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Formulation and Evaluation Study of Bel Powder

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Abstract: A long-standing value, both in traditional and modern medicinal practices, is packed into the extract from the bel fruit (Aegle marmelos), primarily native to the Indian subcontinent and Southeast Asia. Bel powder, synonymous with deep cultural significance in Ayurveda, is a convenient, shelf-stable form of fruit containing health benefits while remaining powdered. The fruit is rich in macronutrients, like carbohydrates, with minimal content of fats and moderate amounts of protein, being a good source of vitamins A and C, calcium, potassium, and magnesium. Bioactive compounds, such as tannins, coumarins, and flavonoids, in Bel powder, add antioxidant, anti-inflammatory, and antimicrobial properties.

Bel powder is also believed to be very variable in its health benefits—it helps digest food, supports the immune system, and balances blood sugar levels. It has a high content of dietary fibre, which promotes easy digestion and stops the appearance of problems like constipation and dysentery. Antioxidant properties will help to prevent immunity weakness and reduce inflammation inside the body. Therapeutic use in animals has been proven for diabetes problem alleviation, protection of the liver, and maintenance of heart health. This therapeutic activity is mainly attributed to the presence of tannins and coumarins as the primary phytochemicals, which provide nutrition to cells to inhibit inflammation.

Both traditional sun drying and modern freeze drying techniques are employed in the production of bel powder to maintain its bioactive properties. On account of its curative potential, it has been widely used in the various realms of culinary application, Ayurvedic medication, nutraceutical, and even cosmetic formulations. Increasing demand for natural supplements as well as products in the Ayurveda line creates a significant requirement for bel powder from countries like India, the U.S., and Europe.

Based on available scientific evidence, it is believable that bel of these will provide the health benefits that it has across the different domains; therefore, their potential effects in the treatment of metabolic disorders and chronic diseases need more exploration. It is safe generally, but a visit to the doctor.

Keywords: Metabolic disorder,cronic disease,Antidibetic, Cardiac disorder,Antioxident

I. INTRODUCTION OF BEL POWDER

Bel (Aegle marmelos L.), the only species of genus Aegle belonging to the family Rutaceae, is native to dry tropical and subtropical regions of South Asia, such as Bangladesh, Thailand, India, Pakistan, Sri Lanka, and Malaysia (Uddin et al., 2016). The fruit grows seasonally and is widely available in Bangladesh. It mainly occurs in abundance throughout the eastern, western, and northern parts of the country along with some districts such as Rajshahi, Rangpur, Dinajpur, Bogura, and Mymensingh, among others (Dhakar et al., 2019).(1,2)

Bael is primarily available in the summers and is a good source of dietary fibre, protein, fats, minerals, and carbohydrates. (2) In addition to these, the pulp of this fruit is rich in several bioactive compounds like carotenoids, phenolics, alkaloids, flavonoids, terpenoids, polysaccharides, and antioxidants, which contribute towards chronic health conditions such as diabetes, cardiovascular diseases, and skin disorders like leukoderma and psoriasis. (Gurjar et al., 2019; Vinita Bisht & Johar, 2017). Ullikashi et al. (2017) also proved that bael is a rich source of vital vitamins and minerals, such as calcium, phosphorus, vitamin C, riboflavin, and vitamin A.(3)

The availability of bael is seasonal, hence different methods of preserving this fruit throughout the year have been developed, namely sun drying, hot air drying, and microwave drying (Sarkar et al., 2020). (3) Drying is one of the oldest preservation techniques that involves the removal of moisture content from the fruit, thus preventing microbial growth and slowing down enzymatic and chemical processes leading to spoilage (Kabir et al., 2022). It really allows the shelf life of the fruit to be highly extended and can thus be used in lots of products, such as pulp powder, preserves, candies, nectar, squash, marmalade, and jelly (Gurjar et al., 2019).(4)

According to Guin é and Barroca (2012), challenges in the food industry are trying to produce products that not only comply with traditional nutritional standards but also stay fresh, flavoured, and stable during storage.

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For such purposes, superior efficiency can be achieved through industrial drying methods such as freeze drying, hot air drying, or microwave drying, which deliver high yields with consistent quality. More comparably, oven drying, which is cost-effective, represents a viable alternative to the shelf life of bael products without badly affecting the quality.(5)

This study was on the production of bael pulp powder and aimed to assess its functional and nutritional compositions. Additionally, a sensory evaluation was conducted on a ready-to-drink (RTD) beverage prepared using bael pulp powder, further highlighting its potential as a consumer-friendly product with both nutritional and sensory appeal.(3,4)

Table 1:

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Proportioning of prepared Bael pulp powder drinks.

Samples	Bael Pulp Powder (g)	Sugar (g)	Salt (g)	Water (ml)	Total volume of drink (ml)
Sample-I	5.00	14.5	0.50	230	250
Sample-II	5.00	14.5	0.50	230	250
Sample-III	5.00	14.5	0.50	230	250

Sample-I: Contains pulp, Gum and Seeds; Sample-II: Contains pulp and gum; Sample-III: Contains only pulp

II. Materials and Methods

A. Collection of Raw Sample

Bel fruits (*Aegle marmelos*) were procured from a local vendor in Dinajpur, Bangladesh. The selected fruits were fully ripe, mature, yellowish in colour, and of high quality, ensuring they met the necessary criteria for further processing. The fruits were stored in a defect-free, ambient environment at a temperature of 25 ± 5°C until they were ready to be used.(5)

B. Preparation of Bel Pulp Powder

The process of preparing bael pulp powder involved the following steps:

1) *Extraction of Pulp:*The outer shells (exocarps) of the bael fruits were carefully cracked open. The pulp was then separated from the shell and transferred into a clean stainless-steel container for further processing.(6)
2) *Classification of Samples*:The pulp was divided into three distinct categories:

- Sample-I: Pulp that includes both gum and seeds.
- Sample-II: Pulp containing gum, but without seeds.
- Sample-III: Pulp devoid of both gum and seeds.

3) *Drying:* The pulp samples were dried in a hot air oven (Universal Oven UN55, Memmert GmbH + Co. KG, Büchenbach, Germany) at a controlled temperature of 60 ± 5°C to ensure proper moisture removal.(5,7)
4) *Grinding and Sieving:* After drying, the samples were ground using a blender (JP1009, Jaipan Industries Ltd., Maharashtra, India). The powdered samples were then sieved through a 1 mm mesh (sieve no. 18) to obtain uniform particle sizes.
5) *Storage:* The resulting bael pulp powder was securely sealed in glass containers and stored under ambient conditions (25 ± 5°C) for future use in further analyses.

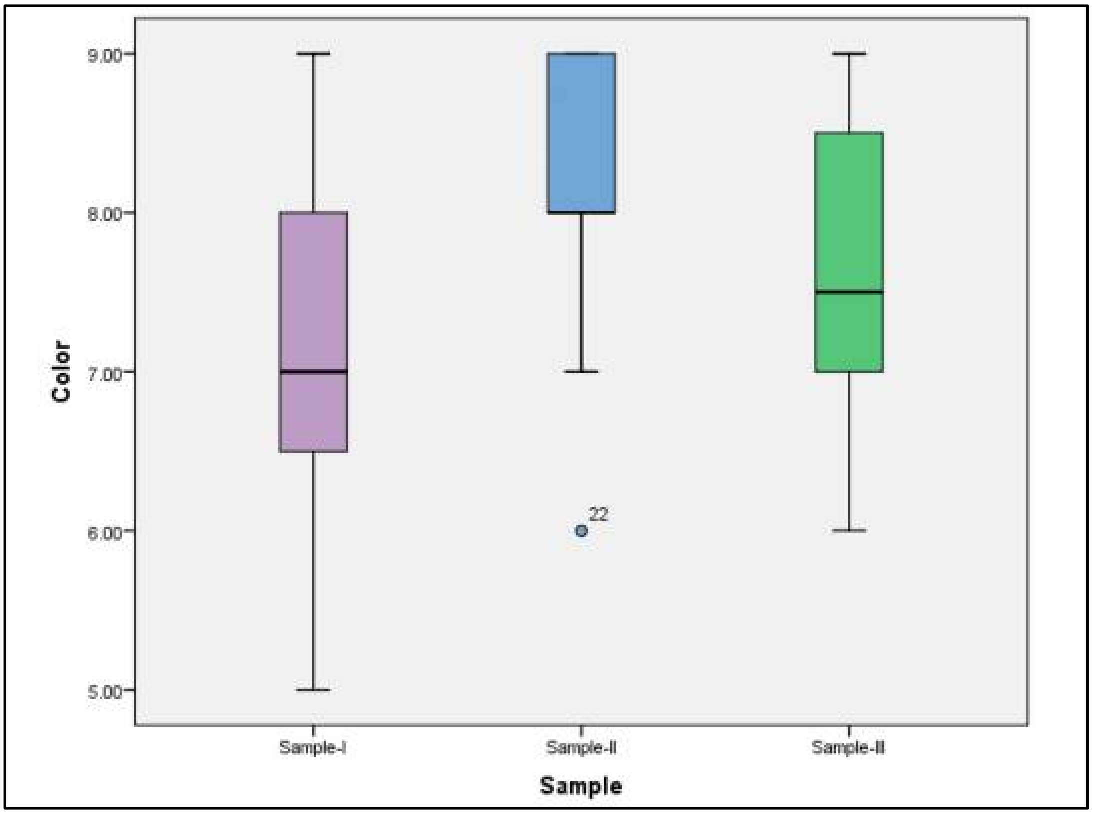

Figure 1. Box plots obtained for the color of prepared drink samples

C. Functional Properties of Bel Pulp Powder

The following functional properties of the bel pulp powder were measured using slightly modified methods from previous studies (Eleazu and Ironua, 2013; Sonawane et al., 2020; Iwuoha, 2004)(7)

1) Bulk Density
2) Water Absorption Capacity
3) Solubility
4) Particle Density
5) Porosity
6) Swelling Power

D. Nutritional Properties of Bel Pulp Powder

The nutritional analysis of bel pulp powder was carried out as follows:

1) Moisture Content: Measured to determine the stability and shelf-life of the powder.
2) Protein, Fat, Ash, and Fiber: The nutritional composition was analyzed according to the methods outlined in AOAC (2012).
3) Titratable Acidity: Determined following the AOAC guidelines (2016).
4) Carbohydrates: The available carbohydrate content was calculated using the subtraction method as described by Mahmud et al. (2019).(7,8)
5) pH: The pH of the powder was measured using a pH meter (Hanna Checker Model HI1270, USA) after calibrating it with buffer solutions of pH 4 and pH 7.

6) Ascorbic Acid: The concentration of vitamin C was determined using the method by Dar et al. (2015) with slight modifications.(7,8)
7) Mineral Content: The levels of phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) were analyzed using three techniques: atomic absorption spectrophotometry (AAS), flame photometry, and spectrophotometry. These methods were based on protocols from AOAC (2003) and earlier studies by Kabir et al. (2022) and Khan et al. (2006).(8)

III. RESULTS AND DISCUSSION

A. Functional Properties of Bael Powder

The functional properties of bael pulp powder, particularly its particle size, density, and ability to absorb water, have significant implications for its application in food products. These properties affect the handling, packaging, and drying processes.(4,5)

1) Bulk Density:

The average bulk densities of the bael pulp powder samples were found to be:

- Sample-I: 679.99 kg/m³
- Sample-II: 798.54 kg/m³
- Sample-III: 820.33 kg/m³

The observed trend indicates that as the content of seed and gum material increases, the bulk density decreases. This phenomenon can be attributed to the correlation between moisture content and particle weight, where particles with lower moisture content tend to weigh less.(5) The results show that Sample-I (with seeds and gum) had a lower bulk density, similar to the findings of Vijayakumar et al. (2013), who reported a bulk density of 680 kg/m³ for wood apple (another name for bael). In contrast, Sample-II and Sample-III exhibited higher bulk densities, likely due to the reduced moisture content and absence of seed and gum in these samples.(9)

A higher bulk density, as seen in Samples II and III, is advantageous in food preparation processes, especially for products that require efficient packaging and handling.(8) However, the lower bulk density observed in Sample-I could be beneficial in the formulation of food supplements and agglomerated products where flowability and instant characteristics are important. A lower bulk density may also indicate a shorter shelf life due to the potential for oxidation in the presence of more air pockets (Chaudhary et al., 2020).(10)

2) Water Absorption Capacity

The water absorption capacity (WAC) of the powder is an important functional property that reflects the powder's ability to absorb and retain water.(8,10) This is crucial in food applications where moisture retention is necessary. Bael powder demonstrated varying WAC across samples. It was observed that the powder's WAC was influenced by its composition, where higher water absorption was noted in samples with less seed and gum.(7,9) This enhanced ability to absorb water is particularly useful in formulations for baked goods, beverages, or instant mixes where rapid hydration is desired.

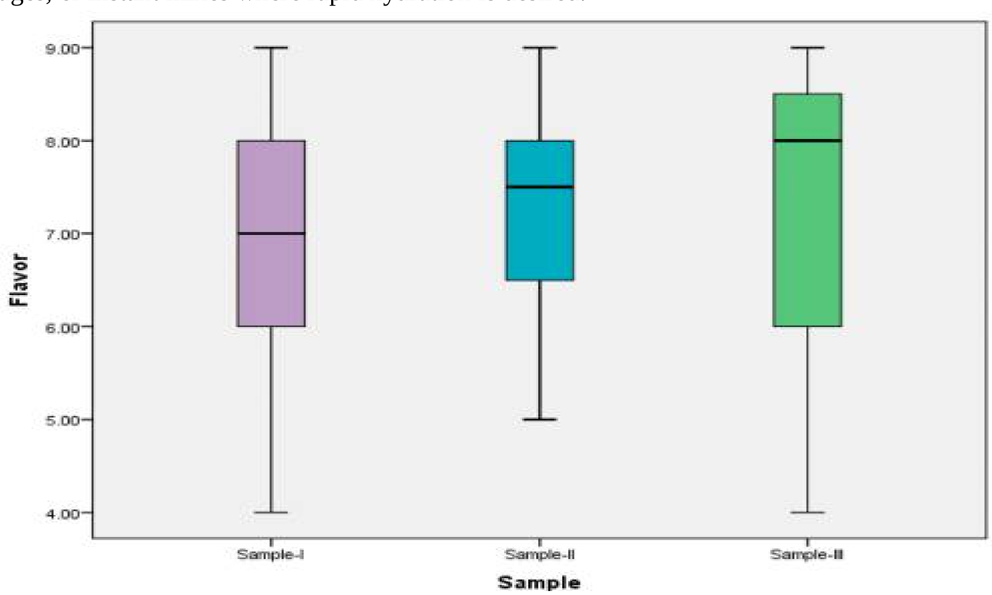

Figure 2. Box plots obtained for the flavour of prepared drink samples

3) Water Absorption Capacity:

The water absorption capacity (WAC) of the bael pulp powder was highest in Sample III (8.5 g/g) and lowest in Sample II (6.5 g/g). This variation is likely due to the differences in the composition of the samples, with Sample-III lacking seeds and gum, which enhances its water absorption. The increased WAC in Sample-III can be attributed to the expansion of fibres and carbohydrates, as well as the smaller particle size, which offers a larger surface area and more exposed hydrophilic groups, allowing for easier interaction with water (Woldemariam et al., 2021). This higher water absorption capacity in Sample-III could be beneficial in food formulations, such as baked goods, where moisture retention is important due to the higher protein content in the powder.(7,8,10)

4) Swelling Power:

The swelling power of bael pulp powder, which affects the texture and mouthfeel of food products, was observed as follows:

- Sample-I: 2.33%
- Sample-II: 3.31%
- Sample-III: 3.22%

Sample I, which contains seeds and gum, had a lower swelling power than the other samples, likely due to the higher degree of intermolecular association and gum content, which forms a coating around the particles and limits their expansion. On the other hand, Sample II and Sample-III exhibited higher swelling powers, with Sample III being slightly less than Sample II. This pattern aligns with findings from previous studies (Vijayakumar et al., 2013) and suggests that removing seeds and gum enhances the swelling capacity, making these samples better suited for applications where texture and mouthfeel are important.(11)

5) Solubility:

The solubility of bael pulp powder was observed to be highest in Sample III (22 g/g) and lowest in Sample-I (16 g/g).(3,7) The increase in solubility in Sample-III could be due to the lack of gum and seeds, which results in a more readily dissolvable powder. This higher solubility is consistent with the increased swelling power observed in the samples and supports the idea that Sample-III would perform better in products like beverages or instant food mixes. Similar results were reported by Kusumayanti et al. (2015), where higher solubility corresponded with greater swelling power.(11,12)

6) Particle Density:

The mean particle densities for the bael pulp powder samples were as follows:

- Sample-I: 1334.78 kg/m³
- Sample-II: 955.55 kg/m³
- Sample-III: 892.30 kg/m³

As expected, particle density decreased as the seed and gum content was reduced. The values for **Sample-I** are in alignment with previous studies on wood apple powder (Vijayakumar et al., 2013), confirming the consistency of the particle density when the seeds and gum are present in the powder.(13)

7) Porosity:

The average porosity values for the samples were☹(13)

- **Sample-I**: 48.61%
- **Sample-II**: 16.38%
- **Sample-III**: 7.94%

Porosity decreased progressively from Sample-I to Sample-III, reflecting the absence of seeds and gum in the latter samples. The higher porosity in Sample-I contributes to better air circulation, which could be advantageous in some food applications, but it also increases the likelihood of oxidation, which may shorten shelf life. The reduced porosity in Sample-III suggests better stability and shelf life, making it suitable for long-term storage in baked goods and beverages.(12,7)

B. Nutritional Composition of Bael Powder

Moisture content is a critical factor in determining the shelf stability and overall quality of bael pulp powder. Among the samples studied, Sample-III exhibited the highest moisture content, which can influence the storage stability of the powder. Moisture levels impact the preservation of nutrients and the potential for microbial growth, highlighting the importance of drying techniques to maintain product quality.(1,13)

1) Moisture Content:

The moisture content of bael pulp powder varies across samples, with Sample-III having the highest moisture content compared to the other two samples. This trend suggests that Sample-III, with the removal of seeds and gum, allowed for moisture to be retained more readily in the powder.(14) Previous research has shown similar findings, with the moisture content of bael pulp powder typically ranging from 6–8% (Sharma and Chauhan, 2017; Gurjar et al., 2019; Vijayakumar et al., 2013). Studies indicate that moisture levels below 8% help to inhibit microbial growth, thus prolonging the shelf life and maintaining the sensory and nutritional qualities of the product (Kabir et al., 2022). These findings are consistent with the data obtained for Sample-III.(14)

2) Ash Content:

The ash content, which represents the total mineral content of the powder, was observed to be:

- Sample-I: 2.67%
- Sample-II: 4.00%
- Sample-III: 4.67%

These results suggest that Sample-III contains the highest mineral content, particularly essential minerals like calcium and magnesium. The ash content values reported are similar to those found in previous studies (Sharma and Chauhan, 2017; U. Singh et al., 2012), indicating that the bael pulp powder retains a considerable amount of mineral elements, making it a valuable source of dietary minerals.(13,15)

Table 2:

Nutritional composition of Bael powder.

Composition	Sample-I	Sample-II	Sample-III
Moisture Content (%)	10.67 ± 1.15^{a}	7.33 ± 1.15^{b}	8.67 ± 1.15^{ab}
Ash (%)	2.67 ± 1.15^{b}	4.00 ± 0.0^{ab}	4.67 ± 1.15^{a}
Protein (%)	10.21 ± 0.51^{a}	10.21 ± 0.51^{a}	11.08 ± 1.33^{a}
Fat (%)	1.77 ± 0.09^{a}	0.87 ± 0.08^{b}	0.98 ± 0.12^{a}
Carbohydrate (%)	67.35 ± 1.13^{b}	72.67 ± 1.53^{a}	70.14 ± 2.02^{ab}
Fiber (%)	7.33 ± 0.58^{a}	5.33 ± 0.58^{a}	4.67 ± 0.58^{b}
Acidity (%)	1.60 ± 0.00^{a}	2.13 ± 0.46^{a}	2.13 ± 0.92^{a}
p^{H}	5.17 ± 0.006^{b}	5.27 ± 0.006^{a}	5.21 ± 0.06^{ab}
Ascorbic Acid (mg/100 g)	54.17 ± 7.21^{a}	54.17 ± 7.21^{a}	58.33 ± 7.21^{a}

Here, each value is expressed as mean ± SD of each sample. $^{a\text{-}b}$ means followed by different lowercase are significantly different at 5% level of significance ($P < 0.05$).

3) Protein Content:

Sample-III demonstrated the highest protein content (11.08%), which was notably higher than values reported in earlier studies by Islam et al. (2011) and Sharma and Chauhan (2017), which reported protein contents of 3.75% and 4.35%, respectively. This indicates that bael pulp powder, particularly without seeds and gum, can be an excellent source of protein, useful for the development of protein-enriched products. The increased protein content in Sample-III could be attributed to its more concentrated nutrient profile after the removal of seeds and gum.(2)

4) Fat Content:

Sample-I, which contains seeds, had the highest fat content among the samples, which is expected as seeds are known to be rich in fats (Kaur & Kalia, 2017; A. Singh et al., 2015). Conversely, the fat content in Sample-II and Sample-III was lower, indicating that the removal of seeds reduces the fat content. This makes Sample-II and Sample-III more suitable for producing low-fat food products.(7)

5) Carbohydrate Content:

The carbohydrate content in bael pulp powder was highest in Sample-II (72.67%), consistent with values reported in previous studies by Islam et al. (2011) and Sharma and Chauhan (2017). The carbohydrate composition is an important factor in the energy density of the powder, and Sample-II could be particularly beneficial in energy-dense foods and beverages.(10,15)

6) Fiber Content:

The fiber content was highest in Sample-I (7.33%) due to the presence of gum and seeds, which are known to be rich in fiber. In comparison, Sample-II and Sample-III exhibited lower fiber contents (5.33% and 4.67%, respectively). These results are consistent with previous research, which suggests that bael pulp, especially in its whole form, is a significant source of crude fiber (Dar et al., 2015). The reduction in fiber content in Sample-III is likely due to the removal of seeds and gum, which contribute the most fiber to the powder.(8)

7) Acidity and Flavor:

The flavor of a product is strongly influenced by its acidity, which contributes to its tart or sour taste. In this study, total acidity measurements indicated that all powdered bael samples had higher acidity levels than the raw fruit, which aligns with findings from previous research (Kaur & Kalia, 2017; Roy & Singh, 1980). (10,11)Generally, acidity levels in dried products tend to decrease, but the degradation of pectic compounds into soluble solids may have led to the increased acidity in bael powder. Pectic and ascorbic acids, which are present in the bael fruit, can contribute to the heightened acidity in powdered form (Shalini et al., 2020). This suggests that the drying process may intensify the tartness of the fruit, altering its sensory profile.(8)

8) pH and Palatability:

pH is another important factor that influences the flavor and palatability of fruit-based products. In this study, the pH of the powdered samples was slightly lower than that of the raw fruit, likely due to the conversion of pectin to pectenic acid during the drying process. This change in pH is consistent with the decrease in pH reported by A. Singh et al. (2014) for bael powder. While the pH of bael pulp is generally high, studies of low-acid fruit pulps (Dar et al., 2015) have shown that pH tends to decrease during drying, which can influence product processing and flavor development. The reduction in pH further supports the notion that drying and processing can alter the overall sensory experience of bael powder.(10,14)

9) Ascorbic Acid Content:

Ascorbic acid, or vitamin C, is an essential nutrient known for its antioxidant properties and its role in preventing scurvy. In this study, the ascorbic acid content in bael pulp powder did not show significant variation across the samples. The findings are consistent with previous reports (Islam et al., 2011; Sharma & Chauhan, 2017) that showed similar ascorbic acid levels in bael pulp. Despite the fact that ascorbic acid is known to degrade quickly when exposed to light, heat, and oxygen (Santos & Silva, 2009), the bael pulp powder retained a significant amount of this vitamin, making it a strong source of ascorbic acid.(3,10)

C. Mineral Content of Bael Powder

Mineral analysis revealed that all bael pulp powder samples had higher potassium content and lower phosphorus content compared to calcium and magnesium levels. Notably, phosphorus, a component of phytate, may reduce the bioavailability of other minerals. Therefore, reducing phosphorus levels could increase the bioavailability of essential minerals like calcium (Kamal et al., 2022; Ravindran et al., 1994).(12)

1) Potassium and Calcium:

The potassium and calcium levels were similar between Sample-I and Sample-II, but Sample-III showed a significant increase in calcium content. This suggests that removing seeds and gum might reduce the phytate content (phosphorus), allowing for better calcium absorption in Sample-III. Previous studies have reported calcium contents of 78.9 mg/100g and 92.9 mg/100g in green and ripe bael pulp, respectively (Anurag et al., 2014; Islam et al., 2011). The results of this study are consistent with those findings, further highlighting the nutritional value of bael pulp powder.(15)

2) Magnesium Content:

Magnesium levels did not differ significantly among the samples. Previous research by Islam et al. (2011) and Sharma and Chauhan (2017) found magnesium concentrations around 243-259 ppm, which aligns with the findings of this study. Variations in mineral content can also be attributed to environmental factors such as climate, soil composition, temperature, and storage conditions (Al-Farsi et al., 2018). Despite these variations, the overall nutritional profile of bael pulp powder remains robust and suitable for meeting dietary mineral requirements.(2,6)

Table3 :

Mineral content of Bael powder.

Samples	Mineral Content			
	Phosphorus (P) (mg/100gm)	Potassium (K) (mg/100gm)	Calcium (Ca) (mg/100gm)	Magnesium (Mg) (mg/100gm)
Sample-I	86.27 ± 0.70[b]	575.0 ± 25.43[b]	454.24 ± 46.28[ab]	291.64 ± 48.64[a]
Sample-II	88.21 ± 0.48[a]	558.33 ± 28.87[b]	427.52 ± 46.28[b]	307.86 ± 56.13[a]
Sample-III	88.67 ± 0.71[a]	658.33 ± 28.87[a]	534.40 ± 46.28[a]	275.45 ± 28.06[a]

Here, each value is expressed as mean ± SD of each sample. [a-b] means followed by different lowercase are significantly different at 5% level of significance ($P < 0.05$).

D. Sensory Evaluation

The sensory evaluation of the Bael powder drink samples was conducted to assess various attributes such as color, flavor, consistency, astringency, taste, and overall acceptability. A group of semi-trained panelists evaluated the drinks based on these sensory attributes using a hedonic scale. The results were visually represented using box plot diagrams to highlight the differences in the sensory perceptions of the panelists (Fig 1-6).(12)

1) Color:

Panelists noted significant differences in the color of the prepared drinks. **Sample-III**, which was the most highly rated, exhibited a vibrant and appealing color, making it visually more attractive to consumers.

2) Flavor and Taste:

Sample-III was also highly appreciated for its balanced flavor and taste. It was described as having a pleasant, mildly sweet flavor, with a smooth and harmonious taste profile. This sample was favored for its more refined and less astringent taste compared to the other samples.

3) Consistency:

Consistency was another key factor in the evaluation. Sample-III had a smooth texture that was appreciated by the panelists, enhancing the overall drinking experience. It displayed optimal consistency, neither too thick nor too thin, which contributed positively to its mouthfeel.

4) Astringency:

Sample-III was less astringent, which was noted as a positive attribute, as higher levels of astringency can often detract from the drink's overall enjoyment.

5) Overall Acceptability:

The overall acceptability score, reflecting how much the panelists liked the drink, was highest for Sample-III, with a score of 7.48/9. This suggests that Sample-III was the most favorable among all the samples tested.

IV. CONCLUSIONS

The results of this study demonstrate that Sample-III, which is free from seeds and gum, yields a substantial amount of powder rich in essential nutrients, including protein, carbohydrates, potassium, calcium, and vitamin C. From a nutritional perspective, Bel pulp powder offers a promising source of high-quality powders that can serve as a valuable ingredient in various food applications.

The sensory evaluation confirmed the overall suitability of the powder, particularly Sample-III, for use in ready-to-drink beverages, highlighting its potential for commercial production. Additionally, the inclusion of the gum and seed components of the fruit may offer further opportunities for product diversification, enhancing the value of bael-based products.

In conclusion, Bel pulp powder has significant potential as a value-added food component in the manufacturing of commercially processed foods. It can contribute essential nutrients to the diet, supporting human health and well-being, while also offering a sustainable option for the utilization of this underused fruit. Therefore, the inclusion of bael powder in various food formulations could play an important role in addressing nutritional needs and enhancing food security.

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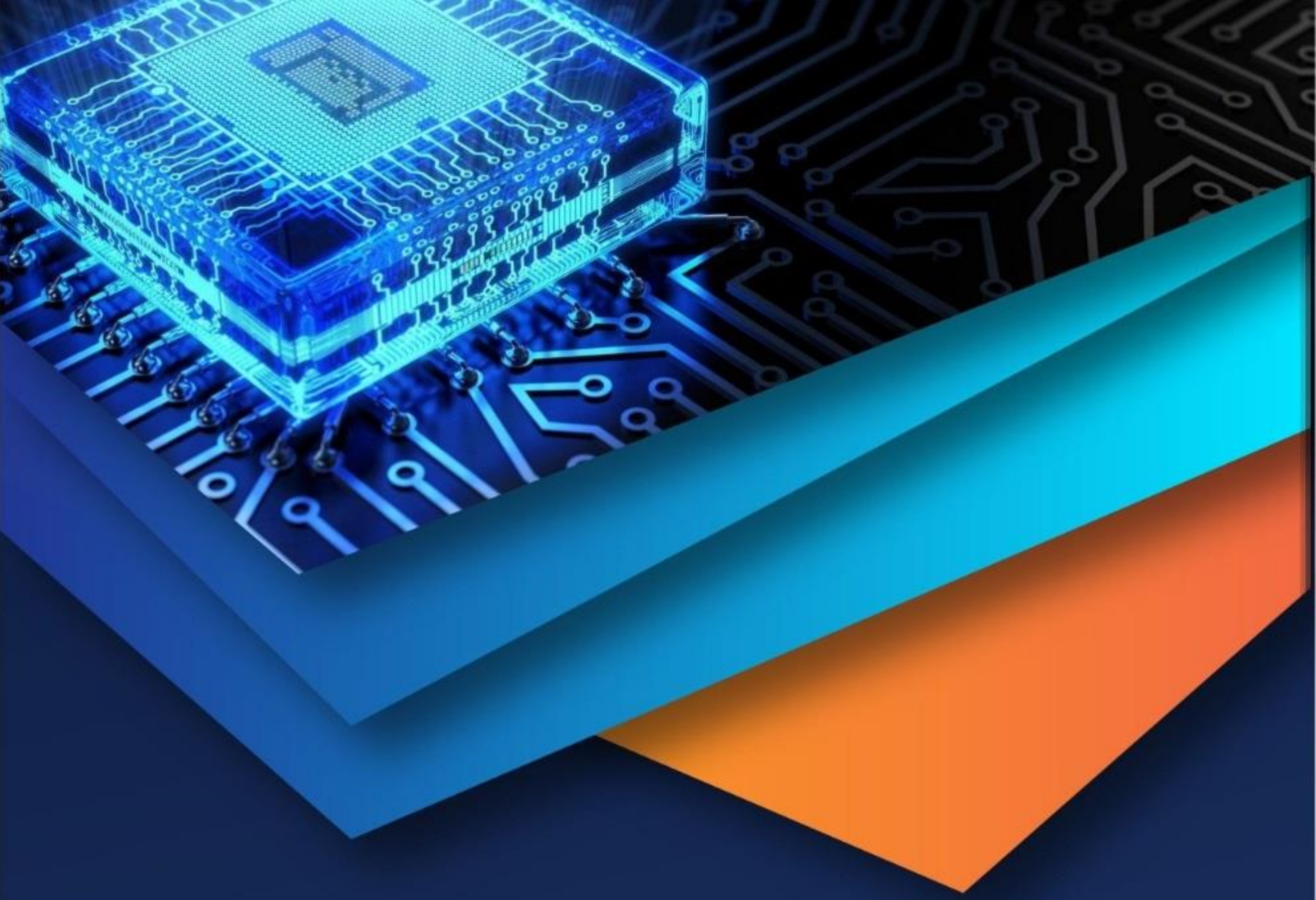

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