

Review

Bael (*Aegle marmelos* Correa) products processing: A review

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Bael (*Aegle marmelos* Correa) being an indigenous fruit occupies an important place from medicinal point of view. The different varieties of Bael such as Mirzapuri, Kagzi Gonda, Kagzi Banarsi, Kagzi Etawah, Narendra Bael-1, Narendra Bael-2, Narendra Bael-5, Narendra Bael-9, Pant Shivani, Pant Sujata, etc are popular. Its nutritional and medicinal properties make this fruit one of the most valuable and a good source of nutrients, and qualities to cure diarrhoea, dysentery and other stomach ailments. This fruit have unlimited potential in its processed form. Bael can be processed to prepare jam, squash, nectar, toffee, slab, powder, ready-to-serve (RTS), wine, etc. The present paper therefore deals with the processing of bael into different products and the medicinal aspects together with physico-chemical changes in bael fruit.

Key words: *Aegle marmelos*, bael, medicinal properties, processing aspects, nutritional properties.

INTRODUCTION

The bael fruit (*Aegle marmelos* L. Correa) is known in India from prehistoric times. This fruit is native to Northern India, but widely found throughout the Indian Peninsula (Rahman and Pravin, 2014). It also grows in Sri Lanka, Pakistan, Bangladesh, Burma, Thailand and most of the southeastern Asian countries (Rakesh et al., 2005).

Roy et al. (1979) stated that the three lobed leaves of bael tree are traditionally used as sacred offerings to "Lord Shiva" according to Hindu customs. It has been said that this tree indicates the presence of underground

water. Bael is a sub-tropical tree but grows well both in tropical and sub-tropical climate up to an altitude of 1219 m. It is medium in size, about 12 to 15 m in height with short trunk, thick, soft, flaking bark and the lower ones drooping. It withstands temperatures as low as -8°C but under severe cold, it sheds its leaves. It is one of the choicest fruits of arid and semi arid zones due to its drought resistance and tolerance to temperatures upto 48°C. In Punjab, it grows up to an altitude of 4,000-ft (1,200-m) where the temperature rises to 120°F (48.89°C) in the shade in summer and descends to 20°F

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Table 1. Nutritional composition of bael fruit.

Nutrient	Amount
Moisture (g)	61.0
Protein (g)	1.6
Fat (g)	0.2
Mineral (g)	1.9
Fibre (g)	2.9
Calcium (mg)	80
Phosphorous (mg)	52
Iron (mg)	0.5
Carotene (µg)	55
Thiamine (mg)	0.12
Niacin (mg)	1.0
Vitamin C (mg)	8
Potassium(mg)	610
Copper (mg)	0.20

(-6.67°C) in the winter and prolonged droughts occur (Lambole et al., 2010).

Its mature leaf emits a disagreeable odour when bruised. Fragment flowers, in clusters of 4 to 7 along young branch lets, have 4 recurved, fleshy petals, green outside, yellowish inside and 50 or more greenish-yellow stamens (Patel et al., 2012). According to Chattopadhyay (1998), bael is a very hardy tree and grows in all type of soils. It thrives well even in swampy, alkaline and stony soils having pH range of 5 to 10. However, for good growth and yield, well drained, humus soils having pH range from 5.5 to 7.5 are best.

There are no standardized names for bael cultivars. They are named after the names of the locality where they are most easily available. Its main cultivated varieties in India are Mirzapuri, Kagzi Gonda, Kagzi Banarsi, Kagzi Etawah, Narendra Bael-1, Narendra Bael-2, Narendra Bael-5, and Narendra Bael-9. Some scientists have tried to identify and compare different varieties of bael fruits grown. Jauhari et al. (1969) surveyed the central and eastern Uttar Pradesh, western Bihar and selected seven varieties for physico-chemical studies. They found the "Kaghzi Etawah" as the best variety having 1893 g weight per fruit and 1583 g pulp per fruit with 36% TSS, 0.33% acidity and 21.7 mg ascorbic acid per 100 g edible pulp.

Bael fruit (*A. marmelos* L. *Correa*) belongs to the family *Rutaceae*, occupies an important place among the indigenous fruits of India. It is known by different names viz. Bael, Bel, Bengal Quince, Bil, Bilva, Bilpatre, Shul, Shaiphal, Vilvum, etc. In ancient Sanskrit poems, this fruit is considered auspicious, sacred and emblem of prosperity. This fruit is considered as of great mythological and religious significance (Sharma and Bhagwan, 1988). It is a large deciduous tropical tree, found all over India in Sub-Himalayan forests, Bengal,

Central and South India and also in Burma.

The utility of bael is mentioned in the Indian ancient system of medicine. Every part of the tree such as root, bark, leaf, flower, fruits, seed and even its latex are important in several traditional system of medicine, that is why it is one of the most important trees in India (Patel et al., 2012). The decoction of the root and root bark is useful in intermittent fever, hypo-chondriasis, melancholia and palpitation of the heart. The leaves and bark have been used in medicated enema. The nutritional composition of bael fruit is presented in Table 1.

The peel of the fruit which is a very hard shell and green to brown in color depends on ripening stage. The appearance of yellow or orange edible pulp is like a boiled pumpkin, possesses a slightly sweet taste and a characteristic floral, terpene-like aroma, very fragrant and pleasantly flavored. The ripe fruit of bael is sweet aromatic, nutritious and very palatable being highly esteemed and eaten by all classes of people (Charoensiddhi and Anprung, 2008). The fruit has excellent aroma which is not destroyed even during processing, thus there is untapped potential for processing bael into various products (Singh et al., 2014).

This fruit is used in Ayurvedic medicine to cure Vatha and Kaphay disturbances in the body. The fully ripened fruit is not much used in medicines. Half ripe fruits are mostly used in medicine (Kumar et al., 2012). The marmelosin ($C_{13}H_{12}O_3$) content which is found in this fruit is known as "panacea of stomach ailments". The following constituents are reported to be present in this fruit: aegelin, alloimperatorin, imperatorin, marmelosin, psoralen, scoparone, scopoletin, tannic acid, Umbelliferone, xanthotoxol and β -sitosterol (Kamalakkannan and Prince, 2005). Bael is reported to contain a number of coumarins, alkaloids, sterols and essential oils. Roots and fruits contain coumarins such as scoparone, scopoletin, umbelliferone, marmesin and skimming (Lambole et al., 2010). Its fresh, aqueous and alcoholic leaf extracts have been reported to have cardiogenic effects in mammals. This fruit also possess hypoglycemic activity, anti-spermatogenic activity, antioxidant activity and anticancer effect. Bael leaf enhances ability to utilize the external glucose load in the body by stimulation of glucose uptake similar to insulin (Dahanukar et al., 2000).

PHYSICO-CHEMICAL CHARACTERISTICS OF FRUIT

Physical characteristics such as average fruit weight, pulp, seed, fibre, rind thickness and shell percentage etc. have been studied by various researchers. Ram and Singh (2003) investigated four bael varieties viz. NB-5, NB-9, NS-1 and Kaghzi. Average fruit weight was varied from 1.011 to 2.09 kg. Cultivar NB-9 recorded highest value followed by cultivar, NS-1. Similar variability in bael

fruit weight was also reported by Jauhari and Singh (1971). It was observed that pulp (%) varies from 57-68.13% and cultivar NB-5 had the highest percentage of pulp (68.13%). Pulp of fruit exhibited various shades of yellow to orange colour. Seed content of bael fruit varied from 2.23 to 3.47%. Cultivar, Kaghzi has highest (3.47%) and cultivar NB-5 has lowest (2.33%) value for seed content. Fibre content varied from 9.91 (Kagazi) to 4.49% (NB-9). The highest percentage of shell was found in cultivar Kagazi (29.50%) while it was lowest in cultivar NB-5 (23.16%). Similar findings have been reported by Roy and Singh (1978).

Physical characteristics of bael cultivars PB7B, PB10, PB11, PB14, Pant Aparna, Pant Shivani, Pant Sujata and Pant Urvashi were studied by Singh et al. (2000). It was observed that the fruits vary in shape such as spheroid-oblong (PB7B and PB11), spheroid (PB10, Pant Shivani, Pant Urvashi), Ellipsoid (Pant Aparna), Oblate (Pant Sujata) and Pyriform (PB14). Maximum fruit length was observed in Pant Urvashi (53.27 cm) and minimum in PB14 (39.87 cm). Diameter was maximum in Pant Sujata (54.53 cm) and minimum diameter was in PB10 (37.37 cm). Fruit weight varied from maximum 2.06 kg in Pant Urvashi to 1.0 kg in PB 14. The mucilage content was maximum in PB7B (17.36%). Minimum pulp content was found in PB 7B (38.19%). Seed content was found maximum in PB11 (3.17%). Similar variation in fibre, mucilage, peel and pulp content was reported by Jauhari et al. (1969).

Prasad and Singh (2001) categorized bael fruit into extra large size (ELS) >1000 g; large Size (LS) >750 to 1000 g; medium Size (MS) >400 to 750 g and small size (SS) <400 g. The results showed that the polar diameter of ELS bael ranges from 13.57 to 17.36 cm. The transverse diameter varies from 13.50 to 17.60 cm. The peel thickness varies from 0.18 to 0.27 cm. The pulp content varies from 78.56 to 78.82%. Maximum sugar content, TSS and non reducing sugars were observed, 4.59%, 34.7^obrix and 14.93%, respectively.

Physicochemical characteristics of three genotypes of bael viz. NB-5, NB-9 and Kaghzi growing under rainfed conditions of Jammu was studied by Bhat and Kumari (2006). They showed variation in fruit weight, pulp, seeds, fiber, shell, TSS, acidity, sugars, ascorbic acid and phenols. NB-9 having larger sized fruits, more pulp, lesser seeds and fiber is ideal for processing. Pulp was extracted by adding water equal to the weight of the pulp and it was utilized for preparing beverages in different proportions. Organoleptic evaluation revealed that bael nectar consisting of 35% pulp, 25°Brix and 0.3% acidity was ideal combination whereas squash having 50% pulp, 1.5% acidity and 50°Brix was more acceptable.

The chemical composition of bael fruit was studied by Ram and Singh (2003). Moisture content of bael fruit varied from 59.0 to 66.67%. Cultivar Kagazi recorded highest moisture content (66.67%) followed by NB-5

(64.20%) and NB-9 (61.77%). The TSS varied from 30.50 (Kaghzi) to 38.50% in NS-1. Carotene content was highest in cultivar NB-9 followed by NS-I and varied from 85.0 to 97.0 IU/100 g. Highest acidity (0.40%) was found in NS-I while lowest was in Kagazi (0.32%). Ascorbic acid content varied from 73.30 to 17.25% and was highest in NB-9. Phenol content varied from 2.38 to 2.87% and was lowest in NS-I. Highest reducing sugar (4.87%) and non-reducing sugar (15.57%) content was found in NB-5 and NB-9, respectively. Total sugar content varied from 16.84 to 19.44% and was highest in cultivar NB-9. Similar observations were also reported by Roy and Singh (1978).

Studies were carried out on bael seed protein concentrate (BSPC) to evaluate the proximate, mineral and amino acid composition, nitrogen extractability and functional properties. The protein content was found to be 70.8 g/100 g BSPC. Calcium and phosphorus were observed in major quantities. The bael seed meal (BSM) lipid is found to be rich in unsaturated fatty acids (75%). Essential amino acids occurred in good quantities in BSPC. Nitrogen extractability of BSPC in water was found to be higher at 1:40 (w/v) ratio and an extraction time of 40 min. Minimum and maximum nitrogen extractability as 14 g/100 g protein and 97 g/100 g protein were observed at pH 4 and 12, respectively. In the presence of sodium chloride (0.1 and 0.5 M), the nitrogen extractability was found to be increased between pH 4-10. Protein precipitability was maximum (90 g/100 g protein) at pH 5.5. SDS-PAGE of BSM and BSPC showed different polypeptides with molecular weights from 205 to 12 kDa (Rao et al., 2011). Volatile compounds in bael fruit pulp were analyzed using the solid-phase micro extraction (SPME)/ gas chromatography (GC)/ mass spectrometry (MS) method (Charoensiddhi and Anprung, 2008). A total of 28 volatile compounds were identified, and the dominant components were monoterpenes and sesquiterpenes. Among these components, limonene was the major constituent producing the characteristic bael fruit flavor.

BIOCHEMICAL CHANGES IN BAEI FRUIT DURING DEVELOPMENT AND RIPENING

The changes in physico-chemical characteristics of bael fruits in their green and ripening stages were studied by Kaushik et al. (2000). The results showed that there is a significant difference ($P < 0.05$) in fruit weight (650 g at green to 764.7g at ripe stage) whereas the length and the breadth did not differ significantly as the fruit turned to ripe from green stage. Specific gravity of the fruit decreased from 1.0 for green stage to 0.94 for ripe stage. Biochemical constituents such as TSS, TSS : Acid ratio, ascorbic acid and carotenoids were significantly higher in ripening stage as compared to green stage. Acidity

Table 2. Chronological progression of physicochemical and biochemical characteristics of bael fruit.

Researchers	Bael varieties	Characteristics
Jauhari and Singh (1971)	NB-5, NB-9, NS-1 and Kaghzi	NB-5 had the highest % of pulp while other varieties like Kaghzi had highest seed content (3.47%). The least seed content was observed in case of NB-5
Pande et al. (1986)	Mirzपुरi, Desi Kanpur local variety	Phenolic constituents and ascorbic acid was present in major amount in both the varieties
Singh et al. (2000)	PB7B, PB10, PB11, PB14, Pant Aparna, Pant Shivani, Pant Sujata and Pant Urvashi	Maximum mucilage content and least pulp content was observed in the case of PB7B
Ram and Singh (2003)	NB-5, NB-9, NS-1 and Kaghzi	NB-9 was reported to have highest value of average fruit weight followed by NS-1
Ram and Singh (2005)	NB-5, NB-9, NS-1 and Kaghzi	Highest carotene and phenolic content was observed in case of NB-9
Bhat and Kumari (2006)	NB-5, NB-9 and Kaghzi	NB-9 contains maximum pulp, lesser seeds. Its fiber is considered ideal for processing

decreased from green stage (0.606%) to ripening stage (0.476%). Significant decrease from 3.8 to 3.50, 6.03 to 4.54 and 3.84 to 2.87% was observed in the case of crude protein, crude fibre and pectin content. Marmelosin content decreased from 0.432 to 0.244%.

The changes in the biochemical composition of the bael fruits at the subsequent stages of fruit development in Mirzपुरi and Desi (Kanpur local) varieties were studied by Pande et al. (1986). The results showed that the dry matter and TSS content of pulp increased gradually with the advancement of fruit. The sugar content increased with the increase in fruit age. The increase in non-reducing sugar content was however poor. The acidity of the both varieties reduced gradually with the maturity of the fruits. Sugar : acid ratio was increased. Crude protein content was decreased rapidly in both cultivars. The ascorbic acid content, tannins of the fruits increased with the maturity. Pectin content increased as the fruit grew and thereafter gradual fall was recorded. Marmelosin content was observed highest in matured fruits. The phenolic constituents were found maximum in immature fruit and a sharp decline was observed with advancement of fruits.

The physical, physiological and biochemical changes in bael fruits during development and ripening were also studied by Roy and Singh (1980). They stated that the diameter (transverse and polar) and weight increased rapidly upto December. The change in weight was observed during ripening after harvest. Physical characters of bael fruit showed a single sigmoid growth curve. The specific gravity was found to be high initially and then it fell gradually. The respiration pattern of the fruit on the tree does not show climatic pattern but on 8th day after harvest climatic is shown. The moisture content of the peel decreases gradually and the peel becomes

dry and woody. The mucilage was found to have increased rapidly up to October and then remained constant. Crude protein fell progressively. Total sugars and non-reducing sugars showed increasing trend during development and there was a steep rise during ripening. Total phenolics fell during development and ripening. The falling trend in acidity was also observed. The chronological progression of physicochemical and biochemical characteristics of bael fruit is presented in Table 2.

PROCESSING OF BAEL FRUIT

Tropical fruits, which are at present under-utilized, have an important role to play in satisfying the demand for nutritious, delicately flavored and attractive natural foods of high therapeutic value. They are in general accepted as being rich in vitamins, minerals and dietary fibre and therefore are an essential ingredient of a healthy diet. Apart from nutritive, therapeutic and medicinal values, quite a few of these tropical fruits have excellent flavour and very attractive colour. Bael fruit is not an easy to eat out of hand item. The bael fruit can be processed for preparation of various products. For all type of products, bael pulp is the first requisite.

As the storage quality of the whole fruit cannot be maintained for long period of time, improvement in the post harvest processing will enhance the effective utilization of the fruit. Because of its hard shell, mucilaginous texture and numerous seeds, it is not popular as a fresh fruit. The fruit has excellent aroma which is not destroyed even during processing. Therefore, there is tremendous potential for processing this fruit into various products. It is usually processed into products like preserves, refreshing beverages, powder,

leather, squash, nectars, toffee, jam, syrup. These products being highly nutritive and therapeutically important can be very easily popularized in internal as well as international markets (Kaushik et al., 2000).

Extraction of bael pulp

Ripened bael fruits are used for extraction of pulp. The important factors in consideration for ideal extraction of pulp are incorporation of water into pulp, inactivation of enzymes by application of heat and pH adjustment. Extraction of bael pulp was obtained successfully by the addition of water to pulp successfully in the proportion of 1:1 and 2:1. A clear juice was obtained by centrifugation of pulp (fruit: water, 1: 2) at 4000 rpm for 10 min. The power law model was used to determine the viscometric constants. Residual enzyme activity was determined for pulp and juice. Pectin methyl esterase activity was minimum (1.163 U) for juice and was maximum (1.375 U) for pulp (fruit: water, 1:1) (Ghosh and Gangopadhyay, 2002). Bael fruit pulp was successfully extracted by addition of water to pulp in proportion of 1:1 and 2:1 and a clear juice was obtained by centrifugation of the pulp (Fruit-water, 1:2) at 4000 rpm for 10 min.

The extraction of pulp from bael fruit is the main hindrance to the processing. Shrestha (2000) reported that the bael fruit pulp extracted by passing through the sieve without addition of water results in very sticky pulp. The pulp so obtained is unfit for handling and nearly 10% loss of pulp results during extraction, partly left with the pomace and partly sticking to the sieve. This may be due to mucilage content of the pulp. Incorporation of water and application of heat results in dilution of mucilage considerably and make the pulp possible to extract commercially.

Moisture desorption isotherm of bael pulp and adsorption isotherm of pulp powder were determined at 20, 30, 40 and 50°C. Static gravimetric method was used by exposing the samples to controlled atmospheres maintained by saturated salt solutions. The isotherms were found to be of type II sigmoid. The isosteric heat of sorption varied between 47.5 - 44.55 kJ g⁻¹ mol⁻¹ at moisture levels 0.5 - 3.5 g/g dry matter for bael pulp and 46.12 - 44.40 kJ g⁻¹ mol⁻¹ at moisture level between 0.25 - 1.125 g/g dry matter for powder (Bag et al., 2009).

The characterization of bael fruit hydrolysate treated with commercial pectinase enzyme was investigated by Charoensiddhi and Anprung (2010). The characteristics of bael fruit hydrolysate showed that bael fruit hydrolyzed at time longer than 2 and 4 h gave greater total carotenoids and antioxidant activities, respectively. Hydrolysis of bael fruit at 6 h resulted in the smallest particle size at 79.92 µm. The hydrolysis of bael fruit resulted in higher soluble dietary fiber and volatile compounds, but it did not affect the prebiotic activity score as compared to non treated sample.

The antioxidant potential of bael fruit pulp extracts was studied by Rajan et al. (2011). Results of phytochemical screening of the aqueous extract revealed the presence of steroid, terpenoid, saponin, tannins, lignin and flavonoids. Alcoholic extract showed the availability of alkaloids and devoid of saponin. *In vitro* antioxidant activity of the plant extract revealed that both extracts showed good antioxidant power.

Sujatha et al. (2011) conducted pharmacognostical and preliminary phytochemical studies on bael fruit base pulp. Fruit pulp revealed the presence of steroids, terpenoids, flavonoids, saponins, phenolic compounds, lignins, fat and oil, proteins, carbohydrates, amino acids and reducing sugars. These results would be of immense value in the botanical identification and standardization of drugs in crude form.

Bag et al. (2011) studied the foam expansion and foam stability of the bael fruit pulp foam. Foams were prepared from various pulp concentrations (PC) by adding different concentration of glycerol monostearate (GMS) and methyl cellulose (MC) at different whipping time (WT). Response surface methodology was used to predict the foam stability and expansion. The optimum conditions achieved after the numerical and graphical optimization for maximum foam expansion and stability was: GMS (3.10 g/100 g pulp), MC (0.32 g/100 g pulp), PC (13.2°Bx), and WT (2 min).

Singh et al. (2012) studied the effect of incubation temperature (28.18-61.82°C), incubation time (97.5-652.5 min) and pectinase concentration (0.64-7.36 mg/25 g bael pulp) on juice yield, viscosity and clarity of juice. The recommended enzymatic treatment conditions were incubation time (425 min), incubation temperature (47°C), pectinase concentration (5.0 mg/25 g bael pulp) and the juice yield, viscosity and clarity under these conditions were 84.5%, 1.35 cps and 22.43%, respectively.

Singh et al. (2014) studied the effect of pre-treatment on various physical and thermal properties of bael pulp. The fruit pulp of bael fruit was extracted and TSS of the extracted pulp was raised to 25°Brix by adding 65°Brix sugar syrup. The pH of pulp was set at 3.0 and 3.5, which was heated at 80- 85°C for 15, 20 and 25 min and kept at refrigerated conditions for 80 days. The TSS, pH, titratable acidity, colour-L*, a*, b*, thermal conductivity and specific heat ranged between 18-25°Brix, 2.6-3.5, 0.15-0.35%, 20.32-56.87, 2.95-20.28, 23.58-64.01, 0.37-0.76 w/m°C, 1.73-2.50 J/g°C respectively. Minimum colour change and maximum sensory score was observed at pH 3 and 15 min heating under refrigerated storage. The zero or first order models were well fitted for the responses of the bael pulp (3 pH, 15 min) stored under refrigerated conditions.

Bael juice

Due to refreshing effect and therapeutic value of bael

fruit, its juice can be commercialized. Singh et al. (2013) has optimized the extraction of juice from bael fruit by using commercial and crude pectinase enzymes. As juice extraction is difficult due to the presence of pectins that hold the water, use of enzymes effectively increase the yield and clarity of juice. Singh et al. (2013) studied the effect of incubation time, incubation temperature, and crude enzyme concentration on the yield, viscosity and clarity of the juice obtained from bael fruit pulp. The recommended enzymatic treatment conditions from the study were incubation time 475 min, incubation temperature 45°C, and crude enzyme concentration 0.20 mL/25 g bael fruit pulp. The recovery, viscosity and clarity of the juice under these conditions were 82.9%, 1.41 cps and 21.32%T, respectively. The variables, clarity, and yield were found as principal components for comparing different samples of the juice treated with enzyme.

Bael fruit beverages

Due to increasing demand of health drinks based on indigenous fruits, this fruit can be processed for making beverages. Various researchers have successfully prepared different beverages from bael fruit. A whey protein enriched bael fruit beverage was prepared by Singh and Nath (2004) by adding whey protein concentrate, pectin and carboxy methyl cellulose. The beverage having 16°Brix, 25% bael fruit pulp, pH 3.9 and 1.75% protein was found the best concerning the overall acceptability. Blended beverages from bael and guava were prepared by Nidhi et al. (2008) by extracting the pulps of both fruits. Bael pulp was extracted by adding equal amount of water to the crude mass and heating it to 80°C for 1 min and passing through pulper. Guava pulp was obtained by adding fruit slices with 25% water, heating at 80°C for 5 min and passing through pulper to obtain homogenous mass without seed and fibres. These pulps were blended in 100:0, 75:25, 50:50, 25:75 and 0:100 proportions. The RTS beverage with pulp 15 and 20%, TSS 15% and acidity 0.26 were prepared by using these blends.

RTS drink, nectar and squash from bael fruit were prepared by Verma and Gehlot (2006). For preparing these products, bael pulp was extracted by adding 1 L of water per kg of crude mass and heating it at 70°C for 1 min followed by cooling and passing through muslin cloth. The TSS and acidity were analyzed in extracted pulp and requisite amount of sugar and citric acid, dissolved in water, were added to pulp as per requirement to meet the specifications. The prepared RTS and nectar were thoroughly homogenized and sterilized. The bael fruit squash was also homogenized and sodium benzoate @ 1 g/ L of squash was added as a chemical preservative after dissolving in small amount of water. The squash was also sterilized after filling in bottles.

Therapeutic beverages from bael fruit were prepared by Verma and Gehlot (2007). Unripe bael fruit is useful in curing dysentery and diarrhoea whereas ripe fruit acts as laxative and good tonic for heart, brain and to cure dyspepsia. Keeping all this in mind, researchers prepared RTS drink, nectar, squash and syrup from the bael fruit. For RTS, they used 1 L of pulp, 1.2 kg sugar, 28 g citric acid and 7.7 L of water. Recommended colour and essence were added after dissolving them in small quantity of prepared RTS. The RTS was pasteurized at 85-88°C for 30 min. For nectar, 1 L bael pulp, 650 g sugar, 15 g citric acid and 3.3 L water were used. For squash, 1 L pulp, 1.5 kg sugar, 20 g citric acid, 1 L water and sodium benzoate @ 1 g/L of finished product were used. The pulp content was maintained at minimum of 25% and TSS at 40%. The fruit syrup should contain 25% minimum fruit portion and 65% TSS. For syrup preparation, 1 L bael pulp, 2 kg sugar, 20 g citric acid, 500 ml water was added. For syrup, generally no preservative is required but for long storage; sodium benzoate can be used.

The wild bael fruit was utilized by Kenghe et al. (2009) for value addition. They prepared squash from this fruit by adjusting the TSS of the pulp and by adding the preservatives. The pulp was obtained by adding water to the crude mass in the equal amount, heating at 80°C for 1 min and passing through muslin cloth. The squash was filled in bottles, crowned and pasteurized at 80°C for 30 min followed by cooling and wax sealing to ensure tightness.

The blended bael RTS was successfully prepared by Kenghe and Zambare (2009). For this fresh, matured, raw bael fruits were taken, cleaned and cut into halves by using knife. The seeds and pulp were removed from the rind, which is boiled with a little quantity of water for a period of time. Then such pulp was filtered. The sugar syrup along with measured quantity of citric acid was added with the pulp to prepare RTS beverage of specific TSS and pulp percentage as per standard and sensory acceptability. The bael RTS is then blended with tamarind RTS with 1:1, 1:5 and 1:9 proportions to ensure the feasibility of acceptance of blended RTS. Jalgera @ 15 ml/ L of RTS, KMS @ 0.9 mg/L of RTS were added in different lots. One lot was kept as control sample. The results suggested that 1:9 ratio is the best for blending and jalgera can be used as a source of natural preservative.

RTS beverage from bael and citrus fruit blends was prepared by Nagpal and Rajyalakshmi (2009). Bael pulp was extracted for this purpose by adding equal amount of water to the crude mass, blended and passed through 20 mesh stainless steel sieves to obtain thick, uniform pulp free from seeds and fibres. Lime and sweet oranges were cut into halves and the juice was extracted using a wooden lime squeezer and juice extractor, respectively. Mandarin oranges were peeled and the segments fed

into a screw type juice extractor to obtain juice. Pineapple was peeled, cut into small pieces, blended and filtered. Bael pulp was blended with the juice of lime, mandarin oranges, sweet orange and pineapple in different proportions. The RTS beverages were prepared by adding sugar, citric acid and water so as to obtain the desired level of TSS, acidity and dilution. The prepared beverages were filled in sterilized glass bottles and pasteurized, cooled and stored at ambient temperature.

Bael wine

Wine is one of the functional fermented foods and has many health benefits. Bael fruit having sufficient sugar content can be used for wine making. Singh et al. (2006) prepared wine from this fruit by adjusting the TSS of pulp to 24°Brix with the help of sucrose and added potassium metabisulphite (KMS) to maintain SO₂ @ 100 ppm along with cyclodextrins @ 0.4% for preparation of must. This was added with the 10% yeast starter culture. The starter culture was prepared by adding 0.05% yeast extract and 0.1% ammonium phosphate at pH 5 to the boiled and cooled bael pulp. The fermentation was carried out at 25°C. The maximum alcohol percentage in the wine was upto 10.08% after fermentation for 88 h at pH 5.

Bael preserve

Green bael fruits are used for preparing preserves (murabba) which is an important Ayurvedic medicinal product and generally prescribed for all types of digestive troubles. This fruit preserve was prepared by Kaushik et al. (2002). The peeling was done by knife by making a slit at the stellar end of the fruit and then inserting the pointed end of the knife under the rind to crack it and remove the rind in pieces. The peeled fruit was sliced crosswise into the pieces of about 2 cm thickness and then washed with water. The slices were pricked at both side with stainless steel forks and blanched in boiling water for 5 min or until they become soft. Sugar syrup of 40% concentration was prepared and citric acid @ 0.6% was added to the syrup. The treated fruits were placed in stainless steel container and sugar syrup was added. The next day, syrup was decanted and its strength was increased by adding 300 g of additional sugar to that by boiling. This was repeated on 4th and 6th day and the syrup was heated to bring the concentration of sugar to 70% and the preserve was stored in glass jars at ambient temperature.

A recipe for preparation of preserve (murabba) from bael fruit was also given by Rakesh et al. (2005). They used 1 kg mature bael fruit slices of 2 cm thickness, 1.25 kg sugar, citric acid 2-3 g and water 1 L. The slices were pricked with stainless steel fork from both sides and

dipped in 2% lime solution for 2-3 h. After removing the slices from the lime water, they were washed thoroughly in running water and then put in boiling water to make them soft. Softened slices dipped in 40% sugar syrup were prepared by using 700 g sugar. The next day, the sugar syrup was drained and half of the remaining sugar was added to the syrup, concentrated and again added to the slices. After 2 days, same procedure was repeated and the TSS of syrup was maintained at 70%.

Bael candy

The candy from bael fruit was prepared by Rakesh et al. (2005). For candy preparation, the recipe was kept same as for bael preserve. The slices in sugar syrup of 70% were drained out and dried at 55-60°C for 8-10 h in oven. The fruits of bael cultivar (NB-9) was used for the preparation of candy and stored in glass jars and polythene pouches at ambient temperature. The changes during storage in quality were judged at monthly interval. It was observed that %TSS, acidity and browning of candy were increased while ascorbic acid was decreased during storage in both types of containers. The study indicated that a good quality of candy can be prepared by bael cultivar NB-9 and in polythene pouches it can be stored for 4 months without any spoilage of organoleptic quality (Mishra et al., 2013).

Toffee is a confection made by caramelizing sugar or molasses along with butter and generally flour. The mixture is heated until its temperature reaches the hard crack stage of 300 to 310°F (100 to 154°C). A recipe for preparation of bael toffee was formulated by Rakesh et al. (2005). It was prepared by using fruit pulp, sugar, glucose, skim milk powder (SMP) and butter. Water, 750 ml was then added for each 1 kg of fruit pulp followed by mixing and heating to up to 80°C. It was screened and the fine pulp was obtained. 1 kg of pulp was cooked until one third of its original volume remained. 500 g sugar, 100 g glucose and 100 g butter were added to the cooking mass. Now SMP was added to the cooking mass after adding small amount of water. Cooking was continued until cooking mass starts leaving the sides of pan. Cooking was stopped and the cooked mass was spread uniformly in 0.5-0.75 mm thick layer. It was allowed it to cool, and cut into pieces and wrapped in moisture proof or butter paper.

Bael slab

Slab, leather or paper can also be prepared from bael fruit. This product was formulated by Rakesh et al. (2005). For this, they added 200-300 ml water to each kg of fruit crude mass. Agitation was carried out, followed by heating it upto 30°C. Sieve analysis was then carried out

using stainless steel sieve. Sugar, citric acid and KMS was added so that the treated pulp contains 35% TSS, 0.5% titratable acidity and 0.07% KMS. Then treated pulp was boiled and spread on aluminium trays smeared with butter. It was then dried at 55-60°C for 15-16 h to achieve a moisture content of 14.5%. Cut slabs were then wrapped in butter paper and packed in polyethylene bags.

Bael fruit jam

The bael fruit can be processed to prepare jam. A mix fruit jam from bael and mango was prepared by Mishra and Chopra (2006). The pulp of this fruit was extracted by adding the water to equal amount of crude mass, followed by heating at 80°C for 1 min and passing through 20 mesh stainless steel sieves. Mango pulp was added to bael fruit pulp. Various combinations of bael and mango pulp were prepared. The final optimized jam had 45% mixed pulp (Bael: mango: 1:1), 70% TSS and 0.5% acidity based on its organoleptic characteristics

A recipe for bael fruit jam preparation has been reported by Rakesh et al. (2005). This consisted of addition of 750 g sugar and 3-4 g citric acid to the 1 kg strained pulp without any seed and fibres. It was then cooked with continuous stirring using a spoon until end point is reached. End point can be judged by doing sheet test of boiling mass. The cooking was then stopped after end point. Hot jam was then filled into clean and well sterilized jam bottles. Jam filled bottles was inverted for 10 min for sterilization of their caps.

Dehydrated bael

According to Rakesh et al. (2005), mature, green bael fruit can be dehydrated by slicing in 1-1.5 cm thick slices and fumigating these slices with SO₂ for ½ h in sulphur box and then dehydrating in an oven at 55-60°C upto constant weight.

Bael powder

Bael powder can be prepared by grinding the dried fruit slices in a grinder. The ground bael powder is packed in polyethylene bags and stored in dry places after proper sealing (Rakesh et al., 2005). A method to prepare bael fruit powder was developed by Rastogi et al. (2005) that consists of spray drying a fruit pulp of bael to obtain a free-flowing, yellow-red powder with good shelf life.

The comparative study of minerals, fat and protein content in green bael and ripe bael powder was carried out by Islam et al. (2011). The analysis showed that the concentration of Na, K, Ca, Mg, Zn and Cu (119, 4821,

92.9, 259, 1.69 and 1.34 ppm) in ripe bael powder is more than that of green bael powder (55.6, 1356, 78.9, 142, 0.66 and 0.67 ppm). Fe and carbohydrate is more in green bael powder (19.3 ppm, 93.73%) than in ripe bael powder (16.22 ppm, 90.33%). Vitamin C is almost same in both types of powders.

The moisture desorption isotherm of bael fruit pulp and adsorption isotherm of pulp powder at 20, 30, 40 and 50°C were determined by Bag et al. (2009). Static gravimetric method was used by exposing the samples to controlled atmosphere maintained by saturated salt solution. The isotherms were found to be of type-II sigmoid. Experimental data were fitted to four isotherm models viz. Anderson, Guggenheim-Anderson-DeBoer (GAB), Oswin and Peleg Models. It was found that Peleg model fits best describing the equilibrium moisture content and equilibrium relative humidity (EMC-ERH) for both the bael pulp and pulp powder. The isosteric heat of sorption varied between 47.5-44.55 kJ/g/mol at moisture levels 0.5-3.5 g/g dry matter for bael fruit pulp and 46.12-44.40 kJ/mol/g at moisture level between 0.25-1.125 g/g dry matter for powder. The chronological progression of different processing aspects of Bael fruit is presented in Table 3.

Bael panjiri

This product is highly nutritive, restorative and is prescribed for stomach ailments. Rakesh et al. (2005) used bael powder 1 kg, desi ghee (butter oil) 1 kg, sugar powder 1.5 kg, wheat flour and dry fruits as per taste for preparation of bael panjiri. Bael powder is roasted in desi ghee. Roast wheat flour was added in small amount as per taste in desi ghee. All the ingredients were then mixed.

Utilization of processing waste of bael

The bael peel and pomace that constitute the 35-40% of the total fruit weight were utilized by Saini et al. (2002) for cattle feed purpose. One hectare bael plantation leaves behind nearly 22-27 quintals of dried waste. They dried the peel and pomace to a constant weight in a tray drier at 60°C. It was ground to powder in a grinder. Ground samples were analyzed for various biochemical constituents. Peel contains 27.34% crude fibres, 31.85% crude protein, 1.0% Ca and 0.14% phosphorus whereas pomace contains 9.98, 10.5, 1.2 and 0.1% of crude fibre, crude protein, calcium and phosphorus, respectively. Palatability of these wastes was adjusted by feeding to the cows after mixing with cattle feed in a ratio 1:3. After mixing with cattle feed, wastes were readily acceptable to the cows, which confirmed that it can be used as animal feed. *In vitro* digestibility of various constituents was also

Table 3. Chronological progression of different processing aspects of bael fruit.

Researcher	Salient features	Processed products
Shrestha (2000)	Incorporation of water and application of heat results in dilution of mucilage	Bael pulp extraction
Ghosh and Gangopadhyay (2002)	Pectin methyl esterase activity was minimum for juice and maximum for pulp	Bael pulp extraction
Kaushik et al. (2002)	Syrup was brought up to the desired concentration of 70%	Bael preserve
Singh and Nath (2004)	Beer having 16°Brix, 25% Fruit Pulp, pH 3.9, 1.75% protein is acceptable	Bael fruit beer
Rakesh et al. (2005)	All products were acceptable	Bael preserve, candy, toffee, slab, jam and panjiri
Verma and Gehlot (2006)	Product was acceptable which was further homogenized and sterilized	Bael RTS drink, nectar and squash
Singh et al. (2006)	Maximum alcohol % was found upto 10.08% after fermentation for 88 h at pH 5	Bael wine
Mishra and Chopra (2006)	Optimized jam having 45% mixed pulp containing bael and mango was acceptable	Bael fruit jam
Verma and Gehlot (2007)	Bael nectar prepared with 20% bael pulp, 15% total soluble solids and 0.25% acidity was found most acceptable among all the treatments.	Therapeutic bael nectar
Kenghe and Zambave (2009)	Jalgerra can be used as a source of natural preservatives	Blended bael RTS
Nagpal and Rajyalakshmi (2009)	The RTS beverages were prepared by adding sugar, citric acid and water so as to obtain the desired level of TSS, acidity and dilution	Bael RTS Beverage
Charoensiddhi and Anprung (2010)	The bael fruit hydrolyzed at time longer than 2 and 4 h gave greater total carotenoids and antioxidant activities, respectively. Hydrolysis of bael fruit at 6 h resulted in the smallest particle size, 79.92 µm.	Bael fruit hydrolysate
Rajan et al. (2011)	Phytochemical screening of the alcoholic extract revealed the presence of steroids, saponins and tannins etc. In vitro antioxidant activity of the plant extracts revealed good antioxidant power.	Bael fruit pulp
Bag et al. (2011)	The optimum conditions for maximum foam expansion and stability was: GMS (3.10 g/100 g pulp), MC (0.32 g/100 g pulp), PC (13.2°Bx), and WT (2 min).	Bael fruit pulp foam
Singh et al. (2012)	The recommended enzymatic treatment conditions were incubation time (425 min), incubation temperature (47°C), pectinase concentration (5.0 mg/25 g bael pulp) and the juice yield, viscosity and clarity under these conditions were 84.5%, 1.35 cps and 22.43% respectively.	Bael juice
Singh et al. (2013)	Optimized juice extraction was carried out using crude enzymes. The recommended enzymatic treatment conditions from the study were incubation time 475 min, incubation temperature 45°C, and crude enzyme concentration 0.20 mL/25 g bael fruit pulp.	Bael juice
Singh et al. (2014)	The pulp can be stored for 60 days under the refrigerated conditions. Minimum colour change and maximum sensory score was observed of the sample at 3 pH and 15 min heating.	Bael pulp

analyzed and it was observed that 40.1% of total peel and 69.6% of the pomace was digestible. Use of these wastes as animal feed not only reduce the feeding and processing costs but also prevent health hazards and environmental pollution.

MEDICINAL USES OF BAEI

The bael fruit is very well known for its medicinal importance. Morton (1987) explained the medicinal composition and uses of bael fruit. The fresh ripe pulp of the higher quality cultivars, and the "sherbet" made from it are taken for their mild laxative, tonic and digestive effects. A decoction of the unripe fruit, with fennel and ginger, is prescribed in cases of hemorrhoids. It is employed in the treatment of leucoderma.

Marmelosin derived from the pulp is given a laxative and diuretic effect. Stem bark and root of aqueous extracts have similar phytochemical compounds (Nirupama et al., 2012). In large doses, it lowers the rate of respiration, depresses heart action and causes sleepiness. A number of chemical constituents from different parts of plant have been extracted like aegelin marmelosin, coumarin, β -sitosterol and alkaloids. The plant is a rich source of amino acid, galactose and fatty acids. The compound isolated from plant show a variety of pharmacological activity.

For medicinal use, the young fruits, while still tender, are commonly sliced horizontally and sundried and sold in local markets and are exported. Because of the astringency, especially of the wild fruits, the unripe bael is most prized as a means of halting diarrhea and dysentery, which are prevalent in India during the summer season. Bitter, light-yellow oil extracted from the seeds given in 1.5 g doses render a purgative effect. Bael herb contains 15.6% palmitic acid, 8.3% stearic acid, 28.7% linoleic and 7.6% linolenic acid. The seed residue contains 70% protein. Leaves, fruits, stems and roots of bael fruit have been used in ethno medicine to exploit its medicinal properties including astringent, anti-diarrheal, anti-inflammatory activities. Compounds purified from bael have been proven to be biologically active against several major diseases including cancer, diabetes, etc (Maity et al., 2009). In Ayurveda, this fruit is used to cure problems related to heart, stomach, intestine, chronic constipation and dysentery; some forms of indigestion, typhoid, debility, fever, hemorrhoids, hypochondria, melancholia and for heart palpitation (Kumar et al., 2013).

The essential oil isolated from the leaves of bael tree has proved to antifungal activity against animal and human fungi like *Trichophyton mentagrophytes*, *Trichophyton rubrum*, *Microsporum gypseum*, *Microsporum audouinii*, *Microsporum cookie*, *Epidermophyton floccosum*, *Aspergillus niger*, *Aspergillus flavus* and *Histoplasma capsulatum* (Dhankhar et al.,

2011). Satyal et al. (2012) collected the bael leaves to obtain, analyze, and examine the bioactivity from its essential oil. The essential oil from leaves was obtained by hydro-distillation. The chemical composition, determined by GC-MS, revealed 82 compounds, with 81 components being identified. The major component was limonene (64.1%), with the other two abundant components being (*E*)- β -ocimene (9.7%) and germacrene B (4.7%). The essential oil of *A. marmelos* showed remarkable brine shrimp lethality. Antimicrobial and antifungal activity of the leaf oil was negligible. Most of the observed biological activity was apparently due to the relatively high level of limonene (64.1%) in the essential oil of the leaf of *A. marmelos*.

The bitter, pungent leaf juice, mixed with honey, is given to allay catarrh and fever. With black pepper added, it is taken to relieve jaundice and constipation accompanied by edema. The leaf decoction is said to alleviate asthma. A hot poultice of the leaves is considered an effective treatment for ophthalmia and various inflammations, also febrile delirium and acute bronchitis.

A decoction of the flowers is used as eye lotion and given as an antiemetic. The bark contains tannin and the coumarin, aegelinol; also furocoumarin, marmesin; umbelliferone, a hydroxy coumarin; and the alkaloids, fagarine and skimmianine. The bark decoction is administered in cases of malaria. Decoctions of the root are taken to relieve palpitations of the heart, indigestion, and bowel inflammations; also to stop vomiting. The fruit, roots and leaves have antibiotic activity, the root, leaves and bark are used in treating snakebite. Chemical studies have revealed the following properties in the roots: psoralen, xanthotoxin, O-methylscopoletin, scopoletin, tembamide, and skimmianin; also decursinol, haplopin and aegelinol. Scientific studies have validated many of the ethnomedicinal uses of bael fruit and reports indicated that the fruit possesses broad range of therapeutic effects that includes free radical scavenging, antioxidant, inhibition of lipid peroxidation, antibacterial, antiviral, anti-diarrheal, gastro protective, anti-ulcerative colitis, hepatoprotective, anti-diabetic, cardio protective and radio protective effects (Baliga et al., 2011).

Diabetes mellitus is a heterogeneous metabolic disease characterized by altered carbohydrate, lipid and protein metabolism. So many traditional herbs are being used by diabetic patients to control the disease. But very few studies are performed to investigate the efficacy of these herbs clinically. An attempt has been made to investigate clinically the antidiabetic activity of bael leaves individually and collectively with the standard oral hypoglycemic therapy in non insulin dependent diabetes mellitus (NIDDM) patients (Ismail, 2009). Antidiabetic effect was more markedly observed when it was combined with the oral hypoglycemic therapy. Bael leaves can be combined in high dose with oral hypoglycemic agents to bring the blood glucose to normal

levels in patients whose diabetes is not controlled with these agents or in those patients in whom these drugs produce adverse effects on dose increments. The unripe or half-ripe fruit is good for digestion. It is useful in preventing or curing scurvy. It also strengthens the stomach and promotes its action. In recent times, focus on plant research has increased all over the world and a large body of evidence has collected to show immense potential of medicinal plants used in various traditional systems (Kumar et al., 2012). The antifungal potential of bael fruit was studied by Parihar and Kumar (2013). The results were referenced against glucanazole antifungal agent. Methanol fruit extract showed strong antifungal activity against most of the strains whereas moderate antifungal potential was shown by leaf extract in aqueous solution.

CONCLUSION

Bael (*A. marmelos*) fruit has a lot of potential to be processed for value addition. Its flavor is acceptable by almost all classes of the people as a refreshing drink in the summer. The bael is still being used only by unorganized sector and is not being given much emphasis for its commercial utilization in terms of value added products. The selected pharmacological studies have been conducted on different parts of this fruit and the literature supports the potential of bael fruit to be processed and formulated to prepare number of products. The focused research is required in the field to investigate the unexplored and unexploited potential of this fruit on the commercial scale. The health and functional foods from the bael is an area which still requires the attention of scientific fraternity.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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