African Journal of Biotechnology Vol. 6 (21), pp. 2477-2483, 5 November, 2007
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2007 Academic Journals

Full Length Research Paper

Physical and chemical characteristics of off vine ripened mango (*Mangifera indica L.)* fruit (Dodo)

Mamiro Peter*, Fweja Leonard, Chove Bernard, Kinabo Joyce, George Victor, Mtebe Kaswija

Department of Food Technology and Nutrition, Sokoine University of Agriculture, P.O. Box 3006, Morogoro, Tanzania.

Accepted 5 May, 2006

The need to develop the best off vine mango ripening technique for both consumption and processing was investigated. Some physical and chemical measurements were performed on mature Green Dodo mangoes before and during a 3-day and 6-day ripening period by smoked pit ripening (SPR), ethylene (fruit generated) pit ripening (EPR), untreated pit ripening (UPR) and room temperature ripening (RTR) as a control method. The post harvest ripening changes in the quality characteristic of ripe mangoes were correlated among treatments and compared with similar changes in other mango varieties. Changes such as formation of sugars, decreased acidity, and increased carotene reflected the most significant chemical changes in ripeness stage.

Key words: Dodo, ethylene, off-vine, nutrients, ripening, smoking.

INTRODUCTION

Mango is one of the important fruit in the tropical and subtropical regions. It is a good source of nutrients, particularly vitamins A and C and dietary fibre (Pal, 1998). Flavour, volatiles, texture, chemical constituents and appearance of flesh colour are the key components that contribute to a high quality fresh mango and in the acceptance of the fruit by the consumer. The observation made by Lodh and Pentastico (1975) shows that palatability and taste of fruits are closely associated with the amount and type of chemical constituents and the physical nature of the product at harvest. Nevertheless, post harvest manipulations have been found to affect the metabolic transformation of chemical compounds already present. Off vine ripening, particularly pit smoking has been reported by consumers to impair favour quality which is critical to consumer acceptability of mangoes. Studies on these parameters that define quality in mango have been reported in literatures (Aina, 1990; Doreyappa et al., 1994). However, only a description of chemical and physical changes occurring in relation to quality of normal ripening that was enhanced by synthetic chemicals is provided (Pal, 1998). In addition, the focus of other studies that have so far been undertaken (Mir and Nath, 1993; Sagar and Khurdiya, 1996) has been the provision of fresh produce out of the harvest season by improvement in storage techniques. However, consumer demand is likely to include better preservation methods as well as improved quality through improving the ripening techniques for both local and export market. In an attempt to develop better means of ripening mangoes, evaluation of the efficacy of the traditional pit smoking method against other post harvest fruit ripening processes including the use of natural ethylene deserves attention. In this study the effect of ripening mangoes using untreated pit ripening method, pit method equipped with freshly ripened bananas for natural ethylene production and room temperature ripening were evaluated against the traditional smoked pit ripening method with the main objective of comparing and assessing their effects on the quality with regard to physical and chemical characteristics of ripe mango pulp.

*Corresponding author. E-mail: Petermamiro@suanet.ac.tz.

MATERIALS AND METHODS

Procurement and sampling of fruits

Fully mature ripe mango fruits of the local Tanzanian cv Dodo was obtained from Milengwelengwe village in Morogoro rural district, Tanzania. The fruits were plucked directly from the same tree and studied during the 2001/02 fruiting season. The sorting of the fruits

were such that only undamaged fruits having uniform size and free from visible symptoms of infection were selected for the study. On arrival the fruits were cleaned with pre-boiled water to remove dirt and latex. A total of 240 fruits were selected and randomly grouped into four groups of 60 mangoes each. The fruits were further randomly subdivided into subgroups of 20 fruits. The 20 fruits in each subgroup formed replicates in each of the four groups. One group was kept as a control, that is, room temperature ripening (25 – 30ºC)-RTR whilst the remaining 3 groups were subjected to the following treatments (i) smoked pit ripening-SPR, (ii) untreated pit ripening-UPR and (iii) ethylene (fruit generated) pit ripening-EPR.

Preparation of ripening pits and the ripening process

All the three pits were dug with same measurements i.e. 45 cm width, 60 cm length and 45 cm depth. Hardboard lids measuring 47 cm width and 62 cm length each were made to securely cover each pit. For the SPR method, the pits were warmed before use by burning half a bucket of dry mango leaves at the bottom of each pit as traditionally done. Clean banana leaves were then spread on the pit floor as beddings. Mango fruits were placed on top of the banana leaves and again covered with the same leaves. Smoke was introduced in the pits for about 5 min by burning the same amount of dry mango leaves as before and directing the smoke into the pits by a chimney like devise. The lids were then replaced immediately adding a lump of soil on top of the lid. With the EPR method, bananas leaves for natural ethylene generation were spread at the bottom of the pit as previous and mangoes were mixed with seven bananas in their initial ripening stage. The fruits were covered with banana leaves, lid replaced and soil covered on top. In the UPR method the procedure followed was as done in EPR except no bananas were added. For the control method, fruits were kept at ambient condition in bamboo woven baskets lined with clean dry banana leaves at the bottom and covered with the same material. Fruits were assessed at three-day interval in three phases designated as D_0 corresponding to time before ripening storage, D_3 during ripening and D_6 at the end of the ripening period. For D_0, D_3 and D_6 samples of mango fruit were evaluated for physical and chemical parameters.

Preparation of samples for analytical assays

Composite samples of ripe fruits from each treatment at each analytical stage were prepared for analyses. Fifteen fruits taken from each lot (five mangoes per replication) were washed in preboiled water and then cleansed with distilled water. The fruits were hand peeled and the edible portion separated from peels and stones by using a stainless steel knife. The mango homogenate was distributed among glass containers, which were immediately capped and stored at –10˚C until use for analysis.

Ripening, spoilage, physiological loss in weight and pulp recovery percentage

The ripening, spoilage, physiological loss in weight (PLW) and pulp recovery percentages were measured, basing on the methods described by Pal (1998) and Doreyappa et al. (1994) and computed as per the formulae below. Observation of visual colour changes was employed by judging the percentage ripening and actual percentages of ripe fruits were calculated per replicate and the mean values per three replicates in each lot were expressed as percenttage. Data on spoilage were recorded on day three and day six during ripening expressed as percentage based on the appearance of visible symptoms of spoilage and unmarketable shrinkage.

$$\textbf{\% Ripening} = \frac{\text{Ripe mangoes}}{\text{Total mangoes}} \times 100$$

$$\textbf{\% Spoiled} = \frac{\text{Spoiled mangoes}}{\text{Total mangoes}} \times 100$$

$$\textbf{\% Physiological loss in weight} = \frac{W_1 - W2}{W_1} \times 100$$

$$\textbf{\% Pulp recovery} = \frac{\text{Mean weight of recovered pulp}}{\text{Mean weight of whole fruit}} \times 100$$

Weight losses, that is, shrinkage during ripening as affected by the test ripening techniques were calculated from all the tree replicates and the mean values were expressed as percentage. Five fruits were marked with a marker pen and weighed before and after ripening. The initial weight (W_1) of the unripe fruits and the final weight (W_2) of the ripe fruit were noted. With regard to pulp recovery, mangoes were thoroughly washed in running tape water and cleansed with distilled water. After washing the fruit samples were hand peeled and pulp was completely removed from the peels and the stone. The finely sliced mango pulp was blended in a blender (Cryodon, England) and passed through a 50 micron stainless sieve to remove fibre. The weights of different fruits components and yield of the final pulp were noted and data expressed in percent.

Chemical analyses

The total soluble solids were determined by a hand held refractometer (0 – 80˚, Portable refractometer, 300003 Sper Scientific, China) according to AOAC method 932.12 (AOAC, 1995). The samples were analysed for moisture content (air oven), protein (Kjeldahl), titratable acidity, lipids, reducing sugars and minerals according to AOAC methods 925.10, 920.87, 922.28, 922.06, 939.03 and 970.12, respectively (AOAC, 1995). The crude fibre was determined by fibretec system following AOAC method (AOAC, 1990). Ascorbic acid was determined by titration against 2,6-dichlorophenol indophenol following AOAC method 967.21 (AOAC, 1995). β-carotene was determined using acetone-petroleum ether (40-60˚C) in the ratio of 1:3 as a solvent, by the method described by Mungi (1983). The method involved extraction and pigment separation. The absorbencies were determined with spectrophotometer at 450 nm after proper calibration of the instrument with standard solution of pure β-carotene (Sigma chemical Co., St Louis, Mo.). The pH values for the samples were measured using a pH meter model HM-7E. Tannin content was determined using the vanillin hydrochloric method as described by Gomez et al. (1997). The minerals were analysed using an atomic absorption spectrophotometry in a Shimadzu Atomic Absorption / Flame Emission Spectrophotometer (AA-630-12).

Statistical analysis

All analyses were conducted in triplicate and standard deviation reported. Descriptive statistics, multivariate analysis and Duncan multiple range test was done for sensory descriptors, physical, chemical parameters and microbial counts with a significance level of $P< 0.05$.

Table 1. Effect of ripening treatments on physico-chemical parameters of mango pulp.

Physical parameters	Initial value	Ripening period (days)	Ripening treatment			
			SPR	UPR	EPR	RTR
Fruit ripening (%)	0	3	67.82[a]	49.23[c]	58.49[b]	29.34[d]
		6	100[a]	82.22[c]	91.11[b]	73.33[d]
Spoilage (%)	0	3	0.00[a]	0.00[a]	0.00[a]	0.00[a]
		6	8.89[a]	2.22[c]	4.44[b]	0.00[d]
Pulp yield (%)	30	3	74.20[a]	73.77[b]	73.58[c]	73.52[d]
		6	73.56[b]	73.48[c]	74.13[a]	73.48[c]
PLW (%)	0.5	3	3.65[a]	3.16[ab]	3.37[b]	2.46[c]
		6	3.89[a]	3.74[ab]	3.88[a]	3.03[b]

Mean values with different letters across rows are significantly different at 5% level.

Table 2. Effect of ripening treatments on proximate composition of mango pulp.

Chemical parameters	Initial value	Ripening period (days)	Ripening method			
			SPR	UPR	EPR	RTR
Crude fat (%)	0.32[a]	3	0.40[a]	0.37[a]	0.40[a]	0.38[a]
		6	0.40[a]	0.40[a]	0.40[a]	0.39[a]
Crude fibre (%)	3.70[b]	3	3.24[a]	3.37[a]	3.15[a]	3.60[b]
		6	3.19[a]	3.18[a]	3.21[a]	3.40[b]
Protein (%)	0.979[a]	3	1.078[a]	1.095[a]	1.077[a]	1.024[a]
		6	1.086[a]	1.086[a]	1.095[a]	1.077[a]
Ash (%)	0.50[a]	3	0.48[a]	0.49[a]	0.48[a]	0.50[a]
		6	0.49[a]	0.50[a]	0.48[a]	0.50[a]
Moisture (%)	79.06[a]	3	80.11[a]	79.31[a]	79.01[a]	78.25[a]
		6	77.74[a]	78.57[a]	78.60[a]	77.56[a]
Carbohydrate %	15.56[a]	3	15.69[a]	15.36[a]	15.88[a]	16.25[a]
		6	17.09[a]	16.26[a]	16.21[a]	17.17[a]

Mean values with different letters across rows are significantly different at 5% level.

RESULTS

Assessment of physical parameters

Results for the physical parameters of ripening, spoilage, PLW and pulp yield are presented in Table 1. Significant variations ($P \leq 0.05$) in all these physical parameters were observed among treatments. The SPR was found to be the most effective method in initiating and accelerating the ripening process amongst all the methods followed by EPR while the least was RTR method. Equally, there was a higher spoilage of mango fruits in the SPR method followed by EPR in the sixth day while there was no spoilage observed in the RTR method. However in the third day, there was no observed significant difference in spoilage in all treatments. Pulp yield showed slight but significant difference, EPR method showing a higher yield compared to other treatments. Equally, physiological loss in weight was slight but significantly different with higher loss observed in SPR and EPR methods.

Proximate composition

The ripening trends on proximate chemical composition observed in mango cv. Dodo are presented in Table 2. Ripening treatments had no significant effect ($P > 0.05$) on these parameters. Crude fibre showed a very slight but significant change during ripening. Ash and moisture content did not show any significant changes during ripening, hence in total mineral content. Similarly, no consistent and appreciable changes were observed in crude fat, carbohydrate and protein content.

Other chemical parameters

Results for other chemical parameters are presented in Table 3. Except for TTA and reducing sugars no significant variations were observed among treatments with respect to the other chemical parameters. While reducing sugars, TSS and β-carotene contents and pH values

Table 3. Effect of ripening treatments on other chemical parameters of mango pulp.

Chemical parameters	Initial value	Ripening period, (days)	Ripening method			
			SPR	UPR	EPR	RTR
Ascorbic acid (mg/100g)	22.36[b]	3	17.97[a]	18.00[a]	18.03[a]	18.15[a]
		6	13.83[a]	13.84[a]	13.83[a]	13.86[a]
TTA (%)	0.72[c]	3	0.23[a]	0.25[a]	0.24[a]	0.29[b]
		6	0.18[a]	0.20[a]	0.19[a]	0.22[b]
pH	2.31[a]	3	4.63[b]	4.50[b]	4.57[b]	4.42[b]
		6	4.64[b]	4.62b[b]	4.63[b]	4.61[b]
Tannin (%)	0.09[a]	3	0.06[a]	0.06[a]	0.06[a]	0.07[a]
		6	0.06[a]	0.06[a]	0.06[a]	0.06[a]
Reducing sugars (%)	1.72[a]	3	3.41[b]	3.33[bc]	3.15[bc]	3.07[b]
		6	3.59[bc]	3.41[b]	3.50[bc]	3.41[b]
β-carotene ug/100g)	840[a]	3	2268[b]	2262[b]	2271[b]	2250[b]
		6	2961[b]	2959[b]	2958[b]	2939[b]
TSS (˚Brix)	9.70[a]	3	18.20[b]	16.00[b]	17.20[b]	15.00[b]
		6	19.70[b]	20.20[b]	20.10[b]	18.90[b]

Mean values with different superscript letters across rows are significantly different at 5% level.

Table 4. Effect of ripening treatments on mineral content of mango pulp.

Mineral (mg/100g)	Initial value	Ripening period (days)	Ripening treatment			
			SPR	UPR	EPR	RTR
Ca	10.53[a]	3	11.65[a]	11.03[a]	11.72[a]	10.21[a]
		6	11.83[a]	11.55[a]	11.69[a]	11.72[a]
Mg	17.09[a]	3	17.66[a]	18.12[a]	17.05[a]	17.21[a]
		6	18.07[a]	17.78[a]	16.98[a]	17.65[a]
K	192.76[a]	3	198.24[a]	197.50[a]	197.85[a]	198.64[a]
		6	197.90[a]	198.01[a]	196.98[a]	197.64[a]
Na	30.51[a]	3	27.13[a]	28.03[a]	28.00[a]	27.84[a]
		6	28.32[a]	26.99[a]	28.21[a]	27.77[a]
P	18.01[a]	3	15.92[a]	16.00[a]	15.54[a]	16.68[a]
		6	15.88[a]	15.67[a]	15.92[a]	15.90[a]
Fe	0.52[a]	3	0.56[a]	0.59[a]	0.60[a]	0.57[a]
		6	0.58[a]	0.61[a]	0.57[a]	0.57[a]

Mean values with different letters across rows are significantly different at 5% level.

showed an increasing trend, ascorbic acid, tannin and TTA showed a decreased trend as ripening progressed. A considerable decrease in the acidity of mango was observed during ripening with a pH shift from 2.31 to 4.64 indicating that the fruit is mildly acidic like most other mango varieties.

Mineral content

The results for mineral composition of mango pulp are presented in Table 4. Though slight changes in mineral levels were observed on ripening, no significant variations ($P > 0.05$) were seen in mineral levels among treatments.

DISCUSSION

The effectiveness of the SPR method could be attributed to earlier achievement of the minimum ethylene concentration required in initiating the ripening process in mangoes (Singh, 1968), due to smoking and higher heat of respiration Narasimham et al. (1971) experienced in the smoked than the unsmoked fruits. Equally, the higher ripening rate in pit ripened fruits than the control fruits would suggest that the volatile accelerators of ripening

tend to accumulate under conditions of restricted ventilation, as was the case with the pits. This could as well be attributed to higher ethylene levels in soil than in air (Abeles et al., 1992), and use of ripening inducers such as ripe bananas and smoke. Similarly, temperature influences on ethylene due to self-heat generation as a result of respiration and lack of ventilation may induce higher ripening rate in pit-ripened fruits (Adel, 1993; Mathooko, 2000). The respiratory activity in fruit and the rate of production as well as action of ethylene, the ripening hormone are temperature dependent.

Despite advantageous higher rate of ripening pit-ripening method, higher fruit spoilage was observed in the same pits. The higher spoilages in pit-ripened mangoes were probably due to higher ripening rates, stacking together, lack of ventilation and increased temperature through self- heat generation. Excessive heat often leads to the presence of water on the surface of products thus creating a favourable environment for moulds and bacteria to grow, thus causing decay (Harris, 1988). The highest spoilage in the SPR mangoes was probably further aggravated by exposure to artificial heat sources causing a relatively higher temperature rise in smoked mangoes than the un-smoked mangoes (Narasimham et al., 1971). Previous study (Singh, 1986), reported that a 9 - 10ºC rise in temperature of the fruit in the stacked state will cause spoilage if the temperature is more than 35ºC, an observation that is similar to the results of the present study. Higher ethylene levels have also been reported to stimulate the germination of fungi spores in the soil and on the surface of the fruits as it is readily metabolised by many soil organisms (Clendennnen, 1997). However, data presented in Table 1 reveal that spoilage does not solely depend on the microbial population alone, but is also governed by other factors such as the mechanical integrity of the exocarp whose permeability is influenced by the degree of ripeness. Apart from the preservative potentiality of smoke (Venugopal, 1995), the SPR mangoes had the highest spoilage possibly due to the interactive effect of both intrinsic and extrinsic factors.

Similarly, significant ($P \leq 0.05$) variations in pulp yield among treatments could be attributed to the degree of firmness of the fruit, which has a positive correlation to the degree of ripeness and hence softness of the pericarp. Softness is aggravated by textural loss caused by enzymatic hydrolysis of cellular components during ripening and over storage time (Kajuna et al., 1997).

The physiological loss in weight is linked to the fact that the mango skin bears stomata and transpiration continues after the fruit has been harvested. The considerable variation among treatments could be attributed to differences in temperature, relative humidity (Simmonds, 1959), atmospheric composition (Adel, 1993), and the degree of ripeness. An increase in temperature increases the loss of the water, which means a loss in weight of the produce (Harris, 1988). The results show a positive correlation between moisture, cell permeability and the degree of ripeness. Simmonds (1959) reported a final rise in water loss at the climacteric phase as the fruit ripens, the change that is related to degenerative changes of the skin. This observation corresponds with the results of the present study. Moisture content underwent slight but insignificant reduction during ripening, a change that has been explained in terms of a maximum rise in water loss in the senescence stage due to degenerative changes of the skin (Simmonds, 1959), resulting from both respiration and transpiration sources (Aina, 1990).

Crude fibre showed a very slight change during ripening that could be attributable to a decrease in insoluble pectin associated with an increase in soluble pectin in the course of ripening (Mathooko, 2000). Crude fat and crude protein contents showed a slight increase as ripening progressed. The observed slight increase in fat concentration agrees with the general observation that a link exists between lipid content, colour and flavour development of the mango during ripening (Gomez-Lim, 1997). A slow change in fat content on extended storage could be due to decreased citrate level, which is believed to be the immediate source of acetyl coenzyme A required for biosynthesis of fatty acid and triglyceride (Gomez-Lim, 1997).

An increase in protein content observed during ripening is in agreement with the findings made in several fruits by Gomez-Lim (1997). Tressel et al. (1975) also reported an increase in the amounts of some proteins and enzymes. Mathooko (2000) described a dramatic increase in protein, reflecting the enzyme required for ripening. The proximate compositions of (Mangifera indica L. cv Dodo) were within reported limits (Singh, 1968; Doreyappa et al., 1994; Morton, 1987).

A three to four fold decrease in TTA from harvest maturity to ripened stage was observed. The variations due to treatment were not significant ($P > 0.05$) among the pit methods; however, the difference was significant ($P < 0.05$) between the pit-ripened samples and the control samples. But no significant variations among treatments were observed in pH values. The variation in the results of TTA against records of pH could be ascribed on human limitation in colour judgment of the exact end point during titration. The decrease in ascorbic acid could be attributed to its susceptibility to oxidative destruction (Aina, 1990), as impacted by the ripening environments. The less effective ripening method tended to maintain the highest amount of ascorbic acid and vice versa. The increase in β-carotene content has been reportedly due to increase in levels of carotene, free geraniol and free mevalonic acid, the precursor in carotene biosynthesis (Mattoo et al., 1975; Modi and Reddy, 1967).

Reduction in tannin contents is linked to their role as flavour contributors (Aina, 1990; Lodh and Pentastico, 1975). This is associated with an increase in extractable flavolans resulting from polymerisation of tannins and other polyphenolic compounds. Arogba (1997) also re-

ported complexing of tannins with minerals and proteins. Thus, the decrease in tannin content as the fruit ripens could be due to a slight increase in macromolecules such as protein. This is evidenced by the results of the present study, which show an increase in protein content.

Degradation of the large pectin molecules binding together the walls of neighbouring cells in the middle lamella associated with increased water solubility (Hobson, 1980) and hydrolytic conversion of starch yielding free sugars (Sagar and Khurdiya, 1996) have been reported to increase the concentration of TSS. A two-fold increase in TSS from harvest maturity to ripe stage was observed in this study. The change in TSS was slow with advancing ripening period due to the fact that there was less and less substrate remaining to be acted on in the last days of storage (Kajuna et al., 1997), as hydrolysis of starch to sugars by amylase proceeded. Agravante et al. (1990) made similar observation.

Also, a two-fold increase in reducing sugar was observed. This was due to more rapid and partial breakdown of non-reducing sugars and other polysaccharides and their subsequent inversion to reducing sugars in the course of fruit ripening (Sagar and Khurdiya, 1996). The significant ($P < 0.05$) variation among treatments could be attributed to the influences of storage temperatures and other environmental conditions (Harris, 1988), which influences the ripening rates. The results of these chemical parameters agreed well with previous reports (Pal, 1998; Doreyappa et al., 1994; Sagar and Khurdiya, 1996; Singh, 1968; Sagar et al., 1998).

Though slight changes in mineral levels were observed on ripening, no significant variations ($P > 0.05$) were seen in total mineral levels among treatments as evidenced by the results on ash content. An increase in the amount of calcium in the fruit has been reported (Kupferman, 1988) to reduce the incidence of disorders such as increasing the firmness of the fruit. On the other hand, the results show that K is the major mineral of mango fruit contributing the major fraction of the ash. The results were within reported limits (Morton, 1987; Paul and Southgate, 1978). the very slight variations observed in some cases could be attributed to the variations in varieties as well as physical environment of plants, which include many factors whose action and interaction must be considered.

In conclusion, this study provides evidence that off vine ripening treatment of mangoes does not induce significant negative alterations on most of the physical characteristics and chemical constituents. However, the treatments induce significant changes in acid and reducing sugars. These changes in the chemical composition of the mature fruit are interrelated and correlated with optimum degree of ripeness and thus play an important part in fruit quality.

ACKNOWLEDGEMENT

The authors acknowledge research funding from the Sokoine University of Agriculture.

REFERENCES

Abeles FB, Morgan PW, Sauveit (1992). Ethylene in Plant Biology. 2nd edn. Academic Press New York pp 1-10.

Adel AK (1993). Post-harvest handling. In: The Biology of Horticulture: An Introductory Textbook. (Edited by Pierce J.E and Read P.E) John Wiley and Sons New York pp 353 - 377.

Agravante JU, Matsui T, Kitagawa H (1990). Starch breakdown and changes in amylase activity during ripening of ethylene and ethanol treated bananas. Acta Hortic. 269: 133-140.

Aina JO (1990). Physico-chemical Changes in African Mango (*Irvingia gabogensis*) during Normal Storage Ripening. J. Food Chem. 36: 205-212.

AOAC (1990). Official Methods of Analysis. Association of Official Analytical Chemists Washington D C.

AOAC (1995). Official Methods of Analysis 16th edition.. Association of Official Analytical Chemists Washington D C.

Arogba SS (1997). Physical Chemical and Functional Properties of Nigerian Mango (*Mangifera indica*) Kernel and its Processed Flour. J. Sci. Food Agric. 73: 321-328.

Clendennnen SK (1997). The Role Ethylene in Banana Fruit Ripening In Biology and Biotechnology of the Plant Hormone Ethylene Kanellis A K (ed). NATO ASI series, p. 24.

Doreyappa GIN, Ramanjaneya KH, Iyer CPA, Subramanyam MD, Dinesh MR (1994). Physico-chemical and Processing Quality of Four New Mango Hybrids in Comparison to Two Commercial Cultivars. J. Food Sci. Technol. 31(5): 385-388.

Gomez MIAB, Obilana DF, Martin M, Madzavamuse M, Monyo ES, (1997). Manual of Laboratory Procedures for Quality Evaluation of Sorghum and Pearl millet ICRISAT (International Crop Research Institute for Semi-arid Tropics) Pantechuru 502 Andhra Pradesh India pp. 29-34.

Gomez-Lim MA (1997). Post-harvest Physiology. In: The Mango: Botany, Production, and Uses (Edited by Litz R E) CAB International pp. 425 - 446.

Harris RS (1988). Production is only half the battle. A training manual in fresh produce marketing for the Eastern Caribbean. Food and Agricultural Organization Of The United Nations, Bridgestone, Barbados. [www.fao.org/vlibrary/x0014e/X0014.htm] site visited on 2/4/2002.

Hobson GE (1980). Enzyme and Texture Changes During Ripening In: Recent Advances in the Biology of Fruits and Vegetables. (Edited by Friend J and Rhodes M J C) Academic Press Inc. (London) Ltd. pp.123-132.

Kajuna STAR, Bilanski WT, Mittal GS (1997). Textural Changes of Banana and Plantain Pulp during Ripening. J. Sci. Food Agric. 75: 244–250.

Kupferman E (1988). Post Harvest Pomology Newsletter 6(2): 3-7 September 1988 Fourth Annual Warehouse Conference Yakima WA.

Lodh SB, Pentastico EB (1975). Physicochemical changes during growth of storage organs. In: *Postharvest* Physiology,Handling and Utilisation of Tropical and Subtropical Fruits and Vegetables The Avi Publishing Co Inc USA pp. 1–40.

Mathooko FM (2000). Manual of Third Country Group Training Programme in Applied Food Analysis: Postharvest Physiology-JKUAT KENYA.

Mattoo AK, Murata T, Pantastico EB, Chachin K, Ogata K, Phan CT (1975). Chemical Changes During Ripening and Senescence. In: Post harvest Physiology, Handling and Utilisation of Tropical and Sub-tropical Fruits and Vegetables. The Avi Publishing Co. New York. pp. 103-127.

Mir MA, Nath N (1993). Storage Changes in Fortified Mango Bars. J. Food Sci. Technol. 30(4): 279-282.

Modi VV, Reddy VV (1967). Carotenogenesis in ripening mangoes. Ind. J.Expr. Bio. 5: 233.

Morton J (1987) Mango (*Mangifera indica* L.). In: Fruits of Warm Climates (Edited by Morton J F). Miami F pp. 221-239.

Mungi P (1983). Nutrient contents of raw and cooked cowpea leaves. J. Food Sci. 48: 1252 - 1254.

Narasimham P, Dalal VB, Nagaraja N, Krishnaprakash MS, Amla BI (1971). Effect of Smoking on Some Physiological Changes in Banana. J. Food Sci. Technol. 8(2): 85.
Pal RK (1998). Ripening and rheological properties of mango as influenced by ethereal and carbide. J. Food Sci. Technol. 35(4): 358-360.
Paul AA, Southgate DAT (1978). McCance and Widdowsons: The Composition of Foods, 4th Revised and Extended Edition of MRC Special Report No. 297, Elservier / North-Holland Biomedical Press. p. 13.
Sagar VR, Khurdiya DS (1996). Effect of ripening stages on quality of dehydrated ripe mango slices. J. Food Sci. Technol. 33(6): 527-529.
Sagar VR, Khurdiya DS, Balakrishnan KA (1998). Effect of strorage temperature and period on quality of dehydrated ripe mango slices. J. Food Sci. Technol. 35(2): 147-150.
Simmonds NW (1959) Bananas. Longman. London. pp. 205-251.
Singh A (1986). Fruit Physiology and Production, 2nd revised edition. Kalyani Publishers New Delhi-Ludhiana. pp. 349-367.
Singh LB (1968). Mango: Botany, Cultivation and Utilisation. Leonard Hill. London. pp. 345-394.
Tressel R, Holzer M, Apertz M (1975). Biosynthesis of Volatiles. In: International Symposium on Aroma Research, Central Institute for Nutrition and Food Research *TNO.* (Edited by Maarse H, Groenen PJ). pp. 41-62.
Venugopal V (1995). Methods for Processing and Utilisation of Low Cost Fishes: A critical Appraisal. J. Food Sci. Technol. 32(1): 1-12.