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Original Research

Nutritional Composition, Bioactive Compounds, and Antioxidant Activity of Fig (*Ficus carica* L.) Jam Varieties: A Functional Food Perspective

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ABSTRACT

Background: Figs (*Ficus carica* L.), widely valued in Asia and the Middle East, are recognized for their rich nutritional profile and medicinal properties, including potential anti-cancer and cardiovascular benefits. Both fresh and dried figs are abundant in fiber, trace minerals, antioxidant polyphenols, proteins, sugars, organic acids, and volatile compounds. This study aimed to evaluate the quality of fig jams prepared with three different sweeteners—white sugar, brown sugar, and honey. **Methods:** The jams were analyzed for their nutritional composition (fat, protein, fiber, vitamin C, carbohydrates, and total solids), chemical properties (titratable acidity and pH), bioactive compounds (total phenolic, flavonoid, and anthocyanin contents), and microbial safety (total viable count, yeast, and mold counts). **Results:** The findings revealed that honey fig jam had the highest acidity (0.048 ± 0.001), fiber (2.38 ± 0.002%), protein (5.95 ± 0.05%), and vitamin C (8.00 ± 0.1 mg/100g) content. White sugar fig jam exhibited the lowest moisture content (36.28 ± 0.28%) and ash percentage (0.70 ± 0.05%). The total soluble solids (TSS) were highest in brown sugar fig jam (67 ± 1.00%) and slightly lower in white sugar and honey fig jams (66 ± 1.00%). Significant differences ($p < 0.05$) in phytochemical compounds were observed among the samples. **Conclusion:** These results highlight the influence of sweeteners on the quality attributes of fig jam, with brown sugar emerging as a favorable option for optimizing both nutritional value, chemical quality and sensory properties. This study provides valuable insights for the development of fig-based products, contributing to the growing demand for functional foods.

Keywords: *Ficus carica*; jam; physicochemical; nutritional sciences; phytochemicals

1. INTRODUCTION

Dietary components such as different micronutrients are mandatory for maintaining proper health condition. Fruits and vegetables are essential components of a balanced diet, providing vital nutrients, dietary fiber, and bioactive compounds that collectively promote human health.[1] Numerous studies have demonstrated the protective effects of fruit consumption against chronic diseases. However, the health benefits of fruits depend not only on their inherent properties but also on the processing methods employed, which can significantly influence nutrient retention, bioactive compound availability, and overall quality.[2,3] However, most fruits and vegetables are seasonal, grown in specific regions with suitable environmental factors, and have a short shelf life.

Due to their seasonal nature and perishability, many fruits require preservation to ensure their availability throughout the year while minimizing nutrient and flavor degradation.[4] Among various preservation methods, jam-making is widely practiced for its ability to extend shelf life while maintaining the fruit's sensory and nutritional characteristics.[5] Jam is medium-moisture food and it's mainly used for food preservation. Jam production involves combining fruit pulp with sugar, acid, and pectin, yielding a product with enhanced flavors, microbial stability, and nutritional value. This method is particularly useful for seasonal fruits like figs, allowing their nutritional and bioactive properties to be preserved and utilized beyond harvest seasons.

Figs (*Ficus carica* L.), one of the earliest cultivated fruits, are a staple in the Mediterranean diet and are celebrated for their nutraceutical properties.[6] Figs are highly nutritious fruit and well known for its functional properties. Rich in bioactive compounds such as polyphenols, flavonoids, and furanocoumarins, figs have demonstrated significant health benefits, including cardiovascular support and anticancer activities.[7,8] Despite their health-promoting attributes, figs are highly perishable and susceptible to rapid quality deterioration, underscoring the importance of effective preservation methods.[9] Figs can be preserved in many ways, such as by making jam or marmalade, or through canning, drying, freezing, and other methods.

Jam-making is a commonly used technique for preserving figs while retaining their bioactive compounds and nutritional value. This process ensures microbial stability, prevents enzymatic browning, and produces a versatile product suitable for large-scale distribution. However, limited research exists on how the jam-making process and subsequent storage affect the antioxidant activity, total phenolic content (TPC), and total anthocyanin content (TAC) of fig jam. These parameters are crucial for understanding the potential health benefits of fig-based products and optimizing their formulation. This study aims to investigate the impact of the jam-making process and storage conditions on the bioactive properties of fig jam. By evaluating changes in antioxidant activity, TPC, and TAC, this research seeks to contribute to the growing body of knowledge on fig preservation techniques, supporting their role as a functional food and an integral part of a healthy diet.

2. METHODS

2.1 Study Design

The experiment was conducted at the different laboratories at Chattogram Veterinary and Animal Sciences University (CVASU), Chattogram, Bangladesh. The study spanned eight months, from October 1, 2021, to May 31, 2022. Fresh fig fruits were procured from local markets in Chattogram. The fruits were carefully selected, sorted, washed, graded, ingredient assembled and prepared for jam by using standard methodology.[10]

2.2 Analysis

Physicochemical properties, including moisture, total solids (including ash), total soluble solids, titratable acidity, and pH, were measured using standard protocols from the Association of Official Analytical Chemists (AOAC). Nutritional composition, including crude fat, crude protein, crude fiber, total carbohydrates, vitamin C, and energy, was also determined using AOAC methods.

For bioactive compound analysis, 5 g of sample was prepared for Total Anthocyanin Content (TAC) and 1 g for total phenolic content (TPC) and total flavonoid content (TFC). Samples were extracted with 10 ml of absolute ethanol for 72 hours with intermittent stirring at 4-hour intervals. TPC was extracted and determined by Folin-Ciocalteu techniques.[11] Standard technique was followed for TAC determination.[12] The total flavonoids content (TFC) of the samples was calculated by using aluminum chloride colorimetric technique.[13] Antioxidant capacity was assessed using the DPPH scavenging method with the absorbance measured at 517 nm.[11]

Microbial stability was assessed using Total Viable Count (TVC) through standard plate counts (SPC). Diluted jam samples were incubated at 37°C for 24 hours. After one month of refrigerated storage at 4°C, TVC was counted. No yeast or mold growth was detected, confirming the microbial safety and stability of all jam samples. Specifically described methods and techniques are used for fungal analysis in jam as per standard.[14,15]

A cost analysis was conducted according to the total cost of the items used in their creation. Sensory evaluation was conducted by a 15-member panel using a 9-point hedonic scale to assess flavor, texture, sweetness, appearance, and overall acceptability.

2.3 Statistical Analysis

All analyses were conducted in triplicate for each sample. Descriptive statistics (mean and standard deviation) were used to summarize the proximate composition and sensory assessment data. Statistical analysis was performed using IBM SPSS Statistics 25. One-way ANOVA was applied to identify significant differences at a 95% confidence level, followed by Tukey's post hoc test to determine group variances. Results were considered statistically significant at a 5% level ($p \leq 0.05$).

3. RESULTS

3.1 Physicochemical Properties of Fig Jam

The physicochemical analysis revealed notable variations among the fig jam samples. Honey fig jam exhibited the highest acidity percentage (0.048±0.001), while white sugar and brown sugar jams showed no significant difference in acidity (Table 1). Acidity levels ranged from 0.35% to 0.48%, exceeding the 0.19%-0.21% range reported by WHO for fig products. The highest TDS (588±2.00 ppm) was recorded in honey fig jam, while the lowest (408±2.00 ppm) was observed in white sugar fig jam. Similarly, TSS percentages ranged from 66±1.00 in white sugar and honey fig jams to 67±1.00 in brown sugar jam. The average pH value was 4.6 across the samples.

Table 1. Physicochemical properties of fig jam, means ± SD, and values in the same row with the same superscripts are statistically significant (P <0.05)

Component	White sugar	Brown sugar	Honey fig jam
Acidity (%, as Citric Acid)	0.0352±0.0002^{a}	0.0352±0.0002^{b}	0.048±0.001^{ab}
TDS (ppm)	408±2.00^{a}	524±2.00^{a}	588±2.00^{a}
TSS (°B)	66±1.00	67±1.00	66±1.00
pH	4.7±0.10	4.6±0.10	4.6±0.10

a, b superscript alphabets are representing statistical differences

3.2 Nutritional Composition

Significant differences were observed in the nutritional profiles of the fig jam samples (Table 2). White sugar jam had the lowest moisture content (36.28±0.28%) and the highest carbohydrate (59.00±0.15%) and energy content (251.36±0.83 kcal). In contrast, brown sugar jam had the highest moisture content (48.85±0.05%) and the lowest energy (197.63±0.26 kcal). Honey fig jam stood out for its superior nutritional attributes, with the highest fiber (2.38±0.002%), protein (5.95±0.05%), and vitamin C (8.00±0.10%) content. Ash content ranged from 0.70±0.05% in white sugar jam to 1.00±0.02% in honey fig jam. There was also change in fiber, fat, protein, carbohydrate, and vitamin C contents across the samples.

3.3 Bioactive Compounds

The bioactive components varied significantly among the samples (Table 3). Sample brown sugar showed the highest Total Anthocyanin Content (TAC) at 61.30±0.65 mg/100 g, while white sugar had the lowest at 14.53±0.56 mg/100 g. Total Flavonoid Content (TFC) was highest in honey fig jam (29.89±0.03 mg QE/g) and lowest in white sugar (18.41±0.01 mg QE/g). Total Phenolic Content (TPC) was lower at honey fig jam (3.71±0.012) and highest was on white sugar (4.26±0.007).

Table 2. Nutritional composition of Fig Jam means ± SD, and values in the same row with the same superscripts are statistically significant (P <0.05)

Component	Formulation of sample		
	White sugar	**Brown sugar**	**Honey fig jam**
Moisture (%)	36.28±0.28^{a}	48.85±0.05^{a}	48.13±0.13^{a}
Fiber (%)	1.8±0.03^{a}	2.04±0.04^{a}	2.38±0.02^{a}
Ash (%)	0.70±0.05^{ab}	0.97±0.03^{b}	1.00±0.02^{a}
Fat (%)	0.07±0.002^{a}	0.05±0.003^{ab}	0.10±0.003^{b}
Protein (%)	2.15±0.05^{a}	3.73±0.03^{a}	5.95±0.05^{a}
CHO (%)	59.00±0.148^{a}	44.36±0.087^{a}	42.43±0.193^{a}
Vitamin-C (mg/100g)	4.00±0.10^{a}	6.00±0.10^{a}	8.00±0.10^{a}
Energy (kcal/100g)	251.36±0.830^{a}	197.63±0.261^{a}	199.56±0.261^{a}

a, b superscript alphabets are representing statistical differences

Table 3. Bioactive compounds, means ± SD, and values in the same row with the same superscripts are statistically significant (P <0.05)

Component	Formulation of sample		
	White sugar	**Brown sugar**	**Honey fig jam**
TAC (mg TA/100 mL)	14.53±0.559^{a}	61.30±0.645^{a}	24.41±0.322^{a}
TFC (mg QE/100 g)	18.41±0.010^{a}	25.17±0.069^{a}	29.89±0.034^{a}
TPC (mg GAE/100mL)	4.26±0.007^{a}	4±0.004^{a}	3.71±0.012^{a}

Superscript alphabet representing statistical difference; TAC= Total Anthocyanin Content, TFC= Total Flavonoid Content, TPC= Total Phenolic Content

3.4 Antioxidant Capacity

The antioxidant capacity of fig jam prepared with different sweeteners—white sugar, brown sugar, and honey—was evaluated, and the results are presented in Table 4. The measured antioxidant values were 3.22 ± 0.005 mg GAE/100 mL for white sugar, 3.26 ± 0.003 mg GAE/100 mL for brown sugar, and 3.23 ± 0.002 mg GAE/100 mL for honey-sweetened fig jam. Although the jam formulated with brown sugar showed a slightly higher antioxidant content, statistical analysis revealed no significant differences among the three formulations ($P < 0.05$), as indicated by the shared superscript letters. These findings suggest that the type of sweetener used does not significantly influence the antioxidant capacity of fig jam.

Table 4. Antioxidant capacity of fig jam, and values in the same row with the same superscripts are statistically significant (P <0.05)

Component	Formulation of sample (mg TE/100 g)		
	White sugar	**Brown sugar**	**Honey fig jam**
Antioxidant (mg GAE/100mL)	3.22±0.005^{a}	3.26±0.003^{a}	3.23±0.002^{a}

Superscript alphabet representing statistical difference

3.5 Microbiological Analysis

Microbial analysis confirmed the safety and stability of all fig jam samples during one month of storage at 4°C. No yeast or mold growth was detected at any point. The Total Viable Count (TVC) was highest in Sample brown sugar (8.1×10^5 CFU/ml) and lowest in honey fig jam (9.5×10^4 CFU/ml), with all counts remaining within acceptable safety limits (Table 05). The absence of yeast and mold across all fig jam samples supports the microbial safety of the product, aligning with observations for various commercial jams.

3.6 Sensory Evaluation

Sensory evaluations, conducted with a 15-member panel using a 9-point hedonic scale, revealed significant preferences for brown sugar fig jam (Table 6). It scored highest for flavor (7.90±0.74), sweetness (8.10±0.74), and appearance (8.00±0.67) (Table 06). Honey fig jam was appreciated for its natural sweetness, while white sugar fig jam received moderate ratings across all attributes. Brown sugar was the most preferred overall. Sensory evaluation revealed no significant differences ($p>0.05$) in taste, mouthfeel, sweetness, and appearance across samples, except for flavor and overall acceptability ($p<0.05$). Brown sugar jam was rated highest for flavor, texture, and spread ability due to the use of pectin, while honey jam was noted for its natural sweetness. Storage conditions influenced sensory attributes over time, with color and texture improvements observed due to varying sweeteners.

Table 5. Microbial analysis

Formulation of Sample	TVC (CFU/ml)			Mold and Yeast		
	0 day	15 days	1 month	0 day	15 days	1 month
White sugar	1.8×10^{2}	3.3×10^{3}	6.5×10^{5}	No growth	No growth	No growth
Brown sugar	2.8×10^{3}	4.8×10^{3}	8.1×10^{5}	No growth	No growth	No growth
Honey fig jam	3.6×10^{1}	6.4×10^{2}	9.5×10^{4}	No growth	No growth	No growth

Table 6. Sensory Evaluation, and values in the same row with the same superscripts are statistically significant (P <0.05)

Component	Formulation of sample		
	White sugar	Brown sugar	Honey fig jam
Taste	7.60 ± 0.843^{b}	8.30 ± 0.483^{a}	7.30 ± 0.949^{a}
Flavor	7.50 ± 0.707^{a}	7.90 ± 0.738^{a}	7.30 ± 0.675^{a}
Mouth feel	7.90 ± 0.994^{a}	7.90 ± 0.994^{a}	7.50 ± 0.850^{a}
Sweetness	7.50 ± 0.972^{a}	8.10 ± 0.738^{a}	6.80 ± 1.317^{a}
Appearance	7.50 ± 0.527^{a}	8.00 ± 0.667^{a}	7.8 ± 0.632^{a}
Overall acceptability	7.80 ± 0.789^{b}	8.40 ± 0.699^{a}	7.50 ± 0.850^{a}

a, b superscript alphabets are representing statistical differences

3.7 Cost Analysis

Cost analysis highlighted significant differences among the jam formulations. White sugar was the most economical at 676.40 BDT/kg, followed by brown sugar at 693.65 BDT/kg (Table 7). Honey fig jam had the highest cost at 1153.65 BDT/kg, attributed to the premium pricing of honey. The results underscore the cost-effectiveness of white and brown sugar jams for large-scale production, while honey jam appeals to niche markets prioritizing premium nutritional value.

Table 7. Production cost of fig jam

Heads	Tk. per Kg	Quantity used (kg/1kg products)	White sugar (BDT)	Brown sugar (BDT)	Honey fig jam (BDT)
1. Expenditure (raw materials)					
Fresh Fig	900	0.500	450.00	450.00	450.00
Sugar	70	0.500	35.00		
Brown Sugar	100	0.500		50.00	
Honey	900	0.500			450.00
Pectin	12000	0.004	48.00	48.00	48.00
Citric acid	1000	0.003	3.00	3.00	3.00
Sub total	536.00	551.00	951.00		
2. Overhead cost @ 15% of raw material			80.40	82.65	142.65
3. Bottling cost	15 Tk./piece	4 pieces	60.00	60.00	60.00
Total production cost of 1 kg fig jam			676.40	693.65	1153.65

BDT = Bangladeshi Taka; Tk. = Short form of BDT

4. DISCUSSION

The physicochemical properties of the different jam varieties indicated that the increased acidity levels were due to the addition of citric acid as a preservative, as well as the degradation of polysaccharides and reducing sugars into acidic compounds during processing.(16,17) Acids content can affect the jam formation, flavor, and overall quality of Jam. The findings of TDS and TSS values also align with another findings, which noted that sugar addition facilitates the transformation of insoluble polysaccharides into soluble disaccharides.(18) The pH values averaged 4.6 across the samples, slightly higher than the range of 3.66 to 3.19.(19) This reduction in pH, influenced by citric acid, improves pectin gelation and enhances the shelf stability of the jam. Low pH level affect the gelling properties and improve gel formation by increasing interactions between pectin molecules.

Ash content ranged from 0.70±0.05% in white sugar jam to 1.00±0.02% in honey fig jam. The fiber content was higher than previously reported by Tanwar et al. reflecting varietal differences.(20) Heat-induced degradation accounted for the reduced fat (0.07%-0.10%) and protein levels in the jams, consistent with earlier findings.(21) Carbohydrate content increased significantly due to sugar addition and the inversion of non-reducing sugars during storage, aligning with previous findings. (22) Adding sugar in jam production is crucial for controlling the properties of jam. Vitamin C content decreased (4%-8%) due to heat treatment and oxidation during processing. The oxidative reactions further contributed to ascorbic acid loss during storage which corroborate with earlier findings. (23) Oxidative stress can take place in several steps of jam production and storage including during thermal treatment.

Brown sugar fig jam also demonstrated the highest antioxidant capacity (3.26±0.003 mg TE/100 g), while white sugar jam had the lowest (3.22±0.005 mg TE/100 g). These findings align with earlier findings, who observed similar trends in fruit preserves over extended storage periods. (24) However, the study by Benedek et al. reported no clear trend in the changes in the antioxidant properties of jam during the storage period.

The microbiological analysis confirmed the safety and stability of all fig jam formulations over one month of refrigerated storage at 4°C. The high sugar content, low pH, and heat application during processing effectively inhibited microbial growth. (25) The absence of yeast and mold in all samples throughout the storage period indicates effective preservation, likely due to the use of citric acid and appropriate processing conditions. Sensory evaluation revealed consumer preference for brown sugar fig jam, which scored highest in flavor, sweetness, appearance, and overall acceptability. The use of brown sugar may have contributed to enhanced caramel-like notes and color, improving the sensory appeal. While no significant differences ($p > 0.05$) were observed for most sensory attributes, overall acceptability and taste differed significantly ($p < 0.05$), with brown sugar jam outperforming others. Honey fig jam was appreciated for its natural sweetness, although it scored lower than brown sugar in key sensory metrics. Storage conditions also played a role in sensory characteristics, with some improvements in texture and color attributed to the type of sweetener used.(26)

From an economic perspective, cost analysis highlighted that jams made with white and brown sugar were more cost-effective compared to honey fig jam. White sugar jam had the lowest production cost (676.40 BDT/kg), followed closely by brown sugar jam (693.65 BDT/kg), making them more suitable for large-scale production. In contrast, the honey fig jam had a significantly higher cost (1153.65 BDT/kg), primarily due to the high price of honey. While this formulation may appeal to health-conscious or premium consumers, its high cost may limit its market accessibility.(27)

This study has a limitation in that the shelf life of the fig jam formulations was not evaluated. Assessing shelf life is essential for determining long-term storage stability, microbial safety, and the preservation of nutritional and sensory qualities over time. Future studies should focus on evaluating the shelf life and overall quality of the products during extended storage periods.

5. CONCLUSION

Jam is a convenient and nutritious food that is easy to consume, digest, and absorb, providing essential nutrients required for maintaining good health. The *Ficus carica* L. plant offers versatile applications in producing various products such as jam, jelly, and cakes. The transformation of fig fruit pulp into jam results in a significant enhancement of physicochemical properties, including increased total soluble solids (TSS) and total acidity, accompanied by a notable reduction in pH and mineral composition. Additionally, the carbohydrate and calorie content of fig jam experienced a substantial rise during processing. Handmade fig jam has proven to be an excellent method of preservation, as it retains the antioxidant capacity of figs, ensuring the quality and nutritional value of the final product. The microbiological quality of all three varieties of fig jam—brown sugar, honey, and white sugar—was found to be satisfactory, with no yeast or mold growth observed during storage. Among the variants, brown sugar fig jam exhibited superior nutritional and physicochemical qualities, followed closely by honey fig jam. White sugar fig jam, while cost-effective, ranked slightly lower in comparison. These findings highlight the potential of fig jam as a nutritious and health-promoting food product, with brown sugar fig jam offering the best balance of quality, sensory appeal, and nutritional benefits.

Ethical Approval

Not required.

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Competing Interests

All the authors declare that there are no conflicts of interest.

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Underlying Data

Derived data supporting the findings of this study are available from the corresponding author on request.

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