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The Physicochemical Characteristics and Quality Evaluation of Bael Fruit (*Limoniaacidissima* L.) Pulp Powder For The Product of Functional Food

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Abstract: *The Bael Fruit (Limoniaacidissima L.) powder without seed pulp was dried for powder by using Multi Commodity Solar Tunnel Drier (MCSTD), Hot air oven, and Tray dryer and compared its drying characteristics, fruit powder yield, physical and functional properties, least gelation concentration, nutritional composition, and sensory acceptance.The aim of the study was to developed storage of powder after physio-chemical properties investigation and nutritional composition estimation for commercial use of Bael Fruit. The Bael fruit pulp gets completely dried within 6-10 hours in all drying methods. The overall drying rate was significantly ($p<0.05$) high in MCSTD dried sample; dehydration ratio, rehydration ratio and co-efficient of rehydration were significantly high in tray dried sample at $p<0.01$. The total polyphenol content and antioxidant activity was significantly higher ($p<0.01$) in MCSTD dried wood Bael Fruit powder. The titrable acidity and pH revealed the medium acidic nature of fruit pulp powder. Organoleptically, the Multi Commodity Solar Tunnel Dried sample was liked very much in terms of its color, test flavor and overall acceptability. Hence, the Bael Fruit pulp could be dried effectively using MCSTD, preserved as dried powder and value added for its industrial exploitation as ingredient to process functional food products.*

Keywords: *Bael Fruit, MCSTD, Physicochemical, Nutritional Composition*

Introduction

The Bael fruit, Aegle marmelos Correa (*Feronia pellucida* Roth., *Crataevamarmelos* L.). The Bael fruit tree is a slow-growing, of medium size, up to 40 or 70 ft height with short trunk, thick, soft, flaking bark. Young suckers bear many stiff, straight spines and a clear, gummy sap, resembling gum Arabic, exudes from wounded branches and hangs down in long strands, becoming gradually solid. It is sweet at first taste and then irritating to the throat. The fruit, round, pyriform, oval, or oblong, 5-20 cm in diameter, may have a thin, hard, woody shell or a more or less soft rind, gray-green until the fruit is fully ripe, when it turns yellowish. Embedded in the pulp are 10 to 15 seeds, flattened-oblong, about 1 cm long, bearing woolly hairs and each enclosed in a sac of adhesive, transparent mucilage that solidifies on drying. The tree grows wild in dry forests on hills and plains land in Bangladesh.Types of Bael fruit depends on high sugar content and low levels of mucilage, tannin and other phenolic.Fruits of this type are standard for medicinal uses rather than for consuming as normal food1. In Bangladesh flowering occurs in April and May soon after the new leaves appear and the fruit ripens in 10 to 11 months from bloom–March to June of the following year.

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A tree may yield as many as 800 fruits in a season but an average crop is 150 to 200, or, in the better

cultivars, up to 400.Bael fruits may be cut in half, or the soft type's broken open, and the pulp, dressed with palm sugar, eaten for breakfast, as is a common practice in Bangladesh. The pulp is often processed as nectar or "Sorbet". Sorbetis made by beating the seeded pulp together with milk and sugar. A beverage is also made by combining Bael fruit pulp with that of tamarind. These drinks are consumed perhaps less as food or refreshment than for their medicinal effects. Mature but still unripe fruits are made into jam, with the addition of citric acid. The pulp is also converted into marmalade or syrup, likewise for both food and therapeutic use, the marmalade being eaten at breakfast by those convalescing from diarrhea and dysentery. A firm jelly is made from the pulp alone, or, better still, combined with guava to modify the astringent flavor.

Bael pulp is steeped in water, strained, preserved with 350 ppm KMS, blended with 25.0% sugar, then dehydrated for 6-12 hrs at 55° C and pulverized. The powder is enriched with 66 mg per 100 g ascorbic acid and can be stored for 120 days for use in making cold drinks. A confection, Bael fruit toffee, is prepared by combining the pulp with sugar, glucose, skim milk powder and hydrogenated fat. Bangladeshi food technologists view the prospects for expanded Bael fruit processing as highly promising. The pulp also contains a balsam-like substance, and 2-furocoumarins-psoralen and marmelosin ($C_{13}H_{12}O_3$), highest in the pulp of the large, cultivated forms. The fresh ripe pulp of the higher quality cultivars, and the "Sorbet" made from it, are taken for their mild laxative, tonic and digestive effects. It has been surmised that the psoralen in the pulp increases tolerance of sunlight and aids in the maintaining of normal skin color. It is employed in the treatment of leucoderma. Marmelosin derived from the pulp is given as a laxative and diuretic. In large doses, it lowers the rate of respiration, depresses heart action and causes sleepiness. For medicinal use, the young fruits, while still tender, are commonly sliced horizontally and sun-dried and sold in local markets. 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 Bangladesh in the summer months.

The Bael fruit is one of the most nutritious fruit and used for the preparation of number of products like candy, squash, toffee, pulp-powder and nectar. The energy value of Bael is found to be at least 1.5 times greater than either of orange or grapefruit. According to, edible portion of Bael contains 61.59% water, 0.6% fat, 1.7% minerals, 6.20% fiber and 81.12 % carbohydrates[1]. B-carotene content is 5.2mg/100g also higher than most of the reputed fruits like apple, guava and mango. Dehydration as drying is the most widely used methods of food preservation. During dehydration of Bael fruit pulp, carbohydrate & crude fat content increased while protein content decreased. It might be due to the destruction of some of the proteins while reacting with the peroxides produced during lipid oxidation. On dehydration as nutrients becomes concentrated, the proximate composition as fiber, ash, total carbohydrates, protein & fat were 6.20%, 4.61%, 81.12%, 2.90%, o.65%, respectively[1].

Ascorbic acid content on drying increased i.e. from 13.35 to 39.62mg/100g of Bael powder. The shelf life of perishables could be extended by arresting the water activity through sun or mechanical means of dehydration.Bael fruit has got high medicinal value. Every part of the fruit posse's medicinal property. Fruits, leaves and stem bark of this fruit have been studied for anti-tumor and antimicrobial activity[2,3].- Fruit pulp has anti-inflammatory, antipyretic and analgesic activity[4]. Bael fruit has anti-diabetic and antioxidant potential by reducing the level of blood glucose and malondialdehyde5. Fruit is much used in Bangladesh as a liver and cardiac tonic and when unripe, as a means of halting diarrhea and dysentery and for effective treatment for high cough, sore throat and disease of the gums. In addition to this, Bael fruits also have hypoglycemic activity, antitumor, larvicidal and antimicrobial activity and hepatoprotective activity[5]. The fruit is a hard-shelled many seeded being the edible portion, without seeds in it. It is an

ideal tree to be exploited for growing in wasteland. Bael fruit is a nutrient rich fruit which contains a surprisingly high amount of protein 3-7% and low levels of sugar and carbohydrates compared to many other fruits. The fruit is rich in Beta-carotene, which also contains significant quantities of B vitamins such as thiamine, riboflavin and small amounts of vitamin C. Bael fruit is useful in preventing and curing scurvy and in reliving flatulence. Mashed seedless pulp of the raw fruit is beneficial in the treatment of dysentery, diarrhea and piles. Bael fruit in the form of chutneys or sherbet is useful in treating hiccups[6].

Bael fruit contains flavonoids, glycosides, saponins and tannins. There are reports that some coumarins and tyramine derivatives were also isolated from the fruits of Limonia[7]. The fruit may be eaten raw but it has a resinous taste and requires sweetening. The ripe fruit pulp makes excellent chutney and it also consumed afresh along with sugar[8]. Many plants and fruits that are rich in medicinal properties are processed into dried powder to encourage their use in various food formulations. While considering all these, the present work was carried out to prepare Bael fruit pulp powder by different methods of drying and to determine the best method of drying as per the quality characteristics. The vast array of health benefits attributed to Bael fruit is mainly due to their nutrients, vitamins, and organic compounds, including tannins, calcium, phosphorous, fiber, protein, and iron. It is rich in nutrients and a great source of fiber, vitamins, calcium, phosphorous, protein, and iron and beta carotene. This fruit is a good source of carbohydrate and dietary fiber. It is also found that the pulp contains appreciable amount of protein and low amount of fat. Furthermore, Bael fruit also contains various important minerals such as calcium, iron, zinc, magnesium and phosphorus. It also contains vital vitamins such as beta-carotene, thiamine, riboflavin and vitamin C. The presence of protein in a food is determined by the presence of essential amino acid in it. It was found that Bael fruit contains appreciable amount of protein include: Presence of Amino Acids as Alanine, Arginine, Aspartic acid, Glycine, Histidine, Isoleucine, Leucine, Phenylalanine, Proline, Tryptophan Tyrosine and Valine[9].Bael Fruit is a good remedy for digestive disorders. The trunk and branches of this fruit trees contain a gum-like substance called 'Feronia gum'. It is commonly used to provide relief from diarrhea and dysentery[10]. Bael fruit is also recommended for people with peptic ulcers or piles since the tree leaves contain tannin, which is known to reduce inflammation. The laxative property of Bael fruit also helps to avoid constipation and the subsequent, pain, discomfort and associated health risks of that condition. These, combined with antifungal and anti-parasitic activities, make this fruit ideal for enhancing digestive health. The aim of the study was to developed storage of powder after physio-chemical properties investigation and nutritional composition estimation for commercial use of Bael Fruit.

Materials and Methods

I. Materials

The mature Bael fruit was procured from the local market at Dhaka metropolitan market areas, scooped out the pulp with seed from hard shell with the help of spoon, separated the seeds for ground the pulp in a mixer grinder and dried into powder by using Multi Commodity Solar Tunnel Drier (MCSTD), cabinet tray drying and hot air oven drier at 60°C.

II. Methods

The fruit pulp powders were determined for its chemical properties such as Titrable Acidity (%),Ascorbic acid (mg 100g-1), pH, TSS (%),Sugar acid ratio(TSS:TA ratio),Reducing sugar (%), Non-reducing sugar (%), Total sugar (%),Total phenolic content (mg/100g) and Ash(g). Titrable acidity, Ascorbic acid and ash content

were determined by previously used method[11]. Reducing, non-reducing and total sugar were determined using a method which was previously used[12]. TSS determined by Abbe refractometer and pH determined by pH meter.Total phenolic content (TPC) was measured by Folin – ciocalteau method[13]. Statistical analysis of the experiment was laid out in Complete Randomized Design. Data obtained on various characters were analyzed statistically according to the analysis of variance techniques. The critical difference (CD) was calculated to access the significance or non-significance of difference between treatment means.

III. Drying Characteristics

During drying, the drying rate of the sample was measured by determining the moisture content at one hour interval until the drying gets completed. The end of the drying was noted by the concordant value inmoisture content. The overall drying rate, dehydration ratio, rehydration ratio, coefficient of rehydrationand drying time in hours were calculated as drying characteristics[14].

IV. Physical and Functional Properties

The fruit pulp powders were determined for its physical properties such as bulk density in g/ml true density in g/ml, porosity, Hygroscopicity and bulk volume; functional properties such as water absorption capacity in g/g , swelling power at 65°C in ml/g and least gelation concentration.

V. Chemical Properties

The totalcarbohydrate (g), protein, fat (g), crude fiber(g), vitamin C (mg), moisture content (g), ash (g), titrable acidity, pH, color value ('L', 'a', 'b') (Tintometer), total phenol content (mg) and total antioxidant capacity (µg) as ascorbic acid equivalent (FRAP assay) were determined in duplicates[11]. The overall acceptability of the fruit pulp powders were calculated by totaling the scores on color, taste, flavor and Acceptability using 9-point Hedonic rating scale suggested by 30 semi-trained panel members.

VI. Statistical Analysis

One way analysis of variance with a subsequent Duncan's test as post hoc comparison was applied for multiple sample comparison. All statistical analysis was done using SPSS 17.0 version software.

Results and Discussions

Drying Characteristics

The Bael Fruit pulp powder was completely dried within 6-10 hours of Multi head Solar Tunnel Drier (MHSTD) at 550C; 6 hours in hot air oven drying at 600C and 7 hours in cabinet tray drying at 600C indicating equilibrium moisture content of 8.25% on dry basis. More than 87.0% of moisture was lost during drying irrespective of type of drying (Table 1).

Table 1: Overall drying rate, dehydration ratio, rehydration ratio and coefficient of rehydration and drying time in hours of wood apple pulp on drying

Parameters	MCSDT drying (55^0C)	Hot air oven drying (60^0C)	Cabinet tray drying (60^0C)
Overall drying rate	8.25 ± 0.001	11.65 ±0.005	7.99 ±0.002
Dehydration ratio	2.5 ± 0.02	3.65 ±0.03	3.89 ±0.09
Rehydration ratio	1.5 ± 0.03	1.52 ±0.04	1.65 ±0.07
Coefficient of rehydration	2.033 ± 0.07	1.88 ±0.09	2.88 ±0.08
Drying time in hours	6-10	4-6	5-7

The overall drying rate (Table 1) was significantly($p<0.05$) high in Multi Commodity Solar Dehydration Tunnel dried sample; dehydration ratio, rehydration ratio and coefficient of rehydration were significantly high in tray dried samples at $p<0.01$. The low rehydration ratio of Multi Commodity Solar Dehydration Tunnel dried sample could be due to high amount of concentrated solids following drying, which in turn would not permit absorption of water on account of pre-occupation of the pore spaces[16].

Fruit Powder Yield

The average number of Bael Fruit Powder depends on the size of the fruit. The average weight of one fruitwas 200g and the pulp weighs about 60g. One kg of fruit alongwith seed yielded 420g of pulp.The Bael Fruit pulp powder yield was significantly ($p<0.01$) high in sun drying (30 g/100g) than hot air oven (26 g/100g) and cabinet tray drying (24 g/100g).

Physical and Functional Properties

The low bulk density of sundried Bael Fruit pulp powder (Table 2) would be advantageous in the use of product for preparing complementary foods[16]. The Multi Commodity Solar Tunnel Drier dried and oven dried samples indicated the highest value for true density, porosity, Hygroscopicity and bulk volume when compared to tray dried sample in which the bulk density was higher. The water absorption capacity of the MCSTD dried sample was significantly ($p<0.01$) higher than the hot air oven dried sample which was significantly ($P<0.01$) higher than the tray dried sample. The high water absorption capacity of MCSTD dried Bael Fruit pulp powder may be due to high molecular expansion during drying which could reflect low bulk density. Though all dried Bael Fruit pulp powders exhibited its least gelation concentration at 5.5%, the firm gel was not observed even up to 16.5% concentration.

Table 2: Physical and functional properties of Bael Fruit pulp powder

Parameters	MCSTD dried sample	oven hot air dried sample	Cabinet tray dried sample
Bulk density(g/ml)	0.70 ± 0.003	0.58 ± 0.01	0.59 ± 0.00
True density (g/ml)	1.45 ± 0.02	1.34 ± 0.05	1.31 ± 0.00
Porosity (%)	44.89± 0.10	39.92 ± 0.04	38.19 ± 0.00
Hygroscopicity (%)	1.20± 0.00	1.70 ± 0.01	1.65 ± 0.01
Bulk volume(g/ml)	4.99 ± 0.007	4.25 ± 0.02	4.10 ± 0.00
Swelling power (ml/g)	0.22± 0.08	0.38 ± 0.01	0.31 ± 0.14
Water absorption capacity (g/g)	1.38 ± 0.02	1.04 ± 0.08	1.01 ± 0.07

* Significant at $p<0.01$

Nutritional and Chemical Properties

Edible Bael fruit composition reported a significant ($p<0.001$) concentrated effect on nutritional composition of powder1. Gopalan reported that the Bael fruit pulp of protein 7.1%, fat 3.7% , carbohydrate 18.1%1, whereas, present study shown only Carbohydrate 15.7%, protein 6.3% , fat 3.2% comparatively.

Chemical parameters like acidity, pH, total phenol and total antioxidant capacity (Table 3) were significantly higher in dried powder than fresh pulp, while the vitamin C content was drastically reduced on drying. The sundried (MCSTD) sample was better in quality in terms of nutritional and chemical parameters.

Table 3: Nutritional and chemical properties of Bael Fruit pulp powder

Nutritional and chemical parameters	Fresh Sample	MCSTD dried sample	Hot air oven dried sample	Cabinet tray dried sample
Total Carbohydrate (g)	15.65	61.67±0.13	57.25±0.88	60.12±0.21
Protein (g)	6.30	18.10±0.12	15.10±0.08	13.18±0.01
Fat (g %)	3.22	06.40±0.05	05.50±0.15	04.20±0.11
Crude fiber (g)	0.98	01.00±0.02	0.90±0.29	01.00±0.01
Ash (g)	1.30	06.50±0.01	06.50±0.45	06.50±0.41
Moisture content (%)	71.50	05.75±0.03	06.70±0.08	06.75±0.01
Titrable acidity (%)	4.57	6.80±0.29	05.61±.07	5.41±0.04
pH	3.51	03.87±0.09	03.50±0.08	03.46±0.02
Vitamin C	3.75	0.60±0.08	0.41±0.06	0.3±0.01
Total phenol(mg/100g)	275	486±2.83	420±4.25	432±0.03
Total antioxidant capacity (µg/g)	1422.85	4250±5.01	3600±0.28	3550±4.21

* Significant at $p<0.01$

The color of the samples (Table 4) indicates a trend of an increase in lightness and redness on drying of the extracted fruit pulp powder. The loss of natural color on Solar drying (MCSTD) was minimum than hot air oven and tray drying process.

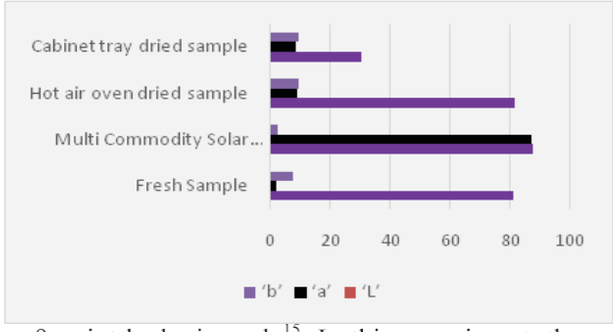
Table 4: Color value of Bael Fruit pulp powder

Variables	Fresh Sample	Multi Commodity Solar Tunnel Drier sample	Hot air oven dried sample	Cabinet tray dried sample
'L'	80.89	87.25	81.22	30.55
'a'	1.99	86.77	8.88	8.21
'b'	7.25	2.45	9.25	9.53

* Significant at $p<0.01$

Sensory evaluation

The sensory evaluation of Bael powder was carried out by a panel of 30 trained panelists at Daffodil International University Food Laboratory. The Mixed powder of different combinations (Lemon, sugar and salt) were evaluated for various sensory attributes such as texture, color, flavor, taste, and overall acceptability.



Methods of Sensory evaluation was adopted with a 9 point hedonic scale[15]. In this experiment, three formulated Bael fruit powder functional beverage were served and data were recorded.

Table 5: Sensory evaluation of Bael powder with different ratios of sugar and lemon juice

Sensory character	Sample Code	Types of sugar solution(^{0}brix) and Lemon Juice In ml with Bael fruit powder	Average scores given by panel member of judges
Color	T_1	10^0brix +5.0 ml	6.4
	T_2	12^0brix+ 7.0 ml	6.8
	T_3	14^0brix +8.0 ml	7.3
Flavor	T_1	10^0brix +5.0 ml	6.2
	T_2	12^0brix+ 7.0 ml	6.5
	T_3	14^0brix +8.0 ml	7.6
Taste	T_1	10^0brix +5.0 ml	6.1
	T_2	12^0brix+ 7.0 ml	6.7
	T_3	14^0brix +8.0 ml	6.9
Overall Acceptability	T_1	10^0brix +5.0 ml	6.6
	T_2	12^0brix+ 7.0 ml	6.4
	T_3	14^0brix +8.0 ml	6.8

Sensory scoring was done to work out the overall acceptability of the product by consumer. The sensory evaluation of the product was undertaken by a panel of judges considering the sensory attributes like color, taste, flavor and overall acceptability on 9 point hedonic score ranging from extremely like to extremelydislike. The mean score for color, flavor, taste and overall acceptability of the Bael powder mixed formula were presented in Table 3. In which sample T3 obtained maximum score of 6.3 for color 6.5 for flavor, 6.9 for taste and finally in overall acceptability was 6.8,while T1 showed minimum score on sensory point of view with respect to color, flavor and taste respectively.

Conclusion

In terms of drying characteristics, physical, functional, nutritional and non-nutritional quality, multi commodity solar tunnel drier used dried Bael fruit pulp powder exhibited highest index than oven dried or tray dried samples. Since, MCSTD drying is also cost effective, the Baelfruit pulp powder could be Solar dried for 5-10 hours and utilized for the preparation of jam, jelly, Sorbet as functional beverage and other products with good gelling nature even during off-season.

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