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SOME ASPECTS OF PRESERVATION, PROCESSING AND EXPORT OF MANGO AND ITS PRODUCTS [1/]

by

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Several chemical methods are in vogue to stimulate ripening and surface colour development in mangoes. Ethylene and acetylene are commonly used for this purpose. Acetylene produced from calcium carbide also degreens the immature fruits effectively but the edible quality remains poor (2,9). Ethylene gas or compounds that release ethylene in-situ on the other hand, are likely to increase the susceptibility of fruits to microbial infection, more so in fruits of lower maturity, and therefore, artificial ripening should be followed with caution (15, 18). Heat treatment using hot water accelerates ripening and is safer to use (14, 16).

Physiological and Biochemical changes during ripening

The ripening process of the fruit essentially involves changes in texture leading to softening, development of colour and odoriferous constituents for consumer appeal and release of carbon dioxide, moisture and heat.

Changes in texture leading to softening is closely related with breakdown of proto-pectin into soluble pectins and conversion of starch to sugar. The other visible change is the disappearance of chlorophyll and development of carotenoids leading to eye appeal. Development of odoriferous constituents and volatile emanations are other marked changes that attract the consumer. Carotene present in the fruit seems to modify the aroma (21). Identification and characterisation of odorous ingredients in mango is in progress (22). Liberation of carbon dioxide, moisture and heat forms an index of the net metabolic activity of the fruit culminating in respiratory climacteric (13). These physiological and biochemical changes that take place during ripening of the fruit after harvest have been studied to a limited extent in this tropical fruit (23-25).

Chemical Composition

The main constituents of the fruit are water, carbohydrates, acids, proteins, fats, minerals, pigments, tannins, vitamins and ethereal substances collectively forming flavour. The fruit is a rich source of carotenoids, specially β-carotene which is precursor of vitamin A. These constituents vary from variety to variety and the unripe or ripe condition of the fruit. Chemical composition of peel, pulp, or stone also differs considerably. However, for fresh trade and processing, pulp portion is important. Peel and stone which are byproducts can be utilised as cattle feeds or for industrial purposes (7, 9-11) (Table 11).

Storage

Mangoes take about one to two weeks to attain edible ripe condition at ambient storage of 30°C ± 5; 60-85% RH. However, the storage life depends on the stage of maturity at harvest, variety and storage temperature. Fruits of lower maturity with a specific gravity less than 1.0 ripen in 3 weeks and those with a specific gravity more than 1.02 take about a week to attain edible ripe stage. Refrigerated storage conditions have been recommended from time to time for several table varieties of mangoes (26-29). Recent investigations on an intensive scale indicate that fruits stored at a temperature below 25°C do not ripen satisfactorily even though critical temperature for development of chilling injury is below 10°C (14). Several factors responsible for low temperature injury in tropical fruits have been critically examined (30). Controlled atmosphere (C.A.) storage is recommended for Keitt mangoes grown in Florida and Alphonso and Pairi grown in India (31,29). However, intensive investigation is essential before C.A. storage is recommended on a commercial scale.

Post-harvest Storage Diseases

Post-harvest decay in mangoes varies from 30-35% during transit, storage and marketing, and is mainly caused by fungi (9, 14). Stem-end Rot, Anthracnose, Tip Rot, Lateral Rot and Sooty Mould are the predominant types of fungal spoilage (7,9,14). Bacterial rots are occasionally seen in some parts of the country. Physiological diseases such as 'Soft Nose', 'Spongy Tissue and internal breakdown have been recorded in some table varieties such as Dussehri and Alphonso. However, the exact causes for these ripening disorders are not yet clearly known (32)(Table 12).

Damage due to weevil and fruit fly is sufficiently large during transit and storage. Unfavourable weather conditions and hail storm in monsoon, prior to harvest, also add considerably to the loss during transit, storage and marketing of fruits.

Packaging

Wrapping of individual fruits in tissue paper treated with BIPHENYL is useful in reducing decay and damage during transit and storage of mangoes. Tissue paper or craft paper lining between layers have also been suggested when fruits are packed in ventilated wooden boxes (9,11). Paddy straw or paper shavings are used as cushioning materials. For internal trade, baskets made of bamboo with paddy straw as cushioning material is preferred in view of the low cost of packaging (33). Fruits wrapped in tissue paper or polyethylene and packed in ventilated card-board cartons are suggested for export purposes (15,34)

Transport

Mangoes are usually transported by road or rail for internal trade. Road transport is preferred over rail in view of the reduction in time for shipme

over longer distances an efficient distribution of the produce. Air cooled ventilated wagons have also been suggested for long distance rail shipment of mangoes (33). Bulk of the raw material in the fresh form is exported to Middle East countries in cargoes at ambient temperature and a small quantity is airlifted to U.K. and European countries (1). The problems and prospects related to air-freighting of tropical fruits are reviewed (35). Refrigerated transport and cool temperature storage is not recommended at present for certain varieties cultivated in India in view of the low temperature breakdown of mangoes (36). However, trial shipment of mangoes grown in Caribbean countries to Britain and Canada by air and refrigerated cargoes has shown promise (34). Problems in long range transport of tropical fruits in the fresh form and the future scope for large scale expansion of the world trade for these exotic fruits have been discussed (37).

Marketing

Mango crop is usually sold to the pre-harvest contractors by the growers and 90% of the produce is brought to the market by the contractors. The fruits are sold from the contractors to the commission agents and wholesale merchants, who in turn, distribute the produce to the consumers through shop-keepers. However, in some places, Fruit Growers Associations play an important role for marketing mangoes. In some states of India, regulated markets also handle the produce for further distribution. Open auction, under-cover and negotiation are the common practices seen in the markets for the sale of mangoes (2,9).

PROCESSED PRODUCTS

Pickles, chutneys and preserves are traditional products made from mangoes in India since ancient times. Canning of ripe mangoes in the form of slices, pulp, started in the late thirties. Recently, a number of new products like nectar, cereal-flakes and fruit bars, have been introduced. Frozen fruit is gaining importance in some of the developed countries.

Products from Raw Mangoes

Dehydrated slices and powder: Raw mango slices of seedling varieties dried in sun are called 'Amchur' and are used as a substitute for tamarind (*Tamarindus indica* L.) in culinary preparations. In Australia, machinery has been developed for peeling of unripe mangoes (38). A product of high quality is obtained by blanching the prepared slices of unripe fruit, sulphitation and dehydration or sun-drying (39). Blanching, however, makes the product too sweet, and in the absence of sulphitation, the product becomes brown with poor keeping quality (40). The dried slices are sometimes powdered although this entails loss of vitamin C (5).

Preservation of mango slices for pickle and chutney: Raw and unripe mango slices are preserved with salt for processing and export. The method consists of addition of 15-20% salt to slices, draining the liquid formed therein, and replacing it with fresh salt. An improved method consists of maintaining slices in 10% brine containing 200 ppm of SO_2 for primary salting for 20 hours and 5% powdered salt with 200 ppm SO_2 for storage (41). Addition of black mustard powder at 0.5% level or 0.1% sodium benzoate in 20% salt solution is also suggested for storing mango slices (42). The fibrous varieties

are ideally suited for brine curing, since table or grafted varieties tend to become soft and mushy during storage. To overcome this, the slices are dried in the sun after salt curing.

Pickles

This is an important indigenous product prepared from the unripe, green mangoes. Pickles are made in almost every Indian home, and also commercially. Mango pickles are classified as salt pickle or oil pickle. They are made from peeled or unpeeled fruit, with or without stones, and with different kinds and proportions of spices. Common salt is the main ingredient. The oil used is either sesame or mustard. Mango pickle prepared from peeled mango and mustard oil is called KASSONDI. Pickles meant for export invariably contain salt, sugar, spices and vinegar. Several recipes used in India and Pakistan have been reported (43, 47).

Microbial spoilage due to moulds is common and could be effectively checked by addition of salt and spices (44). Black mustard powder at 1% level of the slices was found to be very effective in checking mould growth. Salt concentration of over 20% is recommended to prevent microbial spoilage in the product. (45). A preservative emulsion prepared from acetic acid (5 g), brown mustard powder (16 g), orange peel oil (0.2 g), turmeric powder (2.0 g), gum Acacia (8.0 g) and water (100 g) is found to be efficacious at low salt and/or acid level. It does not significantly alter the colour, taste or flavour of the product (46).

Pickles are generally packed in glass jars or sanitary cans. Salt pickles may be packed in glass jars and polyethylene containers. Both lacquered

and plain tin cans have been found to be satisfactory for pickles in oil. For bulk packing, 4 gallon tins and wooden barrels are used. Unless curing is done properly, and salt content adjusted, salt pickles may be spoiled. Heavy spoilage through bulging and bursting of cans is encountered due to yeast fermentation. This can be prevented by initially heating the pickle, cooling and packing thereafter. Heat sterilisation, however, affects the texture of pickles (44).

Mango Chutney

This is essentially a product prepared from peeled, sliced or grated, unripe or semiripe mangoes by cooking them with sugar, salt, spices and vinegar to a thick consistency. Raisins, currant and candied peel are added to the recipes. Well-known types of mango chutneys are Sweet Sliced, Major Grey, Colonel Skinner, Lucknow, Bengal, etc. A number of recipes have been suggested for both sweet and hot chutney (48).

Both brined and fresh slices are used for the preparation of this product. Chutney prepared from mature but unripe slices has good colour and full flavour. Some Indian varieties like Totapuri and Fazli are ideally suited for this purpose. Mango chutney usually contains 55-60% total soluble solids and 1.0 to 1.5% acidity as acetic acid (48).

Processing of Ripe Mangoes

Freezing Preservation: The frozen food industry has developed extensively in recent years in the advanced countries and a great deal of interest is shown on freezing preservation of mango, although the process is not used on a commercial scale. Whole mangoes packed in polyethylene bags and frozen at -30°C

are good for sucking purposes after thawing (49). Peeled mango slices are, however, preferable for freezing in moisture and vapour proof containers (50, 51).

Fruits of four important table varieties (Alphonso, Pairi, Padri and Mulgoa) are essentially used for freezing in the form of slices. Ripe fruits are hand peeled, cut into slices, treated in brine and ascorbic acid solution to prevent discolouration and packed in cans with sugar syrup (40-50%), and citric and ascorbic acid are added. The canned slices are frozen at -30°C. When stored at -17.8°C, frozen slices retain natural colour, flavour, taste and texture even after 12 months (52).

Air-blast freezing and contact plate freezing at -40°C to -45.6°C have been suggested for obtaining finished products of better quality (38). Frozen mango puree from pulp of Alphonso and Pairi with added sugar at 20% level remains in good condition even after 12 months of storage at -17.8°C. Addition of citric acid and ascorbic acid helps in the retention of colour and flavour.

Unripe seedling mangoes peeled and grated, with addition of salt (50:1 ratio by weight) could also be frozen and preserved at -17.8°C. They could be used successfully for preparation of chutney of good quality (52).

Mango Slices in Syrup: Mangoes are generally canned as slices, cheeks, quarters or shoulders and to a limited extent, as cubes or dices. Of the several commercial varieties grown in India, 'Alphonso' is best suited for canning (53). Other varieties such as Dusehri, Banganapalli, Totapuri and Fazli give canned products of mild flavour and pale colour. Since

canning varieties are not fibrous, only firm and ripe fruits have to be used to prevent mushiness of the slices. Calcium treatment before canning proved effective only for retaining the firm texture of Totapuri slices. In Alphonso and Pairi varieties, calcium treatment proved ineffective and also adversely affected the flavour during storage (54).

Steps involved in the canning of the fruit (Alphonso) such as peeling and slicing, are done by hand using different kinds of knives. (Flow Sheet 1, Plates, 11, 12). Mechanised equipment for peeling of ripe mangoes have not been fabricated to the satisfaction and is a serious bottleneck in this industry. Chemical peeling by dipping in a hot lye (NaOH) solution or Na_2CO_3 at 80°C. has been suggested for certain varieties of mangoes (55), but has not been commercially adopted. The prepared slices are covered with hot syrup (30-50°Brix), sealed and processed. Since the fruit has a pH of 4.0 - 4.5, citric acid is added at 0.25 - 0.40% level to the covering syrup. The cans are processed at 100°C for 15 minutes for A 2½ cans (53). Spin-pasteurisation is preferred in the place of stationary retort pasteurisation. The canned product has a shelf-life of over 12 months at ambient temperature. Canned slices of Alphonso and Pairi varieties showed almost no loss of β -carotene after storage for 8 months at 25-30°C. (56).

In some factories, slices are scooped with a curved knife from unpeeled cheeks cut from the fruit to give a smooth surface. The stone and peels are passed through a pulper to get the pulp. In this process, the yield of slices is reduced slightly but pulp yield is higher. Overall yield of prepared fruit is 5-10% higher than by conventional process. The advantage in this method is ease of handling of unpeeled fruit.

Mango Pulp: With the development of ready-to-serve beverage industry, there is an increasing demand for mango pulp which is canned commercially in A-10 packs. Even while canning mango pulp, 0.25 - 0.35% citric acid is added to lower the pH, heated to 85°C, filled hot into cans, sealed and processed at 100°C for 20 minutes (for A 2½ cans) and cooled. Addition of ascorbic acid at 100 mg % in the canning of mango pulp helps in the retention of colour, flavour and carotene (5%).

Mango pulp used in the preparation of jams and squashes, may be preserved in barrels by using SO_2 as a preservative. For this purpose, 0.5 - 1.0% citric acid is added to the pulp, heated to boiling, cooled, SO_2 added at the rate of 1000-1500 ppm, filled into waxed wooden barrels and stored for subsequent use.

Mango Beverages: Mango juice, nectar and squash are the three important beverages prepared on a commercial scale.

As the mango pulp is very viscous, juice is prepared by adding almost equal quantity of water and adjusting the total soluble solids and acidity to taste (12-15% TSS and 0.4 - 0.5% acidity). Mango nectar, another popular product, contains 20% pulp with sugar and acidity properly adjusted to give 15°B and 0.3% acidity as citric acid. These beverages are generally packed in cans. They are heated to about 85°C in heat exchanger, filled hot into cans, sealed, processed and cooled. Mango nectar packed in E-100 tin container shows higher tin pick-up on storage as compared to corresponding pulp. Addition of 0.2% carboxymethyl cellulose (CMC) or 0.2% of gelatin retards tin pick-up to some extent (58). In recent years, bottled beverage (mango based beverage contains 10-15% pulp) has become popular in big cities.

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Mango squash is manufactured to a limited extent. This generally contains 25% juice, 45% TSS and 1.2 to 1.5% acidity and is preserved with SO_2 (350 ppm) or sodium benzoate (1000 ppm).

Mango "leather"

The pulp of the sour and seedling varieties is traditionally dried in the sun on an extensive scale for use as a flavouring ingredient in Indian food preparations. Production figures are not available. The Central Food Technological Research Institute (CFTRI) has worked out conditions for the hygienic drying of the ripe mango pulp in the form of bars for direct consumption. Fruit bars consisting of mango and other fruit pulps have also been developed.

Mango Cereal Flakes, Vermicelli and Powder: A process for the preparation of mango cereal flakes (= fruited cereal) has been developed at CFTRI, Mysore. It consists in adjusting the pH of the pulp to around 5.4 by neutralising part of the acidity with sodium bicarbonate; mixing with precooked wheat flour and sugar; and drying in a double drum drier at 2-3 rpm and steam pressure of 60-65 psig. The dried product is highly hygroscopic and needs moisture-proof packing. The finished product is golden yellow in colour and has the characteristic taste and aroma of the fruit. Various blends have been examined to get the desired end product of acceptable nature (Flow sheet 2) (Table 13).

Mango cereal vermicelli and powder have been prepared by adding cooked wheat flour to obtain a dough of suitable consistency for extrusion through vermicelli press or drying as such by spreading on trays. Drying is done in a hot air cabinet drier (59-63).

Strained baby foods and custards: Strained pulps of apricot, apple, peach and pear, are canned commercially in Europe and U.S.A. for use as baby foods. Strained pulps and custards using mango have been prepared and examined for their suitability and acceptance. The pulp is passed through a 60 mesh sieve to remove the fibre. Sugar is added to this pulp to get the desired blend, the mixture is then homogenised and then canned in AR lacquered cans.

In the preparation of fruit custard, acidity of the pulp is partially neutralised to adjust the pH to 5.3 - 5.6, sugar, skimmed milk powder and precooked starch added, homogenized and canned or drum dried as in the case of mango cereal flakes. The dried product is powdered and packed in laminated flexible packaging material, in bottles or cans. The finished product is hygroscopic and should preferably be packed with an in-package dessicant. Packing in tins under nitrogen and storage at 5°C is also recommended (Flow sheet 3). These products are highly nutritious (64-67).

Mango powder: Production of fruit juice powders has assumed great dimensions in recent years particularly in U.S.A. because of several advantages and a number of patents have been granted for these products. Mango pulp or juice after concentration, is mixed with powdered sugar and dried in a vacuum shelf drier.

Dehydrated mango pulp: Mango pulp is successfully dehydrated in a double drum drier in 6-8 seconds at 141°C yielding a product of golden yellow colour with original flavour, but highly hygroscopic in nature. Different varieties have been examined and their nutritive value studied in detail. In a patented process, cabinet drier at 60-63°C has been used for dehydrating mango pulp (68).

Mango pulp can be dried in a double drum drier at 65 psig. The drum dried product is thin and papery, highly hygroscopic and cannot be powdered. Spray drying of mango pulp has not been successful on account of thermo-plastic nature of the material.

Foam mat dried products. Mango pulp to be dried by foam mat process is mixed with equal quantity of sugar and glyceromonostearate (GMS) at 1% level and whipped in a suitable mixer to produce a stable low density foam. The foam is extruded in the form of strips on the sieves and dried in a hot air drier at 70°C with cross flow drying technique. The product is dried in 45-60 minutes to a moisture level of about 2%. The product is yellowish in colour and reconstitutes instantly but the flavour is slightly affected. Work is in progress to improve the flavour. The resultant product is hygroscopic and requires moisture proof packing. The mango powder is also prepared by puff drying in a vacuum drier or by foam mat drying in a hot air drier at atmospheric pressure. Freeze drying may also be used. This product can be used as a good adjunct in the ice-cream industry

Other products: Mango jam either alone or along with other fruits is prepared commercially. Pectin has to be added to get a good set. Non-fibrous varieties with compact texture, otherwise not suitable for table purposes, canning, pulp or beverages are utilised for preparation of preserves and crystallised fruit at a slightly under-ripe stage. Methods have been standardised for these products. The other products of importance from mango are cheese, butter and ice-cream.

Utilisation of mango waste: Seeds (stones) and peels are the important wastes which constitute 35-55% of ripe as well as unripe mangoes.

Mango kernel flour is potentially a rich source of good quality starch and also contains proteins of high biological value (Table 14). It can be used for edible purposes as well as animal feed. The seed kernels are comparable to most of the cereals, particularly in respect of carbohydrates, fat, protein, minerals, calcium and phosphorus and defatted kernel can be utilised in the preparation of chapaties, etc., by replacing wheat flour to the extent of about 10%. It has not, however, been a commercial success yet in India because of the problems in the collection of raw material. The possibility of utilising peels needs to be explored (69, 70).

III. FUTURE LINES OF WORK

There is need to develop suitable varieties intended for trade in fresh form to meet the export requirements. Similarly, varieties have to be screened among the existing cultivars particularly for canning and freezing. The desired variety should possess qualities such as high flesh yield, small and thin stone, good colour and should also be non-fibrous with compact and firm texture.

Maturity standards for harvest which can be applied in the field conditions and methods of grading the fruit, need to be investigated on all important varieties for inland and export trade. Conditions for packing, transit, storage, ripening and freezing need to be standardized for all the important cultivars meant for export as well as internal trade. Very little is known about the post-harvest physiology and biochemistry of the mango fruit especially regarding its flavour development; intensive research is essential in this field.

Suitable machinery for mechanical peeling and handling of ripe mangoes for processing calls for immediate attention of Food Machinery Manufacturers. A machine developed in Australia for peeling green and firm mangoes can be used with advantage in the chutney industry.

Newly developed products such as mango cereal flakes, powders, strained baby foods, ready-to-serve beverages and foam mat dried products have opened a new avenue for economic utilisation of pulp, a by-product in the canning industry, as well as surplus fruits available in the fresh market. Drum driers of proper size have to be designed and fabricated for large scale production of fruited cereals. Utilisation of waste products, i.e. peel and mango kernel, deserves special attention in order to economise the cost of processing operations and also reduce the cost of the primary finished products.

Long distance transport by air and sea cargo for the fresh fruit and processed products needs to be given a serious thought. The success of International trade is essentially dependent on marketing research to fulfil the consumers' exact requirements and to this effect an organised integrated approach is essential.

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TABLE 1

Estimated World Production and Export of Fresh Mangoes

Country	Production (Quantity: Tonnes)	Export	Importing countries
India	7,000,000	1,486	Middle East, U.K. Europe
Pakistan	1,000,000	-	-
Africa other than South Africa	154,000	-	-
Philippines	151,500	5,245	Hong Kong
U.A.R.	88,000	-	-
Thailand		2,246	Singapore and Malaysia
South Africa			
Brazil			
Mexico	626,500		
Cuba			
U.S.A. (Florida)			
Caribbean region			
Ceylon			
TOTAL:	9,000,000	10,000	

SOURCE: 1. "Survey of India's Export Potential of Fresh and Processed Fruits and Vegetables", 1968, 18, Indian Institute of Foreign Trade, Min. of Comm. Govt. of India, New Delhi.

2. Personal Communication (1970), Development Commissioner (Hort.), Min. of Food & Agri., Govt. of India.

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TABLE 2

Production of Mango and Processed Mango Products in India

Fruit/Products	1969 (Est)	
	Quantity (Tonnes)	Value (Rs. 000)
Mango, fresh	7,000,000	-
Mango - Canned	654	22,85
" Dehydrated	7	79
" Jams	144	6,60
" Jellies	6	56
" Juice	6,498	1,42,77
" Pulp	994	34,48
" Preserves	22	65
" Squashes	170	6,79
" Syrups	1	6
" Nectars	188	6,45
" Ready to serve Beverages	1,654	55,77
" Chutneys	1,088	41,28
" Pickles	2,949	86,59
" Slices in brine	1,599	22,51
TOTAL :	16,149	5,74,73

SOURCE: Reports, 1969, Directorate of Marketing and Inspection, Ministry of Food & Agric., Govt. of India, Nagpur, India.

TABLE 5

Export of Fresh and Processed Mangoes (Quantity: Tonnes; Value Rs. 000)

Fruit/Product	1965-66 (Actuals)		1966-67 (Actuals)		1967-68 (Actuals)		1968-69 (Actuals)		1969-70 (Actuals)		1970-71 (Estimated		1965-76 (Estimated	
	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value
Mango, fresh	636	855	910	1125	16.2	1516	1204	2457	1400	2834	5000	5900	10000	13000
Mango slices in syrup	89	251	181	506	151	366	189	638	292	996	500	1500	8000	17000
Mango juice/ Nectar/Pulp	1357	1977	2010	4792	3558	7955	2920	7597	7620	14946	8000	16000	20000	40000
Mango Pulp		(Included in Juice/Nectar till 70)									500	900	3000	9000
Mango Jams	164	333	81	178	76	280	100	341	575	1010	180	450	600	1800
Mango pickles and chutneys	1882	5145	1709	4287	1589	4087	1950	5065	1968	8925	2000	8000	3000	7500
Mango slices in brine/ dried	548	615	275	615	149	249	192	411	985	1781	1000	1500	2000	3000
Total:	4576	9170	4984	11474	6178	14953	6555	16975	12756	27600	15150	29250	48600	91300

SOURCE: 1. Indian Institute of Foreign Trade; Export Potential of Fresh and Processed Fruits and Vegetables, 1969 - Annex I, A and C.
2. Monthly statistics of the foreign trade of India, Vol. I (Exports and Reexports), 1968, Dept. of Commer. Intell. and Stati., Calcutta, Govt. of India.
3. Personal Communication (1970), Development Commissioner (Hort.), Min. of Food & Agri., Govt. of India.

TABLE 4

Commercial Varieties of Mangoes Cultivated in India
(Physical characters of ripe fruits)

Varieties	Surface colour	Specific gravity	Weight in gr.	Pulp per cent	Peel per cent	Stone per cent
Alphonso	Yellow	1.02	275	70	15	15
Baneshan	Yellow	1.05	400	67	15	18
Pairi	Greenish Yellow	1.02	275	65	18	17
Totapuri	Yellowish pink	1.05	400	78	15	7
Neelum	Yellow	1.05	275	77	15	8
Malgoa	Greenish yellow	1.05	500	74	16	10
Rasalri	Yellow	1.02	250	67	15	18
Fazli	Yellow	1.05	500	65	15	20
Langra	Greenish yellow	1.05	500	65	17	18
Chausa	Greenish yellow	1.02	275	65	15	20

SOURCE: Annual Reports, 1952-1970, CFTRI, Mysore-2A, India.

TABLE 5

Maturity Standards for Harvest - Alphonso and Pairi mangoes

Physical and chemical factors	Group A	Group B	Group C	Group D
Weight	> 320 g (Over mature)	300 g ± 20 g (Physiologically immature)	250 g ± 20 g (Physiologically immature)	< 225 g (Physiologically immature)
Specific gravity	> 1.02	1.01 to 1.02	1.0 to 1.01	< 1
Total soluble solids %	> 10	8 ± 1	7 ± 1	< 6
Acidity % (Malic acid)	< 3.2	3.5 ± 0.2	3.9 ± 0.2	> 4.1
Flesh colour as total carotenoids µg %	> 800	600-800	400-600	< 400
Alcohol insoluble residue %	> 12.5	11.5-12.5	10.5-11.5	< 10.5

SOURCE: 1. Annual Reports, 1968-70, CFTRI, Mysore-2A, India.

2. Subrahmanyam, K., Narayana Moorthy, N.V., Lakshminarayana, S and Shantha Krishnamurthy, Int. Symp. Mango and Mango Culture, 1969, New Delhi, India.

TABLE 6

Specific Gravity Grading and its Relation to Storage qualities of Alphonso and Pairi Mangoes

Specific gravity	< 1.0	1.0 - 1.02	> 1.02
Storage life in days at 30 ± 2°C	16-20	12-16	8-10
Decay in per cent	30-50	10-15	10-15
Fruit quality	Poor	Good	Very Good
Suitability for export	Not suitable	Suitable	Not suitable

SOURCE: Subramanyam, H., et al., 1971 (Unpublished data)

TABLE 7

Effect of Hot Water Treatment on the Incidence of Fungal Spoilage and Ripening Behaviour in Mangoes During Storage at Ambient Temperature (30-32°C; 45-65% RH)

Treatment	Laboratory trials			Semi-large scale trials (Alphonso) 2.5 tonnes						Commercial trials (Alphonso) 100 tonnes
	Cumulative percentage									
	Fungal spoilage			Ripe	Spoilage	Ripe	Spoilage	Ripe	Spoilage	Fungal spoilage
	Alphonso*	Neelum*	Pairi*							
DAYS AFTER	15	12	15	9		12		17		1
Control	50.6	100.0	55.0	5.6	2.1	40.1	12.2	64.2	17.4	55.6
Hot water treatment (52 ± 1°C for 5 mins.)	12.5	89.0	15.0	7.2	0.9	45.2	4.6	77.7	4.8	8.7

* Fruits were treated within a day after harvest

@ Treatment delayed by 8 days.

SOURCE: 1. Subramanyam, H., Narayana Moorthy, M.V., Lakshminarayana, S. and Shantha Krishnamurthy. Int. Symp. Mango and Mango Culture, 1969, New Delhi, India.

TABLE 8

Post-harvest Treatments with Fungicides and Antibiotics to Reduce Decay in Mangoes (Alphonso, Pad'i)

Fungicides/Antibiotics	Method of treatment	Effective concentration per cent	10 days ambient storage decay per cent	F.D.A. Tolerance level ppm.	[illegible]
[illegible]midazole (Thiabendazole) (TBZ) 2-(4-Thiazolyl)benzimidazole)	AQUEOUS DIP hot/cold	0.05-0.10	3-5	5	-
[illegible]ncoyl (Benlate) [illegible]thyl 1-(butylcarbamoyl)- 2 benzimidazole carbamate)	"	0.05-0.10	3-5	5	-
[illegible]ptan N-Trichloromethylmercapto-4- cyclohexene-1,2-dicarboximide)	"	0.25-0.50	7-10	50	<-3
[illegible]hiram Tetramethylthiuram disulphide)	"	0.25-0.50	5-7	7	2-3
[illegible]neb Zinc-ethylenebisdithiocarbamate)	"	0.25-0.50	[illegible]	7	2-3
[illegible]lisan 2,6-dichloro-4-nitroaniline)	"	0.25-0.50	[illegible]	10-20	-
[illegible]rocfungin Heptaene antibiotic)	"	0.05-0.10	[illegible]	-	-
[illegible]reptocycline	"	0.05-0.10	5-10	-	-
[illegible]treated	"	-	[illegible]	-	-

SOURCE: Annual Reports, 1968-70, CFTRI, Mysore-2A, India.

TABLE 9

Effect of Succinic Acid 2,2-Dimethyl Hydrazide (ALAR) on Carotene Development in Alphonso Mangoes after 15 days

Treatment	Carotenoids (µg/100 g)	
	Total	β-carotene
Control	10,985	5.088
a) Cold water; 25°C for 5 min.	10,648	4,627
b) Hot water; 55 ± 1°C for 5 min.	11,355	5,252
c) Cold water; 25°C + Alar-85 (2500 ppm)	10,419	5,075
d) Hot water; 55 ± 1°C + Alar-85 (2500 ppm)	13,510	7,219

SOURCE: Subramanyam, H. and Sebastian, K., Horticulture, 1970, 5(5), 160.

TABLE 10

Effect of 2-chloroethylphosphonic acid (ETHREL) on carotene development in mangoes

Treatment	Alphonso		Pairi		Bulga	
	Carotenoid (µg/100 g)					
	Total	β-carotene	Total	β-carotene	Total	β-carotene
	10th day					
Untreated	13541	8528	4087	1093	8102	[illegible]
Hot water; 55 ± 1° C for 5 min.	14015	8857	6705	1555	8832	[illegible]
Hot water; 55° ± 1° C + Ethrel (500 ppm)	16955	10890	7825	2435	6365	[illegible]

SOURCE: Subramanyam, H., HortScience, 1971 (In press)

TABLE 11

Chemical Composition of Ripe Mangoes

Variety	Per cent fresh weight (pulp)									
	Moisture	Total soluble solids	pH	Acidity as malic acid	Alcohol insoluble residue	Total sugars	Reducing sugars	Vit. C mg.	Carotenoids /u gr.	
									Total	/3-caretene
Alphonso	78-82	17-20	4.1-4.9	0.14-0.64	1.0-2.5	10.5-18.5	2.5-4.0	50-85	8000-17000	4000-12000
Banesban	84-86	14-19	4.0-4.8	0.15-0.30	1.5-2.2	10.5-15.5	4.5-7.0	25-35	3500 -7500	1500 - 4000
Pairi	83-88	14-16	4.1-5.0	0.10-0.34	1.0-3.0	11.8-15.6	2.5-5.2	10-25	3500-8400	1000-2500
Totapuri	85-85	14-16	4.0-4.2	0.20-0.45	1.0-2.5	11.2-15.4	4.0-5.8	10-20	3000-5500	1800-2500
Neelum	81-85	16-18	4.0-4.2	0.15-0.30	1.0-2.2	11.4-15.5	5.0-7.0	10-25	3500-5400	2000-3500
Mulgoa	80-83	14-20	4.2-5.0	0.10-0.25	2.0-3.5	15.0-16.5	3.2-4.0	20-30	1500-3500	800-2000
Dasehri	76-80	18-22	4.4-5.0	0.20-0.30	1.5-2.2	13.5-16.0	2.5-4.0	25-50	3500-5500	2500-3500
Fazli	78-82	18-20	4.2-4.8	0.10-0.20	1.2-2.0	12.4-15.5	5.0-7.5	95-100	3000-600	1500-3000
Langra	80-84	18-22	4.2-4.8	0.20-0.35	1.4-2.2	12.1-14.0	2.4-3.5	100-175	5000-8000	2400-5000
Chowsa	82-86	18-24	4.0-4.6	0.20-0.35	1.4-2.4	16.0-18.0	2.0-3.0	30-60	3000-8000	1200-3000

SOURCE: Annual Reports, 1952-1970, CFTRI, Mysore-2A, India.

1. SOME ASPECTS OF PRESERVATION, PROCESSING AND EXPORT OF MANGO AND ITS PRODUCTS

World Production

Mango is the king among tropical fruits and is greatly relished for its succulence, exotic flavour and delicious taste in most countries of the world. The world's estimated annual production of mango is about 9 million tonnes of which India accounts for 7.0 million tonnes (1) (Table 1). India is also the largest producer of choice table varieties of mango with an estimated production of 2.5 million tonnes of grafted cultivars; rest of the production (4.5 million tonnes) consists of seedling varieties (2).

Export Market and International Trade

The export of fresh mango which was barely 636 tonnes in 1965 (valued at Rs. 0.85 million) has increased to 1488 tonnes in 1969-70 (valued at Rs. 3 million). The targets set for 1975-76 are 10,000 tonnes. The total foreign exchange earned from exports of fresh mango and its processed products has increased 3-fold in the last 5 years due to the popularity of this fruit in gulf countries, U.K. and some parts of Europe (Fig.1). Trade of fresh mango in Europe is about 300 tonnes for EEC (European Economic Community) whereas for the EFTA (European Free Trade Association) the total is estimated at about 400-500 tonnes. For other countries of Western Europe, except Spain, which is a producing country, the imported tonnage is not more than 50 tonnes (3).

NOTE: The figures given in brackets refer to the References (see page 22).
For Tables, see page 26.
For Figure 1 and Plates, please see page 43.

TABLE 12

Storage Diseases of Mangoes

Types of spoilage	Decay percentage	Organisms or causes responsible for decay
Stem-end rot	15-20	Diplodia natalensis Pole-Evans
Anthracnose	10-15	Colletotrichum gloeosporioides Penz.
Lateral rot	3-5	Aspergillus niger. van. Teigh, Rhizopus sp.
Tip rot	1-2	Aspergillus sp.
Sooty mould	50-60 in coastal areas	Meliola mangiferae. Earle.
Soft rot	3-5	Erwinia Carotovorus. Patel.
Black spot	3-5	Xanthomonas mangiferae indicae Patel.
Spongy tissue	35-55 (in Alphonso)	Physiological; causes not known
Black tip	10-15	Physiological, Brick kiln contamination
Soft nose	10-15	Calcium deficiency.

SOURCE: 1. Singh, L.B., 'The Mango', 1960, World Crop Books, Leonard Hill (Books) Limited, Interscience Pub., Inc., New York
2. Annual Reports, 1968-70, CFTRI, Mysore-2A, India.

TABLE 15

Composition and Quality of Cereal Flakes Prepared from Different Varieties of Mango

	Variety	Moisture %	Carotene µg/100 g	Colour	Flavour
1.	Alphonso	1.59	9,488	Bright orange	Strong mango
2.	Pairi	1.48	6,512	Slight dull yellow	Mild flavour
3.	Totapuri	1.99	5,805	Very dull yellow	Very mild flavour
4.	Neelum	2.72	5,890	Orange yellow	Slightly milder
5.	Padri	2.28	7,962	Bright orange yellow	Slightly marked
6.	Alphonso: Pairi (2:1)	2.02	8,048	Orange yellow	Marked flavour
7.	Safeda (Malihabad)	2.47	4,000	Orange yellow	Mild flavour
8.	Safeda (Lucknow)	2.52	2,572	Dull yellow	Very mild flavour
9.	Dasehri	2.04	4,969	Orange yellow	Marked mango flavour
10.	Safeda (Lucknow): Dasehri (2:1)	2.09	2,899	Orange yellow	Marked mango flavour

SOURCE: Girdhari Lal, Krishnamurthy, G.V., Jain, M.L. and Bhatia, B.S., Food Sci., 1960, 9, 121.

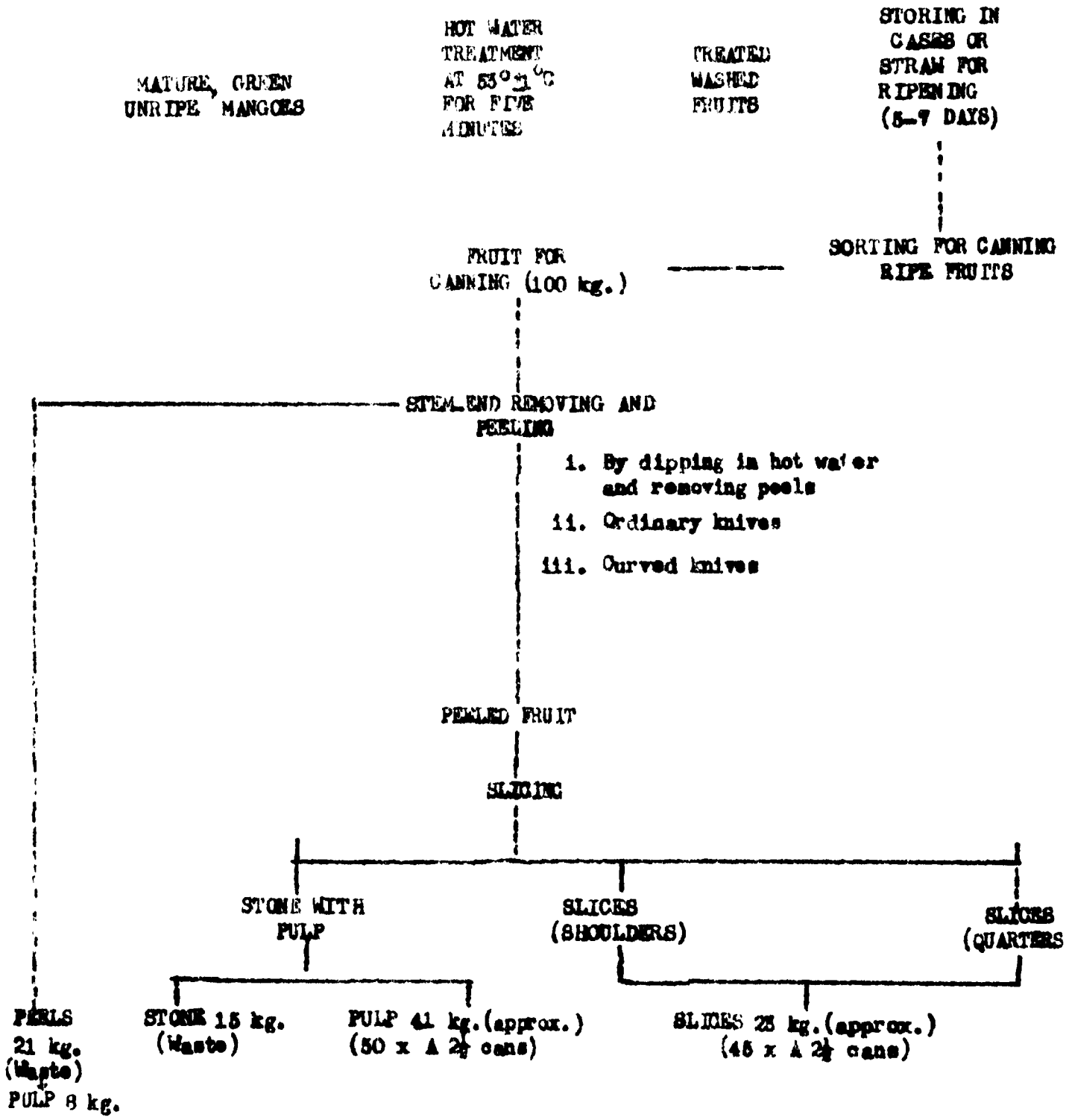
TABLE 14

Chemical Composition of Mango Seed Kernels

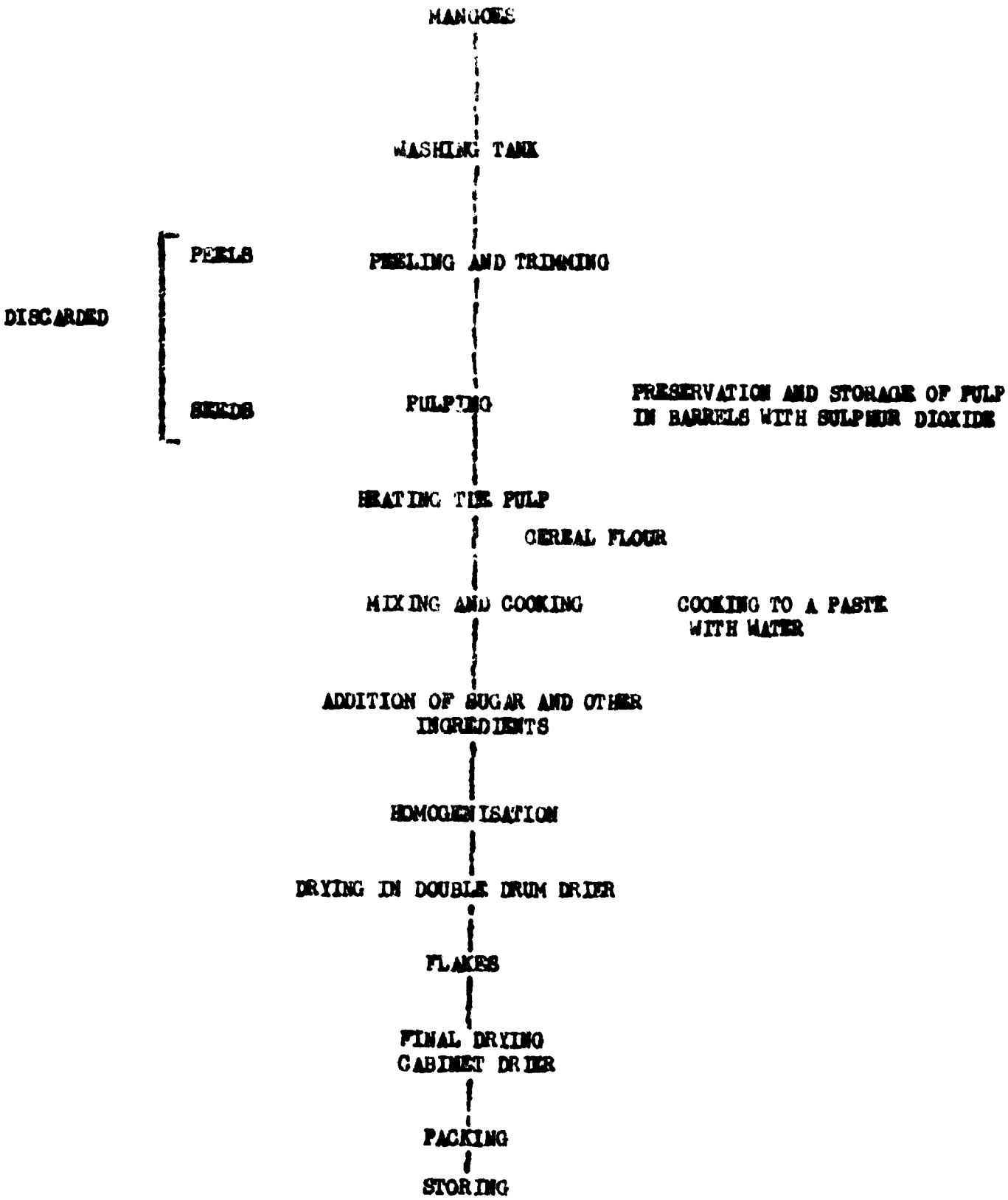
Physico-chemical characteristics (per cent, dry weight)	Alphonso	Pairi
Moisture	3.58	4.12
Ether extract	10.88	12.77
Crude fibre	1.08	0.88
Protein (N x 6.25)	5.87	4.84
Sugars : a) Reducing	2.87	2.88
b) Non-reducing	4.84	4.61
c) Total (as invert)	7.96	7.74
Starch	57.84	55.62
Pectin (as Ca pectate)	0.85	0.52
Total carbohydrate	66.60	65.88
Total tannins	10.61	11.00
Total ash (minerals)	1.90	2.09
Ash insoluble in HCl	0.05	0.02
Calcium (Ca)	0.11	0.09
Phosphorus (P)	0.25	0.22
Calorific value	420	420

SOURCE: Pruthi, J.S. and Sankaran, R. Fd. Hort. J., 1963, 5

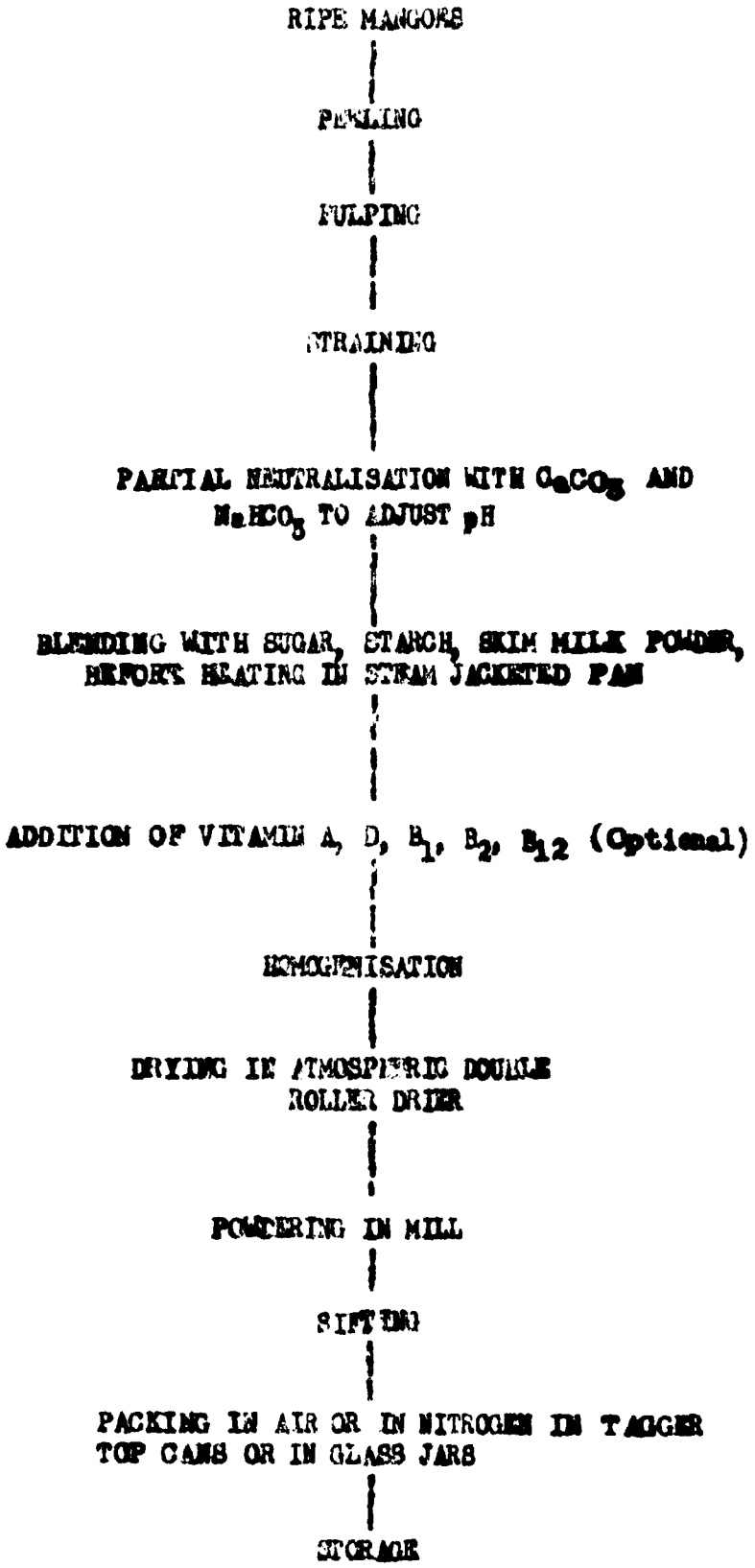
1. FLOWSHEET FOR CANNING OF ALPHONSO MANGOES



2. FLOWSHEET FOR THE PREPARATION OF MANGO CEREAL FLAKES



3. FLOWSHEET FOR THE PREPARATION OF DRIED MANGO CUSTA



KEY TO FIGURE AND PLATES

FIG. 1 - EXPORT OF MANGO AND ITS PRODUCTS FROM INDIA

PLATE 1 - LARGE MANGO TREE; GRAFTED, PAIRI CULTIVAR

PLATE 2 - MANGO TREE IN BEARING - TOTAPURI CULTIVAR

PLATE 3 - TOTAPURI FRUITS IN A BUNCH

PLATE 4 - NEELUM FRUITS

PLATE 5 - TOTAPURI FRUITS

PLATE 6 - BANESHAN FRUITS

PLATE 7 - SOME COMMERCIAL VARIETIES OF SOUTH INDIA

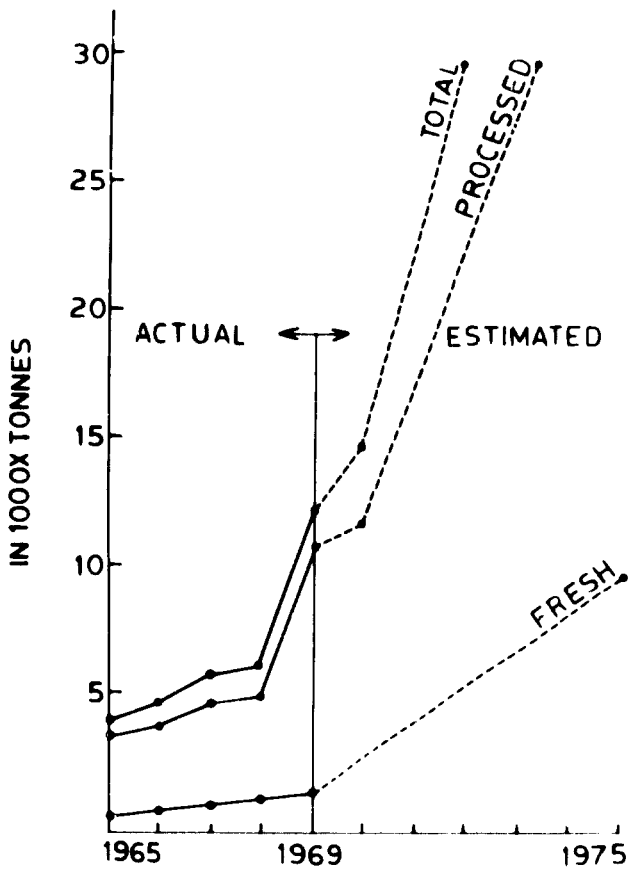
PLATE 8 - HARVESTING MANGOES WITH A BAMBOO POLE

PLATE 9 - RECEIVING OF FRUITS TO THE GROUND

PLATE 10 - RIPENING OF FRUITS IN PADDY STRAW

PLATE 11 - PEELING OF RIPE FRUITS FOR CANNING

PLATE 12 - SLICING OF RIPE FRUITS FOR CANNING



EXPORT OF MANGO AND ITS PRODUCTS FROM INDIA

FIGURE 1

PLATE 1

PLATE 2

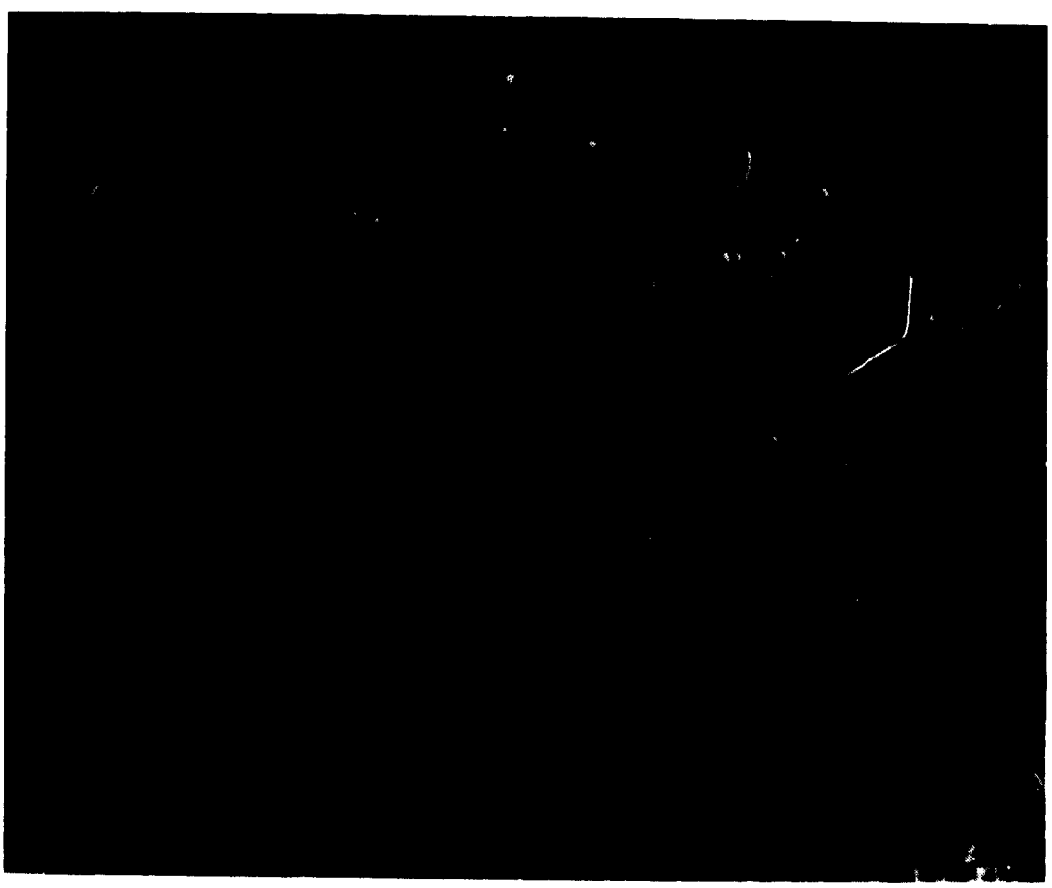


PLATE 3

Philippines and Thailand are the largest exporters of fresh mangoes and India takes the next place. About 80% of India's exports are absorbed by Kuwait, Bahrain and Trucial Oman States. U.K. and France are the leading consumers of fresh mangoes in Europe (1). However, exports of fresh mango constitute only a very small fraction of the production and concerted efforts have to be made if the targets for 1975-76 have to be fulfilled. It is particularly important to take precautions to attain the high standards of quality and appeal needed for sophisticated export markets.

The world production of processed mango products, is estimated at about 20,000 tonnes, of which India's share during 1969-70 was 16,000 tonnes valued at Rs.37.5 million (4) (Table 2). International trade in processed mango products is dominated by India. Total Indian exports of mango products during 1969-70 were about 11,000 tonnes valued at Rs.24.5 million (5,6) (Table 3). Other exporting countries are Philippines and U.A.R. accounting for about 1,700 tonnes (1).

Origin and History

Mango (*Mangifera indica* L.) is a native of India and extends through Burma into the Malayan region. Wild mango trees belonging to *Mangifera indica* L. as well as *Mangifera sylvatica* Roxb. have been recorded from this region. Indian mango exclusively belongs to *Mangifera indica* L. (Plate 1,2). Other species have contributed several cultivated varieties in South East Asian countries (7-10).

Growth and Development

Flowering season for mangoes extends from December to March which are the cooler months of the year in India. Fruiting normally begins in 8-10 years

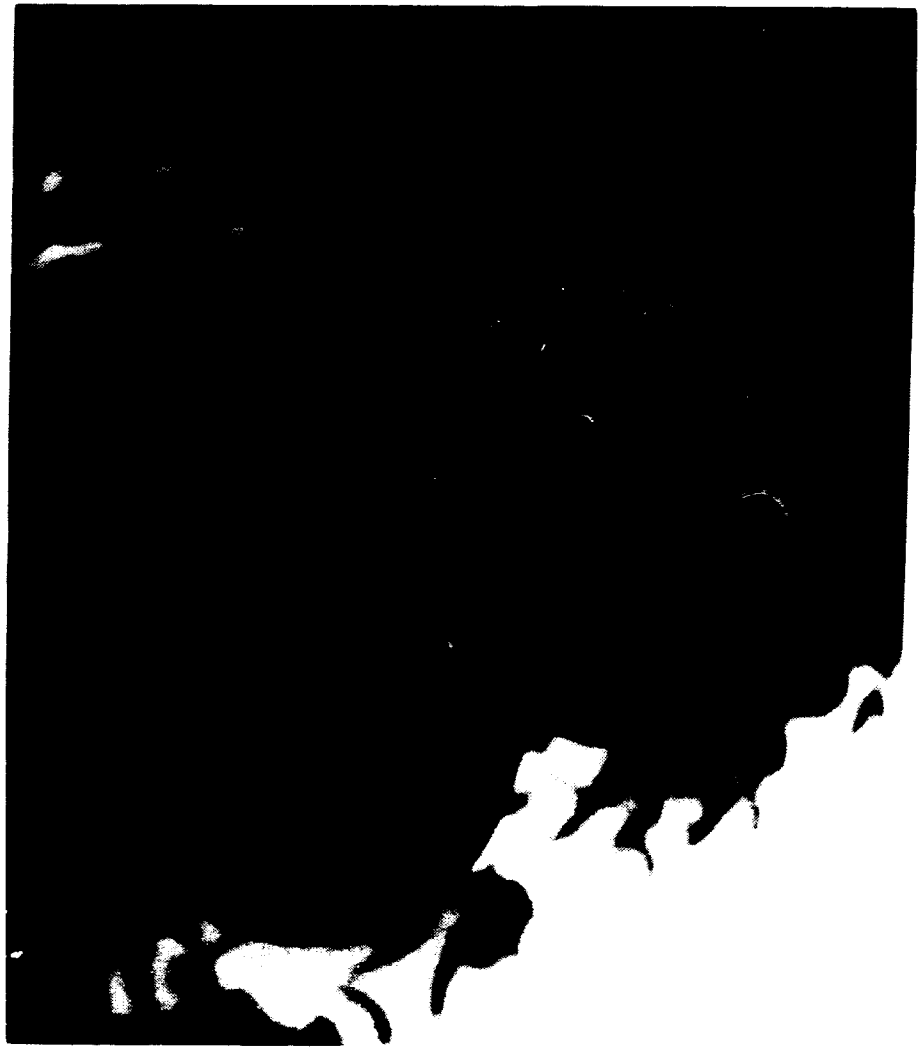


PLATE 4

PLATE 5

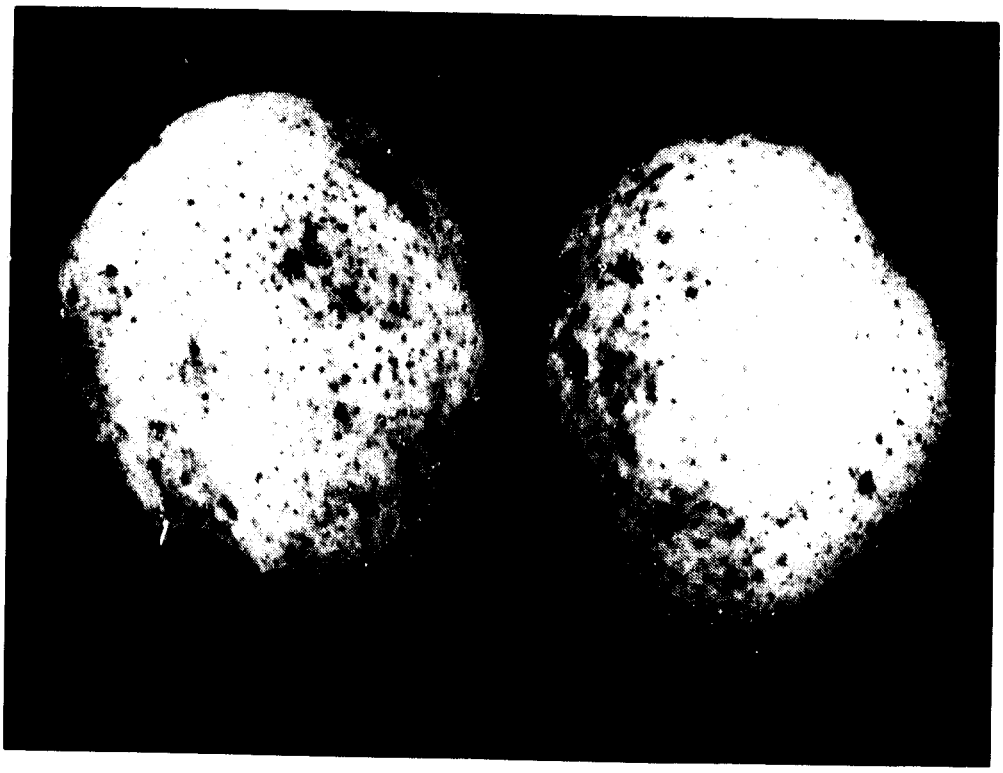


PLATE 6

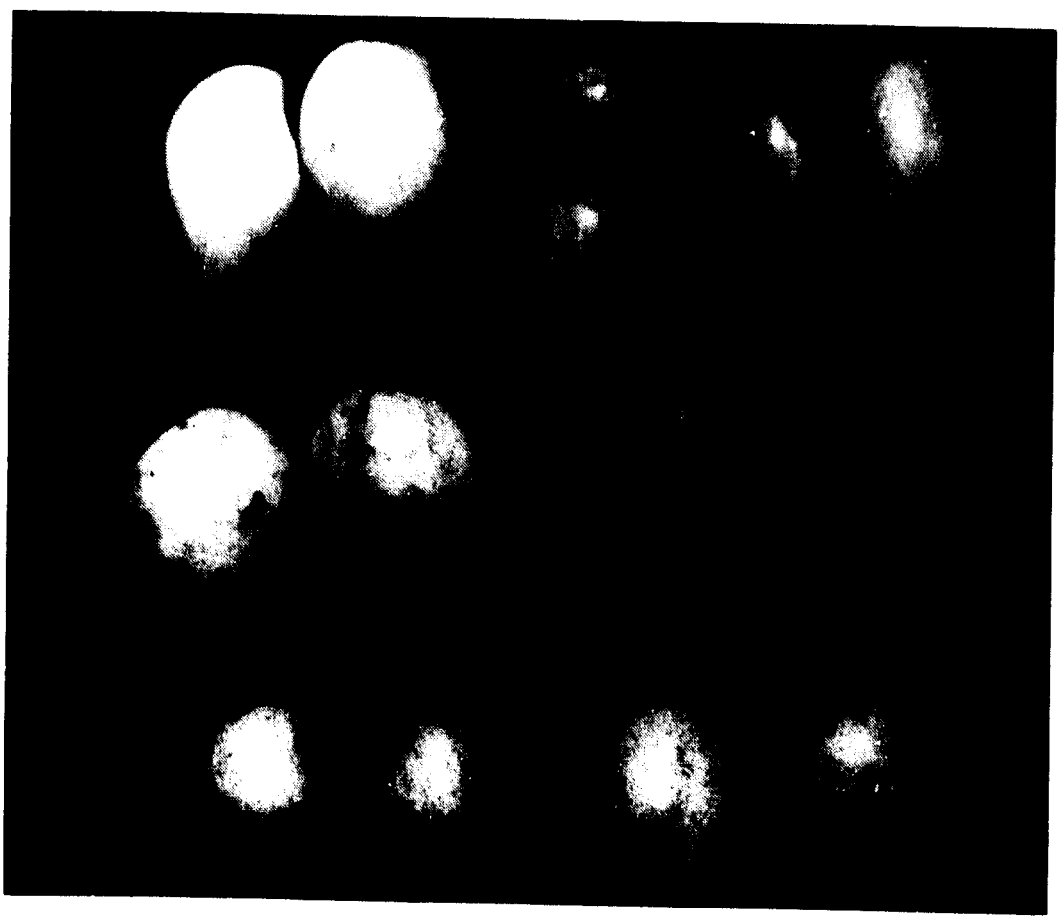


PLATE 7

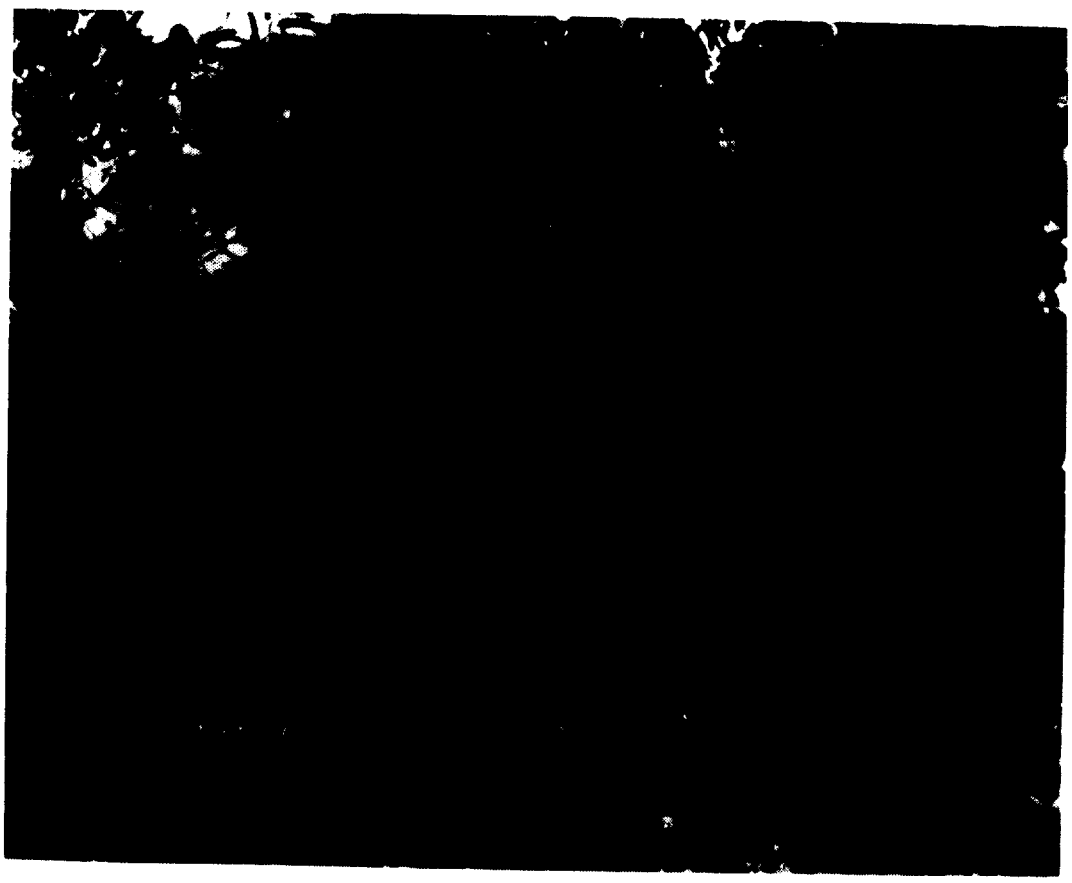


PLATE 8

PLATE 9

PLATE 10

PLATE 11

PLATE 12

United Nations Industrial Development Organization

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ID/WG.88/15/SUMMARY
2[illegible] July 1971

ORIGINAL: ENGLISH

Expert group meeting on processing
selected tropical fruits and vegetables
for export to premium markets

Salvador, Bahia, Brazil, [illegible] - [illegible] October 1971

SUMMARY

SOME ASPECTS OF PRESERVATION, PROCESSING AND EXPORT OF MANGO AND ITS PRODUCTS

by

H.S. Bhatnagar and K. Subramanyam
Central Food Technological Research Institute
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India is the largest producer of choice table varieties of mango in the world with an annual production of 7.0 million tons. Export trade of this luscious fruit, in fresh as well as processed forms can be expanded and promoted through development of less expensive and reliable methods of long distance transport and marketing.

This review summarises the work done in this laboratory and elsewhere, over the last two decades on harvest, maturity, grading, pre-treatments, packing, storage and transport of mango fruit. A critical appraisal has been made of several processed products from mango developed at this Institute and showing export possibilities.

74.09.12

after planting although early bearing cultivars have been evolved in recent years. Some cultivars bear fruit in alternate years. This is generally believed to be due to hormonal imbalance before or during flowering, and efforts are in progress to rectify the defect (7).

The fruit takes 12-16 weeks for full development after setting and its weight continues to increase until harvest. The growth is slower between 9 and 14 weeks which corresponds to the period of development of the stone. The starch continues to accumulate during growth and development. Respiration shows a peak during growth corresponding to the growth climacteric (11,12).

Varieties

A little over thousand varieties are recorded in literature of which 30-35 grafted varieties are cultivated in India on a commercial scale. Ten of the cultivars of *Indica* L. are popular for fresh trade as well as processing, and Alphonso among them, is the choicest variety. Banganpalli, Pairi, Totapuri, Neelum and Mulgoa are other principal varieties cultivated in south and western India. Dusehri, Fazli, Langra and Chausa are popular in northern India. Succulent juicy varieties are popular for dessert purposes and non-fibrous fleshy varieties are largely used for processing. Seedling varieties and premature or preharvest drops are used for pickles and chutneys. Size, shape and colour of the fruit differs considerably from variety to variety (7-10) (Plate 3-7; Table 4).

Harvest Maturity

The mango fruits are harvested from April to July although some cultivars in southern India are also available as late as October and November.

As the harvesting season is very short, there is always a glut of mango on the market.

Fruits are generally harvested when they mature on the tree. Maturity in traditional practice is determined by the shape, size and external colour of the fruit. Several parameters have been suggested from time to time for harvest maturity of the fruit, but none of these indices appear to be useful in commerce. Total soluble solids, acid:sugar ratio, starch content, flesh colour, together with non-destructive characters such as shape, weight and surface colour appear to be useful indices for harvest maturity of mango (13-16) (Table 5).

Harvesting

Green and mature fruits are harvested individually by manual labour with the help of bamboo pole and net attached to it at the end, and are lowered to the ground in a basket with the help of rope (Plates 8,9). In some areas, fruits are clipped leaving a stalk-end of 1 cm to avoid injury. Mechanical harvests are not possible in view of the large spreading habit of the tree.

Acreage and Yield

In India, mango covers an area of 7,48,010 hectares accounting for about 61.2% of the total estimated area under all kinds of fruit crops. Grafted varieties occupy 2,75,934 hectares or 37% of the total area, and seedling varieties about 4,72,076 hectares or 63% of the total area under mango. Number of trees per hectare varies from 100 to175 depending on the variety. Yield of fruits per hectare ranges from 9-16 tonnes, the maximum

being in the Mysore State. Yield depends on variety, cultural practices adopted, and the environmental conditions prevailing during growth and development. The average yield per tree is about 100 kg. although some vigorous trees are reported to yield one tonne per season (2).

Grading

Fruits are graded on the basis of weight and surface colour. Specific gravity grading by water and brine floatation appear to be useful and more reliable than the other methods in vogue. Fruits having specific gravity of more than 1.02 ripen faster and have reduced storage life but are suitable for consumption in fresh state. Fruits with specific gravity of 1.0 to 1.02 require longer period for ripening, have longer storage life, and are also superior for dessert purposes as well as processing. Fruits having specific gravity lower than 1.0 take longer time for ripening and have longer storage life with increased susceptibility to infection. The quality is often poor either in fresh or processed form (14) (Table 6).

Post-Harvest Treatments

Physical methods: In countries where the use of chemical preservatives is prohibited, harvested fruits are often subjected to hot water treatment for the control of decay. Dip treatment of harvested fruits in hot water at 53 $\pm$ 1°C for 5 minutes has been found to be useful for several varieties of mangoes in reducing spoilage and in accelerating the ripening process, besides improvement of quality. Fruit colour in terms of carotene content increases by 10%, flavour is enhanced and the consumer acceptability is also improved, due to this treatment (Table 7). The treatment has met with great success in commercial processing plants since the decay was reduced to a minimum level, besides reduction in cost of labour for handling and sorting the ripe fruits (16)

Chemical methods: Use of several fungicides, antibiotics and chemical regulators have been suggested as post-harvest treatment for fruits in order to reduce spoilage, control ripening and improve external colour and also the market quality of the fresh produce. Experiments conducted at CFTRI have shown that chemicals like CAPTAN, THIRAM, ZINEB, ALLISAN, THIABENDAZOLE, BENLATE (which have been approved for use by Food and Drug Administration Act, USA), AUREOFUNGIN AND STREPTOCYCLINE can also be effectively used as post-harvest aqueous dip treatments either in cold or warm water for reducing decay (14) (Table 8).

Chemical regulators such as ALAR (succinic acid, 2,2-dimethyl hydrazide) and ETHREL (2-chloroethyl phosphonic acid) have been used (at CFTRI) with great success to increase the carotene content in the flesh of mangoes besides accelerating the ripening and also the development of surface colour (17,18) (Table 9,10). Maleic hydrazide and CYCOCEL inhibit the ripening process and also counteract the accelerated ripening induced by hot water dip treatment (19,14). The treatments are given in aqueous solutions as a dip for 5 minute within 24 hours of harvest for maximum benefits.

Fumigation: Methyl bromide, methyl formate and ethylene oxide at concentrations of 32 mg/litre have been suggested for reducing decay, and for extending the storage life of Alphonso mangoes at ambient as well as reduced temperatures (20).

Ripening

In commerce, dry straw or paper cuttings are used for ripening mangoes. These cushioning materials conserve heat and contaminating moulds produce ethylene in sufficiently large amounts to stimulate ripening (Plate 10).

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A brief account of the origin, history, growth and development of this fruit together with the salient features of the important commercial varieties has been given.

Emphasis has been laid on the harvest maturity, methods of harvest and grading practices. Mangoes are harvestedwhen they reach 85% maturity, corresponding to well-known characters such as fruit colour, shape, specific gravity, flesh colour and acid:sugar ratio. Fruit weight, colour and specific gravity are useful indices for commercial grading.

Post-harvest treatments are suggested to minimise losses that occur during transit and storage. Among the several approaches made, treatment of fruits after harvest in hot water as a momentary dip, reduces fungal spoilage and also regulates ripening. Addition of fungicides or synthetic growth regulators in dip water enhances the keeping quality and consumer acceptability. Methods used for ripening fruits have also been discussed. Physiological and bio-chemical changes that take place during ripening, changes in flavouring constituents, and chemical composition of the fruits are presented. Storage and transit temeperature below 25°C impairs the flavour and colour development in the table varieties examined. Storage diseases and ripening disorders in important cultivars have been noted.

Of the several pre-packaging materials examined, ventilated cardboard cartons are recommended for packing fruits intended for export market. Recent trends in transport and marketing are reviewed.

The suitability of several cultivars for processed products has been examined. Fresh mango puree and slices in frozen state will have future scope in view of recent developments in frozen food industry. Processed products like chutney, pickles and slices in brine from unripe fruits and mango jam, slices in syrup and pulp from ripe fruits have shown promise in export trade. Mango nectar, an ideal beverage prepared from fruit pulp has been introduced in the recent years. Mango cereal flakes, developed at CFTRI is a novel product which can serve as an excellent breakfast food, especially for the undernourished group. Foam mat dried products with natural flavour are good adjuncts in the ice-cream industry. Confectionery

based on mango is another product of interest. Starch from the mango kernel is a potential by-product of the waste.

Future lines of work for expansion of world trade for this exotic fruit and its products are indicated.

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