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Morphological, Physicochemical, Nutritional, Minerals Properties and Bioactive Compounds Analysis of Fresh Figs (*Ficus carica* L.) Indigenous to Bangladesh

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ABSTRACT

The present study aims to evaluate the morphological, physicochemical, nutritional, minerals, color properties, and bioactive compounds of round and oval-shaped fresh fig fruits (*Ficus carica* L.). The maximum fruit breadth, stem length, and stem breadth of the oval-shaped fig fruits were 3.26 cm, 2.40 cm, and 0.45 cm respectively. The maximum fruit length was found in the round-shaped fig fruits (3.86 cm). The maximum fruit and seed weight were found in the oval-shaped fruits, calculated as 35.34 g and 11.09 g. The lowest fruit and seed weight were found in the round-shaped fruits, calculated as 28.87 g and 10.26 g, respectively. The highest edible portion was found in the round-shaped fruits at 98.35 g, while the non-edible portion was at its minimum in (1.65 g). The oval-shaped fig fruits exhibited a greener colour compared to the round-shaped fig fruits. The moisture content of the fresh fig fruits was recorded as 80.01 % for the oval -shaped fruits and 80.50 % for the round-shaped fruits. The a_w of the round and oval-shaped fresh fig fruits was calculated as 0.61 and 0.59, respectively. The highest values of bioactive compounds, including vitamin-C, β-carotene, total soluble solid (TSS), and pH were found in the fresh oval fig fruits. These values were recorded as 26.57±0.47 mg/100 g for vitamin-C, 7.49±0.19 mg/100 g for β-carotene, 14.15±0.14 for TSS, and 5.18±0.05 for pH, respectively. The results confirm that the oval-shaped figs were a more abundant source of nutritional and bioactive compounds compared to the round-shaped fresh figs.

Keywords: Fresh figs, morphological characteristics, micro and macro nutrient, nutritional composition, bioactive compounds, color parameter.

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INTRODUCTION

Fig (*Ficus carica* L.) is a deciduous tree from the *Moraceae* family, native to southwest Asia, and it is typically grown in the Mediterranean Region. This plant is one of the earliest cultivated trees and grows up to 7-10 meters tall. Fig fruits are an important crop worldwide, valued for both dry and fresh consumptions (Çaliskan and Aytekin Polat, 2011; Tanwar et al., 2014). Turkey, Greece, Egypt, Morocco, Italy, Spain, Brazil, and other countries were among the main fig producers due to their proper climatic conditions, such as hot and dry summers, and mild winters (Soni et al., 2014; Ara et al., 2023). The color of figs varies from dark purple to green (Solomon et al., 2006). The consumption of figs has positive health effects due to their numerous nutraceutical compounds that may help to prevent cardiovascular diseases and the growth of carcinoma cells (Allegra et al., 2017). Fresh and dried figs, as well as their syrup possess laxative properties (Morton, 1987). The consumption of figs is well recommended for eyesight as well as for liver and spleen diseases (Gani et al., 2018). Figs are used as an expectorant and diuretic. In addition, juice from figs mixed with honey can be used for the treatment of hemorrhages (Soni et al., 2014). Also, the extracts of fig fruits have displayed inhibition of xanthine oxidase, which can help in the management of gout (Batchu et al., 2023). Oily macerates prepared from dried figs are also used for consumption due to their antioxidative and antimicrobial properties (Debib et al., 2018). The dried and fresh figs are reported to be a good source of amino acids, carbohydrates, sugars, fibres, minerals (copper, manganese, magnesium, potassium, and calcium), vitamins, organic acids, and phenolic compounds (Veberic et al., 2008; Slatnar et al., 2011; Khatun et al., 2016) similar to some edible mushrooms (Dospatliev, 2018). The phytochemicals of figs also include arabinose, β-amyrins, β-carotenes, glycosides, β-sitosterols, xanthotoxol, alkaloids, flavonoids, coumarins, saponins, and terpenes (Gilani et al., 2008; Jeong et al., 2009). Fresh fig is an important source of polyphenols, such as rutin (up to 28.7 mg/100 g fresh weight (fw), (+)-catechin, (−)-epicatechin, chlorogenic acid (up to 1.71 mg/100 g fw), gallic acid (up to 0.38 mg/100 g fw) and

Table 1: Leaf area of fresh figs.

Parameter	Figs		LSD
	Round	Oval	
Bottom of the leaf (leaf area/plant, cm^2)	261.34±0.34	337.68±0.20	**
Middle of the leaf (leaf area/plant,cm^2)	518.83±0.17	369.07±0.07	**
Top of the leaf (leaf area/plant, cm^2)	351.74±0.26	365.08±0.08	**

All values are means of triplicate determinations ± SD. ** indicates significant result at p<0.01.

syringic acid (up to 0.10 mg/100 g fw) (Veberic et al., 2008). Also, figs contain hydroxycinnamic acids, such as 3-O-caffeoylquinic acids (3.2 ± 0.9), 5-O-caffeoylquinic acid (43.80 ± 3.80) and ferulic acid (20.50 ± 0.1); flavonoid glycosides like quercetin-3-O-glucoside (31.40 ± 2.10) and quercetin3-O-rutinoside (499.10 ± 1.20); furanocoumarins psoralen (3.70 ± 0.50) (Oliveira et al., 2009; Debib et al., 2014). Figs are an important constituent in the Mediterranean diet due to these natural compounds. In Bangladesh, where fig cultivars are not popular, the fruit trees were planted at the Khamar Division of Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh to explore their growth potential. Two types of figs namely round and oval-shaped figs are planted to evaluate their morphological, physicochemical, nutritional, minerals and bioactive compounds.

MATERIALS AND METHODS

Collection of fresh fig fruits

Two types of fresh fig fruits, namely round and oval-shaped, were collected from the Khamar Division of Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh (24.0958° N, 90.4125° E). The fruits were harvested from the same orchard with three replications from January to June, early in the morning by hand picking, when the fruits reached full maturity.

Analysis of fig fruits

All the morphological characteristics, color variations and physicochemical, nutritional and bioactive compounds of the figs were recorded on a fresh weight basis, using 10 g of fresh fruit. Minerals profiling of the fig fruits was recorded on a dry weight basis, using 1 g of dried fruit powder for each test.

Standards and reagents

All standards and reagents used in the present study were of analytical grade and purchased from Sigma-Aldrich (Germany).

Color measurement

The color of fresh fig was assessed according to the method described by Dervisi et al. (2001), with little modification using a Chroma Meter (Model CR-400, Minolta Corp Japan). For the color measurement, individual fruits were used: oval-shaped fruits weighed 35.34 g and round-shaped fruits weight 28.87 g, with three replications for each type. International Commission on Illumination (CIE) lightness (L*), green (a*), and blue (b*) values were documented using D65 illuminates and a 10E standard viewer as an orientation method. The equipment was calibrated on a standard white tile. Then, it was adjusted to measure the values of L*, a*, and b* and was replicated three times for each treatment.

Physicochemical, nutritional and bioactive compounds analyses

The physicochemical and nutritional analyses of moisture and ash content were determined according to the method described by Ranganna (1995). Vitamin-C and ß-carotene content were determined by the Association of Official Analytical Chemists (AOAC; 2020). pH data were recorded by a digital pH meter (Delta 320, Mettler, Shanghai). Total acidity (%) was measured using Auto Titrator (Metrohm 814, USB Sample Processor, Switzerland). Total soluble solid (°Brix) was recorded using a digital hand refractometer (Model NR151). The water activity of the sample was recorded using Lab Touch-aw (Novasina, AG, CH-8853, Switzerland).

Minerals Analysis

The minerals analyzed in this study were: sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), sulfur (S), boron (B), copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn). Atomic absorption spectrophotometry (Model-AA-7000S, Shimadzu, Tokyo, Japan) was used to assess Na, Fe, Cu, Zn, B, Mn, Ca, and Mg. K was measured using flame photometry, while P and S were assessed with the spectrophotometric method. Individual minerals were quantified by comparing the corresponding protocol procured from the Sigma Chemical Co., USA.

Statistical analysis

All data were expressed in triplicate as means ± standard deviation. One-way ANOVA with post-hoc using Tukey's Multiple Comparison Test was performed to analyze the data. The connotation was distinct at the 95% confidence level. SPSS 17.0 (IBM INC., New York) software was used for statistical analysis.

RESULTS AND DISCUSSION

Morphological characteristics of fig fruits

The leaf area of the round and oval-shaped fresh fig fruits was recorded at the bottom, middle and top of the leaf, and significant differences were found (Table 1). The bottom and middle areas of the leaf from the round fig were larger than those of the oval-shaped figs. The top leaf area of the oval-shaped fruit was larger than that of the round-shaped fig fruit (Table 1). Fruit length, fruit breadth, stem length, stem breadth, fruit weight, seed weight, fruit edible and non-edible portions of the fruits were recorded (Table 2). Fruit length, fruit breadth, stem length and stem breadth were not statistically different. However, the maximum fruit breadth, stem length and stem breadth were recorded as 3.26, 2.40 and 0.45 cm in the oval-shaped fig fruits compared to the round-shaped fig fruits. The fruit length was maximum in round-shaped fig fruits (3.86 cm) compared to the oval-shaped fruits. Fruit and seed weights

Table 2: Morphological characteristics of fresh figs.

Parameter	Figs		LSD
	Round	Oval	
Fruit length (cm)	3.86±0.20	3.83±0.05	NS
Fruit breadth (cm)	3.16±0.12	3.26±0.05	NS
Stem length (cm)	2.33±0.15	2.40±0.10	NS
Stem breadth (cm)	0.43±0.05	0.45±0.05	NS
Fruit weight (g)	28.87±0.22	35.34±0.10	**
Seed weight (g)	10.26±2.00	11.09±0.58	NS
Fruit edible portion	98.35±0.76	97.91±0.07	NS
Fruit non-edible portion	1.65±0.76	2.09±0.07	NS

All values are means of triplicate determinations ± SD. ** indicates a significant result at p<0.01. NS means non-significant differences.

Table 3: Color changes of the fresh figs.

	Figs		
Color value	Round	Oval	**LSD**
L*	28.63±0.94	29.04±0.15	NS
a*	11.51±0.53	12.80±0.33	*
b*	75.49±3.89	76.94±3.54	NS

All values are means of triplicate determinations ± SD. * indicates significant result at p<0.05. NS means non-significant differences.

Table 4: Physicochemical, nutritional and bioactive compounds of the fresh figs.

	Figs		
Parameter	**Round**	**Oval**	**LSD**
Moisture content (%)	80.01±0.78	80.50±1.00	NS
Ash content (%)	0.86±0.02	0.96±0.02	*
Total acid (%)	0.31±0.01	0.22±0.03	*
Vitamin-C content (mg/100 g)	17.64±1.18	26.57±0.47	**
β-carotene (mg/100 g)	6.68±0.13	7.49±0.19	*
TSS (ºB)	13.65±0.15	14.15±0.14	*
pH	5.00±0.10	5.18±0.05	*
aw	0.61±0.01	0.59±0.01	NS

All values are means of triplicate determinations ± SD. * indicates a significant result at p<0.05. ** indicates a significant result at p<0.01. NS means non-significant differences.

were found to be maximum (35.34 g and 11.09 g) in the oval-shaped fruit, whereas they were lowest (28.87 g and 10.26 g, respectively) in the round-shaped fruit (Table 2). The results obtained from this study are partially supported by Mehraj et al. (2013). The highest edible portion was found in the round-shaped fruits at 98.35 g, while the non-edible portion was at its minimum (1.65 g).

Color variations of fig fruits

Color is one of the important quality attributes for consumer acceptability of foods, particularly for fresh fruits and vegetables (Molla et al., 2017). The color in figs is mainly due to the presence of bioactive natural compounds, such as anthocyanin and carotenoids. Figs possess a wide diversity of colors, ranging from dark purple to green (Solomon et al., 2006). The color variation of the two types of figs analyzed in this study is described in Table 3. In this study, the round and oval-shaped figs contained more colors and β-carotene. As fresh fruits, the color values were recorded as L*, a* and b*. L* and b* values were found to be statistically insignificant, whereas a* was statistically significant. The L*, a* and b* values obtained in this study were higher in the oval-shaped fig compared to the round-shaped figs (Table 3). The study results indicate that the irradiation of green color was more prominent in the oval-shaped figs compared to the round-shaped figs (Silva et al., 2009). The β-carotene content values obtained in the present study were higher in the oval-shaped fresh figs (Table 4). These biochemical changes may contribute to retaining more green color in the oval-shaped fig fruit.

Physicochemical, nutritional and bioactive compounds of figs

The physicochemical, nutritional properties and bioactive compounds of the figs are presented in Table 4. The results show that the moisture content and water activity (a_w) did not differ significantly. The moisture content of the fresh fig fruits was recorded as 80.01±0.78 % and 80.50±1.00 %, respectively (Table 4). The moisture content is one of the important factors which facilitates microbial activities and can reduce the shelf life of fresh produces. Many of the physicochemical properties of edible fruits may vary due to changes in moisture content (Omobuwajo et al., 2003). The analysis of ash content in foods

Table 5: Calcium (Ca), Magnesium (Mg), Potassium (K), Phosphorous (P), Sulfur (S) and Sodium (Na) of the fresh figs.

Parameter	Figs		LSD
	Round	Oval	
Ca (%)	1.20±0.10	1.30±0.10	NS
Mg (%)	0.63±0.03	0.67±0.03	NS
K (%)	0.72±0.02	0.48±0.02	**
P (%)	0.13±0.03	0.12±0.02	NS
S (%)	0.80±0.20	0.39±0.01	*
Na (%)	0.01±0.00	0.02±0.01	NS

All values are means of triplicate determinations ± SD. * indicates a significant result at $p<0.05$. ** indicates a significant result at $p<0.01$. NS means non-significant differences.

simply entails burning away of organic content, leaving inorganic minerals. This helps to determine the amount and type of minerals in food. It is important because the amount of minerals can determine the physiochemical properties of foods, as well as retard the growth of microorganisms. The ash content of the round and oval-shaped figs was statistically significant and it was recorded as 0.86±0.02 % and 0.96±0.02 %, respectively. Microorganisms, including yeasts, molds, and bacteria are sensitive to a food's pH. Very low or very high pH values can prevent microbial growth. Practically, no unprocessed food has a pH value high enough to offer much preservative value (FDA, 1999). In this study, the pH values of the round and oval-shaped fruits were found to be 5.00±0.10 and 5.18±0.05, respectively. The acidity level of the round and fig fruits was recorded as 0.31±0.01% and 0.22±0.03 %, respectively, indicating that the acidity level was comparatively low in high concentrations of pH figs. The results confirm that there was an inverse relation between the pH and acidity levels of the round and oval-shaped fruits.

The vitamin-C content of the round and oval-shaped fig fruits was statistically different. The oval-shaped fig had the highest vitamin-C content (26.57±0.47 mg/100 g) compared to the round-shaped fig (17.64±1.18 mg/100 g). The vitamin-C content present in the fruit is considered as the most powerful antioxidants in foodstuffs whose regular intake lowers cancer risks in the human body (Almeida et al., 2011). Vitamin-C is also considered as the most unstable compounds existing in foodstuffs and its content depends on various factors, such as heat, pH, metal content, oxygen content etc. (Mondal et al., 2017). However, according to Jukes (1974), the RDA of vitamin C, i.e. ascorbic acid to prevent scurvy for adults is about 10 mg. This indicates that the current study from the fig fruits found a higher amount of vitamin-C that can prevent scurvy adequately with daily consumption of 100 g of fig. β-carotene is the main safe dietary source of vitamin A. It is essential for normal growth and development, immune system functioning and vision (Liji and Dibakar, 2015). The β-carotene content was found to be significant. The oval-shaped fig fruits had the highest concentration of β-carotene, while the lowest was recorded in the round-shaped fig fruits. The results obtained in this study suggest that both round and oval-shaped figs are a rich source of β-carotene content.

Minerals profiling

Essential minerals are important components of the daily diet, required in relatively smaller quantity and represent 1% or less of body weight (Macrae et al., 1993). The results regarding the mineral and trace element levels in the figs show that the highest concentration of potassium (0.72±0.02) was found in the round fig, while the oval-shaped fig had the highest concentration of Ca (1.30±0.10%) and Mg (0.67±0.03 %) (Table 5). Na was found to be lowest in both the round (0.01±0.00 %) and oval-shaped (0.02±0.01%) figs. Potassium (K) is one of the important nutrients for controlling human blood pressure, therefore round figs are recommended for reducing hypertension in the human body. Similarly, calcium (Ca) is a major component of bones and assists in tooth development (Brody, 1994). In these findings, the highest Ca was reported in the oval-shaped fig. It is indicated that oval-shaped fig fruits constitute a relatively higher amount of Ca and Mg compared to round-shaped figs. These minerals also act as cofactors for many enzymes in the human body (Akpanabiatu et al., 1998). The recommended daily Ca intake for adults ranges from 1000 mg to 1500 mg (Belitz et al., 2004). It is also recommended to take supplements with food to aid in absorption. Compared with other metals, Ca ion and most of its compounds have low toxicity (Lewis, 1996). Iron (Fe) content was highest in the oval-shaped fig fruits (88.70±0.30 ppm), whereas the lowest was recorded in the round-shaped fig fruits (87.10±0.10 ppm). An adequate level of Fe is required for hemoglobin formation in the blood, while excessive intake can result in hemochromatosis. Iron-containing enzymes and proteins participate in many biological oxidations and transport (Alessandra and Robert, 2005). The copper (Cu), zinc (Zn) and manganese (Mn) content of the figs were recorded as17.40±0.40 ppm, 26.00±0.40 ppm and 46.10±0.10 ppm in the round fig, whereas the oval-shaped fruit contained 18.40±0.40 ppm, 21.90±0.10 ppm and 46.90±0.10 ppm. The study results indicate that the oval-shaped fig is a rich source of Cu and Mn, whereas the round-shaped fig is a rich source of Zn (Table 6). It is reported that a deficiency of Mn, Zn and Cu may lead to bone deformities, reduced hair growth and cardiac abnormalities (Mills, 1981). The variation of K, Ca, Mg, Fe, Zn and Cu might be due to geographical variations, growth conditions and cultural and soil nutrient management of the fig. However, the results obtained from this study confirm that both round and oval-shaped figs are rich sources of trace elements.

CONCLUSION

The present study was evaluated to determine the morphological, physicochemical, nutritional, minerals, color properties, and bioactive compounds of round and oval-shaped fresh fig fruits (*Ficus carica* L.). Herein, the oval-shaped fresh figs demonstrated higher levels of morphological, physicochemical, nutritional, minerals, color properties, and bioactive compounds compared to the round-shaped fresh fig fruits. The fresh oval fig fruits showed highest values of bioactive compounds, including vitamin C, β-carotene, TSS, and pH. The results conclude that oval-shaped fig fruits are a richer source of physicochemical, nutritional, minerals, and

Table 6: Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn) and Boron (B) of the fresh figs.

Parameter	Figs		LSD
	Round	Oval	
Cu (ppm)	17.40±0.40	18.40±0.40	**
Fe (ppm)	87.10±0.10	88.70±0.30	**
Mn (ppm)	46.10±0.10	46.90±0.10	*
Zn (ppm)	26.00±0.40	21.90±0.10	**
B (ppm)	33.00±0.50	23.40±0.40	**

All values are means of triplicate determinations ± SD. * indicates a significant result at p<0.05. ** indicates a significant result at p<0.01. NS means non-significant differences.

bioactive compounds compared to round-shaped fresh fig fruits.

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