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Comparison of nutritional status of three mango cultivars during fruit ripening

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Abstract
Mango fruit has a high nutritional value and health benefits due to the phytochemicals present in it. The present study gives information on the nutritional composition of mango fruit and the changes occurring during premature and mature phases of fruit. Three cultivars, Kesar, Alphonso and Rajapuri from Gujarat, Inida, were studied in unripe and ripe stages. Biochemical composition changes during ripening of the mango fruit (*Mangifera indica* L.) were evaluated. The studied parameters included pH, acidity (%), starch, total sugar (%), reducing sugar (%), non-reducing sugars (%), proteins, total phenols, dietary fibres, Sugar acid ratio. The result revealed that the pH, total sugars, reducing and non-reducing sugars, proteins, total phenol content, dietary fibre and sugar acid ratio increase in all varieties while titrable acidity and starch content decreased during ripening of mango fruit.

Keywords: cultivars, *mangifera*, unripe, ripe

Introduction
The fruit provides essential mineral nutrients and vitamins. The quality of a fruit is influenced by variety and nutritional status and environmental conditions during growth of the parent plant. Fruits play a very important role in human nutrition, by providing an additional source of energy, necessary growth factors, carbohydrates, dietary fibers and antioxidants, essential for maintaining normal health. Fruits also contain a very high percentage of their fresh weight as water.

Mango is the most important fruit of India, with more than a thousand varieties known (Iyer, 1991). Most of Indian varieties possess strong aroma and more intense peel coloration, characterized by attractive fragrance, delicious taste. Mango fruits have been used in every stage of growth, while the raw fruits are utilized for products like pickles, chutney or mango sauce, amchoor, the ripe ones are used in making pulp, juice, nectar, squash, mango leather, frozen and canned slices, jam, mango puree, mango cereal flakes, mango powder, mango toffee and mango fruit bars (Singh 1990) [34].

Mango (*Mangifera indica* L.) is a simple fruit of drupaceous type, and contains a single large seed surrounded by fleshy mesocarp. Mango is one of the chief commercial fruit of Gujarat state occupying a very large area compared to other fruits. Kesar, Rajapuri and Alphonso are three important commercial cultivars of mango grown in Gujarat. The famous saffron coloured Kesar variety is grown mainly around the foothills of Girnar Mountains in Gujarat's Junagadh district. Globally it has been recognized as the 'Gir Kesar'after being granted the geographical indication (GI) tag. Kesar is grown in Saurashtra region where rainfall is low. Alphonso one of the most expensive kinds of mango in India is one of the best variety in terms of sweetness, richness and flavor. It is referred as 'Happpus' in Gujarat. Alphonso is more suited to the southern Gujarat where the climate is more humid because of heavy rainfall. Rajapuri variety is known for its large size, thick fleshy mesocarp and a small seed. As it is very sour when ripe and unripe, it is mainly used for pickles. Rajapuri is grown in the middle and North Gujarat where the climate is dry and rainfall is low.

The chemical composition of mango pulp varies with the location of cultivation, variety and stage of maturity. The major constituents of the pulp are water, carbohydrates, organic acids, fats, mineral pigments, tannins, vitamins and flavor compounds.

Development stages of mango fruit has been categorized into 4 growth phases (Singh, 1960). Stage I and stage II were the initial developmental stages of the fruit, where carbohydrates, proteins, enzymes, vitamins were in minimal amount. Stage III and stage IV showed the developmental changes from unripe to ripe fruit, during which lot of biochemical changes take place. Therefore only stage III and IV were considered for the present study.

Materials and Methods
Samples were collected from the orchards of Junagadh Agriculture University (JAU) and Navsari Agriculture University (NAU) at stage III (unripe) and IV (ripe). Five fruits from ten different trees were collected for the three varieties, Alphonso, Kesar and Rajapuri. Pulp of the fruit was isolated and subjected for further analysis. pH and total Acidity, Total sugars (Sadasivam and Manickam 1992) [92], Reducing Sugars (Miller 1972) [19], Non-reducing Sugars (Thimmaiah, 1999) [39], Starch (Devi 2001), Proteins (Lowry et al. 1951) [14], Phenols (Thimmaiah, 1999) [39] were analyzed using standard methods and Dietary Fiber analyzed by the method given by the AOAC (2000 method 985.29).

Results
Ripening was associated with loss of firmness and pulp acidity with increases in total sugars. Preliminary studies showed presence of only three sugars, which were identified as glucose, fructose and sucrose. Biochemical study showed

variation in the concentration of the constituents in mangoes collected from the two different regions.

Physiological parameters of the three different varieties of mango collected at two different stages (unripe and ripe) from two different regions (Junagadh and Navsari) are represented in table 1.

Variation between the cultivars in titrable acidity was perceived to be highly significant at different developmental stages. pH of the pulp in all the three cultivars from the two different locations were found to be acidic in the stage III (pH 2-3) and moving towards the alkaline scale (pH 4-6) except in Rajapuri from Navsari which showed pH to be in contradictory course, rising from lesser acidic value to higher acidic value. Higher pulp pH was noted in Rajapuri from the two locations compared to Kesar and Alphonso.

Starch, total sugars (%), reducing sugars (%), Non-reducing sugars %, proteins and total phenols was on the higher side in Alphonso (table 1). There was no significant variation in the amount of protein in cultivars Kesar and Alphonso collected from the two regions (0.81-0.89%) but in Rajapuri it was significantly low (0.39-0.65). Protein content was found to increase from unripe to ripe stage of fruits in all the cultivars form the two regions.

Dietary fibers were exceptionally more while sugar acid ratio at both the stages was lowest in Rajapuri varieties and hence the taste of fruit was quite sour as compared to other two varieties. Alphonso variety had more sugar acid ratio during stage IV, but it was more in Kesar in stage III. Dietary fiber varied significantly in Rajapuri especially the cultivar from Navsari which showed maximum amount in the unripe and ripe stages. The fibre content increased with the ripening of all cultivars.

Table 1: Physico-chemical attributes of the three different varieties of *M.indica* fruit at unripe and ripe stages collected from two different regions.

Sr.no.	Varieties	Kesar		Alphonso		Rajapuri	
	Stage	Junagadh	Navsari	Junagadh	Navsari	Junagadh	Navsari
pH	III	3.58±1.02	2.91±0.6	2.99±0.9	2.71±0.6	3.17±0.8	4.09±0.7
	IV	5.96±1.1	5.81±0.5	5.57±0.9	4.93±0.9	4.02±0.6	3.83±0.8
Acidity (%)	III	0.50±0.9	0.48±0.9	0.52±0.5	0.58±0.6	0.69±0.8	0.74±0.5
	IV	0. 32±1.02	0.31±1.0	0.30±0.5	0.33±1.1	0.36±0.9	0. 34±0.6
Starch	III	1.11±0.5	1.40±0.6	0.90±1.1	1.58±0.5	1.02±0.5	1.24±0.8
	IV	1.3±0.8	1.45±0.9	1.12±0.5	1.81±0.6	1.33±0.5	1.43±0.8
Total sugars (%)	III	14±1.07	12±0.18	12±1.1	15±0.9	5±0.6	4±0.8
	IV	17±0.9	15±1.2	16±0.8	19±0.5	10±0.4	7±0.8
Reducing sugars (%)	III	2.33±0.8	2.15±0.4	2.48±0.5	2.36±0.4	1.35±1.04	1.30±0.8
	IV	2.45±0.4	2.26±0.8	2.42±0.5	2.47±0.8	2.18±0.5	2.32±0.8
Non-reducing sugars (%)	III	1.22±0.9	1.14±1.0	1.35±0.9	1.30±0.9	1.14±0.5	1.02±1.1
	IV	2.11±1.03	1.92±0.5	2.30±08	2.03±1.1	2.21±0.8	2.20±1.4
Proteins ($100g^{-1}$)	III	0.89±0.9	0.82±0.5	0.84±0.5	0.81±0.6	0.59±1.2	0.65±0.8
	IV	0.97±1.1	0.98±1.0	1.0±0.2	0.99±0.5	0.71±0.2	0.74±0..5
Total phenols (µg/ml)	III	15.81±1.5	31.12±1.2	11.60±1.2	18.55±1.04	11.37±0.9	15.24±1.2
	IV	17.59±1.04	36.01±0.6	16.76±0.8	21.59±1.4	13.76±0.5	17.13±0.7
Dietary fiber (%)	III	8.5±0.9	8.2±0.5	10±0.9	9.6±0.8	11.60±	18.55±
	IV	9.1±1.08	8.5±0.8	11.4±1.8	10±1.2	30.7±1.5	29.3±0.9
Sugar : acid ratio	III	28±0.9	25±0.8	23.07±0.5	25.86±0.3	7.24±0.4	5.40±0.8
	IV	53.12±0.8	48.38±0.6	53.33±0.6	57.57±0.4	27.77±0.5	9.45±0.5

Conclusion

Ripening in mangoes are known to involve numerous metabolic activities leading to changes in carbohydrates and acids resulting in declined sugars acid ratio and development of colours, flavor characteristics and softening of the texture of acceptable quality (Venkatesan and Tamilmani, 2013) [42].

Physiological changes monitored in mango fruits during ripening revealed an increase in the level of total soluble solids and pH while titrable acidity and vitamin C content declined with ripening (Appiah et al., 2011) [2]. Along with the decrease in the percentage of acidity, starch content was found to be reducing in all the 3 cultivars collected from two different regions. In stage III all the three different cultivars collected from Navsari showed starch content maximum compared to Junagadh Alphonso of Navsari showed maximum starch content.

The growth pattern of the mango appears to take the form of a simple, rather than double, sigmoid curve (Lakshminarayana 1970). During growth and maturation of mango, starch accumulation is the main chemical change in the pulp tissue (Leley et al. 1943, Quintana et al. 1984) [13, 24]. In developing mango fruits, acidity increased at early growth phase, reached a peak and then declined gradually until harvest (Wardlaw and Leonard 1936) [43]. Present study had more amount of titrable acidity at stage 3 which is the unripe stage while it got decreased in stage 4, where the fruit was ripe, which can be evidently seen in table 1.

Organic acids are important in relation to the fruits flavor and that influence perception of sweetness and the acidity reduction plays an important role in acid sugar balance. Acidity loss was shown by decreasing titrable acidity and increasing pH values. pH values were seen to be increasing in all varieties from unripe to ripe stages of fruit in present study. A large decrease in citric acid and a small reduction in malic acid were responsible for the loss of acidity. The decline in acidity could be due to susceptibility of citric acid to oxidative destruction as impacted by the ripening environment (Aina, 1990) [1]. Shafique et al. (2006) [29] reported pH of the mangoes ranged from 2.5 to 3.5, 2.7 to 4.2 and 4.2 to 5.4 for immature, mature and ripe mangoes respectively. Acidity of mangoes decreases with maturity due to the breakdown of starch into more sugars thereby lowering down the percentage of acidity of the fruits (Fuchs

et al, 1980; Tandon and Kalra 1986) [5, 36]. In the present study in all the three varieties of mango collected from the two different regions % acidity is found to reduce when the unripe mangoes become ripe. Total sugars and reducing, non-reducing sugar are found to be increased in all the cultivars from mature to ripe stage. Total sugars are found to be maximum in Alphonso from Navsari. An increase in total sugars and reducing sugars may be probably due to accumulation of more sugars in the fruits due to hydrolysis of starch from increase amylase activity during ripening (Pawar et al., 2011) [22]. Alphonso is considered to be the sweetest mango amongst the three different cultivars and table 1 clearly depicts a significant variation in the starch and total sugar content of Alphonso (especially from Navsari) from the other cultivars. Starch content increased with advancement of maturity (table 1). The rate of starch accumulation is rapid in the beginning of fruit growth and showed down later but it continues to increase upto maturity. Some observation was made by several authors in different fruits like Thanaraj et al., (2009) [38] in mango cultivars in Srilanka, cultivars Fazli and Khrihapat from Bangladesh (Rahman et al., 2001) [24], Jain et al., (2003) [9] in Guava and Papaya (Ara et al., 2016) [3]. The gradual decrease in acid content may be due to conversion of acids into sugars by some physiological and biological changes in the fruits.

Total sugar content is also an important parameter which can be used as a measure of quality for most of the fruits. In the present study, total sugar content of Junagadh and Navsari Rajapuri is the minimum compared to Alphonso and Kesar which had almost double concentration of total sugar content. It is well known that Kesar and Alphonso are quality mangoes and have a greater demand than Rajapuri. Because of its lesser total sugar content and more acidity percent which determines the sour taste these mangoes are more preferred for pickles. Just like total sugar content, sugar-acid ratio is also considered a measure of quality of fruit. Quality fruits normally should have lower sugar-acid ratio.

There is a continuous decrease in acidity of fruits during ripening (Krishnamurthy et al. 1971, Shashirekha and Patwardhan 1976, Selvaraj et al. 1989) [10, 31, 27]. The ripening phenomenon is associated with loss of firmness. It appears that pectin polymers became less tightly bound in the cell wall during ripening, and the cell wall loosening involved hydrolysis of galactose containing polysaccharides (Seymour et al. 1989) [28]. An increase in soluble and a decrease in insoluble proteins were reported during ripening of mango fruits (Tandon and Kalra 1983, Sharaf et al. 1989) [36, 30].

In the market consumer acceptance of a particular variety is markedly influenced by sweetness to acid balance and because fructose is sweeter than glucose, a fully ripe Rajapuri from Junagadh is a suitable healthy and economically important variety. Sugar acid ratio increased at stage IV in all the varieties. The ratio was minimum in Rajapuri, so the the flavor of this variety is not much appealing while it was comparatively higher in Alphonso and Kesar due to which these two varieties possess excellent flavor and aroma.

Ripe mango contains up to10-20% total sugars on a fresh weight basis, depending on the cultivar and the stages of ripeness. At the beginning of ripening, reducing sugars make up most of the sugar content, while there are more non-reducing than reducing sugars in completely ripe fruit. Sucrose contributes 57% of the total sugar in ripe Keitt mangoes with fructose and glucose making up 28% and 15% respectively (Medlicott and Thompson 1985) [18]. Sucrose content increases during ripening as a result of starch hydrolysis form increased amylase activity (Mattoo and Mod 1969, Tandon and Karla 1983).

The major textural changes resulting in the softening of the fruits are due to enzyme-mediated alteration in the structure and composition of cell wall, partial or complete solubilization of cell wall polysaccharide (Tucker and Grierson 1987) [41] and hydrolysis of starch and other storage polysaccharides (Selvaraj et al. 1989, Fuchs et al. 1980) [27, 5]. During the development of the fruit on the tree up to the climacteric stage, starch accumulation in the pulp is the main activity. According to Simao et al. (2008) [32] starch content of unripe mango Keitt is seen to be converted to soluble sugars during the ripening. Also changes in physical aspects of starch degradation were observed. During maturity, the total solids increase until fruit ripens, after which they decrease. Non-reducing and total sugars increase gradually showing a fall near ripening, while reducing sugars remain more or less constant during development. Reducing sugars during ripening are several times higher than the non-reducing sugars (Mann et al. 1974) [15].

During ripening, mangoes show a decrease in acidity and an increase in sugars (Tripathi 1980, Morga et al. 1979) [40, 20]. The predominant acids are citric with lesser amount of succinic and malic and tartaric with small amount of citric (Shashirekha and Patwardan 1976).

Acidity of the fruit increases in the initial stages followed by a gradual decline at ripe stage (table 16). Total acidity varied from 0.13 to 0.71%. Jain et al. (1959) [8] reported the presence of oxalic, citric, malic, succinic, pyruvic, adipic, galacturonic, glucuronic and mucic acids, together with two unidentified acids. Stahl (1935) [35] noted the presence of tartaric acid. Citric acid is the major organic acid present in mango fruit. Vitamin C content which is high during the tender green stage decreases rapidly with the growth and development. Crude fibre remains constant.

Proteins are omnipresent in the living organisms with each cell containing a few hundred to many thousands of them. The structural proteins contribute to the form and stability of the cell and organisms, and the enzymes are responsible for the metabolism within. Mango fruit contains 0.5-1.0% protein on a fresh weight basis (Lakshminarayana 1980). In the present study, protein was found to increase in all ripe (stage IV) variety of both regions (table 1). It ranged from 0.59 -0.89 100/g in stage III while in stage IV it ranged from 0.71 to 1.0 100/g. In case of Dashehari mango variety, a decrease in the soluble protein content was observed up to 44 days after fruit set, which increase again until 96 days (Tandon and Kalra 1983) [36]. A Peruvian variety has a remarkably high content ranging from 1.57-5.42% of protein (Jain 1961) [7].

The characteristic odor that appeared in the fruits during ripening is due to components of ester and carbonyl types. Some of the phenolic compounds identified in mango are gallic acid, indigallic acid, gallotannin, quercetin, isoquercetin, mangiferin and ellagic acid (El-Ansari et al.1969, Rhodes 1980) [4, 25].

Palafox et al., (2012) [21] quantified the major phenolic compounds in *Mangifera indica* and identified them as

chlorogenic, gallic acid, vanillic acid and protocatechuic acid. Gallic acid contributes the highest percent to antioxidant activity in mango pulp during ripening.

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