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Nutraceutical changes during ripening of bael [*Aegle marmelos* (L.) Correa] fruits harvested at different maturity periods

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Fruits of two bael selections (CISH B-1 and CISH B-2) were harvested at 320, 335 and 345 days after fruit set and ripened under ambient conditions to observe the changes in nutritional value in fruits during maturity and ripening. Each successive harvesting period had higher TSS, polyphenols and total pectin contents *vis-à-vis* lower tannic acid and marmelosin contents in both the selections. Psoralen content though did not change at all in CISH B-1 with each harvesting period but decreased significantly in CISH B-2. In ripened fruits of selections B-1 and B-2, TSS, polyphenols, tannic acid and total pectin showed an increasing trend with the prolongation of picking stages, while a decreasing pattern was observed in case of marmelosin and psoralen. Upon characterization of total pectin, water extracted fraction revealed an increasing pattern and alkali extracted fraction a decreasing pattern in both the unripe and ripe fruits of selections B-1 and B-2 with the prolongation of harvesting time. Ripened fruits of selections B-1 and B-2, when collected after 335 days of fruit setting, possessed highest amounts of polyphenols (1.50 and 1.61 g/100 g in B-1 and B-2, respectively), tannic acid (1.96 g/100 g in B-1 and 2.02 g/100 g in B-2), total pectin (8.03 and 7.82 g/100 g pulp in B-1 and B-2, respectively) and marmelosin (427 and 300 µg/g in B-1 and B-2, respectively) along with best organoleptic score (7.4 for B-1 and 7.1 for B-2). Therefore, bael fruit harvested at 335 days after fruit set have better nutritional and sensory qualities and more useful for processing as well as phyto-pharmaceutical industries.

Keywords: *Aegle marmelos*, Bael, Maturity, Nutraceutical changes, Ripening

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Aegle marmelos (L.) Correa, popularly known as bael or stone apple, belongs to family Rutaceae and is a medium-sized, slender, aromatic and deciduous tree. It is originated in India and currently grown in many Southeast Asian countries. Leaves, fruits, stem, bark and roots of bael at all stages of maturity are used as medicines against various human disorders[1]. Both unripe and ripe fruits are effective against various stomach disorders and ripe fruits are also good for heart and brain[2]. It is a nutritionally important fruit rich in many vitamins, minerals, carbohydrates and dietary fibre[3]. Bael fruits also possess various pharmacologically active molecules namely marmelosin, psoralen, aurapten, marmelide, luvangetin, tannins, anthocyanins, pectin, etc. which have been proved effective against many diseases including cancer, malaria, diabetes and gastroduodenal disorders[4,5]. Marmelosin, a furanocoumarin, is the pharmacologically active component of bael fruit and known as the panacea for stomach ailments. It shows antihelminthic and antibacterial activities and can also be effective as a laxative and in diuretic treatment[6,7]. Psoralen, another furanocoumarin, is used for antispasmodic, artemicide and cytotoxic properties[8,9]. It helps to increase the level of tolerance of skin to sunlight and in maintaining normal skin colour. It is also effective in the treatment of vitiligo, leucoderma and psoriasis[10]. Tannins (as tannic acid) have astringent, anticarcinogenic, antimutagenic and antimicrobial properties and are wonderful remedy against diarrhoea[6]. The polyphenols are well known antioxidants and have antidiabetic properties also. Pectin is a complex polysaccharide in plant cell wall which is effective in reducing blood cholesterol levels and curing gastrointestinal disorders[11].

Despite their proven therapeutic activities, very few researches have been carried out till date to characterize these nutraceuticals in bael fruit particularly during maturity and ripening. Singh and Roy (1984) have reported that pectin content increased during development and ripening of bael

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fruit, while alcohol insoluble solids, polyphenols and acidity decreased during ripening[2]. But the authors did not mention about the changes in 3 other nutraceuticals like marmelosin, psoralen and tannic acid and also did not differentiate between pectin fractions. Bael fruits can be ripened artificially at high temperature with the exogenous application of ethylene though the composition of fruit, whether ripened naturally or artificially, does not vary much[12]. The Institute has recognized two promising selections of bael, CISH B-1 and CISH B-2 through collection of germplasms, and ripening behavior of these selections has not been studied earlier. To identify the proper stage of harvesting of these bael selections for ripening with optimum nutritional quality, fruits were picked at three maturity stages and the changes in quality characteristics in both unripe and ripe fruits have been studied. These data will be helpful in release of these selections as varieties.

Methodology

Plant materials

Eight healthy fruits of each of CISH B-1 (smaller in size and oval to oblong in shape) and CISH B-2 (bigger in size and round shaped) were harvested at 320, 335 and 345 days after fruit set (DAFS) for the present investigation from the Institute farm. Four fruits from each selection and each picking period were ripened under ambient conditions (34-40°C, 70-85% RH) and various quality parameters were assessed in both unripe and ripe fruits to observe respective changes during ripening. Each fruit served as a replication (n=4). The fruits from both the selections (B-1 and B-2) ripened at 28, 21 and 15 days at room temperature after harvested at 320, 335 and 345 DAFS, respectively. Weight of the fruits ranged between 1040 – 1213 g in B-1 and 2171 – 2573 g in B-2 during three harvest periods.

Chemicals

Five milligram each of marmelosin and psoralen, procured from Life Technologies India Pvt. Ltd., Mumbai, was dissolved in HPLC grade methanol (25 mL) to obtain 200 µg/mL stock solutions. Working solutions of 1, 2 and 4 µg/mL concentrations were prepared by serial dilution in methanol. Similarly, stock solution of tannic acid (2000 µg/mL) was prepared by dissolving 200 mg of technical grade tannic acid (Sigma-Aldrich, India) in 100 mL of HPLC grade methanol and subsequently working solutions of 500 and 1000 µg/mL concentrations were obtained by serial dilution in methanol. Methanol was used because all three compounds were soluble in it.

Extraction of nutraceuticals

The standardized method was followed for the extraction of marmelosin and psoralen from bael pulp[13]. Accurately weighed 5 g pulp was extracted twice with 50+50 mL benzene and after completely evaporating benzene the residue was dissolved in HPLC grade methanol (10 mL). Tannic acid was extracted with 80% methanol in water. The content of total polyphenols was quantified by spectrophotometric method at 760 nm following Folin and Ciocalteu's phenol reagent method[14]. Total soluble solid (TSS) in pulp was estimated by hand refractometer (Erma, Japan), while titratable acidity was measured by titrimetric method using 0.1 N sodium hydroxide solution. Alcohol insoluble solid (AIS) was determined in 30 g bael pulp (without seeds) using 100 mL of 95% ethanol. After boiling for 15 min followed by cooling at room temperature, the mixture was filtered through Buchner funnel with Whatman No. 1 filter paper. Washing of the residue with alcohol followed by acetone was done till it became colorless and then oven-dried it at 45°C until constant weight. Characterization of AIS into three pectin fractions (water soluble, ammonium oxalate soluble and alkali soluble) was done by subsequent extraction using distilled water, 0.05 M ammonium oxalate and 0.05 M sodium hydroxide as per the method mentioned in literature[15]. Total pectin was calculated by adding all three pectin fractions. All the pectin fractions were estimated colorimetrically in an UV-VIS spectrophotometer (Labomed INC., USA) at 525 nm, while standard solution was prepared with galacturonic acid.

HPLC conditions

A Shimadzu, Japan make HPLC (model SCL 10 AVP) combined with photodiode array (PDA) detector and manual injector was used for the quantification of marmelosin, psoralen and tannic acid. The method already reported was followed for the analysis of marmelosin and psoralen[13]. For the determination of tannic acid, the HPLC method mentioned in literature was used with modifications in column length and flow-rate of mobile phase[16]. Reverse phase C-18 column was the stationary phase for all three compounds. The mobile phase for tannic acid was methanol: water (50 : 50, v/v) with a flow-

rate of 1.0 mL/min and it was detected at 277 nm wavelength. All the samples were filtered before analysis using 13 mm diameter nylon membrane filters (Millipore, 0.45 µm thickness). Under these conditions, the retention times of tannic acid, psoralen and marmelosin were recorded as 3.19, 5.62 and 10.76 min, respectively. Twenty µL of either reference standard or sample was injected for HPLC analysis, in triplicate.

Statistical analysis

The statistical analysis was carried out using SAS software through student's *t*-test (LSD) at $p \leq 0.05$ for comparisons of means. Single-factor analysis using a completely randomized design was conducted for calculation of data. Four replications (one fruit as one replication) for each bael selection on each harvest date during both maturity and ripening were taken. For better clarity in statistical calculation, two measurements per replication were used.

Results

Nutraceuticals changes in unripe fruit at different maturities

Fruit weight, TSS and acidity

Bael is a climacteric fruit and matures approximately 11 months after fruit set under north Indian conditions and harvested at unripe but physiologically mature stage. Fruits of two bael selections (CISH B-1 and CISH B-2) were harvested at 320, 335 and 345 days after fruit set and analyzed for their nutraceutical values. Though the average fruit weight in B-1 decreased with successive maturity stages, it increased in case of B-2. TSS remained almost constant during maturity period with highest TSS (31.8 °B in B-1 and 32.3 °B in B-2) recorded in fruit picked at 335 DAFS in both the selections. Slight decrease in TSS was noticed during the 3rd harvest. Titratable acidity first increased to 1.41 and 1.41% at 335 DAFS from 0.89 and 1.13% at 320 DAFS and then decreased rapidly to 0.46 and 0.51% at 345 DAFS in B-1 and B-2, respectively (Table 1 & Table 2).

Marmelosin, psoralen, tannic acid and polyphenols

A decreasing trend with each successive harvesting period was noticed in case of marmelosin and tannic acid, while the trend was reverse in case of total polyphenols in both the selections. In both CISH B-1 and CISH B-2, the lowest marmelosin content was observed at 345 DAFS (523 µg/g in B-1 and 170 µg/g in B-2), whereas, the highest amount of marmelosin was obtained at 335 DAFS in B-1 (685 µg/g) and at 320 DAFS in B-2 (582 µg/g). The declining patterns of marmelosin in unripe fruit of two bael selections were completely different. In selection B-1 it first increased and then decreased, whereas in selection B-2, it declined continuously (Table 1 & Table 2). Though psoralen content did not change in selection B-1 during the maturity period, it declined significantly in selection B-2 from 40 to 9 µg/g during 320 to 345 DAFS (Table 1 & Table 2). The reduction in the content of psoralen was up to 77.50% during April to May. Tannic acid decreased markedly from

Table 1 — Changes in physicochemical and nutraceutical parameters in CISH B-1 fruit before and after ripening

Parameters	320 days		335 days		345 days		LSD ($p \leq 0.05$)*	
	Unripe ± SD	Ripe ± SD	Unripe ± SD	Ripe ± SD	Unripe ± SD	Ripe ± SD	Unripe	Ripe
Average fruit weight (g)	1213 ± 174.52	1012 ± 44.50	1055 ± 47.01	997 ± 57.50	1040 ± 32.33	968 ± 66.50	240.67	154.49
TSS (°B)	29.1 ± 0.31	36.7 ± 0.42	31.8 ± 0.60	36.7 ± 2.71	29.3 ± 0.42	37.2 ± 0.23	0.87	3.72
Titratable acidity (%)	0.89 ± 0.09	0.59 ± 0.04	1.41 ± 0.06	0.70 ± 0.06	0.46 ± 0.16	0.61 ± 0.08	0.26	0.17
Marmelosin (µg/g)	625 ± 122.07	421 ± 51.30	685 ± 324.43	427 ± 46.05	523 ± 141.77	275 ± 8.80	512.39	110.83
Psoralen (µg/g)	102 ± 5.30	42 ± 0.75	100 ± 5.60	20 ± 1.13	102 ± 4.30	9.4 ± 0.70	50.85	2.37
Tannic acid (g/100 g)	1.79 ± 0.09	1.95 ± 0.15	1.63 ± 0.14	1.96 ± 0.06	1.52 ± 0.17	1.72 ± 0.02	0.25	0.19
Polyphenols (g/100 g)	1.44 ± 0.11	1.28 ± 0.28	1.87 ± 0.11	1.50 ± 0.05	1.72 ± 0.09	1.49 ± 0.01	0.27	0.34
AIS (%)	17.5 ± 0.61	15.7 ± 2.70	20.7 ± 2.56	16.7 ± 1.15	15.6 ± 1.90	14.7 ± 0.80	3.32	4.62
Total pectin (%)	20.2 ± 0.07	40.9 ± 0.11	27.6 ± 0.06	48.1 ± 0.16	28.8 ± 0.05	50.1 ± 0.18	0.17	0.36
Water soluble pectin (%)	52.8 ± 0.85	81.2 ± 0.15	65.9 ± 0.25	87.9 ± 1.30	67.4 ± 3.00	79.9 ± 0.40	4.69	1.66
Alkali soluble pectin (%)	29.7 ± 0.15	8.8 ± 0.95	21.4 ± 0.55	5.1 ± 0.96	19.1 ± 0.95	10.2 ± 0.40	1.76	1.97
Ammonium oxalate soluble pectin (%)	17.5 ± 0.55	10.0 ± 0.65	12.6 ± 0.40	7.1 ± 0.40	13.8 ± 0.10	9.9 ± 0.06	1.10	1.19
Sensory score	–	6.7	–	7.4	–	6.2	–	–

* No. of replication = 4

Table 2 — Changes in physicochemical and nutraceutical attributes in fruit of CISH B-2 before and after ripening

Attributes	320 days		335 days		345 days		LSD ($p \leq 0.05$)*	
	Unripe ± SD	Ripe ± SD	Unripe ± SD	Ripe ± SD	Unripe ± SD	Ripe ± SD	Unripe	Ripe
Average fruit weight (g)	2171 ± 86.26	1801 ± 138.50	2216 ± 164.61	2314 ± 62.50	2573 ± 76.17	2292 ± 22.50	303.52	182.59
TSS (°B)	30.6 ± 0.53	36.6 ± 0.72	32.3 ± 2.16	38.1 ± 0.11	28.7 ± 3.82	39.3 ± 0.11	6.97	1.06
Titratable acidity (%)	1.13 ± 0.07	0.61 ± 0.08	1.41 ± 0.17	0.74 ± 0.08	0.51 ± 0.23	0.74 ± 0.03	0.31	0.13
Marmelosin (μg/g)	582 ± 68.07	458 ± 37.50	479 ± 72.33	300 ± 62.45	170 ± 31.41	70 ± 22.40	569.23	122.14
Psoralen (μg/g)	40 ± 1.74	17 ± 3.67	21 ± 1.75	6.4 ± 0.56	9.0 ± 0.40	8.7 ± 3.60	3.56	8.29
Tannic acid (g/100 g)	1.80 ± 0.29	1.99 ± 0.12	1.65 ± 0.13	2.02 ± 0.18	1.54 ± 0.14	1.78 ± 0.03	0.52	0.17
Polyphenols (g/100 g)	1.48 ± 0.10	1.21 ± 0.28	1.79 ± 0.03	1.61 ± 0.03	1.55 ± 0.14	1.54 ± 0.04	0.16	0.33
AIS (%)	15.5 ± 0.84	14.6 ± 1.55	17.8 ± 2.94	16.5 ± 1.95	13.4 ± 0.70	13.7 ± 0.60	3.60	4.10
Total pectin (%)	20.4 ± 0.02	38.8 ± 0.06	25.2 ± 0.02	47.4 ± 0.18	34.5 ± 0.10	52.5 ± 0.11	0.15	0.34
Water soluble pectin (%)	59.8 ± 0.06	80.0 ± 0.30	66.3 ± 1.30	87.8 ± 0.97	71.6 ± 4.85	81.5 ± 1.60	7.33	2.29
Alkali soluble pectin (%)	24.5 ± 0.11	8.9 ± 0.85	24.6 ± 1.10	4.6 ± 0.35	11.9 ± 0.30	8.4 ± 0.50	1.68	1.61
Ammonium oxalate soluble pectin (%)	15.7 ± 0.80	11.2 ± 0.30	9.1 ± 0.80	7.6 ± 0.85	16.5 ± 0.25	10.1 ± 0.00	0.72	0.98
Sensory score	–	6.6	–	7.1	–	6.0	–	–

* No. of replication = 4

1.79 g/100 g at 320 DAFS to 1.52 g/100 g at 345 DAFS in CISH B-1. Similar declining pattern was recorded in CISH B-2 also, where it reduced from 1.80 to 1.54 g/100 g during the 25 days period. The amount of tannic acid did not vary much between selections. A positive correlation between the content of tannic acid and fruit weight was observed, *i.e.*, bigger fruits of CISH B-2 possessed higher amount of tannic acid compared to smaller fruits of CISH B-1, which suggested the possible influence of fruit weight on changes in tannic acid content during maturity. The content of polyphenols increased marginally from 1.44 and 1.48 g/100 g at 320 DAFS to 1.72 and 1.55 g/100 g at 345 DAFS with the highest amount being observed at 335 DAFS (1.87 and 1.79 g/100 g in selections B-1 and B-2, respectively). The changes in the content of polyphenols during maturity showed similar style of variation in the two bael selections (Table 1 & Table 2).

AIS, total pectin and pectin fractions

Alcohol insoluble solids (AIS) showed a declining pattern during maturity, while total pectin exhibited an increasing pattern in both the selections. Though AIS increased slightly in fruits of both the selections sampled at 335 DAFS, it declined thereafter in fruits picked at 345 DAFS (Table 1 & Table 2). Similar pattern was observed in case of total pectin in selection B-1 where it increased at 335 DAFS and then decreased, whereas in selection B-2, the increasing trend was continuous. The content of total pectin was slightly higher in fruit of CISH B-1 than in CISH B-2 (Table 1 & Table 2). Upon characterization of pectin, water extracted (WE) fraction showed an increasing trend and alkali soluble (AE) fraction a declining trend with successive harvesting period in both the bael selections (Table 1 & Table 2). The ammonium oxalate soluble (AOE) portion of pectin did not exhibit any significant change during maturity in unripe fruit of selection B-1, but a sudden and significant jump (from 2.3 to 5.7%) was noticed in fruit of selection B-2 harvested at 345 DAFS.

Changes in nutraceuticals in bael fruit upon ripening

Fruit weight, TSS and acidity

It was noticed that as the maturity advanced the ripening period of fruit declined. The fruit of both the selections (B-1 and B-2) ripened at 28 days when collected at 320 DAFS, at 21 days when picked at 335 DAFS and at 15 days when harvested at 345 DAFS. The physicochemical parameters of bael fruit changed remarkably upon ripening. As compared to unripe fruit the average fruit weight and titratable acidity declined but TSS increased in ripe fruit of both the selections (Table 1 & Table 2). Upon ripening of bael after picking at three stages of maturity, average fruit weight revealed a decreasing pattern in both the selections. TSS did not exhibit any significant change after successive ripening in the fruit of selection B-1, but slightly increased from 36.6 to 39.3°B in the fruit of other selection. Titratable acidity also showed marginal increase in the fruit of both the selections upon successive ripening. Ripened fruit of selections B-1 and B-2, when harvested at 335 days of fruit setting, were found organoleptically better on Hedonic scale [scores 7.4 (out of 9.0) for B-1 and 7.1 for B-2] than fruit harvested after 320 (scores 6.7 for

B-1 and 6.6 for B-2) or 345 (scores 6.2 for B-1 and 6.0 for B-2) days of fruit set (Table 1 & Table 2).

Marmelosin, psoralen, tannic acid and polyphenols

HPLC data revealed that the amounts of marmelosin and psoralen decreased significantly in both the bael selections after ripening, while that of tannic acid increased sharply. The reduction in psoralen content in ripened fruit of selection B-1 irrespective of harvesting stages was more prominent as compared to that of marmelosin. However, in ripened fruit of selection B-2 the decline in marmelosin content was more visible than psoralen at each successive harvesting period. The reduction in these two nutraceuticals was more pronounced in selection B-1 than in selection B-2 upon ripening (Table 1 & Table 2). Fruit of CISH B-1 contained more amounts of marmelosin and psoralen compared to that of CISH B-2 even after ripening. But the content of tannic acid was found slightly more in ripened fruit of selection B-2 than in selection B-1 and there was no significant difference noticed in polyphenols content in ripe fruit of selections B-1 and B-2. When the fruit were ripened, tannic acid content increased significantly in both the selections with the highest amount obtained at 335 DAFS (1.96 and 2.02 g/100 g in B-1 and B-2, respectively). During ripening, tannic acid first increased marginally between harvesting dates and then decreased remarkably with the advancement of maturity. Similar trend was noticed in case of polyphenols also though the initial increment was more visible than the final decrease, which was not significant (Table 1 & Table 2). Like unripe fruit, ripened fruit collected at 335 DAFS possessed highest amount of polyphenols in two bael selections (1.50 g/100 g in B-1 and 1.61 g/100 g in B-2).

AIS, total pectin and pectin fractions

Upon ripening, AIS declined in both the selections. A decreasing pattern of AIS was observed in ripe fruit with the advancement of harvesting stages, whereas, total pectin showed an increasing pattern in two bael selections after ripening (Table 1 & Table 2). Ripe fruit contained lower AIS but higher total pectin. In ripened fruit of selections B-1 and B-2, total pectin increased sharply with the highest amount (8.03% in B-1 and 7.82% in B-2) recorded in fruit harvested at 335 DAFS, which then reduced marginally in ripened fruit collected at 345 DAFS. When AIS was characterized into three fractions in ripe bael fruit, water soluble (WE) fraction increased significantly upon ripening at each harvesting period, which was because of the hydrolysis of pectic substances by pectinase enzyme during fruit ripening. However, alkali extracted (AE) fraction decreased remarkably in ripe fruit as compared to unripe fruit (Table 1 & Table 2) and a variable changing pattern was noticed in fruit picked at different maturity stages. The changes in ammonium oxalate soluble (AOE) fraction of pectin in selections B-1 and B-2 during ripening at different harvesting period did not reveal any specific trend, though its content was marginally increased after ripening.

Discussion

In the present study, changes in various nutraceutical parameters during maturity and ripening of bael fruit were investigated. The decrease in TSS during 3rd harvest might be due to the enzymatic breakdown of soluble matters in over-maturing fruit. The slight decrease in TSS during maturity period is in agreement with the literature, where it has been mentioned that TSS decreased during the end of growth period in guava fruits[17]. A continuous decline in acidity in bael fruit during growth and development has also been reported[2]. Bhattacherjee *et al*. (2016) have reported that marmelosin and psoralen contents in mature bael fruit were less than in immature fruit[18]. Smaller sized fruit of selection B-1 possessed higher amount of marmelosin and psoralen and slightly lower amount of tannic acid than bigger sized fruit of selection B-2. Again the content of marmelosin in both the bael selections was found 5 to 20 times higher than that of psoralen at all the sampling periods. The insignificant variation in the content of psoralen in bael during maturity might be due to its smaller quantity as compared to marmelosin. It was observed from the data that smaller sized fruit of CISH B-1 had slightly higher amount of polyphenols than bigger sized fruit of CISH B-2, which was also confirmed in one of our earlier study[18].

The reason for the decrease in AIS in two bael selections during final harvest might be due to the solubilization of hemicelluloses, celluloses, starch, etc. as bael fruit is also rich in dietary fibre. These observations were in sync with literature where rapid decline of AIS during later stages of fruit development was reported in four guava cultivars[19]. The authors also mentioned that solubilization of celluloses, hemicelluloses, pectins and starch to soluble components by some enzymes (pectinase,

hemicellulase and cellulase) might cause the decrease in AIS. In blueberry fruit also the decrease in AIS with maturation has been reported where the reason for the decline was due to the increase in water uptake and subsequent increase in fruit size[20]. The increase in total pectin during fruit development in bael has also been observed[2]. Our findings on changes in total pectin in bael during maturity period are similar with those in mango, guava and cape-gooseberry fruits[21-23]. The increase in WE and AOE during fruit development might be due to the conversion of pectic substances to soluble constituents by pectic enzymes. It was observed during the maturity period of mango that WE was maximum at the time of final harvest as in the case of CISH B-1 and CISH B-2. The rise in WE and reduction in AE contents in mango were also reported by the authors[21]. It has also been reported in literature that AOE did not show any particular trend and WE increased during mango maturation[24]. Similarly in guava cultivars WE content also increased gradually with fruit development[19]. During the development of blueberry fruits, the initiation of solubilization was happened because of the decrease in AE content and increase in WE content[20].

During ripening it has been noticed that bael fruit require 18–24 days to be ripened artificially[12]. Marginal increase in both TSS and acidity might be due to bigger size and erratic ripening of bael fruit. Though in mango, it has been observed that TSS increased and acidity decreased upon ripening at every successive picking[25]. Same authors have observed that an increase in TSS and sharp decline in tannins and acidity during ripening might help in reducing astringency and improving flavor in mango[25]. During ripening polyphenols increased slightly with successive harvesting stages, which is similar to that reported in mango[26]. The content of polyphenols in bael fruit decreased upon ripening. This result is similar to that observed in guava and strawberry fruits[22,27].

The drop in AIS upon ripening was also reported in mango fruit where the authors mentioned that sharp decline in starch content could be the reason for fall of AIS[21]. The decline in AIS was also noticed during ripening of guava and strawberry fruits[19,28]. The solubilization of pectic substances by various enzymes during ripening might be the reason for decrease in AIS. This result was well supported in papaya fruit where more pectin was solubilized during ripening due to the increased activity of pectin methyl esterase[29]. The increase in total pectin content during ripening was also observed in cherry fruit[30]. The increase in WE (high methoxyl) and AOE (low methoxyl) contents and decrease in AE (protopectin) content of pectin during ripening was also reported in several fruits like mango, guava, blueberry, sweet cherry and cape-gooseberry[20-23,30]. All the authors opined that the initiation of solubilization of pectin by some enzymes caused the increase in WE and AOE contents and decrease in AE content during ripening of fruits. In one of our earlier studies with bael, it was also noticed that with the advancement of growth and development (irrespective of selections), AIS and WE increased while AE decreased and fruits could be harvested around 300 days after fruit set for processing purpose which is the general practice in India[31].

Conclusion

Ripened bael fruit harvested after 335 days of fruit set were found to have the optimum amount of nutritional quality in terms of TSS, total pectin, tannic acid, polyphenols and marmelosin contents as well as better sensory attributes, though psoralen content was found maximum in ripened fruits harvested after 320 days of fruit set. Therefore, it can be concluded that bael fruit of selections CISH B-1 and CISH B-2 harvested at 335 days after fruit set are more suitable for ripening in terms of better nutritional and sensory attributes as well as more useful for processing industries.

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