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# Evaluation of Flexible Packages to Contain Mustard Oil

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*Received 7 April 1988; revised 22 July 1988*

**Packaging and storage studies have been carried out on mustard oil packed in pouches of low-density polyethylene, Nylon-6 (PA)/Ionomer, polyester (PET)/high density-low density polyethylene and metallized polyester/HD-LDPE and stored at accelerated (38°C and 92% R.H) and normal (27°C and 65% RH) conditions. The shelf-life of oil was found to be 20 days in LDPE, 60 days in Polyamide/Ionomer, 120 days in PET/HD-LDPE and more than 120 days in Met.PET/HD-LDPE pouches under the accelerated condition, and at the normal condition, the corresponding shelf-lives were found to be 30 days in LDPE, 60 days in PA/Ionomer and more than 120 days in polyester based materials.**

Mustard oil is obtained from white or yellow mustard (*Brassica alba*) and from black mustard (*B. Nigra*). Crude oil will be dark brown in colour and contains a large proportion of free-fatty acids. Refined oil will be bland and light brown in colour.

The characteristic odour of mustard oil is due to sulphur containing essential oils produced by the hydrolysis of glucosides contained in the seeds.

Traditionally, vegetable oils like mustard oil are packed in tin-plate containers. More recently, rigid plastic containers made of poly vinyl chloride, low and high density polyethylenes, polyester etc. are being used. In recent years, due to escalating prices of such containers, efforts are being made to replace them with more economical and functional pouches made of flexible packaging materials which would also assure a quality product distributed under hygienic conditions. Several studies on the packaging of edible oils in pouches have been made,[1,2] but not on mustard oil. Hence, packaging and storage studies were undertaken to assess the suitability and safety of different flexible consumer packages for packing mustard oil by storing it at various temperature/relative humidity conditions.

## Materials and Methods

*Mustard oil:* Refined mustard oil packed in 15 kg square tin-plate container (Engine brand, Bharatpur) was used.

*Packaging materials:* Flat unit pouches of 100 × 140 mm to hold 20 cl of mustard oil were made by heat-sealing at optimum temperature, pressure and dwell time conditions. The following packaging materials were selected based on their physico-chemical properties.

(1) 125 μm low-density polyethylene (LDPE)
(2) 25 μm polyamide/50 μm Ionomer (PA/Ionomer)
(3) 12 μm plain polyester/112 μm high density-low density polyethylene co-extruded film (PET/HD-LDPE).
(4) 12 μm metallized polyester/112 μm high density-low density polyethylene co-extruded film (Met. PET/HD-LDPE).

Oil stored under refrigeration (4-5°C) served as the control.

*Physico-chemical properties of packaging materials:* The tensile strength, elongation, heat-seal strength were determined according to IS: 1060[3].

Drop test and stack-load tests were conducted according to IS:11352 and grease resistance[4] was determined as per TAPPI-T 480 but instead of turpentine, a red miscible dye (Sudan IV) in mustard oil was used. Transmission to water vapour[5] of the packaging materials was conducted according to IS–1060 and oxygen transmission as per ASTM-D 1434-66[6]. Migration studies on the packaging materials were carried out according to FDA 175.300[7].

*Chemical analyses:* Moisture content, acidity and colour[8] were determined according to IS:548. For colour determination, a cell of 10 mm light path was used. Peroxide value was determined as per AOCS method[9].

*Sensory evaluation:* A group of 10-20 panelists who were habitual users of mustard oil were selected and trained so that they were able to differentiate between the four categories of quality indicated in the odour evaluation proforma. The oil samples were dispersed in water at 0.5% (v/v) in stoppered Erlenmeyer flasks maintained at 40-45°C in a water bath. The panelists were asked to swirl the flask before opening and to match the odour with the control. The evaluation process was completed within 2 hr. Slightly rancid and clearly rancid evaluations were considered as rancid and not acceptable.

*Storage conditions:* Mustard oil packed in the four types of flexible packaging materials were stored at (i) 38±1°C with 90±2 per cent RH (accelerated condition) (ii) 27±1°C with 65 per cent RH. (normal or IS condition), (iii) oil packed in glass bottles stored under refrigeration (4-5°C) served as control. The stored samples were analysed at regular intervals in accordance with the standards[10].

**Results and Discussion**

*Packaging materials:* The physico-chemical properties of the flexible packaging materials used for making the pouches are shown in Table 1. LDPE and PA/Ionomer had nearly the same tensile and heat-seal strengths, whereas both plain polyester and metallised polyester laminates had almost equal, but high tensile strength due to the polyester layer. As regards water vapour transmission property, PA/Ionomer had the highest value, followed by LDPE, PET/HD-LDPE and Met PET/HD-LDPE materials. Resistance to the seepage of fats and oils as determined by the grease-resistance test was found to be best in PA/Ionomer and Met. PET/HD-LD laminates while LDPE had poor resistance.

Performance tests on the pouches carried out indicated that all the four types resisted a flat drop of 1 m height, whereas PA/Ionomer pouch only failed the stack load test with an applied initial load of 10 kg for 24 hr. Although its tensile and heat seal strength were greater than that of LDPE, the lesser thickness of the laminate and probably the applied load resulting in elongation of nylon film and also stretching, resulting in reduced thickness resulted in its eventual rupture. Thus in general, the results indicated that polyester based laminates tested had high physical and barrier properties which are required for long-term storage of oil.

All the four materials exhibited migration levels of 4 to 18 p.p.m. which were well below the maximum prescribed limit of 50 p.p.m. However, the higher value of 12.5 p.p.m. for PET/HD-LDPE as compared to 3.6 for Met. PET/HD-LDPE indicates that each batch of material has to be specifically tested.

*Storage studies:* From an initial moisture content of 0.19 per cent, a gradual increase was observed in accelerated as well as normal storage conditions. As expected, at the high temperature and RH condition the moisture pick-up was more. The differences between the increase in pouches of LDPE, PA/Ionomer and PET/HD-LDPE were not very pronounced, but as expected the metallized PET/HD-LDPE laminate afforded best protection.

The maximum permissible moisture content for mustard oil for raw grade-I variety as per the Indian Standard is 0.25 per cent by mass. Hence, this maximum level has been attained at the accelerated condition of storage at the end of 40 days in LDPE, 80 days in PA/Ionomer, 120 days in PET/HD-LDPE pouches and more than 120 days in Met. PET/HD-LDPE laminate. In the normal storage condition, the critical value was attained at the end of 60 days, 90 days in LDPE and PA/Ionomer materials while at the end of 120 days, the level was well below in Met. PET/HD-LDPE under both conditions of storage.

*Free-fatty acid content:* The oil had an initial FFA value of 0.49 per cent as oleic acid. The increase in the development of FFA was in consonance with the water-vapour transmission rates of the packaging materials used, i.e., highest rate was observed in PA/Ionomer followed by LDPE and then PET/HD-LDPE and Met. PET/HD-LDPE.

Under accelerated storage conditions, the maximum FFA value of 1.41 per cent was observed in the case of polyamide laminate at the end of 120 days' storage, whereas it was only 0.77 per cent after 60 days. The corresponding values were 1.32 and 0.73 per cent for LPE pouch stored samples. Only marginal differences, i.e, 0.78 and 0.79 per cent were observed between plain PET and Met. PET pouches at the end of 120 days of storage from the initial value of 0.49 per cent.

Under normal condition of storage of 27°C and 65 per cent RH also, FFA values increased steadily. With no moisture increase in the control glass bottles, the FFA values remained practically constant. Similar results have been observed in the case of groundnut oil[11] and sunflower oil[12].

*Peroxide value:* The results of the changes in the PV as indicated in the Tables show that under the accelerated storage condition, PV increased rapidly in LDPE whereas it was nearly half in the case of PA/Ionomer laminate. At the end of 80 days' storage, the PV of 59.2 in LDPE decreased to 27.2 after 120 days indicating that peroxides formed initially decomposed to other constituents. Metallized polyester gave good protection against oxidation as indicated by low PV values.

The results of the storage studies under normal conditions have indicated that PV gradually increased in oil stored in all the four types of packaging materials. LDPE indicated highest values followed by PA/Ionomer, PET/HD-LDPE and finally Met.PET/LD-HDPE. The mustard oil under test with an initial PV of 4.9 indicated development off-flavour at a value of 20-25. Similar results have been observed by other workers for refined groundnut oil[11,12] and suntlower oil[12].

Although wide differences were observed in the PV among the four packaging materials, there was enhancement in protection against oxidative changes

TABLE 1. PHYSICO-CHEMICAL PROPERTIES OF PACKAGING MATERIALS

| Property | | LDPE | PA/ Ionomer | PET/HD-LDPE | Met.PET/ HD-LDPE |
|---|---|---|---|---|---|
| Thickness, μm | | 125 | 25/50 | 12/112 | 12/112 |
| Tensile strength, kN/m | MD | 1.8 | 2.1 | 4.4 | 4.4 |
| | TD | 2.0 | 2.4 | 4.4 | 4.5 |
| Elongation (%) | MD | 350 | 100 | 35 | 36 |
| | TD | 400 | 150 | 42 | 42 |
| Heat seal strength (%) | | 87 | 82 | 75 | 60 |
| Water vapour transmission rate, g/sq.m. 24 hr. at 38°C and 90% RH gradient | | 3.6 | 7.2 | 3.3 | 0.6 |
| Oxygen transmission rate, ml/sq.m. 24 hr. atm. at 27°C | | 1600 | 85 | 75 | 2 |
| Grease resistance, 40°C, days | | 10 | 120 | 75 | 120 |
| Migration test, heptane at 38°C, 30 min. | $mg/dm^2$ | 1.29 | 0.79 | 0.89 | 0.26 |
| | ppm | 18.06 | 11.15 | 12.46 | 3.64 |

M.D. – Machine direction, T.D. – Transverse direction

TABLE 2. CHANGES IN MUSTARD OIL STORED AT 38°C AND 92% RH

| Packaging material | Storage period (days) | Moisture content (%) | FFA, (as oleic acid) (%) | PV (m.eq of $O_2$/kg fat) | Colour (Y+5R) | Accept-ability |
|---|---|---|---|---|---|---|
| Initial | 0 | 0.19 | 0.49 | 4.6 | 19 | A |
| LDPE | | | | | | |
| | 20 | 0.20 | 0.55 | 17.0 | 20 | A |
| | 40 | 0.24 | 0.59 | 44.5 | 21 | NA |
| | 60 | 0.26 | 0.73 | 52.7 | 21 | NA |
| | 80 | 0.28 | 0.91 | 59.2 | 22 | NA |
| | 120 | 0.29 | 1.32 | 27.2 | 23 | NA |
| PA/Ionomer | | | | | | |
| | 20 | 0.20 | 0.56 | 9.7 | 19 | A |
| | 40 | 0.22 | 0.63 | 15.2 | 20 | A |
| | 60 | 0.23 | 0.77 | 19.4 | 21 | A |
| | 80 | 0.25 | 0.92 | 22.5 | 22 | NA |
| | 120 | 0.28 | 1.41 | 26.7 | 22 | NA |
| PET/HD-LDPE | | | | | | |
| | 20 | 0.19 | 0.54 | 9.5 | 19 | A |
| | 40 | 0.21 | 0.56 | 14.0 | 20 | A |
| | 60 | 0.21 | 0.62 | 16.9 | 20 | A |
| | 80 | 0.24 | 0.70 | 19.1 | 21 | A |
| | 120 | 0.25 | 0.79 | 20.4 | 21 | A |
| Met.PET/HD-LDPE | | | | | | |
| | 20 | 0.19 | 0.50 | 8.1 | 19 | A |
| | 40 | 0.20 | 0.53 | 12.7 | 19 | A |
| | 60 | 0.21 | 0.59 | 13.6 | 20 | A |
| | 80 | 0.22 | 0.68 | 15.3 | 20 | A |
| | 120 | 0.23 | 0.78 | 18.1 | 20 | A |
| Control | | | | | | |
| | 20 | 0.19 | 0.49 | 4.9 | 19 | – |
| | 40 | 0.20 | 0.50 | 5.8 | 19 | – |
| | 60 | 0.20 | 0.50 | 6.4 | 19 | – |
| | 80 | 0.20 | 0.52 | 7.2 | 19 | – |
| | 120 | 0.20 | 0.55 | 8.1 | 19 | – |

Average of four replicates from two pouches.

A = Acceptable, NA = Not Acceptable.

by the polyamide and polyester layers. Metallization afforded great protection due to its low oxygen transmission rate and opacity but not to the extent as indicated by its low oxygen transmission rate (Table 1). The slight increase in PV in the product stored as control may be due to the head-space as well as

TABLE 3. CHANGES IN MUSTARD OIL STORED AT 27°C AND 65% RH

| Packaging material | Storage period (days) | Moisture content (%) | FFA, (as oleic acid) (%) | PV (m.eq of $O_2$/kg fat) | Colour (Y+5R) | Acceptability |
|---|---|---|---|---|---|---|
| Initial | 0 | 0.19 | 0.49 | 4.6 | 19 | A |
| LDPE | 30 | 0.23 | 0.58 | 19.2 | 20 | A |
| | 60 | 0.25 | 0.69 | 24.0 | 20 | NA |
| | 90 | 0.25 | 0.80 | 27.4 | 21 | NA |
| | 120 | 0.25 | 0.90 | 33.4 | 21 | NA |
| PA/Ionomer | 30 | 0.22 | 0.62 | 14.8 | 19 | A |
| | 60 | 0.24 | 0.69 | 18.4 | 20 | A |
| | 90 | 0.24 | 1.02 | 21.1 | 20 | A |
| | 120 | 0.25 | 1.25 | 24.6 | 21 | A |
| PET/HD-LDPE | 30 | 0.21 | 0.53 | 11.7 | 19 | A |
| | 60 | 0.21 | 0.58 | 15.1 | 20 | A |
| | 90 | 0.22 | 0.62 | 16.1 | 20 | A |
| | 120 | 0.23 | 0.70 | 17.9 | 21 | A |
| Met.PET/HD-LDPE | 30 | 0.21 | 0.52 | 10.1 | 19 | A |
| | 60 | 0.21 | 0.54 | 12.9 | 19 | A |
| | 90 | 0.22 | 0.59 | 13.0 | 20 | A |
| | 120 | 0.22 | 0.66 | 14.2 | 20 | A |
| Control | 30 | 0.20 | 0.50 | 5.3 | 19 | – |
| | 60 | 0.20 | 0.50 | 6.4 | 19 | – |
| | 90 | 0.20 | 0.53 | 7.8 | 19 | – |
| | 120 | 0.20 | 0.55 | 8.1 | 19 | – |

Average of four replicates from two pouches.
A = Acceptable, NA = Not Acceptable.

occluded oxygen.

*Colour changes:* There was no marked change in the colour value of stored mustard oil (Tables 2 and 3). It may be concluded that mustard oil colour is quite stable under the environmental conditions studied. It is probable that direct sun light, diffused light and fluorescent light may have deleterious effects on colour retention.[13]

*Sensory evaluation:* It has been suggested by a number of workers[10,11,14] that chemical indices of deterioration alone cannot indicate the acceptability for practical purposes, but the results must be corroborated by sensory evaluation.

At the accelerated storage condition, both plain and metallized polyester/HD-LDPE gave good protection, with the product remaining in an acceptable condition even upto the end of 120 days. However, Met. PET/HD-LDPE pouch stored samples were rated superior at all withdrawals. Mustard oil packed in PA/Ionomer pouches was acceptable up to 60 days whereas at the end of 80 days, it had become unacceptable. LDPE pouch offered least protection as indicated by the non-acceptability of the sample even at the end of 40 days' storage. Further, it was observed that in the case of LDPE, sealing failure occurred in a few pouches at the high temperature condition and slight seepage of oil was observed at the seals after 20 days and pronounced seepage after 40 days. In the case of PA/Ionomer and plain PET/HD-LDPE pouches, slight seepage was observed after 40 days at the accelerated conditions and at the end of 90 days storage in the normal temperature conditions. No seepage of oil was observed in Met. PET/HD-LDPE laminate even at the end of the storage period of 120 days.

Normal condition stored oil indicated that it remained acceptable only upto 30 days in LDPE pouches and 60 days in polyamide pouches. The product in both types of polyester pouches were acceptable even at the end of 120 days.

Currently, the cost of pouches for packaging 1 kg of oil in 20 cl units would be approximately Rs.2/- for LDPE of 125μm, Rs.6 for PA/Ionomer and PET/HD-LDPE and Rs.8 for Met.PET/HD-LDPE pouches. When the product is packed in 50 cl or 1L, the cost would be correspondingly lower with added advantage of longer shelf-life due to the lower surface area to volume ratio.

In conclusion, it could be stated that only metallised

polyester/HD-LDPE pouch is suitable for long shelf-life and LDPE provides very short shelf-life even when 125 μm thickness film is used.

**Acknowledgement**

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# Suitability of Flexible Packaging Materials for Storage of Pickled Quail Eggs

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**Quality characteristics of quail eggs pickled in oil-based gravy containing 3% salt and 2% acetic acid and subsequently stored in high density polyethylene (HDPE, 330 G), polypropylene (PP, 140 G), 12 μm polyester/0.09 mm aluminium foil/150 G LDPE (PFP) laminated pouches or glass jar were investigated during 9 and 15 months of ambient (19-38°C, 36-85% RH) and refrigeration (4-6°C, 80-85% RH) storage, respectively. The albumen and yolk reached equilibrium pH (4.7-4.8) within 2 and 4 days of ambient and refrigeration storage, respectively. Egg pickle stored in PP showed maximum weight loss followed by HDPE and glass jar but negligible weight loss in PFP laminate. TBA values increased progressively during storage. Refrigerated pickles showed better colour stability. No coliforms, anaerobes, *Salmonella*, and coagulase-positive *Staphylococci* were detected in pickled eggs. Sensory quality of the product declined on storage. HDPE was found to be a cost-effective alternative to glass jar for storage of pickled eggs upto 8 and 15 months of ambient and refrigeration storage, respectively.**

Pickles occupy an important place among the traditional foods in India. With the increasing popularity of quail (*Coturnix coturnix japonica*) production in the country, there is a good scope for utilisation of small, tinted and thin-shelled quail eggs in the form of pickle from the viewpoints of convenience, nutrition and better market value of small eggs. Pickling of chicken and quail eggs in organic acid solutions as the main preservative media has been investigated by several workers[1-6]. However, information on the development and storage stability of oil-based egg pickles[7] is rather scanty. Similarly, flexible packaging of pickled eggs has received very little attention. Lightness coupled with convenience and economy has contributed greatly to the development of flexible thermoplastic films and their laminates for food packaging applications. This study was, therefore, carried out to evaluate the influence of rigid container and flexible pouches on some physico-chemical, microbiological and sensory quality of oil-based pickled quail eggs under ambient and refrigerated storage conditions.

## Materials and Methods

Fresh quail eggs were held for 24 hr at ambient temperature prior to cooking in water containing 2 per cent common salt for 10 min at simmering temperature. After cooking, eggs were cooled in cold water, peeled and washed. Defective eggs with broken albumen surface were discarded.

The ingredients used for pickling consisted of ground red chilli, 10g; black pepper, cumin, aniseed, turmeric, 5 g each; a mix of cinnamon:clove: cardamom (1:1:1), 5g; minced garlic, ginger, common salt, 30g each; acetic acid, 20 ml and refined mustard oil, 150 ml per kg of peeled eggs. Garlic and ginger were fried in oil for about 7 min at medium heat. Spice-salt blend was added and the whole mass was further fried for approximately 5 min. The hot (70°C) gravy, peeled eggs and acetic acid were thoroughly stirred and cooled to ambient temperature. Approximately 100 g of pickled eggs were packaged in either glass jar (150 ml) having unlined plastic cap of 6 cm internal diameter or in high density polyethylene (330 gauge), polypropylene (PP, 140 gauge) and 12 μm polyester/0.09 mm aluminium foil/150 gauge LDPE (PFP) laminated pouches of internal dimensions 12.5 × 10 cm, sealed using a semi-automatic heat sealer and stored at ambient (19-38°C, 36-85 per cent RH; mean 28°C, 61 per cent RH) and refrigeration (4-6°C, 80-85 per cent RH) temperatures, respectively. The water vapour transmission rates (WVTR) of PFP laminate was found to be nil, HDPE 1.7 and PP 6.7 $g/m^2/24$ hr at 38°C and 90 per cent RH and the oxygen transmission rates (OTR) of these flexibles were below measurable quantity, 2228 and 6682 $cm^3$ $O_2/m^2/24$ hr/atmosphere at 27°C respectively prior to storage. Samples were removed from storage at appropriate intervals for analyses.

The albumen and yolk were separated and blended with 5 times their weight of distilled water before pH measurements, in duplicate, using a Beckmann pH meter. The loss in weight of egg pickle was computed by the difference between initial and stored weights.

Five replications per treatment were used for the determination of weight loss. The colour of egg albumen surface measuring about 25 $mm^2$ was measured in triplicate using a Lovibond tintometer in yellow, red and blue units. The lowest colour unit recorded was expressed as dullness. The next higher colour unit was substracted from the yellow unit and expressed as net yellow colour unit. TBA values were estimated in triplicate by the method of Tarladgis *et al*[8]. Nordic Metodisk[9] and Cowan and Steel[10]. Standard methods were followed for bacterial counts and identification of isolates. Pickled eggs were subjected to sensory evaluation by a 7-member taste panel for colour, flavour, texture, saltiness, sourness and overall acceptability using a 7-point hedonic scale. A rating of 1 was the least desirable and 7 the most desirable. For calculating the cost of production of pickled eggs, only the cost of materials utilised for pickling and packaging of eggs was considered.

**Results and Discussion**

The pH of albumen declined rapidly during first 12 hr of storage; however, the rate of decline was relatively faster at ambient (8.86-4.78) than refrigeration temperature (8.86-4.94). The egg albumen and yolk attained equilibrium pH (4.7-4.8) by 2nd and 4th day of ambient and refrigeration storage, respectively. Thereafter, no appreciable changes in pH of egg components occurred under both storage conditions. The rapid drop in albumen pH compared to yolk was due to the faster rate of acid diffusion into the former than the latter egg component.

A progressive increase in loss in the weight of egg pickles, except those packed in laminate, occurred with storage time (Table 1). This could be partly explained by the effect of acid on egg white proteins. In this study, the equilibrium pH was close to the iso-electric pHs of major egg white proteins resulting in their minimal water binding capacity. The synergesis brought about by the acetic acid and osmotic forces created by sodium chloride resulted in the dehydration of coagulated egg white mass[2]. The magnitude of weight loss was comparatively less in refrigerated pickles than those stored at ambient temperature in all the packaging treatments. Of the packaging materials, maximum weight loss was observed with PP followed by HDPE, glass jar and the loss was negligible with the laminate. It is thus obvious that the WVTR of flexible pouches influenced the rate of evaporative weight loss in pickled eggs during storage. Although, reason for the loss in weight of egg pickles stored in glass jar is not obvious, it is presumed that the unlined cap of the container might have allowed the escape of moisture from the product.

Changes in the colour stability of pickled eggs during storage are shown in Table 2. Fresh egg pickle had a yellow colour of 13.8 units. During storage, a progressive reduction in colour intensity, i.e. a decrease in yellow unit and an increase in dullness was recorded regardless of packaging materials and storage conditions. Samples stored in the laminate registered the lowest decline in colour values probably because of the excellent barrier properties of laminate to light and oxygen. The stability of food colour from natural sources is influenced by pH, temperature, light and

TABLE 1. WEIGHT LOSS (%) IN PICKLED QUAIL EGGS PACKED IN DIFFERENT PACKAGES DURING STORAGE

| Storage period (months) | Glass | Laminate | HDPE | PP |
|---|---|---|---|---|
| | *Ambient* (19-38°C) | | | |
| 1 | 0.07 ± 0.01 | 0.11 ± 0.02 | 0.28 ± 0.03 | 1.13 ± 0.05 |
| 3 | 0.21 ± 0.03 | 0.14 ± 0.01 | 0.59 ± 0.02 | 2.75 ± 0.10 |
| 6 | 0.76 ± 0.11 | 0.14 ± 0.01 | 2.43 ± 0.04 | 9.42 ± 0.42 |
| 9 | 1.16 ± 0.14 | 0.16 ± 0.02 | 3.33 ± 0.08 | 15.94 ± 0.33 |
| | *Refrigeration* (4-6°C) | | | |
| 1 | 0.02 ± 0.05 | 0.06 ± 0.01 | 0.18 ± 0.03 | 0.29 ± 0.04 |
| 3 | 0.12 ± 0.02 | 0.11 ± 0.02 | 0.26 ± 0.03 | 0.80 ± 0.12 |
| 6 | 0.31 ± 0.05 | 0.10 ± 0.02 | 0.54 ± 0.08 | 1.62 ± 0.17 |
| 9 | 0.44 ± 0.06 | 0.10 ± 0.01 | 0.69 ± 0.06 | 2.50 ± 0.08 |
| 12 | 0.52 ± 0.07 | 0.08 ± 0.01 | 0.84 ± 0.06 | 3.71 ± 0.13 |
| 15 | 0.66 ± 0.08 | 0.11 ± 0.02 | 0.96 ± 0.09 | 4.82 ± 0.13 |

TABLE 2. COLOUR STABILITY (LOVIBOND COLOUR UNITS) OF PICKLED QUAIL EGGS PACKED IN DIFFERENT PACKAGES DURING STORAGE

| Storage period (months) | Glass | | Laminate | | HDPE | | PP | |
|---|---|---|---|---|---|---|---|---|
| | Y* | D** | Y | D | Y | D | Y | D |
| | *Ambient* (19-38°C) | | | | | | | |
| 1 | 11.8 | 0.4 | 12.8 | 0.4 | 11.9 | 0.6 | 12.1 | 0.4 |
| 3 | 10.7 | 0.8 | 11.7 | 0.6 | 11.0 | 1.7 | 10.8 | 1.6 |
| 6 | 9.4 | 1.2 | 10.3 | 0.6 | 8.8 | 0.8 | 8.4 | 1.2 |
| 9 | 8.0 | 1.4 | 9.6 | 1.2 | 8.2 | 0.7 | 6.4 | 1.0 |
| | *Refrigeration* (4-6°C) | | | | | | | |
| 1 | 13.0 | 0.4 | 13.2 | 0.7 | 13.2 | 0.8 | 12.8 | 0.8 |
| 3 | 12.4 | 0.6 | 12.8 | 0.9 | 12.0 | 1.2 | 11.5 | 1.4 |
| 6 | 11.2 | 0.9 | 11.8 | 1.0 | 11.2 | 1.1 | 11.0 | 0.8 |
| 9 | 10.8 | 0.7 | 11.0 | 0.7 | 10.9 | 0.5 | 10.6 | 1.2 |
| 12 | 10.1 | 0.6 | 10.8 | 0.6 | 10.4 | 0.7 | 10.2 | 1.0 |
| 15 | 9.8 | 0.8 | 10.3 | 1.2 | 9.4 | 1.0 | 9.0 | 1.4 |

Initial Lovibond colour units in pickled quail eggs were 13.8 Y and 0.3 D

*Y - Yellow; **D - Dullness

TABLE 3. THIOBARBITURIC ACID (TBA) (mg MALONALDEHYDE/Kg) VALUES* OF PICKLED QUAIL EGGS PACKED IN DIFFERENT PACKAGES DURING STORAGE

| Storage period (months) | Glass | Laminate | HDPE | PP |
|---|---|---|---|---|
| | *Ambient* (19-38°C) | | | |
| 1 | 0.88 ± 0.05 | 0.82 ± 0.06 | 0.90 ± 0.03 | 1.07 ± 0.11 |
| 3 | 1.01 ± 0.02 | 0.96 ± 0.09 | 1.38 ± 0.06 | 1.47 ± 0.07 |
| 6 | 1.96 ± 0.01 | 1.38 ± 0.09 | 1.98 ± 0.08 | 2.62 ± 0.07 |
| 9 | 2.52 ± 0.03 | 1.92 ± 0.07 | 2.72 ± 0.08 | 3.28 ± 0.10 |
| | *Refrigeration* (4-6°C) | | | |
| 1 | 0.62 ± 0.03 | 0.60 ± 0.03 | 0.63 ± 0.02 | 0.68 ± 0.05 |
| 3 | 0.75 ± 0.04 | 0.68 ± 0.04 | 0.84 ± 0.04 | 0.96 ± 0.03 |
| 6 | 0.98 ± 0.05 | 0.86 ± 0.07 | 1.18 ± 0.06 | 1.48 ± 0.10 |
| 9 | 1.22 ± 0.03 | 0.95 ± 0.02 | 1.32 ± 0.03 | 1.72 ± 0.04 |
| 12 | 1.57 ± 0.01 | 1.27 ± 0.06 | 1.73 ± 0.07 | 1.96 ± 0.02 |
| 15 | 2.26 ± 0.08 | 2.09 ± 0.07 | 2.25 ± 0.10 | 2.69 ± 0.07 |

*Initial TBA value of pickled eggs was 0.28 ± 0.05.

TABLE 4. TOTAL AEROBIC PLATE COUNTS* (Log/g) OF PICKLED QUAIL EGGS PACKED IN DIFFERENT PACKAGES DURING STORAGE

| Storage period (months) | Glass | Laminate | HDPE | PP |
|---|---|---|---|---|
| | *Ambient* (19-38°C) | | | |
| 1 | 3.51 ± 0.12 | 3.58 ± 0.09 | 3.60 ± 0.11 | 3.42 ± 0.15 |
| 3 | 3.73 ± 0.05 | 3.70 ± 0.22 | 3.68 ± 0.06 | 3.87 ± 0.03 |
| 6 | 4.06 ± 0.18 | 3.96 ± 0.26 | 4.18 ± 0.21 | 4.24 ± 0.14 |
| 9 | 4.42 ± 0.04 | 4.32 ± 0.17 | 4.44 ± 0.07 | 4.29 ± 0.10 |
| | *Refrigeration* (4-6°C) | | | |
| 1 | 3.21 ± 0.08 | 3.38 ± 0.08 | 3.18 ± 0.11 | 3.35 ± 0.13 |
| 3 | 3.46 ± 0.28 | 3.45 ± 0.02 | 3.59 ± 0.10 | 3.43 ± 0.18 |
| 6 | 3.58 ± 0.19 | 3.50 ± 0.13 | 3.65 ± 0.03 | 3.42 ± 0.04 |
| 9 | 3.65 ± 0.16 | 3.54 ± 0.18 | 3.68 ± 0.05 | 3.66 ± 0.10 |
| 12 | 3.71 ± 0.04 | 3.81 ± 0.14 | 3.73 ± 0.06 | 3.69 ± 0.10 |
| 15 | 3.86 ± 0.08 | 3.95 ± 0.08 | 3.84 ± 0.23 | 3.78 ± 0.17 |

*Initial counts (log/g) of hard-cooked and of pickled eggs were 4.26 ± 0.14 and 2.82 ± 0.08, respectively.

oxidation[11-12]. Apparently, more colour fading in pickles held at ambient than those held under refrigeration might be because of the increased susceptibility of curcumin pigment of turmeric to oxidation at higher storage temperature.

A progressive increase in TBA value was noticed on storage (Table 3). PP-packed pickles exhibited maximum TBA values followed by HDPE-, glass jar- and laminate-packed samples during storage. It appeared that the permeability of the monolayer thermoplastic films to oxygen and the head space concentration of oxygen in the laminate and glass jar may be the major factors governing lipid autoxidation. Raw egg yolk lipids are reported to be relatively stable to oxidation due to the natural antioxidative mechanism, viz. tocopherol as free-radical terminator and phosvitin as iron chelator[13]. It appeared that the denaturation of lipoproteins due to thermal and acid treatments[14] might have exposed yolk lipids to oxidation. This together with small amount of free iron in the egg yolk[15] and reduction in the antioxidant activity of phosvitin following thermal treatment[16] might have accounted for the increase in TBA values. Parkinson[17] reported that phospholipids of egg yolk, particularly phosphatidyl ethanolamine are among the more labile constituents to lipid oxidation due to the higher concentration of unsaturated fatty acids.

The results of the bacteriological examination of pickled eggs are given in Table 4. There was a marked reduction in bacterial number on pickling. Although, a gradual increasing trend of bacterial counts was observed with storage time, the counts remained fairly low (log 3.2-4.4/g) regardless of packaging and storage treatments. This could be attributable to the inhibitory effect of low pH of the product on the multiplication of bacteria[1,18]. Refrigerated pickles showed comparatively lower counts than those stored at ambient temperature and the difference was less than one log unit. Fischer *et al.*[5] reported that the microbial quality of pickled eggs was more dependent on the acid strength of pickling medium than storage temperature. No coliforms, anaerobes, Salmonella and coagulase-positive Staphylococci were detected in pickled eggs throughout the storage.

A steady decline in mean panel scores for colour, flavour, texture and overall acceptability was observed with the advancement of storage period. Only the mean overall acceptability scores are presented in Table 5 since the corresponding score profiles of other sensory attributes were more or less similar. The reduction in sensory quality of pickle was dependent more on storage temperatures than packaging treatments. Panelists did not greatly differentiate the texture between different packaging treatments, except PP-packed samples which developed a drier texture after 6 months of ambient storage and this appeared to have resulted from the higher WVTR of PP leading to increased dehydration (Table 1). Both saltiness and sourness in pickled eggs were rated from most desirable to desirable.

Egg and pickle gravy accounted for 61.1% and 38.9% of the total of Rs.18 per kg pickled eggs. On adding the cost of packaging materials, the net cost of production of pickled eggs in consumer's unit package

TABLE 5. OVERALL ACCEPTABILITY SCORES* OF PICKLED QUAIL EGGS PACKED IN DIFFERENT PACKAGES DURING STORAGE

| Storage period (months) | Glass | Laminate | HDPE | PP |
|---|---|---|---|---|
| | *Ambient* (19-38°C) | | | |
| 2 | 6.00 ± 0.22 | 6.00 ± 0.31 | 5.86 ± 0.40 | 5.86 ± 0.26 |
| 4 | 5.71 ± 0.28 | 5.86 ± 0.26 | 5.57 ± 0.38 | 5.43 ± 0.30 |
| 6 | 5.43 ± 0.43 | 5.57 ± 0.30 | 5.28 ± 0.42 | 4.86 ± 0.40 |
| 8 | 4.86 ± 0.26 | 5.00 ± 0.26 | 4.86 ± 0.34 | 3.14 ± 0.26 |
| | *Refrigeration* (4-6°C) | | | |
| 2 | 6.28 ± 0.28 | 6.14 ± 0.26 | 6.28 ± 0.28 | 6.14 ± 0.38 |
| 4 | 6.14 ± 0.26 | 6.00 ± 0.31 | 6.14 ± 0.29 | 5.86 ± 0.34 |
| 6 | 5.71 ± 0.28 | 5.86 ± 0.26 | 5.86 ± 0.26 | 5.71 ± 0.18 |
| 8 | 5.57 ± 0.37 | 5.71 ± 0.18 | 5.57 ± 0.37 | 5.57 ± 0.43 |
| 12 | 5.28 ± 0.42 | 5.43 ± 0.36 | 5.28 ± 0.28 | 5.14 ± 0.40 |
| 15 | 5.00 ± 0.38 | 5.00 ± 0.38 | 4.86 ± 0.28 | 4.71 ± 0.18 |

*7 – Like very much; 1 – Dislike very much

of 100g each in glass jar, PFP laminate, HDPE and PP pouches worked out to Rs.3.30, 2.20, 1.86 and 1.84, respectively (Table 6).

These observations suggest that both PFP laminate and HDPE (330 G) film pouches can serve as alternatives to the conventional glass containers for storage of oil-based pickled quail eggs upto 8 and 15 months at ambient (19-38°C, 36-85 per cent RH) and refrigeration (4-6°C, 80-85 per cent RH) temperatures, respectively. However, due to the lack of visibility of product packaged in PFP laminate and its higher cost than HDPE pouches of same size, the latter packaging material can be used economically in lieu of glass jars. Further trial on transport packaging of pickled eggs using crush-proof outer carton is suggested in view of the susceptibility of this product to get crushed in handling, unlike in a glass jar.

TABLE 6. COST OF PRODUCTION OF PICKLED QUAIL EGGS

| Packaging materials | Size | Rate(Rs.) | Cost (Rs.) | | |
|---|---|---|---|---|---|
| | | | Package/ unit | Pickled eggs/100g | Total |
| Glass jar | 150 ml | 18/dozen | 1.50 (45.4) | 1.80 (54.5) | 3.30 |
| Laminate | 12.5×10 cm | 120/kg | 0.40 (18.2) | 1.80 (81.8) | 2.20 |
| HDPE | 12.5×10 cm | 30/kg | 0.06 (3.2) | 1.80 (96.8) | 1.86 |
| PP | 12.5×10 cm | 32/kg | 0.04 (2.2) | 1.80 (97.8) | 1.84 |

Figures in parentheses indicate percent of total cost

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# Packaging and Storage Studies on Malted Ragi and Green Gram Based Weaning Food

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**The shelf-life studies on a low dietary bulk weaning food based on malted ragi and green gram were conducted. The moisture humidity relationship studies at 27°C revealed that moisture content of 11 % and equilibrium relative humidity of 65 % were critical with respect to free flowing characteristics of the product. The product packed in flexible pouches and stored at accelerated (38°C and 92% RH) and Indian Standard (27°C and 65% RH) storage conditions exhibited increases in moisture content, free fatty acids, cooked paste viscosity and decrease in alpha-amylase activity progressively on storage. The shelf-life of the product packed in low density polyethylene pouches was about 2 months and 3 months under accelerated and ambient storage conditions whereas in laminate pouches, the shelf-life was about 3 months and 5 months in the corresponding storage conditions respectively.**

Details about the development and the nutritive value of a low dietary bulk and high calorie density weaning food based on malted ragi (*Eleusine coracana*) and green gram (*Phaseolus radiatus*) developed in this Institute have been reported earlier[1-3]. It was felt desirable to assess its storage stability and also to design an economical functional package for it, as many entrepreneurs showed interest in producing the product commercially. Work was initiated in this direction and the present communication deals with moisture sorption behaviour of the weaning food and also packaging and storage studies of the same in consumer unit packs made up of different flexible packaging materials.

## Materials and Methods

*Sorption studies:* The weaning food blend consisting of 60 per cent malted ragi flour, 30 per cent malted green gram flour, 5 per cent skim milk powder and 5 per cent sugar fortified with necessary vitamins and minerals was exposed at 27°C to different relative humidities ranging from 11 to 92 per cent prepared in different dessicators using appropriate saturated salt solutions[4]. The samples were weighed periodically till they attained practically constant weight or showed signs of mould growth whichever was earlier.

*Packaging and storage:* Freshly prepared weaning food sample of similar composition used for sorption studies was used for packaging and storage studies. The sample (250 g) was packed in unit pouches (130 × 190 mm) made from 200 gauge low density polyethylene (LDPE), 250 guage high density polyethylene (HDPE) and paper/0.009 mm foil/150 gauage polyethylene (laminate) which had 6.5, 2.5 and nil water vapour transmission rate (WVTR) respectively[5].

The unit packs were exposed to 38°C and 92 per cent RH and 27°C and 65 per cent RH, the accelerated and ambient (Indian Standards-IS) storage conditions respectively. The unit packs were withdrawn periodically and analyzed for moisture content, free fatty acids (FFA) and peroxide value (PV) as per standard procedures[6]. The sample was suspended in water (15 per cent w/v) and cooked to boiling in water, cooled to 30±2°C and the slurry viscosity was measured in a Brookfield Viscometer[7]. The alpha-amylase activity of the samples was assayed according to Bernfeld[8]. The weaning food slurry prepared similar to that for viscosity measurement was tested for its flavour (aroma and taste) and for overall quality on a five point scale ranging from very poor to very good according to Amerine[9]. Ten staff members who were familiar with the product participated as panelists and evaluated the samples upto a period of 150 days. The score data were analysed by analysis of variance followed by Duncan's new multiple range test to segregate means[9].

## Results and Discussion

The sigmoidal relationship between moisture content and relative humidity suggested that the product behaved like a typical starchy food with respect to its moisture sorption property[10]. Visible mould growth was observed within 10 days when the product was equilibrated at 92 per cent RH. The sample attained 14.3 per cent moisture and developed off flavour (musty odour) when equilibrated

at 75 per cent RH, even though it was free flowing and free from mould growth. The product equilibrated to 65 per cent RH with an equilibrium moisture content of 11 per cent was free flowing without noticeable off-flavour. Thus, a moisture content of 11 per cent could be considered as the critical limit for shelf life of the product and above this, it was susceptible to rapid deterioration. Below 65 per cent RH, the product remained free flowing and retained its original flavour. The product with an initial moisture content of 5.5 per cent had an equilibrium relative humidity of 15 per cent.

The changes in moisture content and free fatty acids for samples, packed in 200 guage LDPE, 250 guage HDPE and laminate pouches and stored at both ambient and accelerated storage conditions are presented in Fig. 1. As storage period increased, there were increases in moisture content and FFA in all the samples at both the storage conditions. In case of samples stored at ambient temperatures, the moisture content of the sample remained well within the critical level even after storage for 150 days. At any given time, the moisture content was high for samples packed in LDPE and low for laminate and intermediate for HDPE pouches.

The trend in FFA development during storage was almost similar to that of the moisture pick up in different packaging materials at both the storage conditions (Fig.1). Under accelerated storage conditions, FFA values increased from 5.5 to 21.3 and 29.5 per cent in sample packed in LDPE pouches at the end of 70 and 90 days of storage respectively. The FFA values for the samples packed in LDPE pouches were always higher than those samples packed in HDPE and laminate pouches at both the storage conditions. The FFA values for samples stored at accelerated storage conditions were higher than their counterparts stored at ambient storage conditions. This indicates that the product is prone to hydrolytic rancidity. The test for peroxide value remained

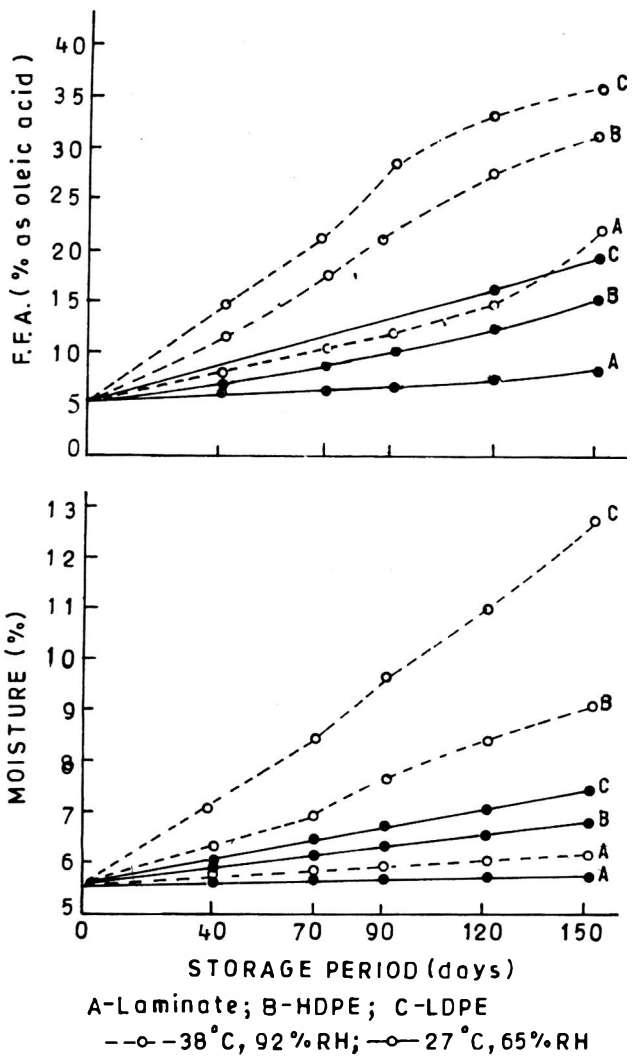


Fig. 1. Influence of storage period on the moisture content and FFA development of weaning food.

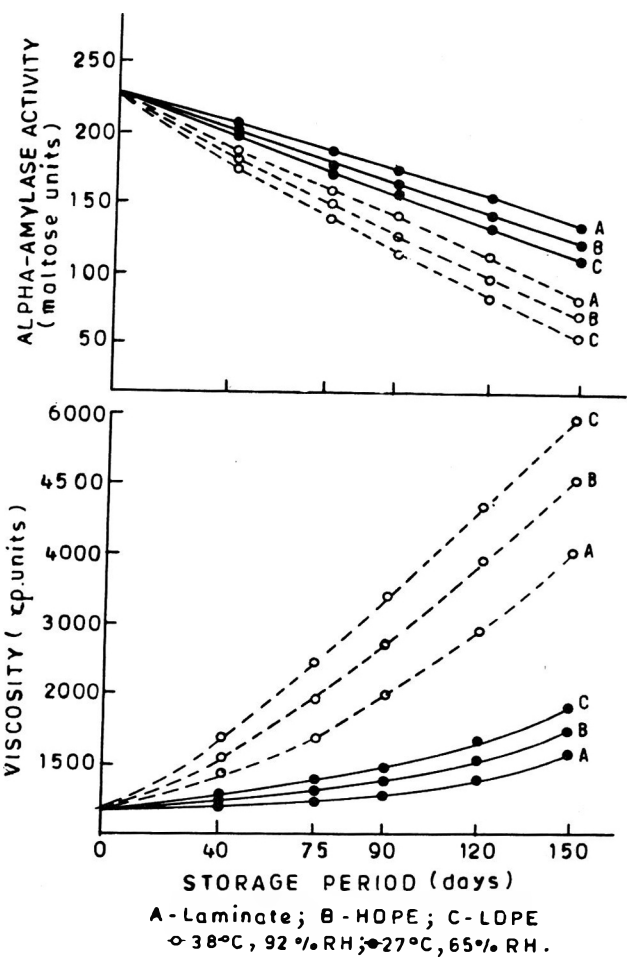


Fig. 2. Effect of storage on viscosity and alpha-amylase activity

negative throughout the storage period at both the storage conditions for all the samples revealing low level of oxidative rancidity in the product. The higher hydrolytic rancidity of the sample could be due to the activity of malt lipase which would not have been completely inactivated during kilning[11].

The changes in alpha-amylase activity and cooked paste viscosity as influenced by packaging material and storage conditions are presented in Fig.2. It may be seen that there was a loss in alpha-amylase activity on storage. The reduction in enzyme activity was slow in the first 40 days of storage, then it became rapid afterwards. However, the decrease in enzyme activity in samples packed in HDPE and laminate pouches was comparatively less than that of LDPE samples. The loss in enzyme activity on storage resulted in an increase in cooked paste viscosity of the samples (Fig.2). The viscosity of a 20 per cent slurry of the freshly prepared sample was 550 CP units and it increased considerably as storage period increased. The increase was very high (6000 CP on 150 days storage) for samples packed in LDPE and stored at accelerated storage conditions. It may be mentioned here that the increase in viscosity of the weaning food is not a desirable feature as high viscosity of high 'dietary bulk' limits intake of food by the child[12].

The flavour and overall quality mean scores analysed for samples packed in different packing materials under different storge conditions upto a storage period of 150 days are presented in Tables 1 and 2 respectively. A mean score of 2.6 and above represent good quality and 1.6-2.5 fair. Under ambient storage, samples packed in LDPE and HDPE pouches showed good quality upto 90 days, and

TABLE 1. FLAVOUR MEAN SCORES OF WEANING FOOD PACKED IN DIFFERENT PACKAGING MATERIALS STORED AT AMBIENT AND ACCELERATED STORAGE CONDITIONS

| Storage period (days) | Stored at 27°C, 65 ± 2% RH | | | Stored at 38°C, 92 ± 2% RH | | |
|---|---|---|---|---|---|---|
| | LDPE | HDPE | Laminate | LDPE | HDPE | Laminate |
| Fresh | $4.5^{a}$ | $4.5^{a}$ | $4.5^{a}$ | $4.5^{a}$ | $4.5^{a}$ | $4.5^{a}$ |
| 40 | $4.4^{a}$ | $4.5^{a}$ | $4.5^{a}$ | $3.4^{b}$ | $3.7^{b}$ | $3.9^{b}$ |
| 70 | $3.6^{b}$ | $3.8^{b}$ | $3.8^{b}$ | $3.2^{b}$ | $3.1^{c}$ | $3.1^{c}$ |
| 90 | $3.2^{b}$ | $3.1^{c}$ | $3.4^{bc}$ | $2.5^{c}$ | $2.4^{d}$ | $2.7^{c}$ |
| 120 | $2.4^{c}_{x}$ | $2.4^{d}_{x}$ | $3.1^{c}_{y}$ | $1.7^{d}_{x}$ | $1.3^{e}_{x}$ | $2.3^{d}_{y}$ |
| 150 | $1.7^{d}$ | $1.6^{c}$ | $2.0^{d}$ | * | * | * |
| $SE_m$ | ±0.18 (54 df) | ±0.17 (54 df) | ±0.18 (54 df) | ±0.17 (45 df) | ±0.20 (45 df) | ±0.20 (45 df) |

Limits for means: ≤0.5 =Very poor: 0.6 – 1.5 = Poor; 1.6 – 2.5 = Fair; 2.6 – 3.5 = Good; ≥ 3.6 = Very good
Means in the same column followed by different superscripts abc ----- differ significantly ($P < 0.05$). Row means followed by different subscripts (x,y,z ....) differ significantly
Other row means do not differ significantly ($P > 0.05$) * Not evaluated due to spoilage.

TABLE 2. OVERALL QUALITY MEAN SCORES OF WEANING FOOD PACKED IN DIFFERENT PACKAGING MATERIALS AND STORED UNDER AMBIENT AND ACCELERATED STORAGE CONDITIONS

| Storage period (days) | Stored at 27°C, 65 ± 2% RH | | | Stored at 38°C, 92 ± 2% RH | | |
|---|---|---|---|---|---|---|
| | LDPE | HDPE | Laminate | LDPE | HDPE | Laminate |
| Fresh | $4.5^{a}$ | $4.5^{a}$ | $4.5^{a}$ | $4.5^{a}$ | $4.5^{a}$ | $4.5^{a}$ |
| 40 | $4.2^{ab}$ | $4.5^{a}$ | $4.3^{ab}$ | $3.5^{b}$ | $3.7^{b}$ | $3.8^{b}$ |
| 70 | $3.7^{b}$ | $4.2^{a}$ | $3.8^{bc}$ | $2.9^{c}$ | $3.2^{b}$ | $3.3^{b}$ |
| 90 | $3.0^{c}_{x}$ | $3.1^{b}_{x}$ | $3.4^{cd}_{x}$ | $1.7^{d}_{x}$ | $2.1^{c}_{xy}$ | $2.5^{cu}$ |
| 120 | $1.9^{d}_{x}$ | $2.7^{b}_{y}$ | $3.0^{d}_{y}$ | * | $1.6^{c}_{x}$ | $1.6^{d}_{x}$ |
| 150 | $1.5^{d}_{x}$ | $2.1^{c}_{y}$ | $2.2^{e}_{y}$ | * | * | * |
| $SE_m$ | ±0.19 (54 df) | ±0.18 (54 df) | ±0.18 (54 df) | ±0.18 (36 df) | ±0.17 (45 df) | ±0.17 (45 df) |

Limits for means: ≤0.5 =Very poor; 0.6 – 1.5 = Poor; 1.6 – 2.5 = Fair; 2.6 – 3.5 = Good; ≥ 3.6 = Very good
Means in the same column followed by different superscripts (a,b,c ...) differ significantly ($P < 0.05$). Row means followed by different subscripts (x,y,z ...) differ significantly ($P < 0.05$). Other row means do not differ significantly
* Not evaluated due to spoilage.

laminate upto 120 days which can be safely considered as the shelf-life. However, under ambient storage, LDPE packed samples showed fair quality (just acceptable) upto a period of 120 days, HDPE and laminate packed samples upto 150 days. Under accelerated storage condition, LDPE and HDPE packed samples showed good quality upto 70 days which can be fixed as the shelf-life, whereas the sample packed in laminate had an extended shelf-life of upto 90 days at accelerated storage condition.

Under ambient storage conditions, the samples in all the packaging materials did not attain the critical moisture level upto 150 days but the sensory quality showed only 90 days shelf-life with LDPE, HDPE and 120 days with laminate packaging material.

In conclusion, it may be stated that for the household or small scale preparation of weaning food and for local distribution, the product may be packed in LDPE pouches. For longer storage and wider distribution, moisture proof laminate packaging materials like paper/foil/poly or metallised polyester/poly would be necessary.

**Acknowledgement**

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# Production of Heat Stable Proteinases by Psychrotrophic Bacteria in Milk

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**Raw and pasteurized milks were found to have psychrotrophs in the range of 1.5-10 × $10^5$ and 1-2 × $10^2$ per ml and proteolytic psychrotrophs in the range of 0.15-2.5 × $10^5$ and 7-12 per ml, respectively. Proteolytic psychrotrophs were identified to belong to five genera viz., *Pseudomonas* (42.3%); *Micrococcus* (32.7%); *Staphylococcus* (15.6%); *Alcaligenes* (7.7%) and *Flavobacterium* (2%). Proteinase produced by *Pseudomonas* sp. (isolate $PM_{26}$) retained nearly 72% of its activity when heated to 75°C for 10 min. A medium containing 1% tryptone and 0.75% yeast extract, at pH 7.0 under shaking conditions with 2% inoculum was found to be optimum for proteinase production. However, malt extract and fermentable sugars (except glucose) did not support proteinase synthesis.**

Transport and storage of milk under refrigeration has encouraged psychrotrophs to grow and bring out structural and functional changes in milk constituents. The milk products which are manufactured from such low temperature stored milks, frequently undergo spoilage due to proteinases and lipases released by psychrotrophic bacteria[1]. Some of the proteolytic enzymes have been found to withstand the milk processing temperatures[2,3] as well as high temperature treatments[4]. These enzymes cause product quality problems such as gelation, bitter flavour and sediment formation in ultra high temperature sterilised milk. The present study was undertaken to identify proteolytic psychrotrophic bacteria present in raw and pasteurised milks and to study the production of proteinases under different nutritional and environmental conditions.

## Materials and Methods

*Isolation and identification of proteolytic psychrotrophs from milk:* Fourteen samples of raw milk and 6 of pasteurised milk were obtained from the Department of Food Science and Technology, Punjab Agricultural University, Ludhiana and analysed for psychrotrophic count (PC) and proteolytic psychrotrophic count (PPC) by pour plate method using tryptone dextrose yeast extract agar (TDA) medium. The medium contained (in g/l) tryptone, 5; yeast extract, 2.5 and dextrose, 1.0 at pH 7.2±0.1. The plates (in duplicate) were incubated at 7°C for 10 days for PC and PPC as recommended by American Public Health Association[5]. TDA fortified with 10 per cent skim milk was used for enumeration and isolation of proteolytic psychrotrophs. The colonies showing a discrete clear zone around them were taken as proteolytic ones and were purified and maintained on TDA slants in a refrigerator. Proteolytic psychrotrophs were identified on the basis of morphological/biochemical characters according to the Bergey's Manual of Determinative Bacteriology[6].

*Assay of proteinase activity:* Erlenmeyer flasks (250 ml) containing 50 ml of tryptone yeast extract broth were inoculated with 48 hr old culture (1 per cent inoculum) and incubated for 48 hr at 22°C on a rotary shaker. The contents were centrifuged at 6000 r.p.m. for 15 min and the supernatant was used to estimate proteinase activity using casein as substrate as reported by Keay and Wildi[7]. For this, 1 g of casein was dissolved in a minimum amount of 0.1N NaOH, adjusted to pH 7.0 with 0.1 N HCl and volume raised to 100 ml with 0.1 M phosphate buffer at pH 7.0. The protein solution was heated to 80°C for 5 min to destroy any protein associated proteinase activity[8], rapidly cooled to 21-25°C and stored in a refrigerator. To 1 ml of the above solution equilibrated at 37°C for 5 min, was added 1 ml of culture supernatant. The reaction mixture, after thorough mixing, was incubated at 37°C for 30 min. The reaction was terminated by adding 2 ml of 0.4 M trichloroacetic acid(TCA) and the mixture was further incubated for 10 min at 37°C. The precipitated proteins were filtered through Whatman No.1 filter paper. A control in which the substrate was precipitated with TCA before the addition of culture supernatant, was run

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simultaneously. The supernatant was used to determine its tyrosine content according to the method of Lowry *et al*[9]. One unit of proteinase activity was defined as the amount of enzyme required to release trichloroacetic acid (TCA) soluble fragments giving blue colour equivalent to 1 μg of tyrosine under the conditions of assay.

*Thermo stability of proteinase:* To study the thermostability of extracellular proteinase produced by psychrotrophs, 1 ml of the cell-free supernatants were heated for 10 min at 40, 50, 60, 65 and 70°C, immediately cooled to about 2°C by immersing in chilled water and used to determine proteinase activity.

*Effect of nutritional and physical conditions on proteinase production: Pseudomonas* sp. (isolate PM 26) which produced highly heat stable proteinase was used to study the effect of tryptone, yeast extract, malt extract, fructose, galactose, mannitol, lactose, sucrose, arabinose, different ranges of pH, agitation and size of inoculum on synthesis of extracellular proteinase in tryptone yeast extract broth at 22°C for 36 hr.

**Results and Discussion**

*Psychrotrophs in milk:* The total viable counts ranged from 5.5 to 45 $\times 10^6$ per ml in raw milks and 2 to $3.1\times10^5$ per ml in pasteurised milks tested during the present study. All the raw and pasteurised milk samples were found to contain psychrotrophic and proteolytic psychrotrophic bacteria which could be attributed to post-pasteurisation contamination. The average count is given in Table 1. The presence of the proteolytic psychrotrophs in milk and milk products has also been reported by many workers[10-13].

*Identification of proteolytic psychrotrophs:* A total of 64 psychrotrophic isolates showing discrete zones of proteolysis around them on TDA medium supplemented with 10 per cent skim milk were picked from various milk samples. They were identified to belong to *Pseudomonas* sp. (31 isolates), *Micrococcus* sp. (18 isolates), *Staphylococcus* sp. (8 isolates), *Alcaligenes* sp. (6 isolates), and *Flavobacterium* sp. (1 isolate). The dominance of *Pseudomonas* could be attributed to their wide spread distribution in natural habitat, rapid multiplication and a diverse metabolic activity and their interactive inhibitory activities against other psychrotrophs in dairy products.[14,15]

*Thermostability of proteinase:* Of the 64 proteolytic psychrotrophs screened for proteinase activity, five isolates viz. *Pseudomonas* ($PM_2$ and $PM_{26}$), *Alcaligenes* ($PM_{12}$ and $M_{70}$) and *Staphylococcus* ($M_{52}$) were selected on the basis of maximum proteinase activity to study the thermal stability of this enzyme. Proteinase produced by *Pseudomonas* (PM 26) exhibited the maximum thermal stability (Table 2) at 70°C and was therefore selected to study the effect of various fermentation parameters on proteinase production. The proteinase produced by *Pseudomonas* isolates have also been reported to retain an appreciable level of its activity when heated up to 80°C for 10 minutes[16].

*Effect of nutritional and physical conditions on proteinase production: Pseudomonas* sp. (isolate $PM_{26}$) synthesized maximum proteinase in the medium containing 0.75 per cent yeast extract and its synthesis showed a linear increase with tryptone (at 0.05-1 per cent level) as shown in Fig. 1. However, supplementation of the medium with malt extract resulted in a decrease of proteinase synthesis, where an enzyme activity of 53 and 20 units per ml at 0.25

TABLE 1. PSYCHROTROPHIC COUNT IN MILK

| | Psychrotrophs | Proteolytic psychrotrophs |
|---|---|---|
| **Raw milk** | | |
| Range ($\times 10^5$/ml) | 1.5 – 10 | 0.15 – 2.5 |
| Mean ($\times 10^5$/ml) | 3.53 | 0.65 |
| **Pasteurized milk** | | |
| Range ($\times 10^2$/ml) | 1 – 2 | 0.07 – 0.12 |
| Mean ($\times 10^2$/ml) | 1.5 | 0.095 |

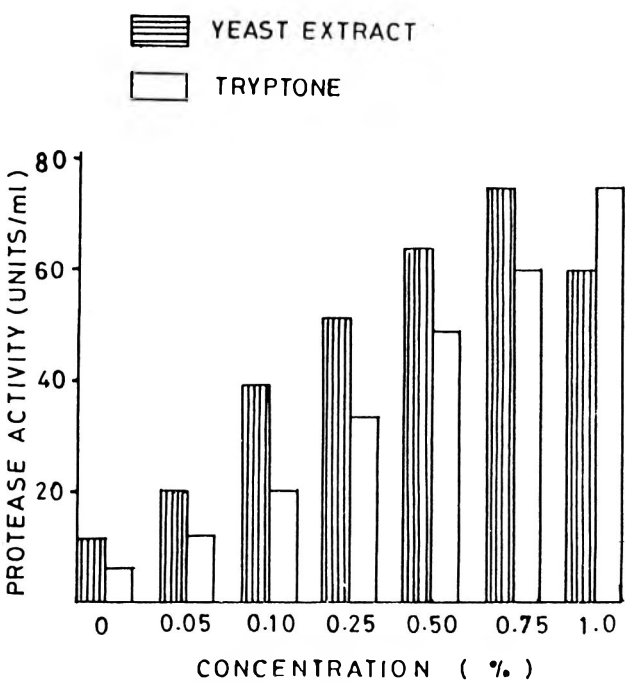


Fig. 1. Effect of yeast extract and tryptone on production of proteinase by *Pseudomonos* sp. (PM 26) in tryptone yeast extract broth, containing 1g glucose per litre at pH 7.2±0.1.

TABLE 2. THERMOSTABILITY OF EXTRACELLULAR PROTEINASE PRODUCED BY PSYCHROTROPHS

| Bacteria | Isolate | Residual activity (% of control) at indicated temp. | | | | |
|---|---|---|---|---|---|---|
| | | 40°C | 50°C | 60°C | 65°C | 75°C |
| *Pseudomonas* sp. | $PM_2$ | 93.75 | 87.50 | 78.12 | 62.50 | 56.25 |
| *Pseudomonas* sp. | $PM_{26}$ | 94.93 | 89.87 | 86.87 | 77.21 | 72.15 |
| *Alcaligenes* sp. | $PM_{12}$ | 75.86 | 72.41 | 65.61 | 48.27 | 37.93 |
| *Alcaligenes* sp. | M 70 | 93.44 | 85.24 | 75.40 | 67.31 | 56.09 |
| *Staphylococcus* sp. | $M_{52}$ | 95.56 | 86.95 | 69.56 | 65.20 | 47.82 |

and 0.5 per cent malt extract respectively was observed against 79 units per ml in the control.

A decrease in proteinase activity was also observed when glucose was replaced by various sugars (Fig. 2). Sucrose supported a minimum (21 units per ml) proteinase activity. Contrary to our observations, inhibitory effects of glucose on proteinase production have been reported in *Pseudomonas fluorescens* which were attributed to catabolite repression by glucose[17].

Maximum proteinase synthesis was observed when the medium was adjusted to an initial pH of 7.0 (Fig.3). Maximum proteinase production has also been observed by Juffs[17] in *Pseudomonas fluorescens* and *aeroginosa* in peptone yeast extract broth at pH 7.0±0.2.

*Pseudomonas* sp. ($PM_{26}$) exhibited more proteinase activity per unit volume under shaking conditions (76 units per ml) than in stationary culture (31 units per ml) which could be attributed to the highly aerobic nature of *Pseudomonas* in general. Maximum

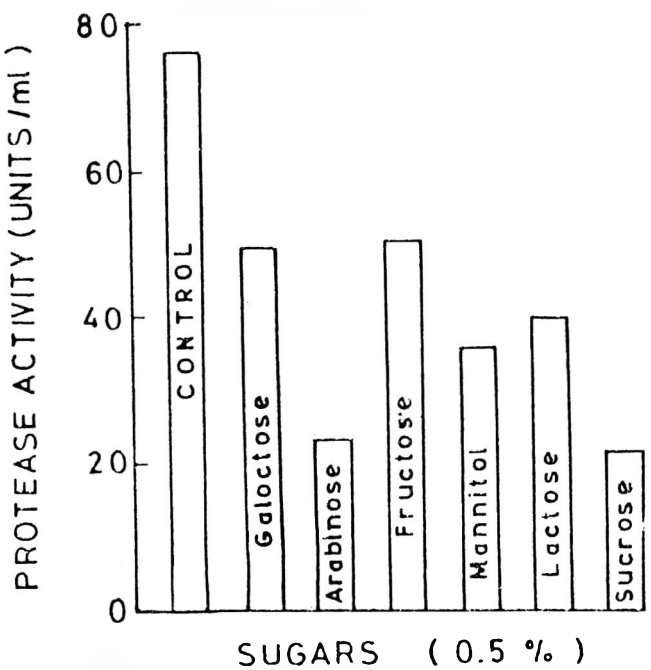


Fig. 2. Effect of various sugars on production of proteinase by *Pseudomonas* sp. (PM 26) in tryptone yeast extract broth, containing 1% tryptone and 0.75% yeast extract at pH 7.2±0.1

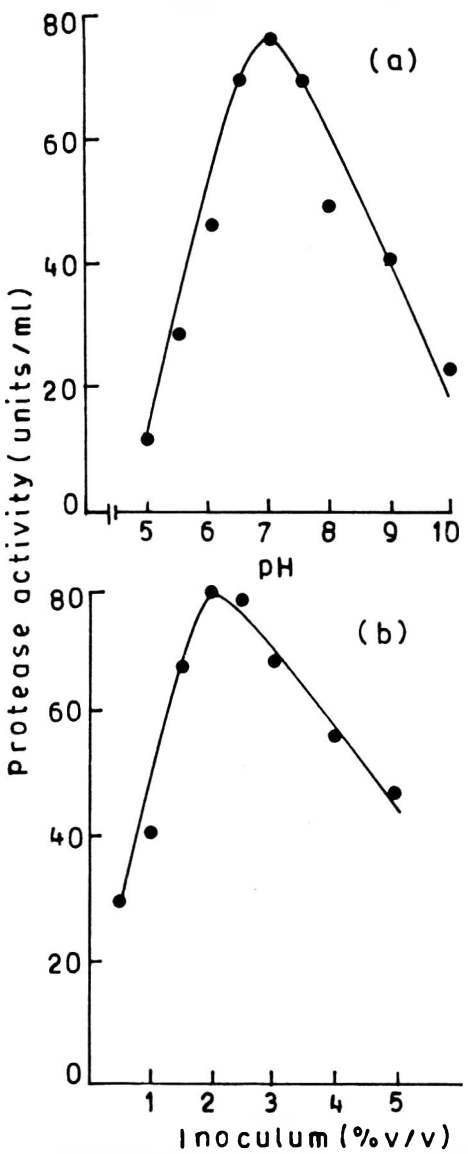


Fig. 3. Effect of pH and inoculum on production of proteinase by *Pseudomonas* sp. (pM 26) in tryptone yeast extract broth.

proteinase production by *Pseudomonas* sp. $PM_{26}$ (80 and 79 units per ml) was observed when the inoculum was used at 2 and 2.5 per cent (Fig. 3b).

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# Stability of Gul Mohar (*Delonix regia*) Carotenoids in Isolated Model Systems

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**Gul Mohar (*Delonix regia*) flower which contains high concentration of carotenoids (1890 μ g/g) were isolated and their stability was tested in microcrystalline cellulose, petroleum ether and in aqueous colloidal systems representing fruit squashes. In petroleum ether and microcrystalline cellulose, Gul mohar carotenoids were considerably more stable than synthetic β-carotene but in squashes Gul mohar carotenoids were marginally superior to β–carotene. In squashes, stability of carotenoids was related to the nature of preservative employed. Samples preserved with sulphur dioxide retained highest concentration, while sorbate treated samples retained the least. Saponified fractions of Gul mohar carotenoids were relatively more stable than unsaponified fractions.**

In recent years, there has been considerable concern about the safety of synthetic dyes used in processed foods[1]. Considerable efforts are being directed towards developing natural or natural equivalent synthetic pigments. Carotenoids have been found most suitable for yellow, orange and red colours, and a number of synthetic or natural carotenoids including β-carotene, β-apo-8′-carotenal, canthaxanthin, annatto extract and saffron are permitted in processed foods. However, their susceptibility to autoxidation has restricted their usage to only a few foods.

Gul Mohar *(Delonix regia)* is a very hardy ornamental tree grown in most tropical countries. It flowers very profusely and the orange-red flowers are very rich in carotenoids. Jungalwala and Cama[2] have reported the composition of carotenoids in petals, sepals and anthers. Feeding of Gul Mohar flowers to poultry (1-10 per cent) has been reported to improve the colour of egg yolk without any signs of harmful effects on birds[3]. In the present paper, the stability of Gul Mohar flower carotenoids in isolated model systems is discussed.

## Materials and Methods

Gul Mohar flowers were obtained from the laboratory campus and 100 g petals were macerated for 5 min in a blender with 200 ml acetone. The mixture was filtered through a sintered glass funnel and the residue was re-extracted with 50 ml aliquots of acetone and filtered till free from colouring matter. The combined filtrate was treated with 100 ml hexane and washed with excess of 5 per cent sodium chloride solution to remove acetone and water soluble substances. Hexane extract was dried over anhydrous sodium sulphate and preserved at 5°C till further use.

For saponification, 50 ml aliquot of the hexane extract was evaporated in a rotary thin film evaporator under vacuum and the residue was treated with 50 ml of 20 per cent ethanolic potassium hydroxide. The mixture was kept at room temperature in a dark place with occasional shaking. After 24 hr, the mixture was treated with 250 ml water and extracted twice with 50 ml portions of diethyl ether to extract carotenoids. The ether extract was washed with distilled water and evaporated to dryness under vacuum in a rotary thin film evaporator. The residue was dissolved in hexane and dried over anhydrous sodium sulphate and stored at 5°C till further use.

*Impregnation of Gul Mohar carotenoids on microcrystalline cellulose and storage:* Known aliquots of saponified and unsaponified hexane extracts of Gul Mohar carotenoids were transferred to 1 l. capacity round bottom flasks containing 50 g microcrystalline cellulose (E. Merck). The flasks were swirlled for uniform mixing and the solvent was evaporated using a rotary thin film evaporator. The coloured powder was ground in a glass mortar to break any lumps and redried under vacuum to remove traces of hexane. Similarly, β-carotene (85 mg, E. Merck) was dissolved in 50 ml hexane and impregnated over microcrystalline cellulose. All operations were carried out under subdued light.

Carotenoid impregnated cellulose (15 g) was stored in petri dishes (8.5 cm dia) over phosphorus pentoxide and saturated solutions of magnesium chloride and sodium nitrate to obtain 0.0, 0.33 and 0.73 water activity ($a_w$) in dark at room temperature (15-35°C)[4].

*Preparation of squash model system and storage:* Aliquots ot hexane extracts of saponified and un-

saponified Gul Mohar carotenoids were evaporated to dryness under vacuum and were dissolved in aliquots of 20 g hydrogenated vegetable oil. These were emulsified with 2 kg sugar solutions of 45° Brix having 0.8 per cent citric acid in a blender for 15 min along with 100 g polyoxyethylene sorbitan mono oleate (Tween-80). One hundred ml of these solutions were filled in 125 ml glass bottles having ground glass stoppers. The stoppers were waxed and bottles were stored in dark at room temperature. Similarly, 50 mg of β-carotene were dissolved in hydrogenated vegetable oil, emulsified with sugar solution and stored in glass bottles along with Gul Mohar carotenoid samples.

*Stability of Gul Mohar carotenoids and β-carotene in petroleum ether solution:* Fifty mg of unsaponified Gul Mohar carotenoids and β-carotene were dissolved in 200 ml petroleum ether (80-120°C boiling fraction) in 500 ml conical flasks. The flasks were covered with aluminium foil and stored in an incubator maintained at 37±1°C in dark. Initially and periodically, aliquots were taken out, diluted to 50 ml and their absorbance was measured at 449 nm.

*Analysis:* Initially and periodically, aliquots of the stored samples were withdrawn and carotenoids were estimated by the methods described earlier[4]. Concentration of total carotenoids was determined by measuring the absorbance of hexane extracts at 449 nm using Shimadzu 240 Graphicord Spectrophotometer. From the absorbance values, the concentration of carotenoids was computed using $E^{1\%}_{449}$ 25000. Moisture content was determined by heating 2 g samples at 100°C for 4 hr in tared aluminium dishes and expressed on total weight basis.

**Results and Discussion**

Total carotenoids in six Gul Mohar flower samples ranged between 1798 and 1936 μg/g with a mean of 1890±56 μg/g. The moisture content in freshly plucked flowers was between 83.4 and 85.4 per cent. Since at this moisture level, flowers are highly susceptible to microbial deterioration, these were dried at 90°C for 3 hr to less than 10 per cent moisture. During the drying, total carotenoids decreased from 1890 to 1485 μ g/g (21.4 per cent). By simple maceration with acetone, carotenoids could be fully extracted.

Susceptibility of carotenoids towards oxidative degradation is a major problem in their usage in colouring foods. Accordingly, relative stability of Gul Mohar carotenoids and synthetic β-carotene was studied in three model systems (Fig. 1). It may be observed that at all the three water activities, Gul Mohar carotenoids are much more stable than β-carotene. Also, for both β-carotene and Gul Mohar carotenoids, the rate of degradation was highest at 0.0 $a_w$ and lowest at 0.73

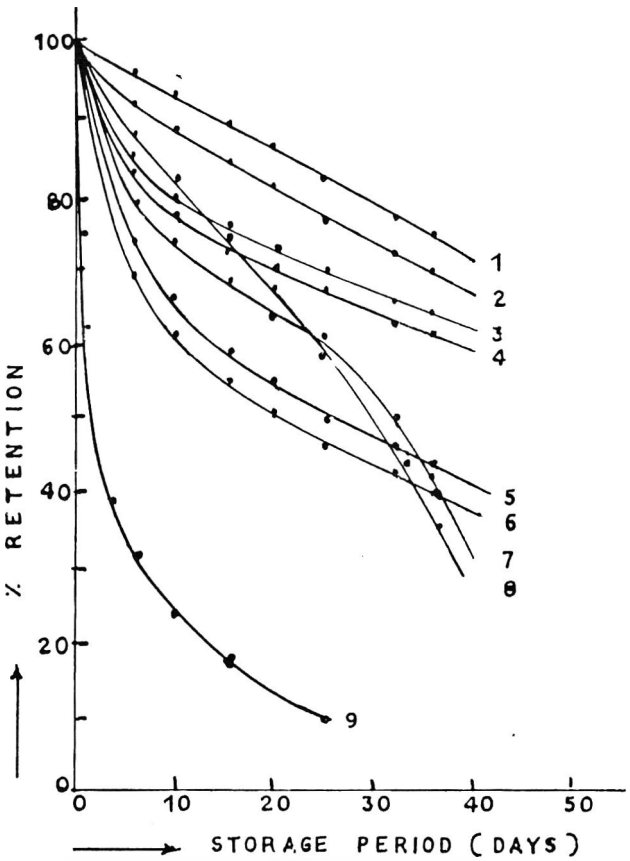


Fig. 1. Effect of water activity on the storage degradation of Gul Mohar carotenoids and β-carotene.
1,3,8, – Saponified fraction and 2,4,7 – unsaponified carotenoids of Gul Mohar at 0.73, 0.33 and 0.0 $a_w$ respectively; 5, 6, 9 – β-carotene at 0.73, 0.33 and 0.0 $a_w$ respectively.

$a_w$. After 32 days of storage at 0.0 $a_w$ β-carotene had undergone complete autoxidation as compared to 50 per cent loss in Gul Mohar carotenoids. Since β-carotene forms the major fraction of total carotenoids of Gul Mohar[2] the enhanced stability of Gul Mohar carotenoids may be due to the presence of natural antioxidants or due to the lipid fraction. In order to understand the role, if any, of lipids on the stability of Gul Mohar carotenoids, these were saponified and the saponified fraction was impregnated on microcrystalline cellulose. It may be seen that even after saponification, Gul Mohar carotenoids were considerably more stable than β-carotene suggesting the presence of natural antioxidants in the carotenoid extract which impart higher stability. Also, the saponified fraction was relatively more stable than the unsaponified fraction at 0.33 and 0.73 $a_w$ but at 0.0 $a_w$ both the fractions underwent degradation at similar rates.

The relative rates of degradation of Gul Mohar carotenoids and β-carotene in petroleum ether (boiling range 80-120°C) solutions are shown in Fig. 2. Gul Mohar carotenoids were remarkably stable in

lipophilic solvent as compared to β-carotene. While β-carotene was completely degraded within 23 days storage at 37°C, more than 90 per cent of the Gul Mohar carotenoids were retained even after 80 days storage under the same conditions. This suggests that Gul Mohar carotenoids extract will be suitable for colouring fatty products like butter, peanut butter, etc.

On the other hand, the stability of Gul Mohar carotenoids was only marginaly higher than β-carotene in aqueous colloidal systems representing fruit squashes (Fig. 2). This is not unexpected because in aqueous, systems, fat soluble antioxidants are not able to exert significant protective effect. Stability of carotenoids and other autoxidisable components in these systems is mainly governed by the dissolved oxygen and water soluble antioxigenic compounds like ascorbic acid. In the present study too, samples containing sulphur dioxide and ascorbic acid retained significantly higher levels of carotenoids. Among the sorbate and benzoate treated samples, sorbate treated samples retained slightly lower level of carotenoids indicating its pro-oxidant action in fruit squashes. Previously, Arya *et al*[5]. have reported that addition of sorbic acid does not influence the stability of carotenoids in fruit squashes.

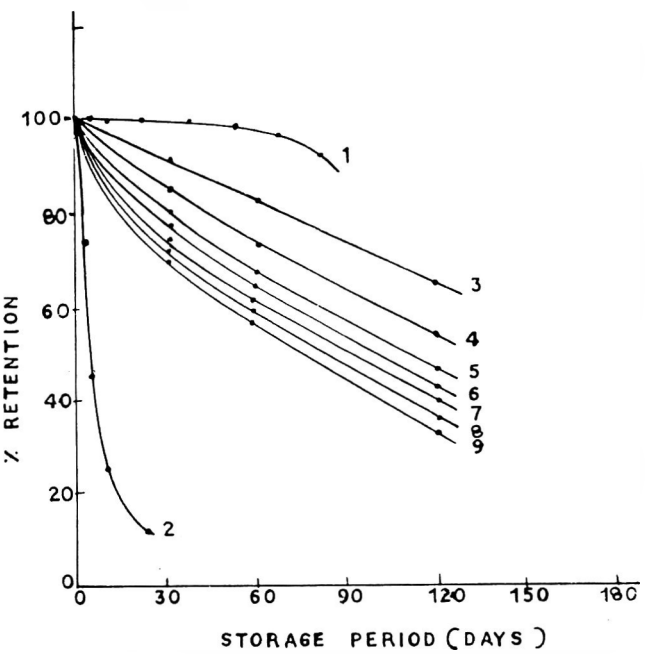


Fig. 2. Stability of Gul Mohar carotenoids and β-carotene in petroleum ether and model squash systems
1 and 2 – Petroleum ether solutions of Gul Mohar carotenoids and β-carotene respectively at 37°C±1°C; 3 to 9 – Model squash systems; 3 and 4 – Gul Mohar carotenoids and β-carotene respectively with sulphur dioxide as a preservative; 5, 6 and 8 – saponified fraction of Gul Mohar carotenoids, total Gul Mohar carotenoids and β-carotene respectively with benzoic acid as preservative; 7 and 9 – Total Gul Mohar carotenoids and β-carotene respectively with sorbic acid as preservative.

Though Gul Mohar is a widely grown popular ornamental tree, its flowers are not put to any use. Gul Mohar carotenoids being more stable than synthetic β-carotene, its flowers can easily be extracted and Gul Mohar colourant can easily be marketed in the form of oil concentrate like Annatto extract. However, before its commercial usage in foods, the product needs complete toxicological evaluation.

**Acknowledgement**

We wish to thank Dr. T.R. Sharma, Director, Defence Food Research Laboratory, Mysore, for his valuable suggestions.

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# Effect of Soaking Pearl Millet in Acid on the Bleaching and Functional Properties of Flours

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**Pearl millet was soaked in 0.2 N HCl for 3,6,9,12,15,18 and 24 hr and bleaching and functional properties of flours were studied. It was observed that HCl was the most effective bleaching agent which removed pigments to the extent of 74.3% during 24 hr soaking time. The functional properties of flours viz. water and oil absorption capacities of HCl treated flours were improved at all soaking times. Nitrogen solubility, gelation, foam capacity and foam stability, emulsifying activity and its stability and bulk density were decreased after soaking pearl millet in 0.2 N HCl.**

The pearl millet (*Pennisetum typhoideum* L.) is the sixth most important cereal in the world's cereal production and is widely cultivated in Asia, Africa and the United States[1]. However, pigments in pearl millet are a serious problem which make its products unacceptable or bittery in taste for consumption[2]. Due to the presence of certain pigments in the pericarp and endosperm layers of the seeds, coarseness and the absence of gluten characteristics in proteins, the pearl millet has remained a food for low socio-economic groups. The wide use of pearl millet depends on removal of the pigments to increase its acceptability.

The removal of bran containing pigments to obtain a white flour is the major objective in pearl millet processing. During traditional milling, some bran is removed and some gets mixed with flour leading to a green colour. Morever, milling by different processes is time-consuming and costly. Reichert[2] observed in millet flour-water pastes, a reversible change in colour from grey to yellow green at alkaline pH and partially irreversible from grey to creamy-white in the presence of acid. The use of acids is, therefore, advocated to remove the pigments and obtain a white flour from pearl millet[3,4]. HCl is found to be the most effective.

Pearl millet is consumed mostly in the form of unleavened *roti* prepared from whole flour and it is not accepted by many consumers because of its green colour. The influence of soaking pearl millet in dilute HCl for varying lengths of time on the removal of pigments and functional properties of flours was therefore studied.

## Materials and Methods

Grains of pearl millet were purchased from the local market of Parbhani. Cleaned grains of uniform size (100 g) were soaked in 300 ml (w/v) 0.2 N HCl for 3,6,9,12,15,18 and 24 hr and then washed twice with water to remove the residual HCl. The grains were dried till moisture was reduced to 14 per cent. The processed grains were then ground in a blender (Sumeet) to pass through 0.25 mm sieve and stored in plastic bottles at 4°C until use.

*Determination of pigments:* The pigment (polyphenols) in the flour was determined according to the methods of AOAC[5] as modified by Cristensen[6].

*Determination of protein and starch:* Crude protein (N × 6.25) and starch in the flour were determined by the methods of AOAC[5] and McCready *et al*[7], respectively. The insoluble residue in 70 per cent ethanol was used for starch determination.

*Functional properties:* Water and oil (refined safflower oil) absorption capacities of flour were determined by the method of Beuchat[8]. Nitrogen solubility of flours was determined in the pH range of 2-12 as described by Narayana and Rao[9]. Least gelation concentration, foaming capacity and foam stability and emulsifying activity and emulsion stability of flours were studied according to the method of Deshpande *et al*[10]. Emulsion stability was evaluated by recentrifugation following heating at 80°C for 30 min in a water bath. Bulk density of flours was determined as per the method of Wang and Kinsella[11].

## Results and Discussion

*Protein, starch and polyphenols:* The effect of soaking pearl millet in 0.2 N HCl for different times on protein, starch and polyphenols is presented in Table 1. The crude protein was decreased from 13.7 to

TABLE 1. EFFECT OF SOAKING PEARL MILLET IN 0.2 N HCl ON PROTEIN, STARCH AND POLYPHENOLS OF FLOURS[a]

| Soaking time (hr) | Crude protein N×6.25 (%) | Starch (%) | Polyphenols (mg/g) | Reduction in polyphenols (%) |
|---|---|---|---|---|
| 0 | 13.7 | 60.1 | 1.21 | – |
| 3 | 13.5 | 60.0 | 1.01 | 15.7 |
| 6 | 13.2 | 59.8 | 0.90 | 25.6 |
| 9 | 13.0 | 59.8 | 0.57 | 53.7 |
| 12 | 13.0 | 58.6 | 0.39 | 67.7 |
| 15 | 12.8 | 58.4 | 0.37 | 69.4 |
| 18 | 12.7 | 58.1 | 0.34 | 71.9 |
| 24 | 12.7 | 58.0 | 0.31 | 74.3 |

[a]Expressed on dry weight basis
Each figure is the average of three determinations.

12.7 per cent, whereas starch from 60.1 to 58.0 per cent after soaking for 24 hr which may be due partly to their hydrolysis and partly their leaching in soaking medium. Kakade and Evans[12] also reported decrease in protein in beans after soaking in water for 1 to 4 days. The polyphenols (expressed as tannic acid) decreased from 1.21 to 0.31 mg/g (74.3 per cent) after soaking pearl millet grains in HCl for 24 hr. In HCl bleaching of millet grains, advantage is taken of the fact that the polyphenolic pigments become soluble in acidic solution at pH 4.5 to 5.0. HCl penetrated through small regions around the embryo and slowly migrated towards other side of the whole grains and finally bleached. As a result, reduction in polyphenols occurred. Similar results are reported on pearl millet by Reichert and Youngs[3] with 0.1 N HCl for 48 hr and by Naikare *et al*[4] with 0.2 N HCl for 15 hr.

*Functional properties:* The data presented in Table 2 reveal that water and oil absorption capacities were increased significantly from 1.85 to 2.70 and from 1.35 to 1.92 g/g flour, respectively, on soaking grains in 0.2 N HCl for 24 hr. Same trend was observed in both these properties when expressed on crude protein basis. The water and oil absorption capacities of flours on crude protein basis were increased from 13.50 to 23.97 and 9.85 to 15.23 g/g protein, respectively, during 24 hr soaking. Though there was a decrease in protein content in HCl-treated flour (Table 1), water absorption capacity was increased significantly. In most cases, using a similar test procedure a greater water absorption was noted for protein isolates than for concentrates which indicated a possible relationship between water absorption and protein content. The water absorption of a particular sample, however, need not be parallel to its protein content. Lin *et al*[13] observed that soy products had higher water absorptions than did sunflower products, although their protein contents were similar. Dev and Quensel[14] reported higher values of water absorption by linseed flour than soybean flour although the linseed flour had lower protein content than soybean flour. It is clear from this, that associated carbohydrate components especially crude fibre and starch play a role in water absorption. On soaking grains in HCl for 24 hr, the polyphenols are leached out. The hydrophilic properties of proteins are related to such polar groups as amino, carboxyl, hydroxyl, carbonyl, and sulfhydril which are primarily responsible for increased water absorption. These polar groups otherwise form the complex with polyphenols and decrease the water absorption capacity. The increase in water absorption in HCl-treated samples in the present investigation may be due to

TABLE 2. EFFECT OF SOAKING PEARL MILLET IN 0.2 N HCl ON WATER AND OIL ABSORPTION, GELATION AND BULK DENSITY OF FLOURS[a]

| Soaking time (hr) | Water absorption capacity (g/g) | | Oil absorption capacity (g/g) | | Bulk density (g/ml) | Least gelation concn (% w/v) |
|---|---|---|---|---|---|---|
| | Flour | Protein[a] | Flour | Protein[a] | | |
| 0 | 1.85 | 13.50 | 1.35 | 9.85 | 0.82 | 14 |
| 3 | 2.25 | 16.60 | 1.40 | 10.37 | 0.93 | 14 |
| 6 | 2.30 | 17.42 | 1.42 | 10.42 | 0.82 | 14 |
| 9 | 2.40 | 18.46 | 1.65 | 12.69 | 0.85 | 14 |
| 12 | 2.35 | 17.19 | 1.70 | 13.01 | 0.81 | 13 |
| 15 | 2.40 | 18.75 | 1.75 | 13.67 | 0.76 | 13 |
| 18 | 2.20 | 17.32 | 1.89 | 13.68 | 0.74 | 12 |
| 24 | 2.70 | 23.97 | 1.92 | 15.23 | 0.73 | 11 |
| SE ± | 0.321 | | 0.293 | | 0.005 | 1.24 |
| CD (P=0.05) | 0.019 | | 0.011 | | 0.014 | 3.62 |

[a]Expressedl on dry weight basis
Each figure is the average of three determinations.

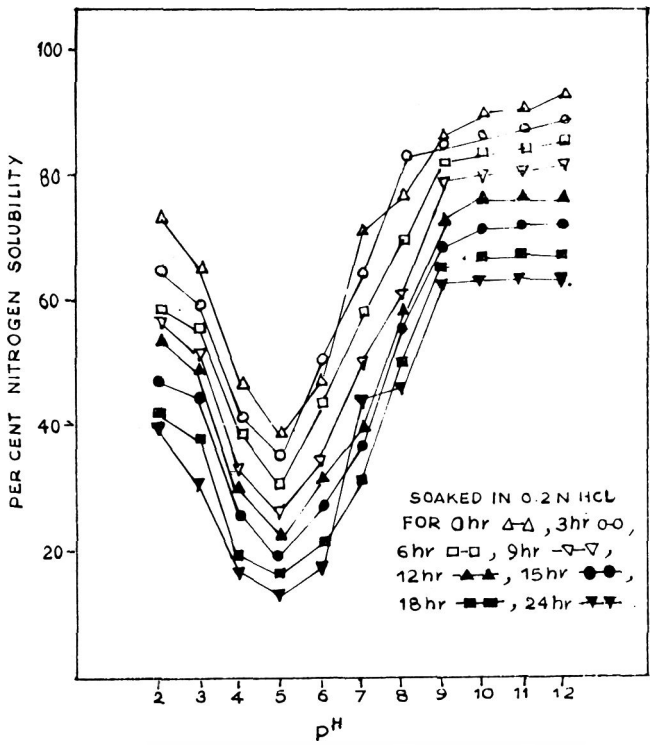


Fig. 1. Effect of soaking pearl millet in 0.2N HCl on nitrogen solubility as a function of pH

more protein available for holding the water. Morever, during soaking, amylose gets hydrolysed and amylopectin becomes available for water absorption which ultimately results into increased water absorption. The increase in the oil absorption capacity of HCl-treated flour could be attributed to the increased capacity of the flour to hold the fat globules as the amount of lipophilic groups on protein increases though total protein content decreased. Morever, after breaking down the polyphenols-protein complex, the polyphenols are leached out and protein becomes available for holding the oil. Oil absorption by flours is primarily due to interactions between hydrocarbon chains of triglycerides and nonpolar amino acid side chains of protein. Dench *et al*[15], however, observed that physical entrapment is the major determining factor in the case of oil absorption, as estimated by the centrifuge method. In the present study, a significantly increased oil absorption and a relatively low bulk density in HCl-treated samples appeared to be broadly consistent with this observation.

The least gelation concentration of HCl-treated millet flours was significantly decreased from 14 to 11 per cent (Table 2) which may be primarily due to decrease in protein content.

It was observed that pearl millet flour had minimum nitrogen solubility of 39 per cent around pH 5.0 (Fig. 1). It was 74 per cent at pH 2.0 and 95 per cent at pH 12.0. The nitrogen solubility was decreased in HCl-treated flours at all durations of soaking. The decrease was maximum in 24 hr soaked sample. The nitrogen solubility of untreated sample was increased even beyond pH 9.0 but there was no significant improvement in HCl-treated samples. However, it either slightly increased or remained more or less constant upto pH 12.0. Soaking the grains in HCl decreased the pH to 4.5 to 5.0 which was close to the isoelectric pH of pearl millet proteins. The proteins being least soluble at their isoelectric pH, they get precipitated and their solubility decreased. The decrease in nitrogen solubility of HCl-treated flours may be partly,

TABLE 3. EFFECT OF SOAKING PEARL MILLET IN 0.2 N HCl ON FOAMING AND EMULSION PROPERTIES OF FLOURS[a]

| Soaking time (hr) | Foaming properties | | | Emulsion properties | | | |
|---|---|---|---|---|---|---|---|
| | Vol increase (%) | Sp. vol. (ml/g) | Vol decrease over 120 min (%) | Emulsifying activity (%) | | Emulsion stability[b] | |
| | | | | Flour | Protein | Flour | Protein[a] |
| 0 | 31 | 1.33 | 15.7 | 20.2 | 68.5 | 12.0 | 88.8 |
| 3 | 31 | 1.32 | 13.6 | 16.5 | 81.8 | 10.5 | 77.7 |
| 6 | 30 | 1.29 | 13.1 | 18.1 | 72.9 | 11.2 | 84.8 |
| 9 | 28 | 1.29 | 12.4 | 17.4 | 74.7 | 11.0 | 84.6 |
| 12 | 26 | 1.32 | 10.2 | 16.8 | 77.3 | 10.6 | 81.5 |
| 15 | 21 | 1.22 | 8.4 | 16.0 | 80.0 | 10.2 | 79.6 |
| 18 | 18 | 1.17 | 7.1 | 15.2 | 83.5 | 10.0 | 78.7 |
| 24 | 21 | 1.14 | 10.2 | 15.0 | 84.0 | 10.0 | 79.3 |
| SE± | - | 0.001 | 0.103 | 0.044 | - | 0.127 | - |
| CD (P=0.05) | - | 0.003 | 0.301 | 0.128 | - | 0.371 | - |

[a]Expressed on dry weight basis

[b]Per cent of the emulsifying activity after heating at 80°C for 30 min

Each figure is the average of three determinations.

due to decrease in protein content and partly to the decrease in pH close to isoelectric pH.

The foaming and emulsion properties of flours were decreased (Table 3) on soaking pearl millet in HCl at all times. The decrease in foam volume of HCl-treated samples was found significant (31 to 21 per cent). The possible reason for decrease in per cent foam volume in HCl-treated samples was due to decrease in the protein content since foaming capacity of flours depends upon the nature and the amount of proteins. During soaking the loss of some dry matter occurs, protein systems are disturbed and some proteins may hydrolyse which result in less foaming capacity. Del Rosario and Flores[16] also observed less foaming capacity in mung bean flour on soaking in water for 12 hr and subsequent sprouting. Soaking pearl millet in HCl also decreased specific volume of foam from 1.33 to 1.14 ml/g. This indicated that soaking caused poor foaming and air uptake during foaming which is also related to the amount of proteins. The foam of untreated flour appeared to be more stable than those of HCl-treated flours. During soaking, protein systems are disturbed as also hydrolysed resulting in lowered foam stability. Since foam stability is correlated with the amount of native proteins present, it is less in HCl-treated flours. The properties like emulsifying activity and emulsion stability of HCl-treated samples were also decreased significantly in 24 hr soaked samples (Table 3). But when expressed on crude protein basis, emulsifying activity was increased from 68.5 to 84.0 per cent, whereas, emulsion stability was decreased from 88.8 to 79.3 per cent. The decrease in the emulsion properties of HCl-treated flours may be due to decrease in protein content during soaking.

It can be finally concluded that soaking pearl millet in dilute HCl can efficiently remove polyphenols and results in decrease in protein and starch content and improvement in some functional properties like water and oil absorption capacity.

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# Control of Potato (*Solanum tuberosum* L. cv. Kufri jyoti) Sprouting by Sodium Naphthyl Acetate during Ambient Storage

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**As sodium salt of α–Naphthalene acetic acid (sodium naphthyl acetate – SNA) was found to be as effective as methyl ester of α-naphthalene acetic acid (MENA) for the control of sprouting of potatoes during storage at ambient conditions (22-35°C, RH 50-80%), parameters affecting efficacy of SNA were worked out. To control sprouting, potatoes were dipped in 10 to 10,000 ppm solutions of SNA for 1 to 30 min. The sprouting decreased with the increase in concentration, but the increase in duration of treatment had no additional inhibitory effect. Sprouting was minimum when tubers were treated on the third day of harvest. Addition of 1000 ppm Benlate to the treatment solution reduced the spoilage. Several batches of potatoes were treated with the same lot of SNA solution without causing any decrease in its concentration or in the efficacy of the treatment, which makes its use more economical in controlling potato sprouting than MENA.**

Storage of potatoes under tropical conditions results in early and excessive sprouting causing huge post-harvest losses[1]. Such storage losses can be minimised by storing the tubers below 5°C or at 8-10°C after treating with physical or chemical sprout suppressants[2-6]. Cold-storage of potatoes requires high cost inputs and sprouting is more vigorous during post-cold storage period[7]. Some of the chemical and physical sprout inhibitors are effective only when the storage temperature is below 20°C. Chemicals like isopropyl N (3-chlorophenyl) Carbamate (CIPC) and irradiation are known to increase the sugar content of stored tubers rendering them unsuitable for processing[8,9].

On the other hand, naphthalene acetic acid (NAA) as its potassium salt and methyl ester (MENA) has been used to suppress sprouting of potatoes [10-12]. Gutherie[11] reported that the efficacy of MENA decreases at temperatures above 28°C due to its volatile nature at higher temperatures. Our earlier report[13] indicated that during storage under ambient conditions (22-32°C), SNA is as efficient as MENA, but as temperatures prevalent in North India during summer months (March to June) are around 35°C, the efficacy of MENA may even be less than SNA besides being more expensive. The present study was, therefore, undertaken to optimise the parameters for controlling sprouting with SNA and work out its economics.

## Materials and Methods

Potatoes (*Solanum tuberosum* L. cv. 'Kufri jyoti') obtained from local market/field were sorted to remove diseased and damaged tubers, washed in water and surface-dried prior to treatment. SNA solution was prepared by dissolving known quantities (198 mg) of α-naphthalene acetic acid in 10 ml of 0.1 N NaOH solution (w/v) and the volume was made up with water containing Tween-80 (1 ml/l). Fungicidal SNA solution was prepared by mixing benlate (2 g/l) to the above solution. MENA emulsion was prepared by blending it with triethanolamine oleate with water and diluting to the desired concentration.

*Treatments:* In one experiment, potato tubers were dipped in SNA solution of 10, 100, 1000 and 10,000 p.p.m. and in another tubers were dipped in 1000 p.p.m. of SNA alone and also with fungicidal SNA solutions for 1, 5, 10, 15 and 30 min. Each treatment consisted of 3 replicates of 2 kg each. After 1, 3, 5, 10 and 20 days of harvest, tubers were dipped in 1000 p.p.m. SNA solution for 15 min and were stored under ambient conditions (22-35°C, and 50-80% RH). Each treatment consisted of 5 replicates of 5 kg each. For studying the reducing sugar content of SNA and MENA treated tubers, the dip treament was given at 1000 p.p.m. for 15 min in solution containing 1000 p.p.m. benlate. To determine the extent of re-usability, batches of 5 kg potatoes were dipped for 10 min in 8 l of 1000 p.p.m. SNA solution (total 205 kg in 41 batches). After every five consecutive dips, NAA concentration in the solution was determined by the method of Bache[14]. Volume of the solution was measured after 20th and 40th dips. Each lot of treated tubers was separately stored under ambient conditions (22-35°C and RH of 50-80%). Untreated tubers were used as controls.

TABLE 1. EFFECT OF SNA CONCENTRATION ON NUMBER OF SPROUTED TUBERS, SPROUT LENGTH, SPROUT WEIGHT AND SPOILED TUBERS AFTER STORAGE UNDER 22-35°C AND 50-80% RH.

| | Storage period (weeks) | Control | SNA concn (p.p.m.) | | | |
|---|---|---|---|---|---|---|
| | | | 10 | 100 | 1000 | 10,000 |
| Sprouted tubers(%) | 1 | 43.3 ± 6.40 | 38.3 ± 2.5 | 28.9 ± 4.60 | 31.6 ± 4.60 | 35.0 ± 1.9 |
| | 4 | 84.7 ± 3.60 | 69.5 ± 2.7* | 53.0 ± 5.00** | 49.8 ± 4.1*** | 42.6 ± 2.4*** |
| | 8 | 100.0 ± 0.00 | 93.9 ± 2.5* | 90.4 ± 4.80* | 84.1 ± 4.8*** | - |
| Av. Sprouts/tuber | 4 | 6.1 ± 0.42 | 3.5 ± 0.24** | 2.3 ± 0.18** | 1.8 ± 0.15*** | - |
| | 8 | 9.7 ± 1.02 | 6.7 ± 0.95* | 6.3 ± 0.90* | 4.6 ± 0.16** | - |
| Mean sprout length (mm) | | | | | | |
| | 1 | 1.5 ± 0.18 | 1.2 ± 0.18 | 0.9 ± 0.13 | 0.9 ± 0.13 | 1.2 ± 0.04 |
| | 4 | 2.1 ± 0.27 | 1.7 ± 0.13 | 1.4 ± 0.08** | 1.0 ± 0.22*** | 1.5 ± 0.22*** |
| | 8 | 3.1 ± 0.18 | 2.5 ± 0.53*** | 2.5 ± 0.53*** | 2.4 ± 0.13*** | - |
| Sprout (g/100 tubers) | 12 | 26.0 ± 1.50 | 20.2 ± 1.20 | 10.5 ± 0.70* | 2.5 ± 0.21** | - |
| Spoiled tubers(%) | 12 | 10.6 ± 0.60 | 10.5 ± 1.50 | 20.1 ± 2.10 | 20.3 ± 2.1 | 60.0 ± 2.5 |

Mean ± SEM.
*, **, *** – Values significantly different from control at P = 0.05, 0.01, 0.001 respectively.
- Not determined due to heavy spoilage.

Tubers were examined periodically for sprouting and spoilage. Total number of sprouts in each tuber were counted and the length of sprouts was measured. About 30 tubers were examined in a replicate. Sprouts of each replicate were removed, weighed and mean of 5 replicates was expressed as fresh weight (g/100 tubers) of sprouts. Number of tubers spoiled due to fungal and bacterial pathogens was noted and expressed together as per cent spoilage. Reducing sugars from the dry samples were extracted by the method of Ranganna[15] and estimated by the method of Nelson[16].

## Results and Discussion

The percentage of sprouted tubers at the end of each week of storage was lower in SNA treated tubers than control and this percentage decreased with the increase in the concentration of SNA. At the end of 4 weeks (i.e. 6 weeks after harvest), it ranged from 42.6 to 69.5 per cent in different treatments as against 84.7 per cent in the control. After 8 weeks in storage, only at 1000 p.p.m. tubers showed significantly less number of sprouts, indicating its greater suppressive effect over longer period. In all the treatments, the sprout length was significantly shorter than that in control. The number of sprouts decreased with increase in SNA concentration and the extent of their reduction was more during early periods of storage (upto 4 weeks). The sprout weight was also significantly lower in 100 and 1000 p.p.m. SNA treated tubers, while 10 p.p.m. was ineffective. The spoilage was more in 100, 1000 and 10,000 p.p.m. SNA treatments than in control. The tendency for increased spoilage (mostly bacterial) in tubers treated with growth regulator alone is probably due to higher ambient storage temperature. (Table 1).

The sprout weights after 8 weeks of storage in tubers dip-treated with SNA solution for different durations were significantly less than in control. Even 1 min dip effectively reduced the sprout yield and was as good as 30 min dip. A 5 min dip treatment can be considered adequate for practical sprout control. Tubers treated with fungicidal SNA solution showed less spoilage than those treated with SNA alone. Duration of dipping in either of these two solutions

TABLE 2. EFFECT OF DURATION OF DIP TREATMENT OF TUBERS IN FUNGICIDAL SNA ON SPROUT WEIGHT AND SPOILAGE AFTER 8 WEEKS STORAGE UNDER AMBIENT CONDITIONS (22-35°C, RH 50-80%).

| Dipping time (min) | Fungicidal SNA | | Spoilage in SNA+ (%) |
|---|---|---|---|
| | Sprout wt[a] (g fresh/100 tubers) | Spoilage[b] (%) | |
| 1 | 1.5 ± 0.5* | 8.6 ± 1.5* | 25.0 ± 1.4 |
| 5 | 1.4 ± 0.1* | 1.6 ± 1.2* | 21.6 ± 2.5 |
| 10 | 5.2 ± 0.4* | 11.7 ± 2.5* | 20.9 ± 1.8 |
| 15 | 1.8 ± 1.0* | 15.0 ± 4.4* | 30.5 ± 1.7 |
| 30 | 2.1 ± 0.6* | 11.6 ± 1.7* | 26.5 ± 3.1 |
| Control | 11.3 ± 0.4 | 4.4 ± 0.9 | 4.4 ± 0.9 |

Mean ± SEM
a – * Significantly different over control (P < 0.05).
b – * Significantly different over corresponding SNA alone treatments (P < 0.05).
+ Treatment included to confirm aggravation of spoilage caused by SNA alone (noted from data in Table 1).

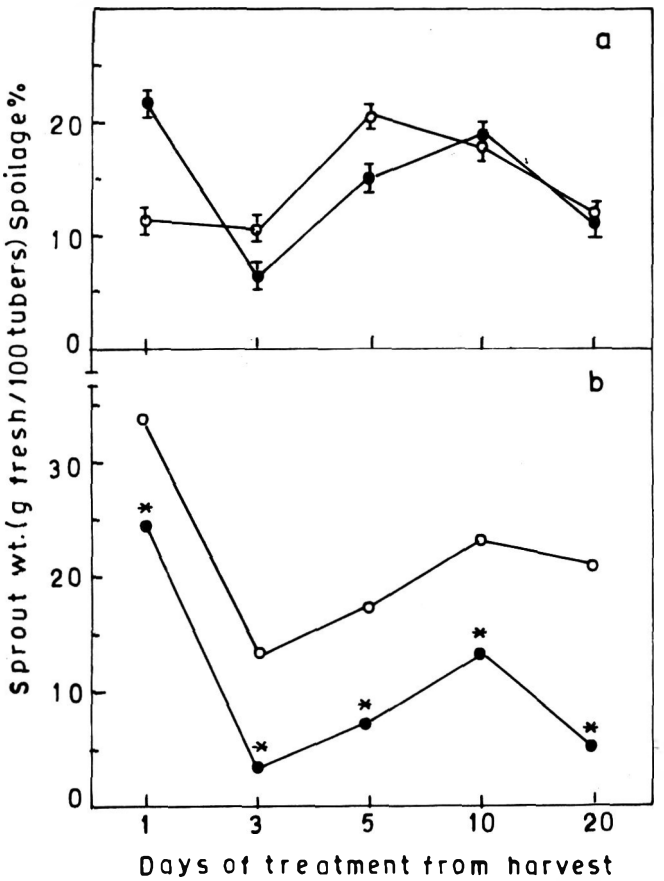


Fig. 1. Effect of time lag from harvest to SNA treatment on (a) spoilage and (b) sprouting of potato tubers at the end of 10 weeks storage under ambient conditions (22-35°C, RH 50-80%). • Treated and ○ Untreated, lines extending the points under (a) indicate SEM, * indicates significant difference ($P<0.05$) over untreated.

did not show any relationship with the extent of spoilage (Table 2).

The sprout formation was significantly less at the end of 10 weeks storage in all SNA treated tubers. Minimum sprouting was found in tubers treated on the third day after harvest. However, the treatment was effective even on tubers held for 20 days before treatment. The spoilage was not much aggravated (Fig. 1).

Re-using the SNA solution for dipping 41 batches of tubers has also shown significantly low sprout weights in the different treated lots. Further, the UV absorption spectra taken for the SNA solution did not show any change in the concentration but one liter of SNA solution was used up for treating 100 kg of tubers (Data not presented)[17].

Dip treatment of potato tubers in SNA and MENA solutions have both effectively controlled sprouting while the latter is twice as costly as SNA. Neither spoilage nor the reducing sugar content differed much from the control tubers. The sugar content in both treatments and control remained low upto 8 weeks but between 8 and 12 weeks of storage, it increased by six to eight fold, yet remaining well within the limits for processing into chips (Table 3). These results are comparable to those reported by Khurana *et al*[18].

The present study indicates that dipping potato tubers after 3 days of harvest in 1000 ppm SNA solution for 5 min. effectively controls sprouting during storage at 22-35°C. Addition of fungicide to the SNA solution reduced fungal spoilage. However, as reported earlier[14], all chemical sprout inhibitors aggravate microbial spoilage (especially bacterial) during storage at temperatures around 35°C, while no such aggravated spoilage occurs when the tubers are stored at 22± 2°C with an RH of 85±5%, as under evaporative cooling storage conditions[19]. Good sprout suppression was achieved even when the treatment was given after 20 days of curing. This gives enough time to trader to give the treatment.

Re-usability studies indicated that the cost of SNA works out to be about 2.5 paise per kg tubers (20 US cents/100 kg). The cost of MENA treatment even after assuming utilisation rate to be the same as SNA solution works out to be 5 paise/kg as it is twice as

TABLE 3. EFFECT OF DIP TREATMENT OF POTATO TUBERS IN SNA AND MENA SOLUTIONS ON SPROUTING, SPOILAGE AND REDUCING SUGAR CONTENT OF TUBERS STORED AT AMBIENT CONDITIONS (22-35°, RH 50-80%).

| Solution | | Sprout wt+ (g fresh/ 100 tubers) | Spoilage+ (%) | Reducing sugars (g/100g d.wt.) | | |
|---|---|---|---|---|---|---|
| Name | Concn (p.p.m.) | | | 4 wk | 8 wk | 12 wk |
| SNA | 1000 | 1.7 ± 0.31* | 9.4 ± 0.9* | 0.35 ± 0.05 | 0.31 ± 0.07 | 1.40 ± 0.03 |
| MENA | 1000 | 0.3 ± 0.04* | 11.4 ± 2.4* | 0.08 ± 0.01 | 0.14 ± 0.03 | 1.20 ± 0.02 |
| Control | – | 24.0 ± 0.22 | 4.6 ± 0.4 | 0.08 ± 0.01 | 0.15 ± 0.02 | 0.93 ± 0.10 |

+ After 12 wk of storage

* Significantly different over control at $P< 0.05$

costly as SNA. Therefore, α-NAA as its sodium salt (SNA) can be used as an effective and economical post-harvest sprout retardant for storing potatoes under tropical conditions. Hence, post-harvest treatment of potato tubers with fungicidal SNA coupled with evaporative cool storage would help in extending the storage life of potatoes.

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# Storage Life and Quality of Robusta Banana in Relation to Their Stage of Maturity and Storage Temperature

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**Green unripe, 'Robusta' banana at two stages of maturity could be held at 15°C and 20°C for one to four weeks, followed by proper ripening at ambient conditions. Fruits remained green, firm and unripe for two to three weeks at these temperatures. The delay in ripening was correlated with reduced rates of softening, peel colour development, increased pulp peel ratio, tannins, total sugars and alcohol insoluble residue in the pulp of the fruit. Weight loss was less in fruits held at 15°C and 20°C. Quality of the fruit after one to four weeks of holding at 20°C was the best followed by fruits held for three weeks at 15°C. By harvesting the fruits early at II stage of maturity, shelf life could be extended from 16 to 21 days at ambient storage.**

In tropics, the shelf life of banana is short at ambient conditions of storage and there is a need to develop a suitable method for extending the shelf life which can help both in internal trade and export. Low temperature storage is one of the practical methods. Reports[1,2] indicate that physico-chemical changes and ripening depend on the cultivar and the harvest maturity. Besides, there is a need to harvest bananas at less mature stages to meet the market demands and this necessitates the study of the effect of harvesting at less mature stage on shelf life and quality of the ripe fruit. Several reports are available for determining the maturity indices in different cultivars of banana[3,4,5]. But a detailed study on the effect of maturity, holding temperatures, duration of holding and its subsequent effect on ripening at ambient conditions, shelf life and quality of the fruit was lacking in 'Robusta' banana, which is gaining importance as a commercial cultivar in fresh trade and export markets. Hence, this study was made and the results are reported.

## Materials and Methods

*Stage of maturity:* Bunches of 'Robusta' banana were harvested from a commercial farm at 115 and 100 days of fruit set. Fruits i) after 115 days of fruit set corresponded with optimum maturity wherein the individual fruits were almost roundish and it is referred to as I stage of maturity, and ii) after 100 days corresponding to less mature stage when they were angular in shape, and it is referred to as II stage of maturity. Hands with 12 to 14 fruits of uniform size, without any blemishes were cut from the bunches. Cut end of the hands was smeared with thiabendazole (500 p.p.m.) and air-dried.

*Storage temperature:* Fruits were kept for storage at room temperature (R.T.) 25±2°C with R.H. of 50-70 per cent, 20°C with 70-75 per cent R.H. and at 15°C with 75-80 per cent R.H.

*Sample size:* At R.T. storage, 4 hands of 12 to 14 fruits were kept for observations on ripening, 3 hands for chemical analysis and 3 hands of 6 fruits each, for recording weight loss during storage. For storage at 15°C and 20°C, 8 hands were kept for observations on ripening and 2 hands were removed after every week and ripened by keeping at R.T. Chemical analysis and weight loss were followed in continuous storage at 15°C and 20°C, and chemical analysis and sensory evaluation were made in ripe fruits stored at 15°C and 20°C followed by ripening at R.T. All the hands at each storage temperature were kept loosely packed in 100 guage polyethylene bags with 4 per cent ventilation.

*Weight loss:* For determining weight loss, individual hands were weighed at regular intervals and the cumulative losses were calculated.

*Firmness:* Firmness of the unpeeled fruit was measured in fruits taken from replicates prior to cutting for chemical analysis, using an effegi 327 pressure tester having a probe of 0.79 cm width.

*Pulp peel ratio:* Pulp and peel were separated, weighed individually and expressed as pulp peel ratio.

*Chemical analysis:* Bulk sample of the pulp was prepared from sub-sample taken from each replicate. Known amount of this sample was weighed for deter-

Contribution No. 184/88

mining moisture, titratable acidity, total tannins, total reducing sugars (TRS) and alcohol insoluble residue (AIR). Moisture was estimated by drying to a constant weight at 70°C. Titratable acidity was determined by titrating an aliquot of the water extract against N/100 NaOH and expressed as per cent malic acid. For tannins, an aliquot of the heated extract of the pulp was taken, colour was developed using Folin-Ciocalteu reagent and the total tannin content measured after the method of Singleton and Rossi[6]. The sample was extracted with 80 per cent alcohol in a Soxhlet apparatus and the total sugars estimated according to AOAC[7] and the alcohol insoluble residue was dried and weighed.

Fruits stored at R.T. were analysed at intervals of 2 to 4 days, whereas those stored at 15 and 20°C were analysed at weekly intervals.

*Ripening:* Ripening of the fruit was followed by observing changes in skin colour, firmness as measured by pressure tester and thumb feeling, and development of aroma. Skin colour was scored using the banana ripening chart, ranging from green[1] to yellow colour flecked with brown spots[8] The average scoring for each hand was calculated. The sensory qualities of the ripe fruits were assessed by a panel of 6 judges using Hedonic rating system with which the fruit was scored as bad, acceptable, normal, good and very good. The parameters judged were peel colour, texture, aroma and taste.

**Results and Discussion**

Physico-chemical changes in 'Robusta' banana harvested at I and II stages of maturity and stored at R.T. are as follows. Total weight loss was 7.1 per cent in I stage and 10.0 per cent in II stage. Maximum changes in firmness, pulp peel ratio and peel colour were observed during 12 to 16 days in group I and 12 to 21 days in group II. Firmness decreased from 12 kg to 1.0 kg and 1.6 kg in I and II stages respectively, pulp peel ratio increased from 1.5 to 3.0 in stage I and 1.1 to 2.9 in stage II. Peel colour increased from 3.2 to 8.0 and 3.2 to 7.2 in I and II stages, respectively. There was an increase of total sugars from 8th day of storage; the increase was from 0.8 to 18.2 per cent in both the groups and a corresponding decrease of AIR from 27.5 to 2.1 per cent in stage I and from 28.8 to 2.9 per cent in stage II. Total tannins increased gradually in both the stages with a slight peak (160 mg/100g pulp) around 13 to 16 days followed by a decline. Titratable acidity also increased from 0.15 to 0.4 per cent followed by a decline. At R.T. storage, the fruits were ripe in 16 days in stage I as against 21 days in stage II.

Corresponding with delayed ripening in fruits of stage II, there was delay in attaining the desirable composition of the ripe fruit as seen by physico-chemical changes. Similar observations on delayed ripening by harvesting at less maturity stages have been made in different cultivars of banana[5,9]. The fruits of II stage were smaller in size as compared to those of I stage because of less growth due to early harvest. With respect to the effect of low temperatures in extending the shelf life, it was observed that fruits harvested at I and II stages could be held at 15°C for a period of 4 weeks and at 20°C for a period of 3 to 4 weeks without affecting the quality of the fruit. In

TABLE 1. PHYSICO-CHEMICAL CHANGES IN ROBUSTA BANANA AT I & II STAGES OF MATURITY AND STORED AT 15 AND 20°C.

| Storage period (wk) | 15°C Storage | | | | 20°C Storage | | | |
|---|---|---|---|---|---|---|---|---|
| | Pulp to peel ratio | Tannins (mg) | Total red. sugars(%) | Alcohol insoluble residue (%) | Pulp to peel ratio | Tannins (mg) | Total red. sugars(%) | Alcohol insoluble residue (%) |
| | I II | I II | I II | I II | I II | I II | I II | I II |
| 0 | 1.5-1.3 | 22- 35 | 0.6- 0.5 | 29.6-30.3 | 1.5-1.3 | 21- 36 | 0. 6- 0.5 | 29.6-30.3 |
| 1 | 1.5-1.4 | 58- 47 | 0.9- 0.9 | 27.8-28.8 | 1.6-1.5 | 49- 58 | 1. 1- 0.9 | 25.4-26.9 |
| 1* | 2.7-2.4 | 145-151 | 18.3-17.9 | 4.5- 2.6 | 2.7-2.5 | 149-157 | 19. 1-19.4 | 2.4- 2.4 |
| 2 | 1.6-1.4 | 59- 90 | 0.1- 0.2 | 27.3-28.3 | 1.9-1.5 | 66- 79 | 1.21- 1.14 | 24.5-27.3 |
| 2* | 2.3-2.3 | 144-150 | 18.1-17.8 | 2.6- 3.1 | 2.7-2.5 | 141-146 | 19. 4-19.3 | 2.3- 2.6 |
| 3 | 1.7-1.4 | 95- 98 | 1.3- 1.1 | 26.6-27.3 | 2.2-1.9 | 141- 98 | 18. 6-11.6 | 3.1-15.3 |
| 3* | 2.3-2.2 | 138-142 | 18.0-19.2 | 3.0- 2.9 | 2.5-2.3 | 141-144 | 18. 7-19.5 | 3.1- 3.5 |
| 4 | 1.7-1.4 | 91- 82 | 1.5- 1.3 | 26.5-28.8 | 2.6-2.2** | 129-149 | 18. 2-18.2 | 3.1- 3.3 |
| 4* | 2.4-2.1 | ND-147 | 17.9-17.0 | 3.5- 3.5 | -- | -- | -- | -- |

*Followed by ripening.
Data are the average of triplicate analysis and on fresh wt basis.
**This was at ripe stage. ND = Not done.

TABLE 2. SENSORY ATTRIBUTES OF ROBUSTA BANANA HARVESTED AT I AND II STAGES OF MATURITY STORED AND AT 15°C AND 20°C.

| Storage period** (wk) | 15°C Storage | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Peel colour | | Texture | | Aroma | | Taste | |
| | I | II | I | II | I | II | I | II |
| 1 | 7.7-6.7 | | 7.0-7.7 | | 7.7-6.7 | | 7.0-6.7 | |
| 2 | 7.3-6.0 | | 7.3-7.3 | | 7.3-6.7 | | 7.0-6.7 | |
| 3 | 6.7-6.0 | | 8.0-7.3 | | 7.7-7.0 | | 8.0-7.0 | |
| 4 | 6.0-5.2 | | 6.0-6.0 | | 6.0-6.3 | | 6.8-6.3 | |

| Storage period** (wk) | 20°C Storage | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Peel colour | | Texture | | Aroma | | Taste | |
| | I | II | I | II | I | II | I | II |
| 1 | 8.0 -7.7 | | 7.3-7.7 | | 7.0-7.7 | | 7.3-7.7 | |
| 2 | 8.3 -8.3 | | 8.0-7.3 | | 7.3-7.3 | | 8.0-7.7 | |
| 3 | 8.8 -8.5 | | 8.0-7.5 | | 7.7-7.7 | | 8.0-7.7 | |
| 4 | 8.1*-8.7 | | 8.0-8.0 | | 7.2-8.0 | | 7.5-7.7 | |

**Followed by ripening. *Fruits were edible ripe after 4 weeks. Each value is the mean score of 6 readings.

stage I the period for ripening of fruits at R.T. after removal from 15°C and 20°C storage was 13 and 11 days after one week, 10 and 6 days after 2 weeks, 8 and 2 days after 3 weeks and 3 and zero days after 4 weeks respectively. In fruits of II stage, it was 16 and 14 days after one week, 14 and 12 days after 2 weeks, 9 and 7 days after 3 weeks, 4 and 2 days after 4 weeks respectively.

Physico-chemical changes in fruits of I and II stages, stored at 15°C and 20°C are shown in Table 1. At 20°C storage, fruits of both the stages were green and hard for 2 weeks and these fruits showed significant changes in composition after removal to R.T. After 3 and 4 weeks of storage, the changes were minimum because the fruits had reached the ripe stage. At 15°C storage, fruits remained unripe even upto 4 weeks, as a result there were significant changes in the composition of the fruit after removal to R.T. for ripening.

Sensory attributes of the ripe fruit as seen from Table 2 indicated good quality of the fruit from 1 to 4 weeks of storage at 20°C but at 15°C, after 4 weeks of storage, the quality was slightly deficient with respect to colour, texture, aroma and taste. However, the fruits were of acceptable quality. Earlier reports on holding banana at low temperature indicated a shelf life of 21 days[4] at 13°C, 18 days at 13°C as compared to 7 days at 29-32°C in 'Dwarf Cavendish' banana[1] and 32 days for full ripening at 13°C in other cultivars[2]. In the present investigation, it was observed that for 'Robusta' banana held at 20°C, maximum shelf life was 4 weeks at the end of which fruits of both the maturity groups were ripe. But at 15°C, even after 4 weeks holding, the fruits had to be ripened by keeping at R.T. for 2 to 4 days. Further, at R.T. storage, fruits of optimum maturity (I stage) ripened early in 16 days as compared to 21 days in less mature group (II stage). Thus, the holding temperature and harvest maturity can alter the shelf life and quality of the ripe fruits.

It can be concluded that shelf life of 'Robusta' banana could be extended by 5 days (16 to 21 days) at R.T. storage by harvesting at slightly less mature stage and to 4 weeks by storing at low temperatures of 15°C and 20°C, without altering the quality of the fruit.

**Acknowledgement**

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# Rheological and Cookie Making Studies on Wheat-Rice Flour Blends

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**Effects of blending wheat flour with broken rice flours (raw rice, pressure parboiled and traditonally parboiled rice) on the farinographic and cookie making characteristics were studied. The farinographic water absorption and dough development time increased with the replacement of wheat flour with those of rice flours particularly with parboiled rice flours. On the other hand, dough stability decreased and the mixing tolerance index increased both pointing to the weakening of the dough. Overall, better cookies were produced by replacing 10% wheat flour with that of raw rice flour. Cookies were equally acceptable even upto 30% level.**

Rice is consumed in the form of whole kernels which are produced by milling of paddy. In the process, a sizeable quantity of broken rice is produced which is an economic loss to the processor. The broken rice is mainly sold as feed and as a brewing adjunct. It could be used for food purposes and the baked products offer a good avenue for its utilization. The incorporation of rice flour is also reported to improve the protein quality of baked products[1]. Products prepared from rice flour could be advantageously used by the gluten intolerant people[2]. The present study was undertaken to assess the effect of blending flours of rice and wheat on rheological properties and quality of cookies.

## Materials and Methods

*Flours:* The samples of wheat variety 'WL-1562' were obtained from the Punjab Agricultural University Farms. Properly cleaned samples were conditioned to 14 per cent moisture and given a rest period of 48 hr before milling on the Quadrumat Junior Experimental Mill. The three types of broken rice kernels used viz. raw, pressure parboiled[3] and traditionally parboiled[4] were obtained after milling the laboratory prepared samples. The brokens were ground in a laboratory stone grinder. These were mixed with wheat flour in proportions of 10, 20, 30, 40 and 50 per cent to produce different blends. The particle size of rice and wheat flours was determined by sieving a 100g sample on a Ro-Tap Shaker for 5 min using a set of British Standard Sieves of 72,100,150 and 200 mesh sizes (Results not quoted).

*Analysis:* Approved analytical methods[5] were used for ash, protein, and diastatic activity. The falling number was determined according to the AACC[5] procedure using falling number apparatus (FN, AB Sweden). The liquification number (LN) was calculated as follows.

$$LN = \frac{6000}{FN\text{-}50}$$

*Physical dough properties and baking performance:* Rheological properties of the dough were studied with the help of a farinograph using the constant flour weight (50 g) method of AACC[5]. Cookies were prepared and evaluated for width, thickness and spread ratio as per the standard AACC method[5]. Cookies were evaluated by a panel of 10 judges for appearance, colour, texture and taste using scores from 1 to 4 corresponding to poor to excellent, respectively.

All the results were expressed on 14 per cent moisture basis unless otherwise stated. The data were subjected to analysis of variance[6].

## Results and Discussion

Chemical composition of different types of flours used is given in Table 1. The data show that while different broken rice flours did not differ much in composition, the wheat flour had higher protein and fat contents than rice flour. The wheat flour had appreciably higher diastatic activity and liquification number than rice flours. The sieve analysis results showed that the rice flours were coarser than wheat flour but amongest the rice flours the pressure parboiled rice flour was the finest.

*Physical dough properties:* Wheat flour blends with both type of parboiled rice flours had significantly higher farinographic water absorption (Table 2) than those for raw rice blends and wheat flour alone. Non-significant difference was, however, observed in the water absorption among blends with two types of par-

TABLE 1. CHEMICAL COMPOSITION OF WHEAT AND RICE FLOURS.

| Characteristics | Wheat flour | Rice flour | Pressure parboiled rice flour | Traditionally parboiled rice flour |
|---|---|---|---|---|
| Protein (%) | 8.60 | 7.40 | 6.80 | 7.24 |
| Ash (%) | 0.52 | 0.60 | 0.56 | 0.54 |
| Fat (%) | 1.60 | 1.00 | 0.86 | 0.80 |
| Diastatic activity (mg maltose/10 g) | 280 | 80 | 68 | 60 |
| Liquification number | 10.17 | 1.50 | 1.60 | 1.85 |

boiled rice flours. Water absorption increased gradually with higher content of parboiled rice flour. The farinographic water absorption which was recorded to be highest at 10 per cent level of incorporation of raw rice flour might have decreased thereafter due to the dilution of gluten which required lesser water to reach the desired consistency. On the other hand, slower rate and higher water requirements together with lower levels of amylases (Table 1) and the presence of gelatinized starch resulting from parboiling might have caused a gradual increase in farinographic water absorption with the increase in the proportion of these. Dough development time invariably increased with the increasing proportion of all the rice flours but more so with the parboiled rice flour (Fig. 1). The effect was found to be significant for parboiled flours and non-significant for the raw rice flour. The increase in the dough development time might be the result of slow rate of water absorption by the rice flour and it was still lesser for parboiled rice flours as observed from cooking times[7]. Dough stability decreased sharply with the replacement of 10 per cent wheat flour with any of the rice flours, but subsequently a non-siginificant improvement in dough stability was

TABLE 2. EFFECT OF BLENDING WHEAT WITH DIFFERENT TYPES OF RICE FLOURS ON FARINOGRAPHIC CHARACTERISTICS

| Characteristics* | Wheat flour (%) | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| | | | **Raw rice flour** | | | |
| FWA (%) | 54.2 | 60.50 | 59.5 | 57.1 | 55.2 | 54.4 |
| DDT (min) | 1.5 | 2.0 | 1.75 | 2.0 | 3.0 | 4.0 |
| Stability (min) | 18.0 | 6.5 | 7.0 | 11.75 | 13.0 | 15.0 |
| MTI (BU) | – | 45 | 35 | 15 | 5 | – |
| | | | **Pr. parb. rice flour** | | | |
| FWA (%) | 54.2 | 65.2 | 68.7 | 70.8 | 73.1 | 74.0 |
| DDT (min) | 1.5 | 2.0 | 5.5 | 7.0 | 12.0 | 17.5 |
| Stability (min) | 18 | 5.75 | 7.0 | 7.5 | 8.5 | 7.5 |
| MTI (BU) | – | 40 | 50 | 60 | 25 | 15 |
| | | | **Tr. parb. rice flour** | | | |
| FWA (%) | 54.2 | 67.8 | 70.6 | 72.8 | 74.8 | 75.6 |
| DDT (min) | 1.5 | 1.75 | 5.5 | 8.0 | 13.0 | 15.5 |
| Stability (min) | 18.0 | 5.5 | 6.0 | 6.5 | 7.5 | 8.5 |
| MTI (BU) | – | 40 | 45 | 60 | 35 | 30 |

CD at 5% level

| Character | Blends | Treatment |
|---|---|---|
| FWA | 5.83 | 8.24 |
| DDT | 3.84 | 5.43 |
| Stability | 2.40 | 3.40 |
| MTI | 13.64 | 19.3 |

*FWA – Farinographic water absorption
DDT – Dough development time
MTI – Mixing tolerance index

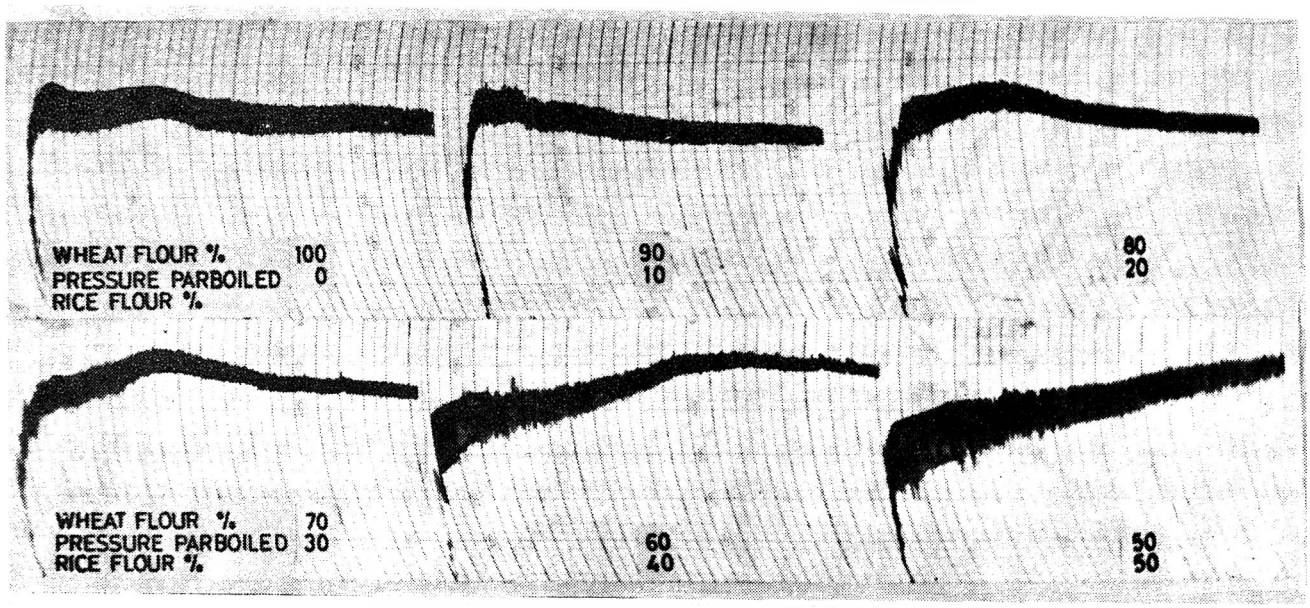


Fig. 1. Farinograms obtained from wheat – pressure parboiled rice flour blends

observed with the increase in the proportion of rice flours. The sharp decrease in dough stability at 10 per cent rice flour blending has been reported earlier[8]. The subsequent change was probably due to the dehydration effect of rice flours on the dough owing to the slower rate of water absorption. A similar behaviour is also reflected in case of MTI.

*Baking performance:* Spread ratio of cookies (Fig. 2, Table 2) increased with the progressive addition of raw rice flour, whereas it decreased when parboiled

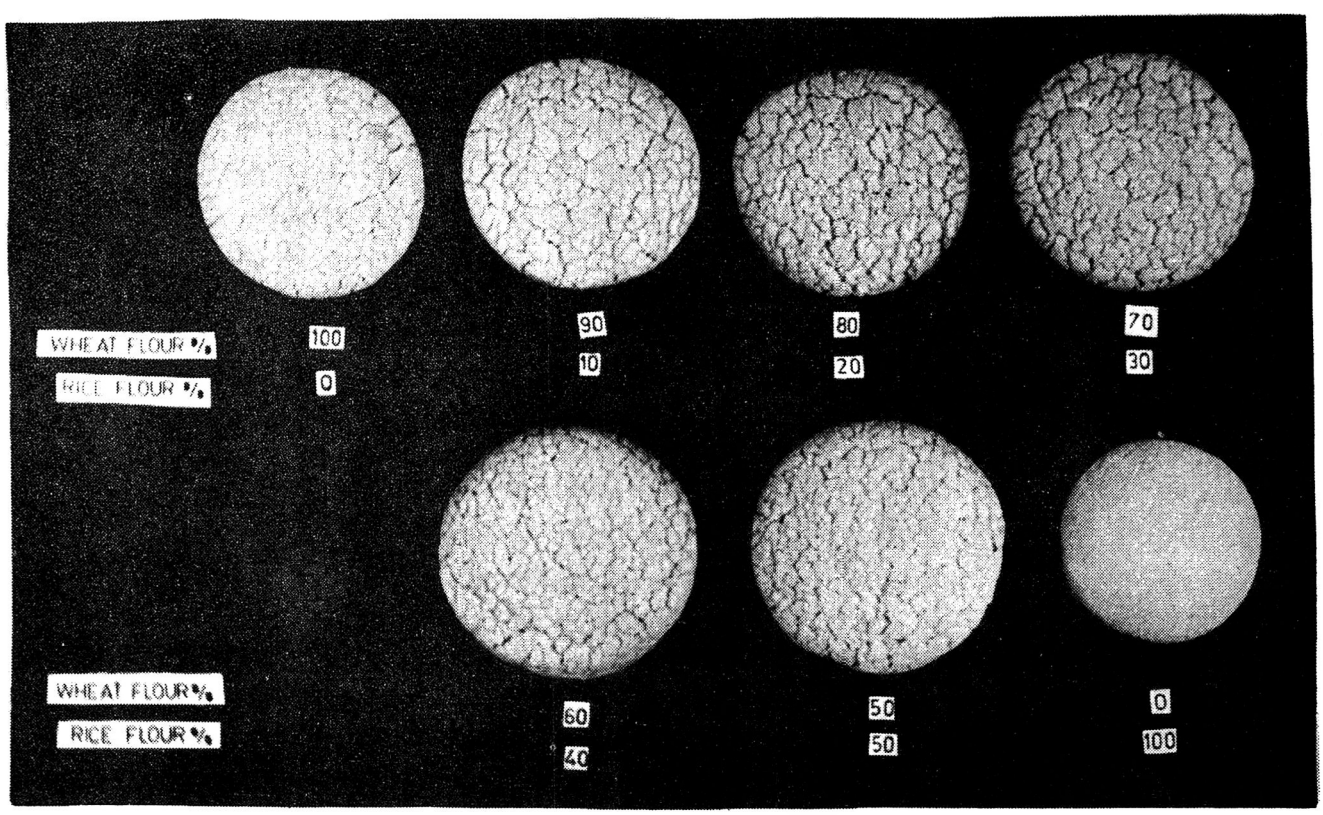


Fig. 2. Cookies prepared from wheat-raw rice flour blends.

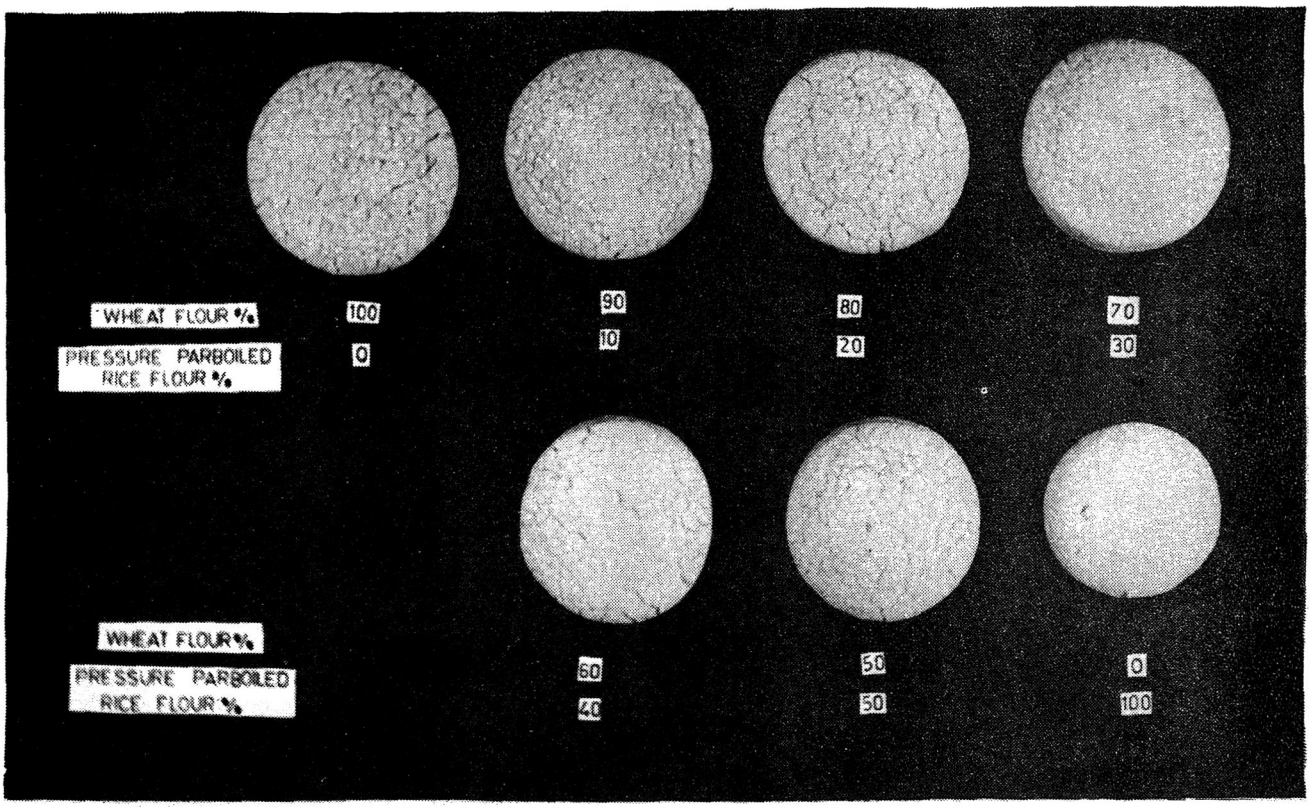


Fig. 3. Cookies prepared from wheat – pressure parboiled rice flour blends.

rice flours were used (Fig. 3, Table 3). Cookies prepared from wheat flour blended with parboiled rice flour had significantly lower spread ratio than those from wheat-raw rice flour blends. This might be due to the gelatinization of starch and coagulation of proteins during parboiling process. A similar differential behaviour was shown by the parboiled and raw rice flours with reference to farinographic characteristics.

TABLE 3. EFFECT OF BLENDING WHEAT WITH DIFFERENT TYPES OF RICE FLOURS ON COOKIE CHARACTERISTICS

| Characteristics | Wheat flour (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 | 0 |
| | | | | **Raw rice flour** | | | |
| Thickness (mm) | 11.2 | 11.16 | 11.08 | 10.90 | 10.84 | 10.20 | 12.30 |
| Width (mm) | 61.15 | 61.36 | 61.40 | 62.66 | 64.65 | 64.26 | 54.40 |
| Spread ratio | 5.46 | 5.50 | 5.54 | 5.74 | 5.96 | 6.40 | 4.40 |
| | | | | **Pr. parb. rice flour** | | | |
| Thickness (mm) | 11.20 | 12.73 | 12.85 | 13.00 | 13.30 | 13.65 | 10.84 |
| Width (mm) | 61.15 | 57.80 | 57.30 | 57.00 | 55.65 | 54.20 | 45.96 |
| Spread ratio | 5.46 | 4.54 | 4.46 | 4.38 | 4.18 | 3.96 | 4.24 |
| | | | | **Tr. parb. rice flour** | | | |
| Thickness (mm) | 11.20 | 12.85 | 13.00 | 13.10 | 13.65 | 13.90 | 10.00 |
| Width (mm) | 61.15 | 56.40 | 56.25 | 56.00 | 53.30 | 51.00 | 36.65 |
| Spread ratio | 5.46 | 4.38 | 4.33 | 4.28 | 3.90 | 3.67 | 3.66 |

| CD at 5% level | | |
|---|---|---|
| Character | Blends | Treatments |
| Thickness | NS | 1.89 |
| Width | 3.60 | 5.52 |
| Spread ratio | 0.64 | NS |

TABLE 4. EFFECT OF BLENDING WHEAT WITH DIFFERENT TYPES OF RICE FLOUR ON SENSORY EVALUATION OF COOKIES

| Characteristics | Wheat flour (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 | 0 |
| | | | **Raw rice flour** | | | | |
| Appearance | 3.4 | 4.0 | 4.0 | 3.6 | 3.4 | 3.2 | 1.2 |
| Colour | 3.2 | 3.8 | 3.8 | 3.6 | 2.6 | 2.6 | 2.0 |
| Taste | 3.0 | 3.6 | 3.2 | 3.2 | 2.8 | 2.8 | 2.0 |
| Texture | 3.0 | 3.8 | 3.2 | 3.2 | 2.4 | 2.4 | 2.0 |
| | | | **Pr. parb. rice flour** | | | | |
| Appearance | 3.4 | 3.2 | 2.6 | 2.6 | 2.6 | 2.2 | 1.0 |
| Colour | 3.2 | 3.2 | 2.8 | 2.2 | 2.4 | 2.6 | 1.2 |
| Taste | 3.0 | 3.2 | 3.0 | 2.8 | 2.6 | 2.6 | 1.2 |
| Texture | 3.2 | 3.4 | 2.6 | 2.6 | 2.6 | 2.4 | 1.0 |
| | | | **Tr. parb. rice flour** | | | | |
| Appearance | 3.4 | 3.6 | 3.2 | 2.6 | 2.0 | 1.8 | 1.4 |
| Colour | 3.2 | 3.6 | 3.2 | 2.6 | 2.0 | 1.8 | 1.4 |
| Taste | 3.2 | 3.2 | 2.6 | 2.4 | 2.2 | 2.2 | 1.2 |
| Texture | 3.2 | 3.4 | 2.6 | 2.4 | 2.2 | 2.2 | 1.2 |

| CD at 5% level | | |
|---|---|---|
| Character | Blends | Treatment |
| Appearance | 0.45 | 0.67 |
| Colour | 0,37 | 0.57 |
| Taste | 0.24 | 0.38 |
| Texture | NS | 0.40 |

The dough tightening and shortening behaviour of the parboiled rice flour as depicted by the farinograph might be responsible for the reduction in the spread ratio. With respect to quality, cookies prepared by replacing wheat flour with raw rice upto a level of 30 per cent were more crisp and had higher mean panel scores than for the control (Table 4) whereas, mean panel scores decreased continuously with increasing level of parboiled rice flours.

It is concluded that good quality cookies could be produced by replacing wheat flour with that of broken raw rice flour to a limited extent.

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# Study of the Effect of Finger Millet *(Eleusine coracana)* and Wheat Malts in Breadmaking

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**The effect of finger millet and wheat malts on equivalent basis of alpha-amylase supplements providing 5-15 SKB units/100g flour on dough properties, paste characteristics and bread quality was determined. At the same level of finger millet malt supplementation, the paste viscosity values were reduced to a lower extent than by wheat malt. This indicated the thermolabile nature of finger millet alpha-amylase as compared to that of wheat malt. The loaf volume and crumb characteristics were equally improved by both the supplements. Finger millet malt produced more reducing sugars in the bread crumb as compared to wheat malt.**

The use of various amylase supplements in breadmaking has been recognized over the years with benefits of better loaf volume, crumb structure, crust colour, flavour and keeping quality of bread. Among the cereal malt supplements, barley and wheat malts have been the first choices exploited since long for improving breadmaking quality of flours. Recently triticale, barley, wheat, rye and oat malts have also been tested for supplementation of flour for improving the breadmaking quality[1]. The amylolytic factors of Indian wheats are of importance in relation to their baking quality[2]. Khapali wheat *(Triticum dicoccum)* malt has been found suitable for breadmaking by Singh *et al*[3]. Harinder *et al*[4]. reported the possibility of improving the breadmaking quality of indigenous wheat flours using amylase supplement from triticale, wheat malts and fungal and bacterial sources. Finger millet is an important tropical millet which is used to some extent for malting[5]. Singh *et al*[6]. observed that alpha-amylase of finger millet malt is more thermolabile than wheat malt. Its use in breadmaking has not been investigated so far. In view of its potential for malting purposes, its use in breadmaking has been investigated as an amylase supplement and compared with the more stable wheat malt alpha-amylase supplement.

## Materials and Methods

Straight grade flour of commercially grown variety 'WL-1562' was milled on Buhler Pneumatic Laboratory Mill (MLU 202) to yield about 72 per cent flour. Composition of the flour was (14 per cent moisture based): 10.1 per cent protein (N × 5.7), 8.3 per cent damaged starch, 2.2 per cent maltose value as determined by AACC methods[7].

*Amylase supplement:* Wheat malt was prepared in the laboratory by steeping to 42 per cent moisture content followed by germination at 20°C for five days. The green malt was dried at 50°C in a through-flow drier. Roots were removed by rubbing and the malt was ground to a fine powder in Falling Number AB Kamas Mill. Finger millet was steeped to 33 per cent moisture, germinated at 35°C for four days and dried at 50°C[6] and milled into flour. The alpha-amylase activity of the malts was determined according to Perten[8]. The activities (SKB units/g) of wheat and finger millet malts were 68 and 37.4, respectively.

*Falling number values:* This was determined according to the ICC method as described by Tara *et al*[9].

*Amylograph paste characteristics:* Weighed samples (60g, 14 per cent moisture basis (mb)) were dispersed in 450 ml of distilled water and the amylograph was adjusted to 1.5°C/min rise in temperature to 95°C. The effects of alpha-amylase supplements on gelatinization temperature (°C) and peak viscosity (BU) were recorded.

*Farinograph curve characteristics:* The procedure for interrupted farinograph technique as used by Harinder *et al*[4]. was followed.

*Baking:* The baking formula consisted of flour (14 per cent mb) 100g, compressed yeast 2.25g, fat 1g, salt 1.5g, $KBrO_3$ 10 ppm, and alpha-amylase supplements 5, 10 and 15 SKB units/100g flour. The dough was optimally mixed in the Swanson mixer fermented for 1 hr 15 min, mechanically sheeted and moulded, proofed for 55 min at 30°C, 90 per cent RH. The loaves were baked at 232°C for 25 min. Loaf volume was measured by the AACC[7] rape seed displacement

method. The loaves were scored for appearance, crust colour, crumb grain and texture next day.

*Crumb analysis:* Peripheral portions of sliced bread were removed and interior section cut into small cubes, air dried at 15-18°C. The samples were ground in Falling Number AB Kamas mill. Amylose content in flour and bread crumb was determined by the colorimetric method of Juliano[10]. Reducing sugars were determined in deproteinized acqueous extracts of the dry crumb by the Nelson's method[11]. A portion of the bread crumb was used for determining the degree of gelatinization by the falling number technique (8g + 25 ml water).

## Results and Discussion

*Diastatic activity:* A marked increase in diastatic activity of the flour was observed as the level of both finger millet and wheat malt supplement was increased from 5 to 15 SKB units/100g flour (Table 1). The diastatic activity of the flour increased by 29.4 and 74.0 per cent when finger millet malt was used for supplementation at 5 and 15 SKB units/100g flour as compared to an increase of 33.8-83.8 per cent by wheat malt supplement used at the same level. The diastatic activity of the flour was desirably increased by both the malt supplements.

*Falling number:* With the increase in malt supplement from 5 to 15 SKB units/100g flour, the falling number values gradually decreased more so in case of wheat malt supplement than finger millet malt (Table 1). The falling number value decreased from 648 to 339 sec in flour supplemented with finger millet malt at 15 SKB units/100g flour, whereas the value decreased from 648 to 264 sec in case of wheat malt supplement at the same level of alpha-amylase supplement.

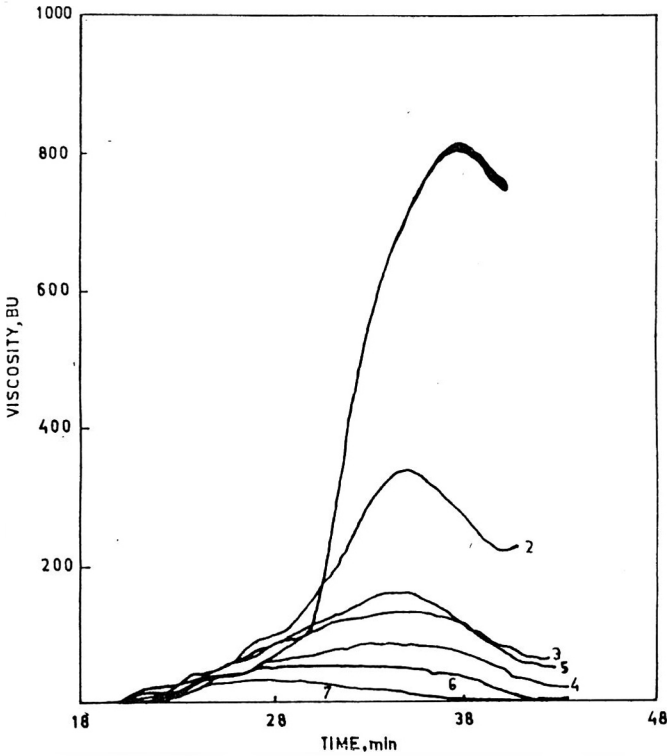


Fig. 1. Effect of finger millet and wheat malt supplement on the amylograms of WL 1562 flour, curve numbers 1, 2, 3 and 4 are for finger millet malt and 1, 5, 6 and 7 are for wheat malt corresponding to 0, 5, 10 and 15 SKB units/100g.

*Amylograph:* Maximum amylograph paste viscosity of the flour was reduced from 790 BU to 330-95 and 140-30 BU by 5 and 15 SKB units/100g flour from finger millet and wheat malt, respectively (Table 1, Fig. 1). Corresponding temperatures at the peak viscosities were 90.8 to 87.8 and 85.5 to 71°C indicating more accelerated gelatinization of starch at

TABLE 1. EFFECT OF FINGER MILLET AND WHEAT MALT SUPPLEMENTS ON DIASTATIC ACTIVITY, FALLING NUMBER VALUES AND THE AMYLOGRAPH PASTE VISCOSITY OF FLOUR.

| Malt supplement | Alpha amylase (SKB units/ 100g) | Diastatic activity* | Falling No. (sec) | Paste characteristics: Gelatinization temp (°C) | Paste viscosity (BU) | Max. temp. (°C) | Viscosity at 95°C (BU) |
|---|---|---|---|---|---|---|---|
| Nil (control) | 0.0 | 204 | 648 | 60.0 | 790 | 90.8 | 730 |
| Finger millet | 5.0 | 264 | 463 | 60.0 | 330 | 87.8 | 220 |
| | 10.0 | 330 | 385 | 61.0 | 160 | 84.8 | 65 |
| | 15.0 | 355 | 339 | 63.0 | 95 | 83.3 | 20 |
| Wheat | 5.0 | 273 | 411 | 60.0 | 140 | 85.5 | 50 |
| | 10.0 | 313 | 343 | 61.5 | 55 | 76.5 | 0 |
| | 15.0 | 375 | 264 | 63.0 | 30 | 71.0 | 0 |

Replications – 2
*mg maltose/10 g flour.

TABLE 2. EFFECT OF FINGER MILLET AND WHEAT MALT SUPPLEMENTS ON THE DOUGH CONSISTENCY BY INTERRUPTED FARINOGRAPHIC TECHNIQUE.

| Malt supplement | Alpha amylase (SKB units/ 100 g) | Consistency (BU) at indicated time intervals (min) | | | |
|---|---|---|---|---|---|
| | | 0 | 15.0 | 45.0 | 75.0 |
| Nil (Control) | 0.0 | 500 | 440 | 425 | 420 |
| Finger millet | 5.0 | 500 | 420 | 370 | 355 |
| | 10.0 | 495 | 360 | 310 | 295 |
| | 15.0 | 495 | 370 | 310 | 300 |
| Wheat | 5.0 | 500 | 420 | 370 | 360 |
| | 10.0 | 495 | 385 | 325 | 305 |
| | 15.0 | 495 | 375 | 320 | 300 |

Farinograph water absorption, 56%
Replications – 2

lower temperature by wheat malt supplement than finger millet malt. The effect of wheat malt on peak viscosity and peak temperature was more drastic than that of finger millet malt alpha-amylase on starch. Paste viscosity at 95°C reached base level for the 10 and 15 SKB units of wheat malt supplemented flour whereas those values were higher for finger millet malt supplement. Significant differences among various sources of alpha-amylase supplements have been the artifact of the optimal range of temperature and thermostable nature of the alpha-amylase[12]. This further confirmed the results of Singh *et al*[6]. that finger millet alpha-amylase was more thermolabile than wheat malt.

*Dough properties:* Using interrupted farinographic technique and the farinograph water absorption of flour (56 per cent) it was observed that both with finger millet and wheat malt supplement, dough consistency practically remained the same. The dough became softer with time as well as increasing levels of either finger millet or wheat malt supplement (Table 2). There was 16 per cent decrease in dough consistency of the control after a rest of 75 min compared to a decrease of 39 per cent of the dough containing 15 SKB units of alpha-amylase/100g of flour. Harinder *et al*[4]. reported similar trend in dough consistency with time as a result of prolonged enzyme action in the dough system.

*Breadmaking:* Doughs with finger millet malt supplement were slightly sticky and extensile at re-mixing stage as compared to wheat malt supplemented doughs which were smooth, elastic and comparatively less sticky at remixing. However, the finger millet doughs handled satisfactorily during sheeting and moulding operations. An increase in loaf volume was observed as the malt supplement was increased to 15 SKB units/100g flour considering the short fermentation time of 1 hr 15 min in which alpha-amylase supplement acted (Table 3). The crust colour was more dark brown in case of both the amylase supplemented bread than controls. The crumb was soft to very soft in case of wheat malt supplemented bread whereas it was medium soft when finger millet malt was used for supplementation of flour.

Crumb analysis indicated more of reducing sugar production in case of finger millet malt supplemented bread compared to wheat malt supplement despite the fact that no sugar was used in the dough system. This indicates that probably there is more of beta-amylase activity in finger millet malt as compared to wheat malt. Falling number values of bread crumb with finger millet malt supplemented bread were lower

TABLE 3. EFFECT OF FINGER MILLET AND WHEAT MALT SUPPLEMENTS ON LOAF VOLUME AND CRUMB CHARACTERISTICS OF FLOUR

| Malt supplement | Alpha amylase (SKB units/ 100 g) | Loaf vol (ml) | Specific vol | Crumb characteristics | | |
|---|---|---|---|---|---|---|
| | | | | Amylose[a] (%) | Reducing[b] sugars as dextrose (%) | Falling No.[c] (sec) |
| Nil (control) | 0.0 | 460 | 3.4 | 19.9 | 1.3 | 151 |
| Finger millet | 5.0 | 485 | 3.7 | 19.7 | 3.7 | 264 |
| | 10.0 | 500 | 3.8 | 18.6 | 3.1 | 355 |
| | 15.0 | 495 | 3.8 | 17.9 | 3.0 | 347 |
| Wheat | 5.0 | 500 | 3.8 | 18.5 | 2.5 | 448 |
| | 10.0 | 485 | 3.7 | 18.2 | 2.7 | 423 |
| | 15.0 | 515 | 3.9 | 18.1 | 2.8 | 413 |

[a] Amylose content in flours 19.9%
[b] Reducing sugars content in flour 0.21%
[c] Falling number value of bread crumb
Replications – 2

than those of wheat malt supplemented bread, but was higher than that of the control loaf. This was probably the artifact of retrogradation on the pasting properties of bread crumb. It was concluded that where wheat malt is not readily available finger millet malt can also be used profitably as a diastatic supplement for bread-making.

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# Quality Aspect of Osmanabadi Goat Meat

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**The Osmanabadi goats were categorised into age groups of (a) 6 to 8 months, (b) 8 to 10 months, (c) 10 to 12 months and (d) 12 to 14 months for studies. The per cent decrease in moisture content from meat of those of (a) group to (d) group was 74.07 to 63.35. The protein content was maximum in (a) group (17.4%); for other groups the protein content was almost the same (16.26 to 16.55%). The ether extract content increased with increase in age of male kids. Ash content decreased with increase in age. The carbohydrate content decreased with increase in age. The carbohydrate content estimated by difference ranged from 2.86 to 3.30%. The above contents were almost same in different age groups. Test panel results showed that the colour, appearance and acceptability of lean meat was excellent in the (b) and (c) age groups; however, the acceptability of lean meat from (a) and (d) age group was also good. The tenderness decreased with increase in age. The meat was more juicy at lesser age. In male kids, selected for slaughter, the lean meat, bone, carcass length and rib eye muscle area in each group had highly significant correlation with dressed carcass weight of respective age group in male kids. Prediction equation would help in predicting dressed carcass, lean and bone from slaughter weight as also dressed carcass from carcass length. The meat from the (b) showed better composition from the point of view of nutrition and leanness. The sensory quality of this sample was better than other samples. There was hardly any advantage in rearing the kids beyond 10 months of age, which results in slower increase in dressed carcass weight and reduction in lean percentage.**

Osmanabadi is an indigenous goat breed of Marathwada region which is mainly raised for meat purpose, having population of 1.29 million heads on 6.18 million hectares of land. The meat has been recognized as nutritious, delicious and palatable. No systematic research work had been carried out on meat quality of male kids slaughtered at different ages. There is also no scientific information regarding the quality of Osmanabadi goat germplasm which could be compared with other breeds in the country.

## Materials and Methods

Sixty four Osmanabadi male goat kids were categorised into age groups of (a) 6 to 8 months, (b) 8 to 10 months (c) 10 to 12 months and (d) 12 to 14 months and the investigation was carried out in randomized block design. The individual animals were slaughtered by Halal method. Four major cuts : shoulder, rack, loin and hindeuarter were obtained with due care. From each major cut, the representative proportionate sample of lean meat was taken by using sampling probe[1]. The chunks were mixed properly for evaluating the chemical composition and sensory properties of the meat.

*Chemical composition:* The contents *viz* moisture, protein, ether extract and ash in lean meat were studied using standard AOAC procedures[2]. The carbohydrate content in lean meat was determined by difference.

*Sensory evaluation:* The lean meat was evaluated for sensory quality on a nine point Hedonic scale. The maximum score of nine was given to the extremely like product. The score was arranged in the descending order. The sample receiving more than 80 per cent score was excellent, 60 to 80 per cent good, 40 to 60 per cent satisfactory and below 40 per cent was not acceptable. The sample was evaluated by semi-trained panel of fifteen judges. The samples were tested before cooking, for their colour, tenderness, juiciness and acceptability and cooked meat samples were evaluated without adding spices.

The co-efficients of correlation 'r' values were estimated as the ratio of proximate co-variance or the cross products of phenotypic standard deviations for two characters.

Regression analysis was carried out to find out the co-efficients and to use these co-efficients further for prediction of slaughter weight.

TABLE 1. PROXIMATE COMPOSITION OF LEAN MEAT OF MALE KIDS AS PER CENT.

| Age group (months) | Water (%) | Protein (%) | Ether extract (%) | Ash (%) | Soluble constituents (%) |
|---|---|---|---|---|---|
| 6-8 | 74.07 | 17.40 | 4.49 | 1.16 | 2.89 |
| 8-10 | 69.31 | 16.55 | 9.77 | 1.07 | 3.30 |
| 10-12 | 67.05 | 16.58 | 12.67 | 1.05 | 2.86 |
| 12-14 | 63.26 | 16.26 | 16.00 | 0.99 | 3.25 |
| S.E. ± | 0.207 | 0.135 | 0.131 | 0.015 | 0.166 |
| C.D | 0.595 | 0.386 | 0.376 | 0.043 | 0.475 |

TABLE 2. MEAN PERCENT SCORES FOR LEAN MEAT OF MALE KIDS.

| Age group (months) | Colour | Tenderness | Juiciness | Acceptability |
|---|---|---|---|---|
| 6-8 | 77.70 | 88.82 | 88.82 | 77.70 |
| 8-10 | 88.82 | 88.82 | 88.82 | 88.82 |
| 10-12 | 88.82 | 77.70 | 77.70 | 88.82 |
| 12-14 | 88.82 | 77.70 | 77.70 | 77.70 |
| S.E. ± | 1.984 | 2.545 | 2.236 | 2.526 |
| C.D. | 5.673 | 7.275 | 6.392 | 7.219 |

## Results and Discussion

The composition of lean meat in respect of moisture, protein, ether extract, ash and carbohydrate is presented in Table 1.

The water content in lean meat was maximum in group (a) and thereafter with the advancement of age it decreased. This might be due to increase in the ether extract content. From the nutrition point of view, though the protein content of group (a) was significantly superior to protein content in samples from other age groups, the effective requirement in diet is not much affected. With respect to ether extract value, it may be specifically mentioned here that the group (b) when slaughtered gave best sensory scores. Ash content showed a declining trend with increasing age. It decreased from 1.16 per cent in group (a) to 0.99 per cent in group (d). Moisture, protein, ether extract and ash contents in 'Jamnapari' and 'Barbari' male kids as reported by Singh[3] are comparable to those observed in 'Osmanabadi' in this study. Angora kids slaughtered at 7 months of age showed higher protein and comparable fat content[4] to those observed in 'Osmanabadi' kids. Owen[5] reported fat content as 6.43 and 12.01 per cent in 'Malavi' male goats slaughtered at 4 to 8 and 9 to 14 months of age. The values were comparable with the values of fat content in lean meat of 'Osmanabadi' male kids of same age.

Sensory scores for various physical properties of lean meat are presented in Table 2.

The colour of the meat improved to certain extent after 8 months of age and then it remained constant. This may be due to the effect of increased fat content which reduces the blood red colour to a more pleasant shine. The tenderness reduces with age due to toughening of myofibrilar proteins of meat and this phenomenon is universally observed in all animal tissues; however, all the samples were equally good in tenderness. Juiciness is directly correlated with combined effect of tenderness, fat content, tissue structure and marble fat. From overall acceptance point of view, the acceptability of the meat of the animal of groups (b) and (c) were better than others.

The correlation co-efficient amongst meat traits and dressed carcass of 'Osmanabadi' male kids slaughtered at different age groups with respect to lean, length of carcass, rib eye muscle area and dressed carcass were highly significant.

From Table 3, it is seen that the significant increase in dressed carcass weight with increase in age has been observed. The dressing percentage also increased with increase in age.

This reflects true growth. Similar observations were made by Singh[3] in 'Jamnapari' and 'Barbari', Ghanekar *et al*[6]. in 'Angora-Desi' cross bred kids, Owen[5] in 'Malawi' male kids, Pant[7] in Assam local goats; and Khan and Sahni[8] in 'Jamnapari' kids. The

TABLE 3. EFFECT OF AGE GROUP ON PHYSICAL PARAMETERS OF OSMANABADI MALE GOAT MEAT.

| Age group (months) | Wt at Slaughter (kg) | Dressed carcass (kg) | Dressing (%) | Carcass length (cm) | Rib eye muscle area (Cm) | Lean wt unit (cm) | Bone wt. (kg) | Lean wt. (%) | Bone wt. (%) |
|---|---|---|---|---|---|---|---|---|---|
| 6-8 | 13.9 | 6.3 | 45.7 | 53.70 | 10.66 | 4.25 | 1.41 | 66.9 | 22.2 |
| 8-10 | 16.8 | 8.0 | 47.8 | 56.70 | 14.00 | 5.60 | 1.69 | 69.4 | 20.9 |
| 10-12 | 18.8 | 9.2 | 49.1 | 64.70 | 16.10 | 6.05 | 1.86 | 65.4 | 20.3 |
| 12-14 | 20.7 | 10.3 | 49.9 | 66.43 | 19.98 | 6.81 | 1.91 | 65.8 | 18.8 |
| S.E. ± | | 0.082 | 0.435 | 0.453 | 0.133 | 0.040 | 0.014 | | |
| C.D. | | 0.237 | 1.24 | 1.295 | 0.324 | 0.118 | 0.046 | | |

increase in dressed carcass weight from group (a) to (b) is to the extent of 26.9 per cent, whereas the same from (b) to (c) 14.76 per cent, and group (c) to (d) 11.9 per cent. The kids should, therefore, be slaughtered at or around 10 months of age.

The area of rib eye muscle ranged from 10.6 $Cm^2$ in group (a) to 19.9 $Cm^2$ in group (d). A steady increase in rib eye muscle area has been observed with increase in age and weight.

The weight of lean as well as bone increased with increase in age and weight. The bone weight ranged from 1.4 to 1.9 kg from group (a) to (d). The lean weight was the least (65.43 per cent) of dressed carcass in group (c) and the highest (69.45 per cent) of dressed weight in group (b).

The prediction equation would help in assessing the dressed carcass weight, lean and bone from slaughter weight as well as carcass length. In case of meat animals, linear relationship exists between slaughter weight, dressed carcass muscle and bone.

The regression equation of the form of $Y = a + bx$ was worked out for predicting Y value. The dressed carcass yield, lean weight and bone weight can be directly calculated by putting slaughter weight in place of 'x' in respective age group.

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# Studies on Influence of Age of Sheep and Post-mortem Carcass Conditioning Treatments on Muscular Collagen Content and Its Thermolability

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**Male lambs, male yearlings and ewes – were sacrificed and thigh muscles (SM and ST) were used within 1 hr post-mortem for studies on age-related changes. For studies on postmortem carcass conditioning treatments, ewe carcasses were subjected to either Achilles tendon suspension at 2-3°C for 24 hr (direct chilling, $C_1$) or pelvic suspension at RT (26±2°C) for 7 hr followed by chilling at 2-3°C for 17 hr (delayed chilling, $C_2$) or left untreated (unconditioned, fresh, F). SM and ST muscles were dissected out within 1 hr post-mortem from F-carcasses and after 24 hr post-mortem from conditioned ($C_1$ or $C_2$) carcasses. The effect of age of the animal is marginal ($P>0.05$) on collagen content and very significant ($P<0.001$) on its solubility on heating-solubility decreasing with age. The stretching/contraction of muscles due to post-mortem conditioning of ewe carcasses had marginal ($P>0.05$) influence on both content and solubility of collagen. Cooking under pressure resulted in significantly ($P<0.001$) greater solubility than cooking without pressure. The interaction age × cooking was highly significant ($P<0.001$) whereas conditioning × cooking was not significant ($P>0.05$).**

Many attempts have been made to study the changes in collagen content in muscles and its solubility on heating as influenced by the chronological age of the animal and post-mortem storage of muscles and also their relationship to meat tenderness. Decrease in tenderness as age of the animal advances was found to be associated with decrease in collagen solubility but not with the quantity of collagen in muscle[1-3]. In respect of post-mortem changes in connective tissue, no changes in alkali insoluble content of meat from different animals during aging were noticed[4]. Bouton and Harris[5] opined that the changes in connective tissue are unlikely to contribute significantly to increase in tenderness achieved during aging as also Jeremiah and Martin[6]. Post-mortem conditioning treatments of ewe carcasses exert different restraining influence on thigh muscles resulting in contraction or stretching of muscles as reported from this laboratory recently by Mahendrakar *et al*[7]. Very little information is available on the effect of contraction or stretching of muscles on quantity and quality of collagen. With this in view, the present investigation was designed to study the changes in collagen content and its thermal stability as influenced by chronological age of sheep of local breed and by the carcass conditioning treatments at ambient temperature (26±2°C) prevalent in tropical regions as well as effect of cooking of muscles to "well done" or "very well done" state as practised in India.

## Materials and Methods

For studies on age-related changes, the experiment was planned on a replicated 3×2 factorial basis using 18 animals belonging to 3 age groups (6 each) with age as the first factor and cooking as the second (Fig. 1). Eighteen Bannur sheep-six male lambs of 5-6 months age (live wt. 8.9±1.0 kg), six male yearlings of 24-25 months age (live wt. 20.4±3.7 kg) were sacrificed and thigh muscles (SM and ST) were dissected out within 1 hr post-mortem. The differences in quantity and quality (thermolability) of intramuscular collagen of male and female sheep, if any, were ignored and the results on male lambs and male yearlings were compared with those of ewes.

For studies on effect of conditioning treatments, the experiment was also planned on a replicated 3×2 factorial basis using 18 Bannur ewes aged 4-5 yr (live wt. 22.5±3.1 kg) with conditioning treatment as the first factor and cooking as the second (Fig. 1). The conditioning treatments for carcasses were: $C_1$: Achilles tendon suspension (conventional) at 2-3°C for 24 hr – direct chilling or $C_2$ : Pelvic suspension at RT (26±2°C) for 7 hr followed by chilling at 2-3°C for 17 hr. (Tender stretch suspension) – delayed chilling. Thigh muscles (SM and ST) were dissected out after 24 hr post-mortem from conditioned ($C_1$ and $C_2$) carcasses and within 1 hr post-mortem from unconditioned (F) carcasses.

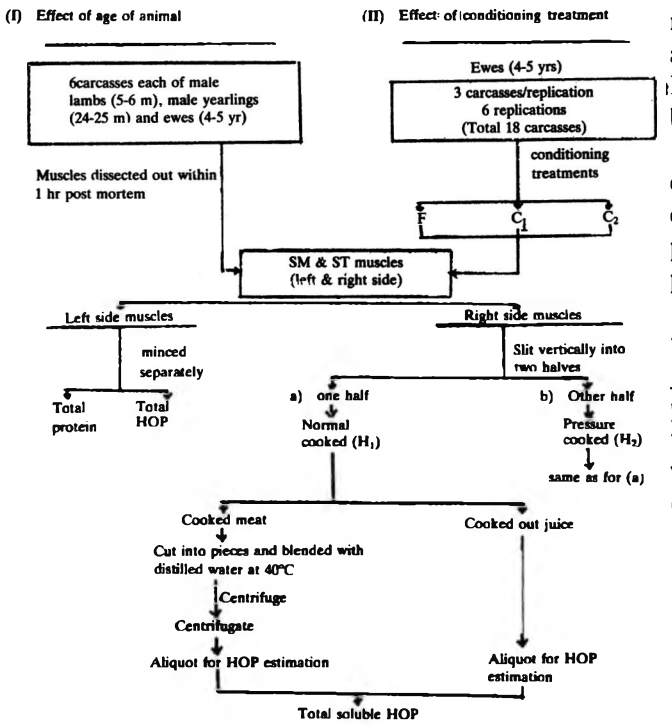


Fig. 1. Experimental design.

*Muscles:* The left thigh muscles (SM and ST) were minced separately and the mince was used for estimations of total protein[8] and total hydroxyproline (HOP).

The right thigh muscles (SM and ST) were slit vertically into two halves and one half was cooked normally and the other half pressure cooked as mentioned below:

*Normal cooking ($H_1$):* Muscle in 250 ml beaker covered with petri dish was immersed in water-bath at room temperature (26±2°C), heated to boil and allowed to remain at this temperature for 30 min. Beaker with muscles was then taken out from water bath and allowed to cool.

*Pressure cooking ($H_2$):* Muscle in 250 ml beaker covered with petri dish was placed in a pressure cooker fitted with a pressure gauge, heated till steam pressure reached 1 kg/cm$^2$ and maintained at this pressure for 20 min and allowed to cool.

Cooked muscles were washed with distilled water on the surface and washings collected in the cooked out juice. In order to determine the solubilized hydroxyproline (HOP) content in water held in cooked meat, the latter was cut into small pieces, homogenized with water at 40°C[9] in a Waring blender for 2 min and the extract centrifuged at 4000 r.p.m. for 30 min.

Aliquots of cooked out juice and centrifugate as well as a sample of muscle (left-thigh) mince were hydrolysed with 6N HCl under a steam pressure of 1 kg/cm$^2$ for 8 hr. HOP content in hydrolysates was determined according to Woessner[10] and soluble HOP calculated according to Williams and Harrison[9]. Collagen was expressed as 7.14 × per cent HOP[11].

*Statistical analysis:* The results were analysed using Analyses of variance technique appropriate to the design[12] and Duncan's New Multiple Range Test[13] was used to segregate the treatment means. Simple correlation co-efficients were determined between collagen content and its solubility on heating.

## Results and Discussion

*Influence of age of animal:* The collagen content in muscles from aged ewes was not significantly different from that in muscles of lambs and yearlings (Table 1)

TABLE 1. EFFECT OF AGE ON CONTENT OF COLLAGEN AND ITS THERMOLABILITY.

| Age (months) | Collagen (g/100g protein) | | Soluble collagen Soluble HOP as % total HOP. SM | | | ST | | |
|---|---|---|---|---|---|---|---|---|
| | SM | ST | $H_1$ | $H_2$ | Means | $H_1$ | $H_2$ | Means |
| 5-6 (male lambs) | 4.84a | 4.27a | 25.25 | 60.42 | 42.84a | 22.86 | 75.57** | 48.72a |
| 24-25 (male yearlings) | 4.50a | 4.32a | 9.13 | 27.66 | 18.40b | 7.66 | 30.93 | 19.30b |
| 4-5 yr (ewes) | 4.19a | 4.01a | 4.63 | 19.73 | 12.18c | 4.86 | 26.32 | 15.59c |
| Means | | | 13.02x | 35.94y | | 11.79x | 43.94y | |
| SEm | | ±0.24 (30 df) | | ±2.10 (25 df) | | | ±1.72 (25 df) | |

Values are average of 6 replicates.

**P < 0.01 between Sm-$H_2$ and ST-$H_2$.

indicating that quantity of collagen is not markedly altered (P>0.05) during the growth of the animal, as also reported in the case of bovine animals by Davey and Gilberg[4] and Reagan *et al*[14]. On the other hand, increase[15] as well as decrease[16] in amount of collagen as age advances have also been reported.

Heat lability of collagen is profoundly (P<0.001) influenced by the age of the animal as well as the method of cooking, the interaction age × cooking being highly significant (P<0.001). Highest quantity of collagen is solubilized on heating of lamb muscles followed by yearling and ewe (Table 1) suggesting that the collagen solubility decreased as age of the animal advanced confirming the definite negative correlation between the two.

Cooking under pressure solubilized collagen 3-5 times (P<0.001) more than normal cooking in either of the muscles.

The decrease in thermolability of collagen with age of the animal is attributed to be due to increase in crosslinkages in collagen[5,6,16].

*Influence of carcass conditioning treatments:* The quantity of muscular collagen was not affected (P>0.05) by carcass conditioning as anticipated; the changes in solubility of collagen on heating were also marginal (P>0.05) (Table 2).

The direct chilling with conventional Achilles tendon suspension of sheep carcasses ($C_1$) was found to exert different restraining influence on thigh muscles resulting in significant contraction of SM (~ 21 per cent) and stretching of ST (~ 13 per cent) muscles whereas delayed chilling under pelvic suspension ($C_2$) stretched both muscles (~ 24 per cent in SM and ~ 33 per cent in ST) as reported earlier[7].

These observations imply that contraction/stretching of muscles during 24 hr conditioning treatments to ewe carcasses have no significant (P>0.05) effect on collagen content and its thermolability. Recently, Jeremiah and Martin[6] reported that post-mortem ageing of LD and ST muscles from cattle even upto 20 days did not alter significantly intra-muscular collagen content or solubility. Other workers[17,18] indicated that subtle conformational changes in collagen molecules on swelling under the influence of post-mortem lactic acid accumulation may not necessarily affect the solubility characteristics of collagen.

On the other hand, cooking procedures had profound (P<0.001) influence on collagen solubility – pressure cooking solubilizing 5-8 times more collagen than normal cooking (Table 2). However, the interaction conditioning × cooking was found to be non-significant (P>0.05).

Several authors from their observations regarding collagen solubility as a function of cooking temperature indicated that solubility increases with temperature of cooking[19] and extent of dissolution of collagen depends on the duration of heating and internal temperature reached[20].

Simple correlations between content of collagen and its solubility on heating was found to be positive (r = 0.06 to 0.54) but generally not significant (P>0.05) both for muscles from ewe carcasses subjected to conditioning treatments (F, $C_1$ and $C_2$) as well as from animals of different age groups. Similar observations were made in LD and ST muscles of cattle upon post-mortem aging by Jeremiah and Martin[6] and in various muscles of bulls of different ages by Augustini and Temisan[3].

In conclusion, age of the animal had little (P>0.05) influence on collagen content but very marked influence (P<0.001) on its solubility on heating – solubility decreasing with age. The stretching/contraction of muscles due to post-mortem conditioning of ewe carcasses had marginal (P>0.05) effect on both

TABLE 2. EFFECT OF CARCASS CONDITIONING TREATMENT ON CONTENT OF COLLAGEN AND ITS THERMOLABILITY

| | Collagen (g/100 g protein) | | Soluble collagen Soluble HOP as % total HOP | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | SM | | | ST | | |
| | SM | ST | $H_1$ | $H_2$ | Means | $H_1$ | $H_2$ | Means |
| F | 4.19a | 4.01a | 4.63 | 19.73 | 12.18a | 4.86 | 26.32** | 15.59a |
| $C_1$ | 3.64a | 3.16a | 1.99 | 18.14 | 10.06a | 2.69 | 22.75 | 12.72a |
| $C_2$ | 4.14a | 3.64a | 3.96 | 21.97a | 12.97a | 3.31 | 25.96 | 14.64a |
| Means | | | 3.53x | 19.95y | | 3.62x | 25.01y | |
| SEm | | ±0.27 (30 df) | | ±1.43 (25 df) | | | ±1.46 (25 df) | |

Animals: Bannur ewes (age 4-5 yrs)
Values are average of 6 replicates.
**P < 0.01 between SM-$H_2$ and ST-$H_2$.

content and solubility of collagen. Pressure cooking led to greater solubility than normal cooking. The interaction age × cooking was highly significant ($P<0.001$) whereas conditioning × cooking was not.

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## RESEARCH NOTES

### DRYING STUDIES ON ARECANUT (*A. CATECHU* LINN.)

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**Ripe arecanut fruit is dried for 6-7 weeks to recover dried arecanut kernel by dehusking. During this prolonged period, fungus infestation upto 10-15% is quite common. Therefore, accelerated drying techniques like use of solar dryer and natural convection agricultural waste fuelled dryer were studied in comparison to open sun-drying. In the solar dryer, spreading density was 50 kg/m$^2$ compared to 15 kg/m$^2$ in open sun. A saving in time by 10 days (25%) was observed without any deterioration in quality. The hot air dryer takes 10 times more capacity and drying was achieved within 10 days. Use of hot air dryer using agricultural waste as fuel is, therefore, economically feasible for arecanut drying also.**

Arecanut is an important plantation crop grown in the west coast of India and in North east. The area under this crop is 1,86,500 ha producing annually 2,24,200 t of arecanut[1]. Arecanut is extensively used as a masticator throughout India, Burma, Srilanka and Malaysia. It is generally chewed along with *Pan* and a little slaked lime, *Kattha;* spices and tobacco are also sometimes added.

Arecanut is used either in the raw or cured form. The cured form is mainly used in southern India and the raw arecanut is used in the rest of the country. The fully mature fruits from areca palm are collected for use as raw nut, as these are less astringent and keep better.

For recovering the raw nut from the fruit, husk is peeled off. This is generally done after six to seven weeks of drying in the open sun. Due to drying, the husk gets fibrous and kernel in the fruit gives rattling sound when shaken. The raw nuts can also be recovered by cutting fresh matured fruit into two halves and further drying till the husk is separated from the kernel but that may cause deterioration in quality of *chali,* which gets exposed to drying air, though saving in time can be achieved. However, the main harvesting season of arecanut which is from August to October, coincides with the NE monsoon and hence drying of whole fruit is considered safe compared to cutting. Due to inclement weather during drying, the wetting of kernel results in fungus infestation of the fruits which many times penetrates inside and damages the kernel. The damage due to fungus infestation has been reported to be as high as 10 per cent. The drying characteristics for arecanut in mechanical through flow dryer have been studied by Nambudiri[2]. He reported that drying temperature above 80°C develops stress cracking, hence gradual increase in temperature from 45-60°C has been recommended. This is in case of mechanical dryer where hot air is forced over the material and material surface temperature reaches to hot air temperature which results in stress cracking. In case of natural convection dryer, the surface heating is also gradual as that of moisture diffusion from centre to the surface. To avoid the deterioration in arecanut quality during prolonged drying, a rapid method of arecanut drying is necessary. With this objective, drying studies were conducted on mature nuts in the open sun, in CPCRI solar dryer[3] and also in natural convection batch dryer using agricultural waste as fuel[4] at Central Plantation Crops Research Institute, Kasaragod and results are presented here.

Fully ripe arecanut fruits of 'Mangla' variety grown on west coast were selected for study. The moisture content was determined by cutting ripe nut in to small pieces and oven drying at 105°C ± 1°C for 24 hr. The open sun-drying was done at spreading density of 15 kg/m$^2$ as practised conventionally. In solar dryer, spreading density was 50 kg/m$^2$ and in the natural convection dryer using agricultural waste/husk as fuel, the capacity was 150 kg/batch and 150 kg/m$^2$. In the open sun and in solar dryer, nuts were turned in every evening. The bed thicknesses at spreading densities of 15 kg/m$^2$, 50 kg/m$^2$ and 150 kg/m$^2$ were 25 cm, 10 cm and about 5 cm respectively. The dryer was operated for 9-10 hr per day and over night tempering time was allowed. The fully dried samples were analysed visually for fungus infestation and rattling sound.

The initial moisture content of arecanut fruit with kernel was found as 70 per cent wet basis. The initial weight of 50 nuts was found as 1960 g. The drying in the CPCRI copra dryer was done at 80°C with one kg of coconut husk and shells per hour. The drying was considered to be complete when the weight of 50 fruits was reduced to the range of 625-650 g and actual moisture content at that period was determined by oven method at 105°C for 24 hr. The drying time required was 10 days, 30 days and 40 days, in CPCRI

TABLE 1. ANALYSIS OF DRIED ARECANUT FRUIT BY DIFFERENT METHODS

| Drying method | Bed thickness (cm) | Drying time (days) | Initial wt. (kg) | Wt of 50 nuts (g) | Final wt (kg) | Moisture content (% wt.) | Wt of kernel (g) | Wt of husk (g) | No. of rattling nuts | No. of nuts needing polish | No. of fungus infested nuts |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Natural convection dryer | 25 | 10 | 150 | 630.8 | 48.00 | 6.81 | 382 (60.5) | 248.8 (39.5) | 15 (30) | 19 (38) | – |
| **Solar dryer | 10 | 30 | 50 | 663.8 | 17.00 | 11.44 | 410 (61.8) | 253 (38.2) | 21 (42) | 17 (34) | – |
| Open sun-drying | 5 | 40 | 15 | 663.3 | 5.00 | 11.31 | 400 (60.3) | 263 (39.7) | 24 (48) | 20 (40) | 5 (10) |

*CPCRI Natural convection dryer using agricultural waste as fuel
**CPCRI Solar cabinet dryer
Values in parantheses are in per cent

hot air dryer, solar and open sun-drying, respectively. The moisture content were found as 6.81, 11.44 and 11.31 per cent for arecanuts dried in open, solar dryer and CPCRI dryer, respectively (Table 1). The loosening of husk was more in open drying (48 per cent) and least in CPCRI dryer (30 per cent). This shows that though enhanced drying can be done for arecanuts, husk is not uniformly loosened as it is achieved in open sun-drying. There was no fungus infestation in the nuts dried in CPCRI and solar dryer whereas there was 10 per cent infestation in open sun-dried material. The visual observation of colour and appearance of *chali* indicated that product dried in the dryers has good colour without cracks or shrinkages. The fixed cost of dryer per day has been reported to be Rs.1.44 and Rs.1.75 (only for turning the nuts once) for CPCRI dryer and solar dryer respectively. Therefore, drying costs per kg amount to Rs.0.53 Rs.1.35 and Rs.0.75 for fresh fruits and Rs.0.99, Rs.2.54 and Rs.1.40 in terms of kernel when dried in CPCRI dryer, solar and in open sun-drying, respectively. It can be concluded from the study that use of copra dryer for arecanut drying is economical as it saves time and avoids fungus infestation as the drying costs lower than open sun-drying. The use of solar dryer permits higher drying density per square meter and helps in saving time as well as drying space without use of any external energy.

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# EQUILIBRIUM MOISTURE CONTENT OF DEHYDRATED MUSHROOM (*PLEUROTUS SAJOR CAJU*)*

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**Equilibrium moisture content (EMC) of dehydrated mushroom (*Pleurotus sajor caju*) was determined at five levels of temperature ranging from 10 to 50°C and relative humidity ranging from 30 to 95% using static desiccator technique. For the safe storage of mushroom, the humidity and temperature are so prescribed as to have the corresponding equilibrium moisture. Four isotherm equations viz., Harkin's and Jura, Smith's, Henderson's and Chung and Pfost's were examined using the data obtained. It was found that Smith's equation gave the best fit over the entire range of relative humidity and temperature. Free energy change and heat vapourization of mushroom decreased as the moisture and temperature increased. Mould growth was observed at relative humidity greater than 80%.**

Mushrooms are highly perishable; dehydration, freezing and canning have been found suitable for preservation provided they are processed within 2 days after harvest[1]. The present study was intended to find out optimum conditions of moisture and temperature for increased storage period of dehydrated mushroom. Standard equilibrium moisture content models have been checked and tested to show the temperature-relative humidity relationship with moisture content of the material for the best fit of the data. Free energy change and latent heat of vapourization of the absorbed moisture were also evaluated from the obtained data.

The fresh mushrooms (*Pleurotus sajor caju*) were taken and dried in hot air oven for one hour at 60°C. When the moisture of the dried mushrooms reduced up to 12 per cent (approximately), the initial moisture content of the dried mushrooms were found out by standard hot air oven method. The sorption study was carried out on it using static desiccator technique. The experiment was conducted at 10, 20, 30, 40 and 50°C and for each temperature, five relative humidity levels ranging from 30 to 95 per cent were used. Constant relative humidities were maintained inside the desiccator using saturated salt solutions[2]. Four replicates, each weighing 2 g of sample were taken for each set of temperature-relative humidity condition. The observations in the change of weight of samples were taken at an interval of 24 hr. When the changes in the weights of samples were less than 0.001 g between two successive weighings, at this point the samples were considered as equilibriated to the respective relative humidity.

Equilibrium moisture content of mushrooms at different temperature and relative humidity levels is shown in Table 1. The values of equilibrium moisture content decreased with the increase of temperature. Mould growth was observed for all temperatures when the relative humidity was more than 80 per cent. Due to this, the data of more than 80 per cent relative humidity were not considered. It was found that the

TABLE 1. EQUILIBRIUM MOISTURE CONTENT (EMC) OF MUSHROOM AT DIFFERENT RELATIVE HUMIDITY AND TEMPERATURE

| Temp (°C) | R.H. (%) | E.M.C. (% d.b.) |
|---|---|---|
| 10 | 34.2 | 8.2255 |
| | 57.8 | 14.4024 |
| | 75.4 | 26.9259 |
| | 81.8 | 36.0340 |
| | 95.5 | 61.5590 |
| 20 | 33.6 | 8.6637 |
| | 43.9 | 10.7330 |
| | 54.9 | 12.1695 |
| | 59.2 | 14.5756 |
| | 81.0 | 30.3918 |
| 30 | 32.8 | 6.1266 |
| | 43.6 | 9.3799 |
| | 56.3 | 11.5017 |
| | 75.6 | 22.9111 |
| 40 | 32.1 | 5.6136 |
| | 43.4 | 7.8324 |
| | 49.2 | 9.4739 |
| | 71.5 | 18.3816 |
| | 81.0 | 28.4856 |
| 50 | 31.4 | 4.9358 |
| | 46.3 | 7.5294 |
| | 68.6 | 15.4431 |
| | 74.7 | 19.6863 |
| | 79.1 | 25.1942 |

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time required to reach equilibrium ranged from 14 to 16 days. The optimum conditions (i.e., relative humidity and temperature) are so prescribed as to have a corresponding EMC in Table 1.

The data were examined using four isotherm equations viz., Harkins and Jura[3], Smith[4], Henderson[5] and Chung and Pfost[6]. Smith's equation, which can be stated in its linear form as:

$$Me = W_b - W^1 \ln(1\text{-}rh)$$

Where,

Me = Equilibrium moisture content (% wb.)

rh = Relative humidity, decimal

$W_b$, $W^1$ = Constants

gave the 'best-fit' over the entire range of relative humidity and temperature with a minimum standard error of 1.0134 and co-efficient of determination in the range of 0.9734 to 0.9898. The co-efficient of determinations for other three equations viz., Harkins and Jura, Henderson and Chung and Pfost were 0.8869 to 0.9873, 0.9447 to 0.9890 and 0.9446 to 0.9877 respectively.

Equilibrium reaches when free energy gradient across the interface is zero. Free energy change between the material and surrounding is the energy required to transfer the water molecules from vapour state to solid surface or *vice-versa*. Free energy change may be calculated using following formula:

$$\triangle F = -RT \ln rh$$

where,

$\triangle F$ = Free energy change, cal/g mol

R = Universal gas constant

T = Temperature, °k

rh = Relative humidity, decimal

Free energy changes were calculated at 8, 10, 12, 14, 16, 18, 20 and 22 per cent moisture content (d.b.), for each levels of temperature studied. The values of relative humidity corresponding to different moisture content were taken from isotherms. Free energy changes at a particular temperature decreased as the moisture content of mushroom increases.

Heat of vapourization was calculated using Othmer's equation[7]. At each moisture content, the ratio of heat of vapourization of moisture in product to that of free water was computed as the slope of the family of straight lines representing Othmer's equation. A plot of variation of latent heat to moisture content is shown in Fig. 1. Heat of vapourization of mushroom for a particular temperature decreased as the moisture content increases.

To increase the life of dehydrated mushroom, the optimum conditions i.e., humidity and temperature are recommended corresponding to the equilibrium moisture content. The fitness of Smith's equation is purely emperical as it does not satisfy the end condition at low relative humidity.

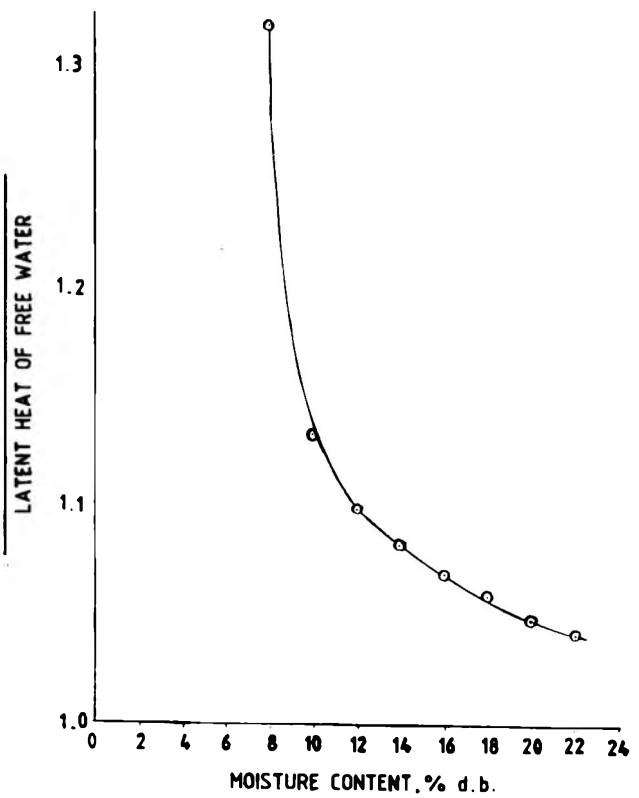


Fig. 1. Variation of isosteric heats of sorption for mushroom.

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# EFFECT OF DEPIGMENTATION OF PEARL MILLET ON RHEOLOGICAL PROPERTIES OF FLOUR AND SENSORY QUALITY OF *ROTI*

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**The rheological properties of flour of pearl millet soaked in 0.2 N HCl for 24 hr and sensory quality of *roti* were studied. The viscosity (cold paste) increased on heating to 90°C (hot paste) and subsequently on cooling to 30°C (cooked paste) in both the untreated and HCl-treated flour samples. The solubility and swelling powers of both the samples increased slowly upto 60°C, but beyond that, the increase was significant. In general, decrease in viscosity and increase in solubility and swelling power was observed in HCl-treated sample. The HCl-treated pearl millet flour *roti* showed improved colour, texture and taste but inferior aroma (41%). However, the overall quality was not adversely affected.**

Pearl millet (*Pennisetum typhoideum* L.) is the sixth most important cereal in the world and enjoys a significant place in the dietaries of many developing countries including India. The grains are rich in proteins and fat. In India, it is mainly cultivated for human consumption. But it has remained as food only for the economically weaker sections due to the coarse nature of the grains, presence of pigments in the pericarp and endosperm layers of the grains and the absence of gluten-like character of the seed protein[1].

In India, pearl millet is eaten in many forms[2] but mostly as millet *roti (bhakri)* traditionally prepared with stone ground millet flour. The *roti* looks grey in colour and tastes bitter because of pigments and therefore is not liked by many people. In our previous study[3], we observed that soaking pearl millet in 0.2 N HCl for 24 hr can efficiently remove the pigments and thus creamy white grains are produced. The rheological properties of any soaked material are of utmost importance because the molecular size and shape of substances in solution significantly influence their viscosity, and ultimately solubility and swelling behaviour. So, raw materials are subjected to rheological testing in product development and process control in industry. In the present investigation, attempts have been made, therefore, to study the rheological properties of untreated and HCl-treated flour and sensory quality of *roti* from such flour.

Pearl millet was purchased from the local market of Parbhani. Samples of cleaned seeds (100 g) of uniform size were soaked in 300 ml (w/v) 0.2 N HCl for 24 hr and then thoroughly washed (twice) with water to remove the residual HCl. The seeds were dried to 14 per cent moisture content. The processed seeds were then ground in a blender (Sumeet) to pass through 0.25 mm sieve and stored in plastic bottles at 4°C until use.

The rheological properties such as the viscosity at 30°C prior to heating (cold paste), after heating to 90°C (hot paste) and after cooling to 30°C (cooked paste) of all samples were determined by using a Brookfield Synchrolectric viscometer. Eight per cent slurry of millet flour in water was used with spindle number 1,3 and 4 at different shear rates. The beaker containing flour slurry was then placed in boiling water bath and hot paste viscosity was determined immediately after heating and cooked paste viscosity after cooling to room temperature.

The solubility and swelling behaviour of HCl-treated millet flour were determined at 30, 40, 50, 60, 70, 80 and 90°C according to the method of Leach *et al*[4].

The *bhakri* (unleavened *roti)* from the flour was prepared by adopting essentially the procedure of Olewnik *et al*[5] with slight modications. Sensory quality of samples of these *rotis* was carried out for colour, texture, aroma, taste and overall quality by a trained panel of 15 judges with a maximum score of 5 for each of the parameters. Statistical analysis of the data was carried out by the method of Amerine *et al*[6].

The data on flour paste viscosities are presented in Table 1. It was observed that the cold paste viscosity of untreated and HCl-treated flour samples increased at all the shear rates with increase in temperature from 30 to 90°C. The effect of rate of shear on viscosity indicated that as the shear rate increased from 6 to 60 there was a decrease in viscosity. The hot paste viscosity at 90°C in both the samples at all the shear rates showed a tremendous increase which could be because of gelatinization of starch. Rathi[7] reported the temperature range for initial, mid and final gelatinization of pearl millet starch to be 69.7, 74.0 and 77.5°C, respectively. In the present investigation, the hot paste viscosity was determined after heating at 90°C which was above the gelatinization temperature of pearl millet starch and therefore viscosity might have been increased due to gelatinization of starch. The results obtained in the present investigation are comparable with those reported by Badi *et al*[8] and Belia and Martson[9] for different varieties and hybrids of pearl

TABLE 1. EFFECT OF SOAKING PEARL MILLET GRAINS IN 0.2N HCL ON FLOW BEHAVIOUR OF FLOURS AT DIFFERENT TEMPERATURES

| Temp°C | Apparent viscosity (cP) at indicated shear rate (rpm) | | | |
|---|---|---|---|---|
| | 6 rpm | 12 rpm | 30 rpm | 60 rpm |
| | **Untreated flour** | | | |
| 30[a] | 9 | 5.7 | 3.6 | 3.2 |
| 90[b] | 5600 | 3100 | 1840 | 1080 |
| 30[c] | 14000 | 89000 | 5040 | 3400 |
| | **24 hr HCl treated flour** | | | |
| 30[a] | 4 | 2.7 | 1.9 | 2.3 |
| 90[b] | 5060 | 12795 | 1720 | 1020 |
| 30[c] | 11900 | 8000 | 4400 | 3100 |

a Cold paste prior to heating
b Hot paste immediately after heating
c Cooked paste after cooling

millet starches. The cooked paste viscosity at room temperature further showed a very high value both in untreated and HCl-treated flours. The large increase in viscosity after cooking and subsequently, cooling to room temperature in both the samples may be due to retrogradation of starch in the flour and formation of a thick gel of viscous mass. In general, the decline in the viscosity (cold paste, hot paste and cooked paste) in the HCl-treated sample could be attributed to the decrease in the pearl millet starch, due to hydrolysis which is primarily responsible for viscosity. The decrease in starch on treating the grains in 0.2 N HCl for 24 hr was reported earlier[3].

The results of the solubility and swelling characteristics of flours are presented in Table 2. The solubility of untreated flour was increased from 0.60 to 0.61 per cent 90°C. The rate of increase was initially low upto 60°C, however, it was higher beyond 60°C. The solubility of HCl-treated flour was increased from 1.74 to 9.12 per cent at 90°C. It was higher at all the temperatures in HCl-treated samples since amylose is hydrolysed during soaking and amylopectin becomes more accessible for water which results in increased solubility. The increase in the swelling of untreated and HCl-treated flours was not much when temperature was increased from 30 to 60°C. But beyond 60°C, it increased significantly and was found to be maximum at 90°C (12.5 per cent in untreated and 17.8 per cent in 24 hr HCl-treated flour). The increase in swelling power of HCl-treated flours at all the temperatures may be due to hydrolysis of linear chain polymer of starch i.e. amylose. Leach *et al*[4]. postulated that the bonding forces within the starch granules would influence the manner of swelling and indicated that the swelling values increase with temperature. Higher values for solubility and swelling obtained at higher temperatures revealed that these were due to relaxation of homogeneous and strong bonding forces within the starch granules of pearl millet. Wankhede *et al*[10] also reported increased solubility and swelling of starch granules at higher temperatures in finger millet and foxtail millet.

TABLE 2. EFFECT OF SOAKING PEARL MILLET GRAINS IN 0.2 N HCl ON SOLUBILITY AND SWELLING OF FLOUR IN WATER AT DIFFERENT TEMPERATURES[a]

| Temp. (°C) | Solubility (%) | | Swelling (%) | |
|---|---|---|---|---|
| | Untreated | HCl-treated | Untreated | HCl-treated |
| 30 | 0.60 | 1.74 | 0.32 | 3.41 |
| 40 | 1.15 | 2.70 | 1.55 | 5.62 |
| 50 | 2.26 | 4.45 | 1.95 | 7.68 |
| 60 | 3.62 | 6.27 | 2.64 | 8.33 |
| 70 | 5.44 | 7.64 | 6.32 | 11.20 |
| 80 | 5.90 | 8.75 | 7.50 | 13.85 |
| 90 | 6.61 | 9.12 | 12.54 | 17.78 |

a Each value is the average of three determinations.

The data on the average score for the different sensory parameters are presented in Table 3. The highest mean scores for colour and texture were observed in 24 hr HCl-treated samples. Though the highest mean score for colour was observed with 24 hr HCl-treated millet flour *roti*, the mean score for aroma was found to be less in comparison. This has indicated that though the colour improvement could occur on soaking pearl millet grains in 0.2 N HCl, it imparts fermented aroma during long term soaking. It could be finally concluded from the data that improvement in colour, texture and taste can occur in *roti* after soaking pearl millet grains in 0.2 N HCl for 24 hr. However, the overall quality of HCl-treated sample *roti* was more or less comparable to that of the untreated one.

TABLE 3. AVERAGE SCORE OF SENSORY QUALITY OF UNTREATED AND HCl-TREATED PEARL MILLET FLOUR *ROTI*

| Type of *roti* | Colour | Texture | Aroma | Taste | Overall quality |
|---|---|---|---|---|---|
| Untreated flour | 2.9 | 2.7 | 3.1 | 3.0 | 1.8 |
| 24 hr HCl-treated | 4.0 | 3.1 | 2.0 | 3.1 | 2.1 |
| SEM± | 0.691 | 0.756 | 0.643 | 0.556 | 0.153 |
| LSD* (2l df) | 2.02 | 2.21 | 1.80 | 1.63 | 0.45 |

*LSD: Least significant difference at P = 0.05

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## ERRATA

1. In paper "Effect of Potassium on Nitrogen and Carbohydrate Contents of Tea Leaves (*Camellia sinensis* (L) O. Kuntze) and Quality of Made Teas" by M.N. Devchoudhary and K.L. Bajaj, appeared in this journal 1988, Vol.25, No.2, pp 105-107, the following changes are to be effected.

   In page 105, line 11, tea quality[3] should be read as tea *quality,*

   In Table 1, in glutamic acid under the 4th column *185.0* should be read as **285.0**

   In Table 2, under 2nd column heading concn *(mg/100g dry)* should be read as **(g/100g dry)**

2. In 'Research Note' on "Composition of Uncommon foods" by B. Goel and A. Kumar appeared in this *Journal* Vol.26 No.1, 1989, page 45, in Table 2 under column heading "Carotene" *(mg/100g)* should be read as **(μg/100g).**

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# MICROBIAL AND BIOCHEMICAL CHANGES DURING *DHOKLA* FERMENTATION WITH SPECIAL REFERENCE TO FLAVOUR COMPOUNDS

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**Microbial and biochemical changes occurring during *Dhokla* fermentation were studied to find out optimum concentrations of microbial metabolites that impart typical aroma, flavour and texture to the product. During the course of fermentation from zero to 18 hr, population of *Lactobacillus fermentum*, *Leuconostoc mesenteroides* and a yeast, *Hansenula silvicola* rose from $6 \times 10^6$/g, $3 \times 10^6$/g and $7 \times 10^6$/g to $35 \times 10^6$/g, $24 \times 10^6$/g and $27 \times 10^6$/g respectively; pH dropped down from 5.3 to 4.0; total titrable acidity increased from 0.33 g/L to 1.2 g/L; total volatile fatty acids (VFA) comprising acetic, propionic, isobutyric and iso- valeric acids increased from 54.8 to 582.8 mg/L; acetoin content rose gradually from 0.7 to 7.2 μg/g and volume of the batter increased from zero to 95.6%. At 16th hr of fermentation, the product exhibited the best sensory qualities which could be attributed to 0.95 g/L total titrable acidity, 8.6 μg/g acetoin, 479 mg/L total VFA and 84.8% rise in volume of the batter.**

*Dhokla* originated in Gujarat, is one of the popular indigenous fermented foods of India. It is liked as snacks all over the country because of the sour taste and spongy texture. In Maharashtra, *dhokla* is prepared by fermenting a mixture of Bengal gram flour and curds for 16 to 18 hr and steaming the batter for 20 min. The desirable sensory qualities of fermented foods are attributed to microbial activity. Studies on *idli* fermentation[1] have shown that *Leuconostoc mesenteroides* is responsible for spongyness of *idli*. Microbial population at zero hr and at the end of fermentation has been reported for *idli, khaman* and *dhokla*[1,2]. Per cent increase in volume of the batter and chemical changes viz. changes in amino nitrogen, free sugars, vitamins namely, niacin, thiamin and riboflavin have been reported for fermented batters of *idli, khaman and dhokla*[1-4]. This paper presents microbial and biochemical changes with special reference to diacetyl, acetoin and volatile fatty acids developed during *dhokla* fermentation.

Two hundred grams of *dhokla* batter was prepared in the laboratory by mixing Bengal gram flour with curds in 1:1.5 (W/W) ratio in a sterile beaker, aseptically distributed into 10 equal aliquots and allowed to ferment at room temperature (28±2°C). The experiment was performed in duplicate. The batters were examined for change in volume, microbial population, pH, lactic acid, total titrable acidity, diacetyl, acetoin and volatile fatty acids at an interval of 2 hr between zero and 18 hr of fermentation. The corresponding steamed products were examined for chemical parameters and evaluated for taste, flavour and texture.

Ten-fold dilutions of the batters in 0.1 M sterile citrate buffer were tested microbiologically for enumeration of lactic acid bacteria using Deman Rogosa Sharpe agar[5] (pH 6.7) and Davis yeast extract salt agar[6] (pH 6.6) for yeasts. The plates were incubated at room temperature (28±2°C) for 48 hr and all the counted colonies were identified according to Bergey's manual[7] for bacteria and Lodder[8] for yeasts.

pH values of batter, curds and 10 per cent suspension of Bengal gram flour were determined with a pH meter and that of the steamed product with pH paper (range 2.0 to 4.5 and 3.5 to 6.0). Ten per cent suspensions of all the samples were used for: (i) detection of lactic acid by paper chromatography[9]; (ii) estimation of total titrable acidity by titrating 10 ml filtrates against 0.02 N sodium hydroxide solution using phenolphthalein as indicator, and (iii) estimation of volatile fatty acids by gas chromatography[10] (the filtrates were acidified to pH 2.0 with orthophosphoric acid, centrifuged at 7000 r.p.m. for 30 min and two microlitre of the supernatent was used for analysis). Total diacetyl and acetoin contents were estimated in filtrates of 10 per cent suspensions of the samples and diacetyl alone in the distillate (collected at 86-87°C) of the filtrate by the method of Brenner *et al.*[11]. The acetoin content was calcultated by difference.

Change in volume of the batter commenced at the 10th hr of fermentation and increased gradually from zero to 95.6 per cent.

Changes in microbial population of lactic acid bacteria and yeast are illustrated in Fig. 1. The organisms were identified as *Lactobacillus fermentum, L. lactis, L. delbrueckii, Leuconostoc mesenteroides* and the yeast *Hansenula silvicola* of which *L. lactis* and *L. delbrueckii* became extinct from 12th hr and 10th hr of fermentation respectively. The total count excluding these two species increased from $16 \times 10^6$ to $86 \times 10^6$ during the fermentation.

Results of chemical examination of batters during fermentation and of steamed products are detailed in Table 1. pH of the batters dropped from 5.25 to 4.00

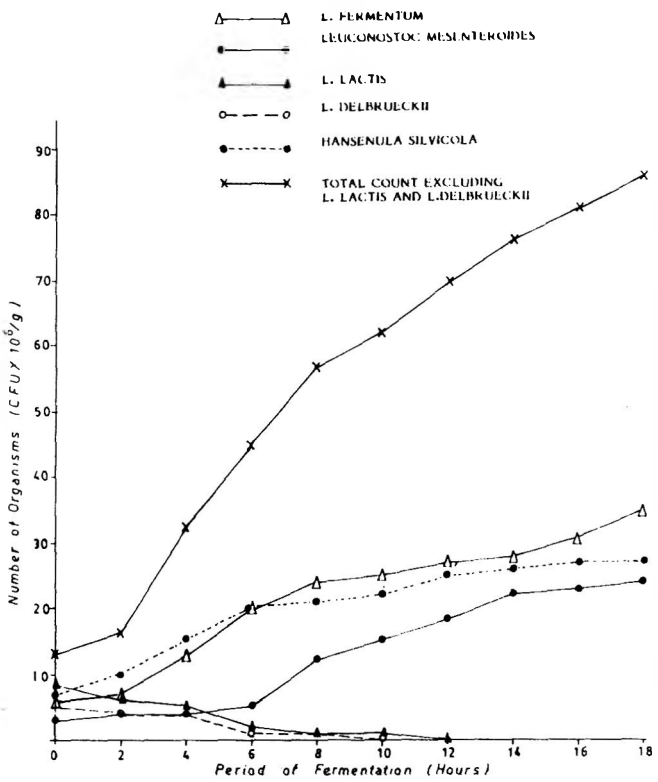


Fig. 1. Changes in the microbial population during fermentation

and that of product from 5.5 to 4.5. Lactic acid was detected in all the batters and products. Total titrable acidity of the batters increased from 0.33 to 1.2 g/l and 0.07 to 0.5 g/l in the products indicating production of acids by the proliferating microorganisms. The diacetyl content of the batters increased from 0.03 to 5.2 μg/g but it was absent in the products because of total loss during steaming. The acetoin content of the batters gradually rose from 0.7 to 9.6 μg/g during zero to 12 hr followed by a decline with further extension of fermentation upto 18 hr. This could be due to conversion of acetoin to 2,3-butanediol in acidic conditions according to Hammer and Babel[12]. The acetoin content of the product showed increase from 0.07 to 0.95 μg/g.

Total volatile fatty acid (VFA) content of the batters showed gradual rise from 54.8 to 582.8 mg/l and of products from 66.3 to 696.4 mg/l (Table 2). The flavour of the product could be attributed in addition to acetoin to VFA namely acetic acid, propionic acid, iso-butyric acid and iso-valeric acid which showed rise during fermentation. This is in agreement with the reports of Wiseblatt Kohn[13] and Marglith and Schwartz[14]. The VFA content of the products was more than their batters probably because of release of particle (flour) bound VFA during steaming.

As regards sensory qualities of the products, characteristic pleasant flavour was exhibited by the products of batter fermented for 12 hr while medium sour taste with 14 hr of fermentation. Highly spongy texture was obtained with fermentation for 16 hr when the per cent increase in volume was 84.8. Thus, the best sensory qualities were recorded for the product of batter fermented for 16 hr when total titrable acidity was 0.95 g/l, acetoin 8.6 μg/g and total VFA content 479.6 mg/l. The optimum concentration of these metabolites in the corresponding product were 0.39 g/l, 1.5 μg/g and 605.6 mg/l respectively. Flavour compounds e.g. diacetyl, acetoin and volatile fatty acids have been reported from curds[14] and acetoin content of wine to range between 0.7 and 8.6 μg/g[14]. Smith and

TABLE 1. CHEMICAL EXAMINATION OF BATTER DURING FERMENTATION AND OF STEAMED PRODUCTS

| Fermentation period (hr) | Total titrable acidity in lactic acid (g/l) | | pH | | Diacetyl in batter (μg/g) | Acetoin (μg/g) | |
|---|---|---|---|---|---|---|---|
| | Batter | Product | Batter | Product | | Batter | Product |
| 0 | 0.33 | 0.07 | 5.25 | 5.5 | 0.03 | 0.7 | 0.07 |
| 2 | 0.46 | 0.08 | 5.20 | 5.5 | 0.04 | 1.8 | 0.12 |
| 4 | 0.53 | 0.10 | 5.00 | 5.5 | 0.10 | 2.5 | 0.16 |
| 6 | 0.60 | 0.12 | 4.80 | 5.0 | 0.30 | 3.0 | 0.25 |
| 8 | 0.67 | 0.15 | 4.75 | 5.0 | 1.00 | 4.5 | 0.50 |
| 10 | 0.74 | 0.20 | 4.56 | 5.0 | 1.60 | 6.0 | 2.00 |
| 12 | 0.80 | 0.27 | 4.52 | 5.0 | 2.50 | 9.6 | 2.05 |
| 14 | 0.89 | 0.45 | 4.25 | 5.0 | 3.20 | 9.4 | 1.70 |
| 16 | 0.95 | 0.39 | 4.20 | 5.0 | 4.50 | 8.6 | 1.50 |
| 18 | 1.20 | 0.50 | 4.00 | 4.5 | 5.20 | 7.2 | 0.95 |
| Curds | 6.73 | | 3.5 | | 2.03 | 8.02 | |
| Bengal gram flour suspension | 0.01 | | 6.5 | | Nil. | Nil. | |

TABLE 2. CHANGES IN VOLATILE FATTY ACID CONTENT (MG/L) OF BATTERS DURING FERMENTATION AND OF THE STEAMED PRODUCT

| Type of product | Fermentation period (hr) | Acetic | Propionic | Isobutyric | n-butyric | Isovaleric | Isocaproic | n-caproic | Total VFA |
|---|---|---|---|---|---|---|---|---|---|
| Batter | 0 | 14.3 | 8.7 | 7.1 | 0.6 | 5.0 | 12.4 | 6.7 | 54.8 |
| St. product | | 8.0 | 3.8 | 8.6 | Nil | 20.0 | 23.6 | 2.2 | 66.3 |
| Batter | 4 | 80.1 | 24.0 | 11.5 | 0.3 | 27.5 | 10.0 | 2.1 | 155.5 |
| St. product | 4 | 38.2 | 22.8 | 29.5 | Nil | 45.5 | 18.0 | 1.1 | 162.1 |
| Batter | 8 | 120.1 | 38.2 | 16.1 | 0.3 | 34.4 | 6.7 | Nil | 216.0 |
| St. product | 8 | 66.1 | 50.8 | 48.6 | Nil | 55.5 | 13.0 | Nil | 234.1 |
| Batter | 12 | 300.8 | 50.6 | 25.1 | 1.8 | 45.9 | 5.8 | Nil | 430.0 |
| St. product | 12 | 136.8 | 66.2 | 85.2 | 1.9 | 140.6 | 10.8 | Nil | 441.5 |
| Batter | 16 | 515.1 | 56.6 | 27.1 | 28.4 | 48.1 | 4.4 | Nil | 479.6 |
| St. product | 16 | 160.2 | 71.2 | 98.2 | 49.4 | 217.8 | 8.7 | Nil | 605.6 |
| Batter | 18 | 378.9 | 58.0 | 31.4 | 59.3 | 51.0 | 4.1 | Nil | 582.8 |
| St. product | 18 | 188.0 | 72.2 | 109.1 | 73.6 | 244.6 | 8.9 | Nil | 696.4 |
| Curds | | 20.6 | 16.9 | 4.8 | 1.1 | 8.6 | 20.9 | 1.3 | 74.3 |
| B.G. flour | | 6.5 | 3.4 | 20.3 | Nil | 4.8 | Nil | 23.0 | 57.9 |

B.G. flour = Bengalgram flour St. product = Steamed product.

Coffman[15] identified acetoin and diacetyl in preferments of bread.

The values of total titrable acidity, diacetyl, acetoin and total VFA at zero hr of fermentation are contributed by the ingredient viz. curds and subsequent rise in these between zero and 18 hr of fermentation is due to rise in microbial population particularly of *L. fermentum*, *L. mesenteroides* and *H. silvicola* resulting in increased metabolic activity.

To conclude, acetoin and volatile fatty acids are the compounds imparting characteristic flavour to *dhokla* at their optimum concentration.

The authors are thankful to Dr. R.V. Gadre for gas chromatographic analysis and Dr. (Mrs.) S. Dey for her help in estimating diacetyl and acetoin.

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*J. Fd. Sci. Technol.*, 1989, Vol. 26, No.2, 116-120

# BOOK REVIEWS

*Ion-Exchange Chromatography of Proteins:* by Yamamoto S. Nakanishi, K and Matsuno R, Vol. 43, Chromatographic Science Series, Marcel Dekker Inc., New York and Basel, Price: Bound illustrated US $ 110 ( US & Canada) $ 132 (All other countries) pp: 416; 1988.

The book 'Ion Exchange Chromatography of Proteins' by Yamamoto S. Nakanishi, K. and Matsumo, R. is the 43rd volume of the monographs, Chromatographic Science Series, edited by J. Cazes of Sanki Laboratories Inc, Pennsylvania, USA. Even though one can recall a similar titled book 'Ion Chromatography' by J.C. Tarter in the above series, the contents and approach of these two books are entirely different.

The book is basically divided into ten major chapters, mainly consisting of theoretical aspects of ion exchange chromatography including equilibria, diffusion considerations and axial dispersions, experimental methods and apparatus, various ion exchangers available, factors affecting separation, large scale operation and design calculation procedures. Added to this, there is an exhaustive appendix list for numerical calculations and derivation of some of the equations for the general reader. The book has also a glossary of symbols running for nearly 13 pages and an exhaustive reference list well indexed. It has nearly 100 tables and a fair number of diagrams wherever needed. The book runs for nearly 400 pages and is hardbound with an attractive cover page of a three axes graphical representation of a typical elution profile.

Coming to the details of each chapter; in the introduction part, the authors have explained in detail the terminology, brief history of ion exchange chromatography (abbreviated as IEC), and the characteristics of it in selectively using for proteins with enough theoretical considerations. Importance is given to a beginner in the field also in explaining the basic considerations of IEC.

The second, third, 4th and 5th chapters consist of the theoretical aspects in general-equilibria, diffusion, and axial dispersion respectively. General theoretical aspects include symmetrical and asymmetrical elution profiles, skewness and Kurtosis of the same, Laplace transformation, adsorption isotherms and distribution co-efficients, under a set of given boundary conditions, linear and non-linear isocratic elution, mass balance or rate theory, plate theory and number and its experimental verification and resolution of two components. With this background theory, the reader is carried onto ion-exchange chromatography of proteins with special reference to surface change, stepwise and continous profiles, effect of ionic strength and methods for predicting peak position and peak width of proteins with a particular ion exchanger. The authors have also attempted criticism of the earlier models and equations from page 102-106 which is noteworthy. The chapter on equilibria is dealt with in very great detail which generally does not find a place in many of the reviews and books. This has been done with nearly 12 diagrams of special relevance to proteins. It is felt that in this chapter, the treatment does not invoke thermodynamics to a large extent (for example effect of temperature).

In the chapter on diffusion in ion exchanger, the authors initiate their theoretical discussions from Nernst-Planck equation, go through the Donnan potential theory, and explain in detail the experimental methods with adequate theory to follow along with worked out examples. Due to paucity of sufficient experimental data, the authors appear to have restricted the axial dispersion treatments to only 10 pages.

In the general experimental methods and apparatus, the authors have dealt with in detail the various models available in terms of gradient formers, column selection, method of sample injection, elution, regeneration and concentration of samples. This is followed by theoretical considerations and selection of proper ion exchangers and the factors that affect the separation behaviour. The latter portion of this chapter is mainly devoted to detailed analysis constituting peak shape, resolution and use of isocratic elution methods. Some of the artifacts arising in many situations are also discussed.

The last two chapters are mainly devoted to large scale operation and design calculation procedures of linear and stepwise elution profiles. Worked out examples are of great help to a beginner in the field.

Overall, the book provides up-to-date applications of both high or medium performance ion exchange chromatography with special reference to proteins. The book treats both the theoretical and experimental procedures parallelly in a well knitted fashion. It can serve as an important reference for food and pharmaceutical chemists, biochemists and biotechnologists and analytical chemists.

V. PRAKASH
C.F.T.R.I., MYSORE

*Problems and Prospects of Marine Fishing and Fish Processing in Karnataka:* edited by I. Karunasagar and N.V. Sripathy, published by Forum of Fishery Professionals, Mangalore; pages: 170, Price: Rs.50; 1988.

This book is a collection of papers presented during the seminar on "Problems and prospects of marine fishing and fish processing in Karnataka" held during 19-20 June 1986 at College of Fisheries, Mangalore. The book is divided into 6 sections.

Section I deals with the present status of marine fisheries resources of Karnataka coast and discusses future prospects for exploitation. Karnataka, occupying the fifth place among the maritime states has shown considerable progress in the development of its marine fisheries in recent years with the adoption of modern fishing techniques with trawlers, purse seiners and gill netters. This has, however, resulted in the over exploitation of 0-40 Km zone while the zones above 40 Km are neglected totally. Many suggestions are made with a view to increasing the present landings by judicious exploitation of the unexploited zones and to prevent over-fishing in the 0-40 Km sites. It has been recommended further that mechanised fishing of shrimps at the present level should be maintained and the mesh size has to be increased to 30 mm in order to obtain maximum sustainable yields.

Section II deals with the monetary needs of the fishermen community in Karnataka and the leading role played by different financial institutions in lending loans. There appears to be a perceptible improvement in the fishing industry, thanks to the inputs generated by the loans offered by these organisations, the repay position of the borrowings has, however, remained unsatisfactory. Apart from wilful default on the part of fishermen borrowers, difficulty in getting fish/prawn catch statements either from borrowers or from marketing agency seemed to be the bottleneck in the recovery process. For improving the condition of the industry, a number of useful suggestions are given.

Section III deals with the fisheries socio-economics and co-operatives. Karnataka has set up successful co-operatives which have channalised loans and undertaken fish marketing. Of the 121 fisheries co-operatives, 61% were running on profit. The factors that ensure the success of co-operatives have identified as internal leadership, membership quality, logic of operation, environmental factors and Government policy. However, large scale mechanisation has resulted in uncalculated displacement of labour resulting in the deterioration of quality of life. A survey conducted on the labour conditions in the fishery factories in Dakshina Kannada has revealed that the labourers are relatively underpaid and are deprived of medical benefits at present. Fixing of minimum wages and providing compulsory medical benefits through legislation should render their jobs more attractive and secure which, in turn, would stimulate higher industrial output in this sector.

Section IV deals with the condition of different fish processing industries in Karnataka and the availability of raw materials for processing. Although shrimp forms the major item of export, export potentials of other items like seer, tuna, mackerel, sardine and pomfret needs to be examined. Presently, however even the export of frozen shrimps is no longer a profitable business and out of 63 processers who have been in business since 1960-62 only 8 have remained in the run. Excessive competition among exporters, static level of production, high cost of diesel for the boats, steady increase in cost and restriction in consumption of electricity, purchase tax on prawns, cess imposed by MPEDA, export inspection fee collected on F.O.B. value basis – all these costs are adversely affecting the viability of the industry. Production of more prawns by adopting deep sea fishing and by brackish water prawn culture and provision for providing fuel and electricity at low cost to fishermen are some of the suggestions made to solve the problem. Dried fish is another important commodity which attracts the attention of consumer especially in the case of shark, anchovies, ribbon fish and sole. However, there is an urgent need to improve the quality of dried fish. At present, canning industry in Karnataka uses only 3% of fish landed in the state and is working at 20-25% installed capacity. The situation can be improved by the introduction of new technology with diversification and intensive sales promotion. Development can also be made in fishery by-product industry by setting up gutting and filleting centres in centralised locations. Chitin and Chitosan are the two important by-products of commercial importance, that have been suggested as feasible candidates for commercial production.

Section V deals with fish handling, distribution and marketing. Although the infrastructural requirements such as landing and berthing facilities, preservation and processing facilities, fisheries link roads, transport facilities and markets have developed in Dakshina Kannada, these amenities are far from adequate in Uttara Kannada. Frozen fish is distributed through a cold chain network numbering 60 out of which 25 are owned by KFDC. KFDC has marketed fish worth about 80 lakhs internally. The existing marketing infrastructure built up by KFDC can be made use of profitably by private concerns.

Section VI deals with marine fishery development

plans. The areas identified for further development are brackish water fish culture, deep sea and off shore fisheries, diversification of fishing gears and crafts, infrastructural facilities, fisher folk welfare measures, fisheries co-operatives and fisheries legislation. There is need to introduce intermediary crafts to be operated beyond 50 m for identified resources like carangids, catfishes, pink perch, lizard fish, black rub, bulls eye and white baits. In brackish waters, prawn culture should be given priority over fish culture. Nine different centres have been identified by CMFRI as suitable for this purpose in Karnataka.

The book has been comprehensively edited by I. Karunasagar and N.V. Sripathy. The book is quite informative and will be highly useful for persons engaged in work on various aspects of marine fishing and fish processing.

S.B. WARRIER
B.A.R.C., BOMBAY

*Systems and Components for Large Heat Pumps:* Institute International DU Froid, International Institute of Regrigeration, 177, Boulevard Maloherbes, F-75017, Paris; 1985-2; pp: 317; Price: (not indicated).

The book under review "Systems and Components for Large Heat Pumps" is the Proceedings of the meetings of the Commission E 2 (covering heat pumps and energy recovery) held at the Norwegian Institute of Technology at Trondheim (Norway) during 19-21 June 1985. The papers (34) presented are divided into 7 sections, covering: (1) Systems Simulations (2) Industrial Heat Pumps (3) Absorption Heat Pump Systems (4) Heat and Mass Transfer in Absorption Systems (5) Heat Pumps in District Heating (6) Components and Control for Large Heat Pumps, and (7) Performance Operating Experience.

Heat pump as an effective energy saving apparatus has received ever-increasing attention by industrial applications. It can raise the temperature of various forms of waste heat contributing to their effective utilisation. Optimization of large heat pumps in industrial plants including the food and chemical industries has been dealt with, especially aspects of drying, distillation and evaporation. Other papers covered mathematical model, simulation aspects. Papers presented have covered various aspects of different types of heat pumps, viz. compression, absorption and storage tanks.

Energy analysis and simulation of heat pumps are presented with an emphasis on ways to improve thermodynamic efficiency. Results from computer simulation of large heat pumps with non-azeotropic mixtures as working fluids have led to optimization of multi-stage heat pump systems for achieving increase in performance.

The Industrial AHPs (Absorption Heat Pumps) have been used in sewage treatment system and biogas production. Use of geothermal Heat Pump for raising source of utilisation of geothermal energy for energy conservation, protecting from environmental pollution and modernisation of cities, etc. have been covered.

Simulation tools in relation to various aspects can enhance safe design and predictable performance of heat pumps using structured surface to enhance heat transfer in falling film flow.

Some elements of vapour compression heat pump systems are considered. Improvements are discussed with regard to compressors, heat exchangers and capacity control methods. Also, collation of data on various systems for controlling heat pumps and operating experience have been useful to investigate how various installations perform in practice. Heat pump systems for industrial applications will continue to become increasingly more economical as capital costs decrease on a leaning curve and unit cost of input energy increases.

This book will be a useful addition to any scientific and technical library.

H. KRISHNAMURTY
C.F.T.R.I., MYSORE

*Progress in the Design and Construction of Refrigeration Systems:* Institute International DU Froid, International Institute of Refrigeration, 177, Boulevard Maloherbes. F-75017, Paris; 1985-1; pp: 355; Price: (not indicated).

The book under review 'Progress in the Design and Construction of Refrigeration Systems' is the Proceedings of the meetings of the Commissions: $B_1$, $B_2$, $E_1$, and $E_2$ – Theromodynamics and Transport Processes, Refrigeration Machinery, Air-conditioning, and Heat Pumps and Energy Recovery, respectively held at Purdue University, USA, during August 5-8, 1986. This publication contains papers (34) presented within the frame-work of the IIR Commissions, and constitutes the 62nd volume in the Series "Refrigeration Science and Technology" of the International Institute of Refrigeration.

The Proceedings are published in the following Sections: (1) Expansion devices, (2) Non-azeotropic mixtures, (3) Heat-Pump Modelling and Verification,

(4) Air-conditioning, (5) Special Heat Pumps, (6) Heat Exchangers and High Temperature Heat Pumps, besides Plenary Sessions.

Research and development in the field of design and construction of refrigeration systems is receiving greater attention towards optimization of design, reduction of thermal losses, amelioration of the thermodynamic cycle of solar absorption, refrigeration system, etc.

Review of open-cycle desiccant air-conditioning concepts and systems, study on capillary tube, suction line heat exchanger for the performance to reduce energy consumption in domestic refrigeration apparatus; influence of superheat setting for an expansion valve of usual design and with integrating action using a mathematical model and use of micro-electronics for optimal performance, study on the influence of superheat on COP (co-efficient of performance) and useful experimental data on expansion device experimental system have been covered.

For possible increase in COP, low condensing pressure and good capacity control, application of non-azeotropic mixtures have also been discussed. Based on molecular behaviour, the existence of azeotropic mixtures have been explained with insight for a suitable equation of state needed to analyse the vapour compression refrigeration systems operating with a mixture of refrigerants.

Modelling and verification of a vapour compression heat pump for its energestical efficiency with a technical and economic aspects, the process of selecting and prioritizing potential control scenarios made easier for understanding of heat pump dynamics gained through modelling exercises; analysis of heat pump system using gas engine; simple transient model to predict dynamic behaviour of the vapour compression cycle during the start up have been covered.

Influence of frosting in tubes on air-flow, optimizing control of capacity-controlled heat pump air-conditioner, low investment and running cost, noise reduction, recovery of heat utilisation, have been dealt with.

Modelling and utilisation of characteristics of special heat pumps for performance, improvement of energy saving with other aspects as new defrosting systems, using water as carriers of heat from the source to the consumer and F12 as refrigerant, temperature boundary effect and utilisation of waste heat, etc. have been reviewed.

R-142b as new refrigerant for use in high temperature heat pumps as R114 has some drawbacks; R&D on high temperature heat pump and its evaluation of thermal stability costs as well as durability testing and a concise over-view of different types of absorbers in thermal adsorption cycles, augmenting of heat transfer rates, use of turbulence promoters for increase of transfer co-efficients, measurements of swirl-flow boiling inside horizontal tubes, etc. have also been covered.

This book will be a useful addition to any scientific and technical library.

H. KRISHNAMURTY
C.F.T.R.I.' MYSORE

*Food Texture-Instrumental and Sensory Measurement:* Howard R. Moskowitz, Marcel Dekker, Inc., New York and Bassel pp: 335; Price: 89.75 (US & Canada); $107.5 (All other countries) 1987.

*Food Texture-Instrumental and Sensory Measurement:* Howard R. Moskowitz, Marcel Dekker, Inc., New York and Bassel pp: × + 335; Price: 89.75 (US & Canada); $107.5 (All other countries) 1987.

The subject matter of the book under review is presented in three parts, viz., Part I: Physical measure of texture, Part II: The relationship between physical and subjective measure, and Part III: Subjective measures of texture. The three parts comprise 3, 4, and 5 chapters respectively and all the authors are acknowledged experts.

The three chapters in the first part would be of interest to those concerned with texture of food and its measurement. Of particular mention is the first chapter by Dr Micha Peleg, who has presented the topic of food rheology crisply and lucidly. The second chapter, by Dr D W Stanley, on food microstructure and texture is of particular relevance from the point of view of illustrating the utility of various measurements in understanding and interpreting an observed phenomenon. The chapter on OTMS and Ottawa Pea Tenderometer details the various steps and other inputs that have gone into the design and development of these instruments and yet how other factors may slow down their adaption by the trade.

In the second part, subjects ranging from the psychophysics of fluid texture to auditory components of crispness and crunchiness are dealt with.

And sensory texture has, in its various form and applications, been presented in the last five chapters (Part III) which also deal with methodologies for dairy products, effect of fats on food texture and its optimization through consumer evaluation.

The chapter on food psychorheology by Dr Drake is thought provoking and emphasizes the need to define the area and has its own theories.

It is also a matter of some satisfaction that approaches like multidimensional scaling, multiple regression (linear and non-linear), and response surfaces are dealt with though not in detail.

The last chapter, on optimization, and earlier chapters of the third part do create some misgivings. Hedonic tests are mainly meant for measuring the consumer (for a product) whereas in sensory analysis one analyses a product. Also, the use of a consumer panel in product development is not methodically sound and may prove disastrous. For consumer studies, it is considered safe to take only the final (one, two or three) products through simple and minimum questions, and not 26 or odd questions as given in the illustration. The final product, for consumer studies, may be selected based on the results of optimization experiments through a trained panel participation.

Now, looking at the title of the book, the presentation expected to cover (in that order): i) sensory aspects of texture as it is primarily a sensory attribute, available methods, their comparison, and purpose through illustrative examples covering various fields of food technology, ii) the instrumental methods with their role, progress made, interpretations, and future needs, again through illustrative examples, iii) inter-relationship between sensory and instrumental measures (with reasons, status, illustrations, and future needs), and finally, iv) more advanced and deserving usage of sensory methods in product development, selection of alternate raw-materials, partial replacement of ingredients, effect of processing variables, quality control and assurance. Alas! that is not the case here.

The editor has asserted and claimed in the preface that the present book is different from others on the subject and has dealt extensively with subjective aspects. The terms 'sensory and subjective' need to be differentiated. Though sensory analysis is, in a way, subjective in nature the converse may not be true, for, there are two major parts of sensory analysis, viz., analytical, and affective, and essentially subjective analysis falls under the latter. The two terms have been used interchangeably in the present volume.

The main deficiencies of the book are: i) lack of clear demarcation among the three parts, ii) not so logical an arrangement of chapters, iii) no distinction between the terms sensory and subjective, and iv) over-representation of certain type of textures and instruments.

In spite of these limitations, the book would be a desirable addition to libraries particularly those not subscribing to texture or rheology journals but it is beyond the reach of individuals.

NAGIN CHAND
C.F.T.R.I., MYSORE

## *AFST(I) News*

**Parbhani Chapter**

The Annual General Body Meeting of the Chapter was held on 5th December 1988 and the following office bearers were elected:

| | | |
|---|---|---|
| *President* | : | Dr. U.M. Ingle |
| *Vice-President* | : | Dr. D.N. Kulkarni |
| *Secretary* | : | Dr. D.K. Dev |
| *Jt. Secretary* | : | Prof. (Mrs) Vijaya Nalawade |
| *Treasurer* | : | Prof. S.D. Rathi |

First Circular

# Association of Food Scientists And Technologists (India)
## CFTRI CAMPUS, MYSORE-570 013

## NATIONAL SYMPOSIUM
**on**

**IMPACT OF POLLUTION IN AND FROM FOOD INDUSTRIES AND ITS MANAGEMENT**

**4 & 5th MAY 1989 AT CFTRI, MYSORE**

The AFST (1) has decided to conduct a National Symposium on the above subject. A large number of participants from Food and other Allied industries, research organisations, agricultural universities and government agencies are expected to attend the Symposium.

Environmental pollution is the hot news of the day. Pollution in Industries and due to Industries are causing concern in the safety and health of the public. Many environmentalists are waging a relentless war against such pollution affecting the air we breathe as well as the food and water we consume. Although information about higher pesticide residues in food, contamination from mycotoxins or salmonella, death of fish due to discharge of effluents of industry into river and sea; dust, noise and foul odours causing concern, are flashed quite often, no systematic account is available.

The aim of this Symposium is to present the correct appraisal of the situation in various food industries in different sessions for two days. Poster Sessions on the general aspects connected with Food Science and Technology will be held to make the seminar more comprehensive.

The seminar gives an opportunity for interaction amongst Food Scientists, Technologists, Food Industrialists, Exporters, Quality and Pollution Control Agencies.

AFST (1) requests your kind participation in this seminar which is of vital importance to the Food Industries.

**N.A. Pandit**
*President*

**P.L. Raina**
*Hony. Exec. Secretary*

## Dedication of Information Centre Of FOSTIS at CFTRI.

The new building of Food Science and Technology Information Service at CFTRI, Mysore, which also houses NICFOS, was dedicated to the Nation by Sri K.R. Narayanan, Union Minister of State for Science and Technology, at a function held at CFTRI, Mysore on 18th December 1988. NICFOS with active support from CSIR and DSIR under the NISSAT Programme has, over the years, developed into a full fledged information service centre to meet the information needs of users at National and International levels in Food Science, Technology, Nutrition and Allied areas through its multifaceted action programmes in Library, Documentation, Abstracting, Micrography and Reprographic Services. These include 'Food Technology Abstracts' (Monthly), 'Food Digest' (Quarterly), 'Food Patents' (Quarterly), 'Microform Information Service' (Quarterly); Bibliographies, Monographs, Directories and State-of-the-Art Reports. These are fully backed up by photocopying and micrographic services.

With the establishment of the Central Computer facility devoted for information retrieval, it is now made possible to provide personalised service to individuals or organisations based on their need-based user interest profiles. This latest service with the backing of the Data-base on Food Science and Technology covering the world literature marks a new era in the setting up of the National Information Centre for Food Science and Technology (NICFOS).


Statement about ownership and other particulars about the periodical entitled JOURNAL OF FOOD SCIENCE AND TECHNOLOGY as required to be published under Rule 8 of the Registration of Newspapers (Central) Rules 1956.

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# INSTRUCTIONS TO AUTHORS

1. Manuscripts of papers (in triplicate) should be typewritten in double space on one side of bond paper. They should be complete and in final form. The paper should not have been published or communicated for publication anywhere else. Research Notes should clearly indicate the scope of the investigation and the salient features of the results. Only *invited* review papers will be published.

2. The typescript should be arranged in the following order: Title (to be typed in capital and small letters for Research Papers and all capitals for Research Notes), Authors' names (all capitals) and Affiliation (capitals and small letters). Also give a short running title not exceeding 10 words as a footnote.

3. **Abstract:** The abstract should indicate the principal findings of the paper and typed in single space. It should not be more than 200 words and in such a form that abstracting periodicals can readily use it.

4. Use names of chemical compounds and not their formulae in the text. Methods of sampling, number of replications and relevant statistical analyses should be indicated. Footnotes especially for text should be avoided as far as possible.

5. **Tables:** Tables as well as graphs, both representing the same set of data, should be avoided. Tables should be typed on *separate* sheets. Nil results should be indicated and distinguished clearly from absence of data, which is indicated by '——' sign. Tables should not have more than *nine* columns.

6. **Illustrations:** Graphs and other line drawings should be drawn in Indian ink on tracing paper or white drawing paper preferably art paper not bigger than 20 cm (OY axis) × 16 cm (OX axis). The lettering should be twice the size of the printed letter. Photographs must be on glossy paper and must have good contrast; **three copies** should be sent.

7. **References:** Names of all the authors along with title of the paper should be cited. Abbreviations such as *et al.*, *ibid*, *idem* should be avoided. References should be serially numbered as superscripts in the order they are cited in the text and the same order should be maintained in the reference list. The titles of all scientific periodicals should be abbreviated in conformity with the World List of Scientific Periodicals, Butterworths Scientific Publication, London, 1962.

   Citation should be as follows (note the underlines also):

   (*a*) *Research Paper*: Jadhav S S and Kulkarni P R, Presser amines in foods, J Fd Sci Technol, 1981, 18, 156.

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

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

   (*d*) *Proceedings, Conferences and Symposia Papers*: Nambudiri E S and Lewis Y S, Cocoa in confectionery, Proceedings of the Symposium on the Status and Prospects of the Confectionery Industry in India, Mysore, May 1979, 27.

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

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

8. Consult the latest issue of the *Journal* for guidance. For "Additional Instructions for Reporting Results of Sensory Analysis" see **issue No. 1** of the Journal.

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## Research Papers



## Research Notes



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