Pineapple

to 7.63 mg/100g (T_3M_7). Out of the nine mixies selected for the study, only one mixie (M_3) had non-metalic container, but was fixed with metal blades. The fruit juices pulped in M_3 recorded less Fe pick up, when compared to other mixies. The grape and pineapple fruit juices pulped in brand nine (M_9) showed the highest Fe uptake over the control. Similarly, iron contents of the tomato and apple juices, when pulped in M_7 and M_2 increased from 4.92 to 7.63 and from 2.22 to 5.10 mg/100 g, respectively. When the increases in Fe contents over control values were compared with individual juices, it was found that the values were 3.83 mg % (in T_4M_9) for pineapple juice, followed by apple juice (2.88 mg % in T_2M_2), tomato juice 2.71 mg % in T_3M_7) and grape juice (1.44 mg % in T_1M_9). The increases in the Fe contents of the different fruit juices over the control values and the interaction between mixies and fruit juices were highly significant.

Nickel : The mean Ni content of the fruit juices ranged between 0.76 (T_1M_3) and 2.92 mg/100 g (T_2M_5). Similar to Fe, the fruit juices pulped in brand 3 mixie (M_3) exhibited the least Ni pick up. The values of increase in Ni contents were 0.18 for grape juice (M_1), 1.48 for apple juice (M_5), 0.38 for tomato juice (M_6) and 0.28 mg/100 g for pineapple juice (M_7). However, variations in the Ni contents between fruit juices were observed, when pulped in different brands of mixies. The amounts of Ni picked up by the juices during pulping of the fruits in the various mixies (values over the respective control fruit juices) were not uniform.

Zinc : A significant increase in the Zn content was observed in all the samples after pulping in different mixies. The mean Zn content of the fruit juices ranged between 0.68 (T_1M_3) and 2.67 mg/100 g (T_2M_6). When the maximum per cent increase in Zn content was compared, it was found that the values were 1.25 for apple juice (in M_6) followed by tomato juice (0.84 in M_1), pineapple juice (0.49 in M_8) and grape juice (0.44 in M_9).

Chromium : Chromium was not found either in the control juices or in the juices after pulping in different mixies.

BIS (1975) (IS:7732:1975), BIS (1966) (IS:388:1966) and Swaminathan (1989) had specified the maximum permissible limits for Fe and Zn contents in the fruit juices like apple, pineapple, grape, tomato and other vegetable juices. The values noted in the present study (Fe and Zn) were found to be less than the permissible limits mentioned in the standards after pulping in different mixies.

Effect of pH and acidity on metal uptake : The correlation coefficient between metal uptake, pH

TABLE 4. CORRELATION COEFFICIENTS BETWEEN METAL UPTAKE, pH AND ACIDITY

	Metal uptake		
	Fe	Ni	Zn
pH	−0.3459**	+0.6417**	+0.9978**
Acidity	+0.5969**	−0.5369**	−0.8695**

** Significant at 1% level

and acidity are given in Table 4. It could be seen that Fe uptake by the fruit juices was positively correlated with increasing acidity. The correlation was highly significant. However, with respect to Ni and Fe uptake, it was found that their uptake was negatively correlated with acidity. These correlations were also highly significant. The study proved that mineral migration is due to a complex set of factors and acidity is only one of the factors.

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Popping Qualities of Minor Millets and Their Relationship with Grain Physical Properties

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Popping qualities of various genotypes of foxtail millet viz., 'PS-1', 'PS-2', 'PS-3', 'PS-4', 'PS-2616'; finger millet viz., 'PES-110', 'PES-176', 'PES-400', 'VL-124', 'VL-146', 'VL-149', 'VL-204'; Barnyard millet viz., 'Madira-21' and 'Madira-29' and local sample of proso millet were determined. The results revealed that proso millet possessed the best popping potential followed by finger millet, foxtail millet and barnyard millet. Foxtail millet showed significant positive correlations between 1000 kernel weight and popping %; 1000 kernel weight and expansion volume; 1000 kernel volume and expansion volume. Finger millet also showed significant positive correlations between hydration capacity and popping % and between % floaters and expansion volume.

Keywords: Minor millets, Popping quality, Physical properties, Foxtail millet, Finger millet, Barnyard millet, Proso millet.

Minor millets are generally consumed by the people of low socio-economic status. Poor grain quality characteristics such as rough texture, high fibre content, lack of gluten and typical flavour limit their uses in various food preparations. Popping of millets produces a porous product of low bulk density and pleasing texture with a distinct appealing flavour (Malleshi and Desikachar 1981). Popped products are generally used as snack food either after spicing or sweetening. Besides, popped millet flour with improved flavour and texture has wide scope for use in various traditional food preparations. Use of popped sorghum and millet flours in weaning mixes for children has been found acceptable (Malleshi 1986; Srivastava 1996). Popping quality affects the acceptability of products and relates to certain physical properties (Malleshi and Desikachar 1985).

Five genotypes of foxtail millet *(Setaria italica)*., seven genotypes of finger millet *(Eleucine coracana)*, two genotypes of barnyard millet *(Echinochloa colona)* were analysed for physical characteristics and popping qualities. Four genotypes of finger millet viz., 'VL-124', 'VL-146', 'VL-204', 'VL-149'; barnyard millet viz., 'Madira-21' and 'Madira-29' were obtained from the Vivekananda Parvatiya Krishi Anusandhan Shala, Almora, U.P., whereas three genotypes of finger millet viz. 'PES-110', 'PES-176' and 'PES-400'; five genotypes of foxtail millet viz., 'PS-1', 'PS-2', 'PS-3', 'PS-4' and 'PS-2616' were obtained from the Department of Plant Breeding, College of Agriculture of the G.B. Pant University of Agriculture and Technology, Pantnagar. Samples of proso millet were obtained from local market, Haldwani, Dist. Nainital, Uttar Pradesh, India.

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Grains of genotypes of different millets were studied for grain colour, thousand kernel weight, thousand kernel volume, grain hardness by Kiya hardness tester in terms of kilogram force (Kgf) (Subramanian and Jambunathan 1981), per cent floaters (Murty et al. 1983) and hydration capacity (Dhingra et al. 1992). Grain moisture was determined by AACC (1962). Grains were moistened and conditioned before popping. In the preliminary experiments, a simple method for moistening of grains, which can be followed at household level with little technical know-how, was developed for maximum popping. The conditions for moistening and drying of grains of various millets for maximum popping were worked out by varying the time for soaking and drying the grains. The treatment showing maximum popping was chosen. For this purpose, finger millet and foxtail millet grains were soaked for 60 min and 5 min followed by air drying for 12 h and 1 h, respectively. The different pre-treatments required for popping of finger millet and foxtail millet could be attributed to differences in physico-chemical properties of these millets (Malleshi 1986). The moisture contents of finger millet and foxtail millet after moisture and drying treatment ranged from 22.25 to 24.00 and 13.30 to 14.50%, respectively. Popping was done using common salt as heating medium, in an open iron pan, containing sample (2 g), and common salt (granules size : 40 mesh) at a ratio of 1:20 at 240 to 260°C for 15-25 sec. The number of popped grains per sample were recorded and expressed as popping per cent. The expansion volume was calculated by taking the ratio of total popped volume (ml) to original weight of raw kernels. Each sample was analysed in 6 replicates and data were statistically analysed by

TABLE 1. PHYSICAL CHARACTERISTICS AND POPPING QUALITIES OF FOXTAIL MILLET, FINGER MILLET, PROSO AND BARNYARD MILLETS

Genotype	1000 kernel weight, g	1000 kernal volume, ml	Grain hardness Kgf	Hydration capacity, ml/ 1000 grains	Per cent floaters	Grain colour	Popping %	Expansion volume, ml/g
				Foxtail millet				
'PS-1'	2.9	3.0	2.68	0.10	99.30	Yellow	77.94	3.90
'PS-2'	1.2	2.0	2.52	0.13	99.60	Brownish yellow	65.84	2.50
'PS-3'	2.6	2.7	2.29	0.12	100.00	Yellow	60.21	3.00
'PS-4'	2.5	3.5	2.48	0.40	100.00	Yellow	67.79	3.30
'PS-2616'	2.6	3.2	3.99	0.16	100.00	Pale yellow	34.41	3.13
CD at 5%	0.2	1.8	0.80	0.05	0.85	-	2.65	0.52
				Finger millet				
'PES-110'	2.9	3.9	1.10	0.23	72.33	Dark red	72.66	4.46
'PES-176'	2.8	4.0	1.38	0.20	41.00	Yellow brown	72.35	3.96
'PES-400'	3.0	4.0	1.28	0.23	82.33	Red	82.60	3.90
'VL-124'	3.2	4.3	2.00	0.23	70.06	Dard red	55.47	3.68
'VL-146'	2.7	4.0	1.03	0.32	45.33	Dark red	68.97	3.15
'VL-149'	2.6	3.8	1.63	0.50	93.66	Light yellowish brown	81.30	4.18
'VL-204'	2.7	4.0	1.53	0.52	67.00	Dusky red	87.54	3.68
CD at 5%	0.3	1.9	0.92	0.02	1.73	-	3.95	0.48
				Proso millet				
Local sample	5.4	4.1	1.05	0.36	100.00	Yellow	92.77	6.51
				Barnyard millet				
'Madira-21'	3.9	5.0	3.08	1.06	100.00	Olive and olive yellow	54.20	4.71
'Madira-29'	3.5	5.8	3.72	0.70	100.00	Olive yellow	48.85	4.60
CD at 5%	0.2	1.7	0.95	0.03	0.35	-	2.82	0.50

using one way analysis of variance (Snedecor and Cochran 1967).

Grain moisture of various genotypes of foxtail millet, finger millet and barnyard millet ranged from 13.30 to 14.50, 22.25 to 24.00 and 6.56 to 7.06%, respectively. Proso millet sample had 13.75% grain moisture. The data presented in Table 1 show that colour of raw grains of genotypes of foxtail millet, proso millet and barnyard millet was towards yellow, whereas finger millet had different colours towards red yellow. The highest value for grain hardness was observed for genotype 'PS-2616' (3.99 Kgf) of foxtail millet and 'VL-124' (2.0 Kgf) of finger millet. Per cent floaters as an indicator of grain density did not differ significantly among genotypes of foxtail millet, barnyard millet and proso millet, whereas significant differences were observed among all the genotypes of finger millet. Popping per cent of foxtail millet, finger millet and barnyard millet genotypes ranged from 34.41 to 77.94, 55.47 to 87.54 and 48.85 to 54.20, respectively. Of all the millets, the highest popping (92.77%) and expansion volume (6.51) were observed for proso millet. Significant differences in the puffing yield of various genotypes of finger millet (Malleshi and Desikachar 1981), proso millet, foxtail millet and barnyard millet have been reported (Delost-Lewis et al. 1992; Malleshi and Desikachar 1985). Relatively lower values obtained for expansion volume for different millets as compared to those reported by Malleshi and Desikachar (1985) are attributed to the different methods of computing expansion volume.

There were significant positive correlation (r = 0.92) between 1000 kernel weight and popping % and (r = 0.97) between expansion volume and 1000 kernel weight in case of foxtail millet. Thousand kernel volume was also significantly positively correlated with expansion volume (r = 0.81). In finger millet, significant positive correlation (r = 0.78) was observed between hydration capacity and popping % and also (r = 0.85) between per cent floaters and expansion volume. Grain hardness failed to show significant relationship with popping quality of millets. Proso millet showed the highest potential for popping, followed by finger millet, foxtail millet and barnyard millet.

In conclusion, millets viz., proso millet, finger millet, foxtail millet and barnyard millet can well be popped by simple processing technique. Popping qualities of millets vary from genotype to genotype and relate to grain physico-chemical characteristics, specially grain hydration capacity, 1000 kernel

weight and 1000 kernal volume. Further studies are needed to establish the biochemical basis for genotypic variations in popping qualities of millets.

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Effect of Carbon and Nitrogen Sources on the Interaction of Mycotoxigenic Fungi and Mycotoxin Production

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Effect of carbon and nitrogen sources on the interaction of three mycotoxigenic fungi viz., *Penicillium citrinum*, *P. griseofulvum* and *Myrothecium roridum* and their effect on mycotoxin production was investigated under co-culture conditions. Production of citrinin by *P. citrinum* was suppressed, when grown with other two fungi in a medium, containing lactose and dextrin. Cyclopiazonic acid production by *P. griseofulvum* was inhibited by other two fungi in lactose and starch media. *M.roridum* did not produce roridin in a mixed culture. Preferential response towards different nitrogen sources by three fungi was observed and amount of mycotoxin produced varied with nitrogen source present in the medium. Similar effect was observed on biomass production by the three fungi under study.

Keywords: Carbon source, Nitrogen source, Interaction, Mycotoxin.

Natural incidence of mycotoxins and infestation of mycotoxigenic moulds on agricultural commodities has been reported to be quite common all over the world (Kamimura et al. 1986; Tanaka and Ueno 1988). These contaminated commodities are generally channelled through livestock and poultry, causing mycotoxicosis and secondary mycotoxicosis of animals and man, respectively. Carbon and nitrogen sources present in food commodities are reported to play a vital role in fungal metabolism and mycotoxin production (Miller and Greenhalgh 1985; Surekha and Reddy 1992). However, no information is available on the effect of carbon and nitrogen substances on the interaction of *Penicillium griseofulvum*, *P.citrinum* and *Myrothecium roridum*, which were common components of spermosphere of fennel and production of cyclopiazonic acid (CPA), citrinin and roridin, respectively. Hence, it was considered worthwhile to study the effect of carbon and nitrogen sources on the interaction of three mycotoxigenic fungi and its effect on biomass and mycotoxin production.

Fifty ml aliquots of buffered Asthana and Hawker's medium A, containing glucose (gl^{-1}) 10.0; KNO_3 3.5; KH_2PO_4 1.75; $MgSO_4$ 0.75; pH adjusted to 5.5 were taken in 250 ml Erlenmeyer conical flasks. Glucose and potassium nitrate of basal medium was substituted with different carbon and nitrogen compounds (Table 1), respectively so as to supply equivalent amounts of carbon and nitrogen. Flasks, thus, prepared were sterilized at 15 lbs pressure for 30 min and inoculated with monosporic cultures of *Penicillium citrinum*, *P. griseofulvum* and *Myrothecium roridum* individually and collectively and incubated at 27±2°C for 15 days. At the end of the incubation period, cultures were harvested on previously dried and weighed Whatman filter paper No. 42 for determination of biomass. pH of the culture filtrate was also recorded. Citrinin, cyclopiazonic acid and roridin were estimated as per the methods of Damodaran et al (1973); Rathinavelu and Shanmugasundaram (1984) and Rao et al (1985), respectively.

From Table 1, it is evident that the fungi responded differently with the type of carbon source present in the medium. *P. citrinum* produced maximum citrinin in medium, containing D-glucose and sucrose, while it was least in medium, containing lactose. Chary and Reddy (1986) also reported that D-glucose and sucrose supported the production of good amount of citrinin. Interestingly *P.citrinum* produced citrinin even in the absence of carbon source. *P.citrinum* was suppressed by other two fungi under study for production of citrinin in medium, containing lactose and dextrin. *P. griseofulvum* preferred D-glucose, followed by D-fructose for the production of CPA, while lactose was the least preferred carbon source for CPA production. CPA production by *P. griseofulvum* was totally inhibited by other two fungi in medium, containing starch and lactose. *M.roridum* produced maximum amount of roridin in medium, containing D-glucose and sucrose. *M.roridum* failed to produce roridin in the medium, containing dextrin and lactose. It elaborated only trace amounts of roridin in medium, containing starch and D-fructose. In mixed culture, *M.roridum* did not produce roridin except in medium, containing D-glucose and sucrose, where it was produced in traces.

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TABLE 1. EFFECT OF CARBON AND NITROGEN SOURCES ON GROWTH AND MYCOTOXIN PRODUCTION BY THREE INTERACTING FUNGI

	Name of the fungus	Final pH	Dry, weight, mg	Citrinin, ppb	Cyclo-piazonic acid, µg	Roridin, intensity
Carbon sources						
D-glucose	A	7.2	271.9	740	ND	ND
	B	7.1	239.7	ND	440	ND
	C	7.7	269.3	ND	ND	+4
	D	7.4	287.0	560	350	Trace
D-fructose	A	7.5	191.4	640	ND	ND
	B	7.2	210.0	ND	415	ND
	C	7.6	348.7	ND	ND	Trace
	D	7.4	247.0	440	395	ND
Sucrose	A	7.5	192.5	730	ND	ND
	B	6.9	210.7	ND	325	ND
	C	7.6	270.0	ND	ND	+2
	D	7.3	250.0	550	305	Trace
Lactose	A	7.4	167.0	110	ND	ND
	B	6.9	201.0	ND	130	ND
	C	7.7	361.5	ND	ND	ND
	D	7.6	391.0	55	ND	ND
Starch	A	7.5	220.3	360	ND	ND
	B	6.5	229.5	ND	220	ND
	C	7.7	309.8	ND	ND	Trace
	D	7.5	262.5	340	ND	ND
Dextrin	A	7.7	202.6	520	ND	ND
	B	6.6	280.0	ND	275	ND
	C	8.0	302.7	ND	ND	ND
	D	6.8	220.0	140	240	ND
Without carbon source	A	7.8	40.0	40	ND	ND
	B	7.1	48.0	ND	ND	ND
	C	7.6	20.0	ND	ND	ND
	D	7.6	19.5	30	ND	ND
Nitrogen sources						
Ammonium sulphate	A	6.7	228.5	540	ND	ND
	B	6.5	182.5	ND	275	ND
	C	6.8	243.0	ND	ND	Trace
	D	6.9	242.5	450	260	ND
L-arginine	A	6.8	270.0	950	ND	ND
	B	6.6	213.0	ND	350	ND
	C	7.2	250.0	ND	ND	Trace
	D	7.2	282.5	600	165	ND
Barium nitrate	A	5.0	330.0	840	ND	ND
	B	5.7	360.5	ND	175	ND
	C	7.5	480.0	ND	ND	ND
	D	6.9	422.0	540	155	ND
Potassium nitrate	A	7.2	271.9	740	ND	ND
	B	7.1	239.7	ND	440	ND
	C	7.7	269.3	ND	ND	+4
	D	7.4	287.0	560	350	Trace
L-methionine	A	6.8	190.0	970	ND	ND
	B	6.9	188.0	ND	210	ND
	C	6.6	261.0	ND	ND	+2
	D	6.9	190.0	430	165	Trace
Urea	A	6.9	272.5	580	ND	ND
	B	6.9	200.4	ND	340	ND
	C	7.3	242.0	ND	ND	Trace
	D	6.5	232.5	530	325	ND
Without nitrogen	A	5.5	48.0	50	ND	ND
	B	5.8	49.5	ND	ND	ND
	C	5.8	60.0	ND	ND	ND
	D	5.4	47.0	20	ND	ND

A = *P.citrinum*; B = *P.griseofulvum*; C = *M.roridum*;
D=*P.citrinum* + *P.griseofulvum* + *M.roridum*; ND = Not detected

The biomass production by *P.citrinum* was maximum in medium, containing D-glucose, followed by starch as a source of carbon, while *P.griseofulvum* preferred dextrin for maximum biomass production. On the other hand, *M.roridum* attained maximum mycelial growth in medium, containing lactose followed by D-fructose. Interestingly, the biomass production in mixed cultures was maximum in medium, containing lactose and least in medium, containing dextrin. The pH changes were, in general, towards alkaline side. The final pH range was from 6.5–8.0.

Table 1 shows that *P.citrinum* produced maximum amount of citrinin in medium, containing L-methionine, followed by L-arginine and the least in medium, containing ammonium sulphate and urea. Chary and Reddy (1986) reported that ammonium sulphate was a poor substrate for production of aflatoxin and citrinin by *A.parasiticus* and *P.citrinum*, respectively. However, citrinin production in methionine containing media was inhibited to a maximum extent in the presence of other two fungi under study. *P. griseofulvum* produced maximum amount of CPA in medium, containing potassium nitrate and minimum in medium, containing barium nitrate. In mixed cultures, CPA production by *P.griseofulvum* was inhibited maximally in medium containing L-arginine, while it was least effected in urea and ammonium sulphate containing media.

The biomass production by *P.citrinum* was maximum in medium, containing barium nitrate and minimum in L-methionine medium. *M.roridum*, and *P.griseofulvum* preferred barium nitrate as their nitrogen source for the mycelial growth. Contrary to this, barium nitrate inhibited mycelial growth of *P.aurantiogriseum* (Surekha and Reddy 1992). The biomass production in mixed culture was maximum in medium, containing barium nitrate. In general, the biomass production in mixed cultures was comparatively low. The pH drift was towards alkaline side and the final pH was near neutral. In medium, containing barium nitrate and supporting the growth of *P.citrinum*, the final pH was strongly acidic (pH 5.0). No correlation could be observed among final pH, biomass and mycotoxin production.

From the present investigation, it is clear that the behaviour of fungi is likely to be influenced by their surroundings. The organisms are likely to be influenced by the presence of other organisms. In most of the cases, the amount of mycotoxin produced in mixed cultures was less than what

they produce in individual cultures. Inhibition of mycotoxins production in mixed cultures by different fungi has also been reported (Girisham and Reddy 1986; Krishna Reddy and Reddy 1989). Interestingly, stimulation in mycotoxin production in mixed cultures was not observed at all. Thus, observations made in pure culture for the production of mycotoxin may not reflect its behaviour in nature. However, the biological effect of individual and combined mycotoxins has to be examined. The natural incidence and inference reached by cultural conditions may not be the same and one has to be careful in reaching any decisive conclusions. Detailed investigations in this direction are more desirable and may be rewarding.

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Nutritional Changes in Soymilk Subjected to Different Physical and Chemical Treatments

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Soymilk samples, prepared by using atmospheric and pressure blanching with different levels of sodium bicarbonate for different periods of time and subjected to different heat treatments were compared for the loss of nutrients viz., B-vitamins, minerals and amino acids. The atmosphere blanching resulted in considerable losses of vitamins B_1, B_2 and amino acid-methionine and these losses were further increased by the use of sodium bicarbonate during blanching. However, the content of available lysine remained unaffected by sodium bicarbonate, but heat treatment caused a considerable loss in available lysing content. The contents of phosphorus and iron were not affected by sodium bicarbonate and only a slight loss was observed in calcium content.

Keywords: Available lysine, Blanching, Thiamine, Riboflavin, Methionine, Soy milk.

Among soybean products, soymilk is gaining sale potential in many of the Asian countries. Soy milk prepared by the traditional method presents the problem of beany flavour (Chin 1947). The Illinois method (Nelson et al. 1976), which makes use of blanching soybean with sodium bicarbonate could overcome the above problem. However, considerable losses of nutrients in alkaline pH, particularly of vitamins B_1 and B_2 have been reported (Perry et al. 1976). The degree of heat treatment had also been reported to affect the nutritional quality of soymilk (Fukushima 1975; Tomar and Chauhan 1988). Comparatively, pressure cooking is known to have less adverse effect on the nutritional value of foods. However, there is no information on the effects of pressure-blanching of soybeans on the nutritional quality of soymilk. Therefore, the present investigation was planned to evaluate the effects of pressure and atmospheric blanching, using sodium bicarbonate and also to study the effects of different heat treatments given to soymilk on the nutritional quality of soymilk.

Soybean seeds ('Bragg') procured from the Crop Research Centre of G.B. Pant University of Agriculture and Technology were dehulled and cotyledons were used for the preparation of soymilk. Pressure blanching (1:5 w/v, 15 psi) in water for 5, 8 and 10 min each, treated with 0 to 1% sodium bicarbonate and 3, 5 and 8 min with 0.3% sodium bicarbonate was used. Similarly, for atmospheric blanching (bean to water ratio 1:10 w/v), dehulled cotyledons were boiled without sodium bicarbonate for 60, 70 and 80 min with 0.3% sodium bicarbonate for 25, 35 and 40 min and with 0.5% sodium carbonate for 20, 30 and 40 min. After blanching, cotyledons were washed thoroughly with fresh water and then ground to a smooth slurry in a Colloid mill (Kem Dyne Co., Calcutta). The smooth slurry, thus, obtained was diluted with water in the ratio of 1:11 (w/v) on cotyledon weight basis. The suspension was passed through a homogenizer (M-type-3, M/s Gaulin Corporation, USA) at 4500-5000 psi. The samples of soymilk were subjected to different heat treatments namely boiling for 5 min and sterilization for 22 min at 15 psi. A control sample of soymilk was prepared by a hot extraction method (Stevechen 1988). One set of samples was used as such without boiling.

Analytical methods : The proximate composition of soybean seeds and soymilk was determined by using standard AOAC (1984) methods. The minerals (calcium, phosphorus and iron) were analysed, using the procedures described by Ranganna (1986). Available lysine was estimated according to the method of Carpenter (1970). The thiamine and riboflavin contents were determined, using the photo fluorimetric method of AOAC (1984).

Soybean seeds used for the present investigation and the milk made from them contained respectively, moisture, 11.8 and 94.3%; proteins, 39.8 and 2.9%; fat, 20.5 and 1.2%; ash, 5.6 and 0.24%; calcium, 0.2% and 60 mg/100 ml; phosphorus, 0.5% and 24 mg/100 ml; iron 0.014% and 3 mg/100 ml; methionine, 1.58 g and 1.50 g/100 g proteins; available lysine, 6.87 and 3.27 g/100 g proteins; thiamine, 1.1 mg/100 g soybean and

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TABLE 1. EFFECT OF DIFFERENT BLANCHING AND HEAT TREATMENTS ON THIAMINE AND RIBOFLAVIN CONTENTS (mg/1000 ml)

Level of sodium bicarbonate, %		Blanching time, min		Heat treatment of soymilk					
				Unboiled		Boiled		Sterilized[1]	
A	B	A	B	A	B	A	B	A	B
				Thiamine, mg/1000 ml					
Control		-	-	1.02	-	-	-	-	-
0	0	5	60	0.20	0.19	0.20	0.18	0.20	0.18
		8	70	0.18	0.17	0.18	0.17	0.17	0.16
		10	80	0.18	0.16	0.18	0.16	0.17	0.16
0.1	0.3	5	25	0.19	0.14	0.18	0.14	0.17	0.13
		8	35	0.18	0.13	0.16	0.13	0.16	0.11
		10	45	0.17	0.11	0.15	0.11	0.15	0.10
0.3	0.5	3	20	0.18	0.10	0.17	0.09	0.13	0.08
		5	30	0.17	0.09	0.15	0.07	0.13	0.07
		8	40	0.16	0.07	0.14	0.05	0.13	0.05
				Riboflavin, mg/1000 ml					
Control		-	-	1.20	-	-	-	-	-
0	0	5	60	0.16	0.15	0.15	0.14	0.14	0.13
		8	70	0.14	0.12	0.13	0.12	0.12	0.11
		10	80	0.13	0.11	0.12	0.11	0.12	0.10
0.1	0.3	5	25	0.14	0.12	0.14	0.11	0.13	0.10
		8	35	0.14	0.11	0.13	0.10	0.12	0.09
		10	45	0.12	0.10	0.11	0.09	0.10	0.08
0.3	0.5	3	20	0.11	0.08	0.11	0.06	0.11	0.06
		5	30	0.11	0.07	0.11	0.07	0.10	0.06
		8	40	0.10	0.05	0.10	0.05	0.11	0.05

All values are average of duplicates
Control : Soymilk prepared by hot extraction method from overnight soaked beans
[1] Sterilization at 15 lbs/inch^2 for 22 min; A-Blanching under pressure, 15 psi; B-Blanching at atmospheric pressure

1.02 mg/100 ml soymilk and riboflavin, 0.5 mg/100 g and 1.2 mg/1000 ml. These results are in accordance with those reported by Bourne (1976) and Tomar (1985).

Effect of blanching and different heat treatments on vitamins, amino acids and mineral contents of soymilk

Thiamine and riboflavin : The pressure blanching resulted in greater losses of thiamine and riboflavin contents of soymilk as compared to atmospheric blanching (Table 1). The use of increasing levels of sodium bicorbonate and blanching time caused additional losses in thiamine and riboflavin contents of soymilk. The loss in thiamine content was further aggravated by the use of sodium bicarbonate during heat treatments (boiling and sterilization) of soymilk (Table 1).

Available lysine and methionine : The results presented in Table 2 showed that the contents of available lysine and methionine were greatly affected by blanching methods and heat treatments. However, the use of sodium bicarbonate caused a slight loss in available lysine content. On the other hand, considerable loss in methionine content, probably due to degradation of sulphur containing amino acids at alkaline pH was observed.

Minerals : The results of minerals content indicated that there was no effect of heat treatments, but blanching exhibited a slight decreasing effect (Data not shown). Calcium content of soymilk prepared by pressure-blanching was lower as compared to that by atmospheric blanching. This indicated more loss of calcium into blanching water under pressure-blanching, which might be due to comparatively faster hydration of cotyledons, whereas in atmospheric blanching, due to slow hydration, some of calcium might have formed a complex with proteins.

From the results, it may be concluded that atmospheric blanching with 0.5% sodium bicarbonate for 40 min (present recommendation for soymilk) results into considerable losses of essential nutrients and therefore, should be replaced by pressure blanching (15 psi) with 0.1% sodium bicarbonate for 8 min in order to minimize the losses of nutrients.

TABLE 2. EFFECT OF DIFFERENT BLANCHING AND HEAT TREATMENTS ON AVAILABLE LYSINE AND METHIONINE CONTENTS (g/100 g PROTEIN) OF SOYMILK

Level of sodium bicarbonate, %		Blanching time, min		Heat treatment of soymilk					
				Unboiled		Boiled		Sterilized[1]	
A	B	A	B	A	B	A	B	A	B
				Lysine, g/100 g proteins					
Control		-	-	3.62	-	-	-	-	-
0	0	5	60	3.50	3.00	3.30	3.00	3.10	2.90
		8	70	3.50	2.95	3.20	2.90	3.00	2.85
		10	80	3.45	2.90	3.30	2.90	3.00	2.85
0.1	0.3	5	25	3.50	3.20	3.40	3.20	3.00	3.00
		8	35	3.45	3.20	3.35	3.05	3.10	2.95
		10	45	3.40	3.15	3.50	3.10	3.00	2.90
0.3	0.5	3	20	3.45	3.90	3.35	3.10	3.05	2.85
		5	30	3.50	3.15	3.40	3.10	3.05	2.80
		8	40	3.40	3.15	3.30	3.05	3.10	2.75
				Methionine, g/100 g proteins					
Control		-	-	1.50	-	-	-	-	-
0	0	5	60	1.40	1.30	1.30	1.25	1.25	1.20
		8	70	1.35	1.28	1.30	1.25	1.25	1.19
		10	80	1.30	1.20	1.25	1.15	1.20	1.13
0.1	0.3	5	25	1.35	1.25	1.30	1.23	1.27	1.20
		8	35	1.30	1.20	1.25	1.19	1.20	1.15
		10	45	1.25	1.15	1.20	1.13	1.10	1.10
0.3	0.5	3	20	1.15	1.10	1.10	1.05	1.05	1.00
		5	30	1.10	1.00	1.05	0.95	1.03	0.90
		8	40	1.05	0.95	1.00	0.80	0.95	0.75

All values are average of two determinations
Control : Soymilk prepared by hot extraction method from overnight soaked beans
[1] Sterilization at 15 psi for 22 min; A-Blanching under pressure (15 psi); B-Blancing at atmospheric blanching

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Variations in Hydration of Paddy Grains Within and Among Panicles of Pure Variety During Parboiling

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Paddy grains within a pure variety exhibited variations in hydration during parboiling. To find out the influence of the position of grains within panicles/hills, samples collected from 'Adt 36' variety were soaked at 65°C for 4 h, open-steamed (0 kg/cm²) for 5 min and air-dried. The grains that were completely translucent or otherwise were segregated and counted. In most cases, majority of grains in the primary panicles as well as those occupied top position in the panicles attained the stage, ready for complete parboiling quickly as compared to the grains representing lower positions.

Keywords: Parboiling, Variation in soaking, Translucency, Opaque, Panicles, Hill.

Over half of paddy produced in India is parboiled (Bhattacharya 1985). Among the three steps of parboiling process viz., soaking, gelatinization and drying, the soaking causes extensive quantitative (leachate loss, kernel bursting) and qualitative (colour, smell) changes (Pillaiyar 1988). Each variety of paddy has its own optimal soaking time. Freshly harvested sample absorbs water at a lower rate than the stored one (Bhattacharya and Subba Rao 1966). Though the difference in moisture uptake persists initially in samples having different initial moisture content, it levels off, as the soaking progresses to practically the same level, irrespective of the initial moisture content (Ali and Ojha 1976). In a study on parboiling characteristics involving 52 pure varieties/cultures (received from breeding stations), differing widely in dimension, weight and physico-chemical characteristics, heterogenity in soaking behaviour of individual grains within samples was noticed (Pillaiyar 1995). This study was undertaken in order to find out as to whether the position of grain in a hill/panicle would bring about such variation in soaking-ability among grains of the same panicle.

A few hills of 'Adt 36' paddy crop at the field of Soil and Water Management Research Institute (Tamil Nadu Agricultural University) Kattuthottam were randomly selected and labelled on the day of harvest. Individual panicles in each hill representing top, mid and bottom positions were labelled and removed separately. Within each panicle, grains representing top half and bottom half were hand-stripped separately. The samples were soaked simultaneously in a device, consisting of perforated bunker and slotted aluminium tubes with provision to soak 60 samples at a time (Pillaiyar 1995). The bunker was kept in the Haake circulating bath, maintained at 65°C and removed at the end of 4 h. While removing the bunker from the bath, water drained automatically. The bunker with the samples was, then, placed in a steamer, open-steamed for 5 min, air-dried in shade for two days and shelled in the laboratory Satake rice machine (Type THU). The brown rice sample kept over a partially illuminated glass stage was segregated into two fractions - one, the grains that were fully translucent and the other, with opaque portions, with an aid of a magnifying glass and counted separately. Grains having uniform moisture distribution would express full translucency even on mild steaming. The moisture content was determined by desiccating the samples in air oven at 105°C, till constant weight and expressed on wet basis.

Wide variations in completion of soaking among grains were noticed. In 4 h-soaking, as high as 96% of grains attained the stage, ready for parboiling in one sample whereas in another, it was 67% (Table 1). Nearly, 81% of grains in the panicles that occupied top position of the hill were found to absorb the required moisture for complete parboiling

TABLE 1. NUMBER OF GRAINS HAVING SUFFICIENT MOISTURE FOR PARBOILING IN 4-H SOAKING

(For every 100 grains)

Hill No.	Top most panicle			Middle panicle			Bottom panicle		
	U	L	Mean	U	L	Mean	U	L	Mean
1	78	80	79	-	-	-	74	73	74
2	77	76	77	84	77	81	-	-	-
3	-	-	-	71	71	71	79	81	80
4	91	96	94	81	76	79	77	73	75
5	75	76	76	78	78	78	78	67	73
Mean	80	82	81	79	76	78	77	74	76

U, Upper half; L, Lower half

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in 4 h-soaking, whereas it was less in the low positions (middle panicles, 78%; bottom panicles, 76%). However, the grain moisture in all these cases ranged from 29.8 to 30.3%. A similar pattern of differential moisture absorption by grains within a pure variety/culture was noticed in an earlier study also (Pillaiyar 1995). Slow absorption of moisture by the grains representing the bottom position of panicles as observed in this study suggests that these grains, which are comparatively young to those in the top and middle positions of panicles offer some resistance for water absorption. Flowering and fertilization do not begin simultaneously at different positions on the panicles of rice plant (Ramiah and Rao 1953; Matsubayashi et al. 1968) and this results in uneven maturity of individual grains, located at different positions (Mahadevappa et al. 1969). Generally, filling will be poor in the grains, representing lower positions in a panicle and those in late tillers. It has been indicated that the activities of the sucrose synthase and invertase were higher and lower, respectively, in the endosperm cells of the top spikelet, as compared to the basal spikelet. Poor synthesis of the starch leading to partial grain filling in the basal spikelet is due to a lower activity of sucrose synthase (Patel and Mohapatra 1996).

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Effect of Incorporation of Skin, Gizzard, Heart and Yolk on the Quality of Frozen Chicken Meat Sausages

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Addition of skin, gizzard and heart in the preparation of sausages sigificantly (P<0.01) reduced fat separation values, percent moisture, crude proteins, other extractives and juiceness scores. Sausages prepared with raw meat obtained significantly (P<0.01) higher scores for appearance, flavour, juiceness, firmness and overall acceptability as well as higher percent cooking losses and moisture content, while the pH and 2-thiobarbituric acid (TBA) values were lower. Frozen storage (-18±1°C) of sausages for 60 days significantly (P<0.01) increased the pH, TBA values, percent ether extractives and protein contents, while the mesophilic counts, percent moisture and organoleptic scores were reduced.

Keywords : Sausages, Skin, Gizzard, Heart, Storage, Organoleptic scores.

With the phenominal growth of poultry industry in India, the availability of spent layers has increased manifold, causing problem for their disposal. Processed food products such as sausages are considered a potential solution for utilizing spent meat. Effective utilisation of low quality components of hen such as skin, gizzard, meat and yolk (SGH + yolk) is essential for the economic production of sausages. Poultry skin, gizzard and heart are reported to have poor emulsifying capacity (Lyon and Thompson 1982). Chicken patties prepared with cooked meat had lower organoleptic scores (Lyon and Cox 1982). Hence, an effort was made to incorporate cooked meat, skin, gizzard, heart and yolk in sausages and evaluate their quality during storage.

Forty spent-chicken were utilized in four trials for this study. In each trial, one half of the dressed carcasses after initial chilling was partially cooked at 15lb/sq. inch for 15 min. to facilitate deboning. The other half of the carcasses was deboned raw. The skin, gizzard, heart (SGH) and the yolk material of the carcasses were kept aside for incorporation in the sausages. Four types of formulations viz., R_1 and R_2 for the raw meat, C_1 and C_2 for the cooked meat were prepared. The formulations of R_2 and C_2 comprised chicken meat (either raw or cooked as the case may be), fat, gizzard, and heart (SGH), and yolk at levels of 720 g, 100 g, 150 g, and 30 g respectively, totalling to 100 g. The formulations of R_1 and C_1 comprised chicken meat (raw and cooked, respectively) and fat at levels of 850 g and 150 g, respectively. Additional ingredients added for each formulation were, salt 25 g, *maida* 30 g, onions 30 g, ginger 14 g, $NaNo_3$ 1.4 g, spice mix 21 g, sugar 10 g, turmeric powder 5 g, and garlic 5g. Processing of each formulation and preparation of linked sausages was done as per the procedure outlined by Naidu (1988). The linked sausages for each formulation were packed in 100 gauge polythene bags and frozen-stored at -18±1°C. The samples for 0 day (fresh) and at the end of 15, 30, 45 and 60 days were drawn and evaluated for quality. Cooking losses of sausages were determined according to the procedure described by Naidu (1988) and expressed as percent. Fat separation values were estimated as per the procedure detailed by Kondaiah and Panda (1989) and expressed as ml of fat per 100 g of mix. Physico-chemical characteristics like pH and 2-thiobarbituric acid (TBA) value were estimated by the methods of Lakkonen et al (1970) and Witte et al (1970), respectively. The proximate composition and total aerobic mesophiles were estimated as per AOAC (1980) and Chestnut et al (1977), respectively. Organoleptic evaluation was carried out on a 7-point Hedonic scale. The data obtained for various parameters were analysed statistically according to Snedecor and Cochran (1963).

Formulations of C_1 and C_2 recorded significantly (P< 0.01) lower percent cooking losses, which might be due to the initial loss of moisture on partial cooking of meat. On the other hand, the fat separation values were significantly low in SGH and yolk-added (C_2 and R_2) sausages, which could be attributed to the effect of yolk in reducing the fat separation values, which, in turn, contributed to the increased product yield. These findings concur with the results of Kondaiah and Panda (1989). Sausages prepared with cooked meat (C_1 and C_2) had resulted in significantly (P<0.01) higher mean

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TABLE 1. EFFECT OF INCORPORATION OF SGH IN THE FORMULATION ON THE CHEMICAL AND SENSORY CHARACTERISTICS OF SAUSAGES

	R_1	R_2	C_1	C_2
Cooking loss, %	22.58^b±0.44*	24.87^a±0.52	20.61^c±0.20	21.25^c±0.29
Fat separation value, ml	2.54^a±0.14	1.20^c±0.05	1.94^b±0.09	1.32^c±0.07
pH	5.64^b±0.01	5.69^b±0.01	5.80^a±0.01	5.78^a±0.01
TBA values	0.57^b±0.02	0.61^a±0.04	0.64^a±0.02	0.63^a±0.03
Mesophilic counts, 20g/cm^2	4.30^a±0.06	4.27^a±0.06	4.32^a±0.05	4.27^a±0.04
Moisture, %	64.24^a±0.37	57.76^b±0.33	55.63^d±0.42	54.62^c±0.67
Ether extractives, %	16.35^a±0.17	10.27^b±0.05	16.03^a±0.19	11.60^b±0.09
Crude proteins, %	15.39^a±0.18	15.11^b±0.21	15.26^a±0.20	14.89^b±0.22
Sensory characteristics				
Appearance	4.85^a±0.19	4.45^b±0.26	4.30^c±0.21	4.35^c±0.18
Flavour	5.40^a±0.18	5.50^a±0.18	5.10^b±0.16	4.90^b±0.19
Juiceness	5.20^a±0.15	5.05^b±0.17	5.05^b±0.15	4.80^c±0.21
Firmness	5.45^a±0.19	5.40^a±0.18	5.30^a±0.14	4.95^b±0.15
Overall acceptability	4.95^a±0.21	4.80^b±0.23	4.60^c±0.24	4.60^c±0.21

Means superscribed with the same letter in rows are not significantly different (P<0.01).
* Standard error

pH and TBA values (Table 1). Similar increase in pH of cooked ground beef was observed by Hegarthy and Ahn (1976) and higher TBA values in cooked meat-added sausages by Kondaiah et al (1988). Higher degree of oxidation in cooked meat than in raw materials might be responsible for such changes. Cooked meat-added sausages (C_1 and C_2) had significantly (P<0.01) lower mean percent moisture contents and also the sausages added with SGH and yolk (R_2 and C_2) too recorded significantly (P<0.01) lower moisture content than their counterparts (R_1 and C_1). Loss of moisture, while cooking the meat and the presence of giblets, were responsible for lowering the moisture content of respective sausage samples. These findings concur with the results of Kondaiah et al (1988). The percent values of ether extractives and crude proteins were significantly (P<0.01) higher in R_1 and C_1 sausages formulations, due to the addition of more fat and presence of more content of chicken meat portion in the above formulations. Further, the SGH+yolk addition in sausages significantly reduced the fat separation values. Percent moisture, crude proteins, ether extractives and juiciness scores, while Kondaiah et al (1988) observed higher fat and crude protein contents in SGH-added sausages.

Sausages prepared with raw meat (R_1 and R_2) scored significantly (P<0.1) superior scores for appearance, flavour, juiciness, firmness and overall acceptability (Table 1). Loss of volatile compounds, while cooking and retention of more moisture and fat in raw meat sausages are responsible for lowering the flavour and juiciness scores for cooked-meat sausages which, in turn, might have reflected in lowering the overall acceptability scores. Similar to the present observations, Kondaiah et al (1988) in chicken sausages and Lyon and Cox (1982) in chicken patties observed lesser scores for flavour and juiciness with the addition of cooked meat.

In the present study, irrespective of type of formulation, frozen storage of sausages yielded significantly (P<0.01) lower per cent cooking loss at 15 days and later on with slight reduction upto 60 days (Table 2). This might be due to loss of moisture. These findings are in agreement with those reported by Matlock et al (1984). Fat separation values of sausages increased significantly on storage. Frozen storage of sausages for 60 days significantly (P<0.01) increased the pH and TBA values, whereas the mesophilic counts decreased drastically (Table 2). Liberation of metabolites resulting from bacterial activity and oxidation of fatty acids during storage might be responsible for such increases. In agreement with the results of Kondaiah et al (1988), in the present study also, frozen storage of sausages has caused a significant (P<0.01) and gradual reduction in the mean mesophilic counts upto 45 days and thereafter with slight reduction of counts at 60 days of storage (Table 1). Storage of sausages from 15 to 60 days significantly (P<0.01) reduced the percent moisture content and slightly increased the percent ether extractives and protein contents in sausage samples. Loss of moisture at longer periods of storage may be due to drip while thawing

TABLE 2. EFFECT OF STORAGE (-18±1°C) ON THE CHEMICAL AND SENSORY CHARACTERISTICS OF SAUSAGES

	Stored period, days				
	0	15	30	45	60
Cooking loss %	24.00^{a}±0.81	21.52^{b}±0.45	21.68^{b}±0.42	20.99^{b}±0.31	20.98^{b}±0.31
Fat separation values, ml	1.27^{cd}±0.06	1.45^{bc}±0.15	1.75^{b}±0.17	2.01^{ab}±0.08	2.26^{a}±0.14
pH	5.63^{c}±0.02	5.70^{b}±0.01	5.73^{ab}±0.02	5.74^{ab}±0.01	5.76^{a}±0.01
TBA values	0.34^{d}±0.01	0.57^{c}±0.01	0.66^{b}±0.01	0.74^{a}±0.01	0.75^{a}±0.01
Mesophilic counts, log/cm^{2}	4.62^{a}±0.05	4.50^{a}±0.02	4.18^{b}±0.03	4.09^{c}±0.01	4.04^{c}±0.01
Moisture, %	58.99^{a}±0.78	59.04^{a}±0.48	57.34^{b}±0.28	56.46^{c}±0.33	55.63^{d}±0.22
Ether extractives, %	13.12^{b}±0.22	13.64^{a}±0.11	13.77^{a}±0.12	13.72^{a}±0.20	13.85^{a}±0.18
Crude proteins, %	14.29^{b}±0.14	14.69^{ab}±0.16	14.91^{ab}±0.15	15.21^{a}±0.14	15.72^{a}±0.16
Sensory characteristics					
Appearance	5.32^{a}±0.18	5.37^{a}±0.12	4.62^{b}±0.18	3.98^{c}±0.19	3.63^{c}±0.15
Flavour	5.50^{a}±0.12	5.53^{a}±0.17	5.43^{a}±0.12	4.93^{b}±0.17	4.31^{c}±0.15
Juiceness	5.56^{a}±0.10	5.62^{a}±0.11	5.12^{a}±0.12	4.56^{b}±0.09	4.25^{b}±0.13
Firmness	5.68^{a}±0.15	5.61^{a}±0.16	5.56^{a}±0.12	4.93^{b}±0.14	4.37^{c}±0.12
Overall acceptability	5.87^{a}±0.18	5.37^{a}±0.12	4.68^{b}±0.12	4.31^{c}±0.12	3.93^{c}±0.12

Means superscripted with the same letter in rows are not significantly different ($P<0.01$)
* Standard error

of samples and this in turn, reflected in increasing the ether extractives and protein contents. These findings are in agreement with the results of Dhillon and Maurer (1975).

Significant reductions in the organoleptic scores of sausages for appearance and overall acceptibility were noticed at 30 days of storage, while the scores for flavour, juiciness and firmness were significantly lower at 45 days storage.

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RUMEN MICROBES AND DIGESTIVE PHYSIOLOGY IN RUMINANTS. Edited by Ryoji Onodera, Hisao Itabashi, Kazunari Ushida, Hideo Yano and Yasuyuki Sasaki. Published jointly by Japan Scientific Societies Press 2-10, Honjo, 6, Chome, Bunkyo-ku Tokyo-113, Japan and S. Karger A.G. Basel, Switzerland. pp 259, 1997, Price: not mentioned.

World's steadily expanding population, coupled with economic improvement among developing Nations, has intensified the demand for food and made it imperative that food production including livestock products be increased. In this context, it is considered that ruminants are of great importance as livestock, because of their capability to utilise plant fibre efficiently as their chief source of energy and they do not compete for foods with human beings. The digestion of plant polysaccharides in the rumen is accomplished by the synergistic activity of various microbes present in rumen e.g., bacteria, protozoa and fungi. Thus, improvement in the digestibility of plant fibre, which forms the bulk of energy source in ruminants is of paramount importance. This book represents a long awaited source of information on modern techniques for rumen manipulation. As a direct rendering of the theme on role of rumen microbes in improving the ruminant nutrition, the book offers a considerably researched findings and exhaustive reviews under four different sections, viz., Carbohydrate metabolism and utilisation; Protein metabolism and utilisation; Lipid and mineral metabolism and utilisation and Energy metabolism-Methane and milk production.

The cellalolytic rumen bacteria represent a major genetic resource for polysaccharide - degrading enzymes. Effective utilisation of this resource, either for improving rumen function or for industrial lignocellulosic fermentation requires an understanding of the molecular biology of these bacteria. At the outset in section one, Cheng et al, Karita et al and Nagamine et al have presented some clear picture of genomic mapping and sequencing of cellulosome and cellulase system of rumen microorganisms to make the subject really fascinating. The cloning of specific genes for the production of enzymes (eg., Xylanase) for better utilisation of fibrous resources has been well dealt by Nagamine et al, in a specific article under the chapter.

The second part of the book is devoted to various aspects of protein utilisation in ruminants and measures to bring improvement therein. Onodera et al have provided an impressive account on the role of rumen microorganisms in the synthesis of essential amino acids, specially on the importance of lysine and phenylalanine. Wallace has presented a detailed account of on the peptide metabolism in ruminants, an area that will probably grow in future. Current knowledge on the role of carbohydrate supplementation in microbial protein synthesis from protein and NPN sources in improving the efficiency has been detailed. Though the chapter on protein metabolism is just an overview of research findings, the authors seemingly have attempted to provide a comprehensive account on the subject.

As mentioned, the third section provides an account of lipid and mineral metabolism and utilisation. Lipids are not only energy sources but their extremely variable nature and chemical structure have a marked influence upon their nutritive value. The chapters by Fujihana et al and Kimura provide a good information on various methods to bring both qualitative and quantitative improvement in the meat quality. Additionally, the chapters on mineral metabolism are also informative.

The last chapter comprising papers on energy metabolism and methane production is extremely interesting. Considering the environmentalists' criticism for livestock production, the chapter is noteworthy. Kurihara et al have given a laudable summary of the knowledge on dietary manipulation to reduce methane production in ruminants and Ushida et al have presented an excellent overview of role of cilliate protozoa on rumen methanogenesis. In general, the section deals with almost all aspects of nutritional modulation to lower methane production.

To summarise, the book is interesting, stimulating and provides easy access to the understanding of the complexities of rumen process. The pictorial and graphical presentation of information on various aspects of rumen microbiology have made the book a valuable reference on digestive physiology.

There are few typographical errors but they do not in any way hinder the otherwise flawless writing exhibited in this book. The organisation of the book is very good and the style of language is readable. Detailed references and index add to the usefulness of the book for teachers, researchers and specialists in the area of animal nutrition and activities related to eco-friendly sustainable animal production programme.

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OBESITY II: RECENT ADVANCES IN UNDERSTANDING AND TREATMENT. Edited by Cathy A. Thibeault. Updated transcripts from the IBC conference "OBESITY" held during March 1997 at Boston. Published by International Business Communication, 225, Turnpike Road, Southborough, MA 01772 - 1749 USA, pp 326, 1997, Price: US $495.

The above book published by IBC-USA is an excellent addition in the field of medicine with reference to obesity.

The book is divided into various sections viz., genomic screening and search of obesity genes, β3 agonists and receptors in treatment of obesity, role of peptide hormone in obesity and novel therapeutic approaches for type II diabetics. The book also contains a subject index, which makes it rather easy to pick up the relevant articles.

As it is well known, obesity is one of the causes of morbidity and mortality of many chronic diseases like Diabetes, Hypertension, Coronary heart diseases etc.

As thought earlier, obesity is not just due to lack of dietary control and exercise, but is itself a chronic disease. Research is being done with reference to monogenic obesity, polygenic obesity and body mass index (BMI) as these genetic factors are involved in the disease.

β 3 receptors agonists, which are known to increase energy expenditure, are also discussed. Uncoupling proteins are involved in modulation of energy expenditure.

It is also observed that there is correlation between plasma leptin level and body weight change during over-feeding and starvation state. High fat diet increases body weight and also leptin level but on restricted diet, body weight decreases by 10% and leptin level drops by 50%.

Research is going on still to understand control of hunger, which involves complex peripheral and central regulatory pathway including nutrients, peptides and body energy status. Among amino acids peptide galanin receptor is found in various regions of CNS, pituitary, endocrine pancreas etc. Galanin injected into hypothalamic paraventricular nucleus stimulates food intake in rats, thereby weight gain.

Research is also on to know the relation between obesity and Type II diabetes. Thiazolidinedione (PPARα) a potent and diabetic compound activates Peroxisome Prolifesatoractivated receptor - gamma and is effective in reducing blood glucose levels and triglycerides in NIDDM.

The book also deals with metabolic advantages of insulin secretagogues against oral insulin secretagogues viz., repaglimide (Rapid onset/short acting) and sulfonylureas - glibenclamides (slow acting/long lasting).

The book is of valuable use to medical practitioners in general and diabetologists and dietitians in particular to combact obesity and other related chronic diseases effectively. Updated version, after completion of the on-going research on some of areas indicated above, will be most welcome.

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