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Biochemical composition of Philippine Mulberry (*Morus* spp.) fruits

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Abstract

Mulberry (*Morus alba* L.) fruits from five varieties were gathered during the dry (March-April) and wet (July-August) seasons. Two hundred fifty (250) grams of fruits of each of the varieties were tested at the Regional Standards and Testing Laboratories- Department of Science and Technology Region 1, Philippines for ash, moisture content (MC), crude protein (CP), crude fat (CF), total carbohydrates (TC) and sodium contents. Fruit samples were also submitted to the Food Technology Laboratory of DMMMSU-MLUC Sugar, pH, Titratable acidity (TA), anthocyanin and Vitamin C. Analysis of Variance (ANOVA) in Factorial CRD and significant differences among the means were determined by Tukey's Honest Significant Difference (HSD) test. Results revealed that during dry season, Alf-004 berries were high in ash (0.88g/100g), CP (1.62g/100g), TC (74.40g/100g) and Vitamin C (0.09g/100g). Also, Alf-058 fruits were high in sodium (16mg/100g) and pH (5.10). Alf-025 berries were high in anthocyanin content (64.45 g/100g). Alfonso berries were high in CF (0.69 g/100g), sugar (17.50g/100g) and Vitamin C (0.11 g/100g). However, during wet season Alf-004 berries were high in ash (1.14g/100g), CP (2.60g/100g), CF (0.67g/100g), Sodium (36g/100g), anthocyanin (38.65g/100g) and TA (0.039 g/100). Alfonso berries were determined with high TC (66.76g/100g), Sugar (11.00g/100g), pH (4.43), anthocyanin (39.80g/100g) and Vitamin C (0.10 g/100g). Alf-023 berries were determined high inmc both during dry and wet seasons. Alf-004 and Alfonso were the varieties identified with higher biochemical components and appeared to be promising for further exploitation besides being identified as high leaf yielding varieties suited for cocoon production.

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Introduction

Mulberry or 'Amoras' in the Philippine dialect is of genus *Morus* belonging to the Moraceae family. It is a deciduous tree grown in various temperate areas of the world. It grows to about 3.5 meters high, leaves are ovate and flowers are unisexual. Fruiting spikes are axillary, peduncled, dark purple or nearly black when ripe, fleshy, and 1.5 to 3 centimeters long. They are wind pollinated and some cultivars will set fruit without any pollination. The fruits yield 30% fat, and other substances like sugar, pectin, citrates and malates.

Mulberries have a sweet, juicy and refreshing taste. It is highly appreciated for its sweet and unique fruit flavor and abundant composition of nutrients. There are dozens of mulberry species and they range in color, shape, and taste.

Mulberry fruits have a remarkable place in traditional Chinese medicine and have been used to treat sore throat, cure fever, prevent liver damage, strengthen the joints, facilitate discharge of urine, and lower blood pressure (Lui *et al.*, 2004; Li *et al.*, 2009), treat tinnitus, dizziness, constipation in the elderly and anemia (Li *et al.*, 2009; Chang *et al.*, 2011; Wang *et al.*, 2013). Its medicinal worth is attributed to the presence of active ingredients with notable therapeutic functions (Ercisli & Orhan, 2007), as cited by Sivakumar *et al.* (2015).

Studies revealed that mulberry fruits contain not only appreciable amounts of proteins, carbohydrates, fats, fibers, mineral contents, and some vitamins, but also many bioactive compounds such as anthocyanin, flavonoids, and alkaloids (Onose *et al.*, 2013). Ercisli and Orhan (2007) accounted that mulberry is rich in anthocyanin compounds, and identified the major anthocyanins in the fruit extract. Anthocyanins were reported to have therapeutic benefits and are responsible for the color attribute and biological characteristics such as antioxidant, anti-proliferative, antimicrobial, anti-cancer, and anti-neoplastic properties as well as neuroprotective and anti-inflammatory properties (Liang *et al.*, 2012). Mulberry has also been known to be rich in 1-deoxynojirimycin

(DNJ) which inhibits postprandial hyperglycemia by inhibiting alpha-glucosidase in the small intestine (Asano *et al.*, 2001; Gui *et al.*, 2001). It has anti-virus (Durantel *et al.*, 2001; Lazar *et al.*, 2007); and anti-tumor (Lou *et al.*, 2011) activities, and modestly decreases serum triglyceride (TG) level in human (Kojima *et al.*, 2010), as cited by Sivakumar *et al.* (2015).

To date, the Sericulture Research and Development Institute (SRDI) has evolved mulberry varieties that were considered high leaf-yielding for the silkworms. Fruit-bearing varieties were also developed for the production of other products. However, the fruits are not utilized efficiently, especially during the peak seasons of the year like dry (March) and wet (July) where most of the fruits are wasted since mulberries, specifically the leaves are intended for silkworm food.

Further, mulberry fruit product consumption has been rapidly increasing because of biological benefits, nutritional value, and taste, (Aramwit *et al.*, 2010), as cited by Raman *et al.* (2015).

Given the above-mentioned biochemical components of the mulberry fruit and its beneficial and nutritional value, the result of the study can serve as a basis for further tests on the possibilities of using the varieties in the pharmaceutical industry thereby making moriculture a potentially profitable enterprise. This can be a means to uplift the living status of the sericulture farmers and clients in the community. Moreover, it can help sustain product diversification initiatives of the institute such as wine and vinegar production. The resulting data on the biochemical components of the mulberry varieties studied will serve as an important basis for the formulation and standardization of the products produced. The high content of biochemical compounds in the mulberry fruit pave for the development of industrial functional food drinks such as puree or mulberry juice and smoothies; candies out of dried mulberry fruits, mulberries, ice cream and coated mulberry fruit (dark chocolate). Therefore, this study initially evaluated new genotypes with better biochemical characteristics -the most important quality criteria of mulberry fruits, provides vital information necessary to

strengthen and promote the industrialization and commercialization of mulberry fruit products, could help develop an improved understanding and appreciation of the nutraceutical and medicinal value of mulberry fruit which in turn could promote its consumption by the general public. Furthermore, to promote the value addition of mulberry, it is imperative to characterize the fruit traits from the chemical point of view as well as to enable them to fit into current processing industry requirements example superior qualitative and sensorial properties combined with higher contents of health-promoting bioactive compounds (Donno *et al.*, 2015) as cited by Krishna (2018).

The experiment determined the biochemical composition of five mulberry fruiting varieties for ash, moisture content (MC), crude protein (CP), crude fat (CF), total carbohydrates (TC), sodium, sugar, pH, anthocyanin, Vitamin C and Titratable acidity (TA) during the dry and wet seasons and to identify the best variety with the highest biochemical contents during the dry and wet seasons.

Materials and methods

Description of the Raw Materials

Mulberry fruit has a pink color then turns red when ripe and finally turned into dark purple or black. Ripe mulberry fruits were harvested from the plantation of the Sericulture Research and Development Institute (SRDI) specifically at the Mulberry Breeding and Improvement Unit where it is abundant during the month of March-April and July- August. Five fruiting mulberry varieties (Alf-004, Alf-025, Alf-023, Alf-058, and Alfonso [NSIC Mb₀₁]) were used in the study. These varieties were selected based on previous breeding evaluation; and found promising in terms of morphological, biochemical characters, and bioassay tests.

Preparation of Mulberry Fruit Samples

Good quality and fresh mulberry fruits of the five varieties were manually picked at the ripe stage (colored black). Fruits were sorted and washed carefully in running tap water and then dried. Two hundred fifty (250) grams of fruits of each of the varieties were taken as a sample, placed in plastic bags, and stored below 4°C in a refrigerator.

Their size ranged from 1-2cm in length. Three packs of 250g mulberry fruit samples from each variety were used as replicates. After sampling, the fruits were immediately submitted to the Regional Standards and Testing Laboratories of the Department of Science and Technology Regional Office 1 for the biochemical determination of ash, moisture content (MC), crude protein (CP), crude fat (CF), total carbohydrates (TC) and sodium. Likewise, fruit samples were submitted to the Food Technology Laboratory of the Don Mariano Marcos Memorial State University-Mid-La Union Campus to determine the sugar, pH, Titratable Acidity (TA), anthocyanin, and Vitamin C contents. The various biochemical parameters were determined using corresponding test methods (Table 1). Two observations were done in this study. Fruit samples were gathered during the dry (March-April) and wet (July-August) seasons.

Table 1. Biochemical parameters gathered and the test method used.

Parameter	Test Method
Ash	Gravimetric method
Moisture Content	Gravimetric method
Crude Protein	Kjeldahl method
Crude Fat	Solvent-Extraction/Gravimetric (petroleum ether)
Total Carbohydrate	Calculated by difference
Sodium	Atomic Absorption Spectrophotometer
Sugar	%Brix (Refractometer)
pH	Pen-type pH meter
Anthocyanin	Spectrophotometric pH differential method
Vitamin C	Iodine Titration
Titratable Acidity	Titration method

Data Analysis

Descriptive statistics of ash, moisture content, crude protein, crude fat, total carbohydrates, sodium, sugar, anthocyanin, vitamin C, pH, and titratable acidity from the selected mulberry fruiting varieties were represented as Mean. Experimental data were computed and statistically analyzed using Analysis of Variance (ANOVA) through Factorial Complete Randomized Design (CRD). Significant differences among the means were further tested by Tukey's Honest Significant Difference (HSD) test using the Statistical Tool for Agricultural Research (STAR).

Results and discussion

Evaluation of the genetic source of variation among genotypes of different fruit species is always critical to the initiation of a breeding program. Knowing the biochemical characteristics is the most important quality criterion of mulberry fruits, especially in terms of human health. Mulberry is one of the fastest-growing temperate trees and produces abundant excellent fruits each year. It is generally too ripe in early summer, with harvests spread out over a full month. Once a tree is mature it can produce between 60 and 100 gallons of fruit. <https://practicalselfreliance.com/growing-mulberries>.

Mulberry trees can be harvested many times for their fruits in a long harvest season of about 2-3 months (Erdogan & Cakmakci, 2006). Further, Karlidag (2012) reported that harvested mature berries may show variation in terms of mineral concentration at every harvest date.

Ash (g/100g)

Ash is an indicator of mineral content and a good source of potassium, phosphorous and magnesium. Finding of the earlier workers have established that the morphological, as well as biochemical traits of fruits, are affected by several factors such as genetic, climatic, soil structure, etc. (Gundogdu *et al.*, 2011). Further, mulberry fruits, even from the same species, may contain different amounts of chemical composition as well as different antioxidant properties (Liang *et al.*, 2012).

The data on the ash content of the selected mulberry fruiting varieties viz; Alf-004, Alf-025, Alf-023, Alf-58, and Alfonso were compared (Table 2). Ash content during the dry season was significantly different between the selected mulberry varieties with a range of 0.58g/100g (Alf-025) – 0.88g/100g (Alf-004). Fruits of Alf-004 recorded the highest amount of ash with 0.88 g/100g followed by Alf-58 (0.78g/100g). The third highest ash content was recorded by Alf-023 (0.67g/100g) however, it was comparable with the ash content of Alfonso fruits with 0.65g/100g. Lower ash content was observed in variety Alf-025 (0.58g/100g).

Table 2. Ash content of the different fruiting mulberry varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	0.88 a	1.14 a
V ₂ -Alf-025	0.58 d	0.68 c
V ₃ -Alf-023	0.67 c	1.02 b
V ₄ -Alf-058	0.78 b	1.12 a
V ₅ -Alfonso	0.65 c	1.01 b

* Means followed by a common letter in a column are not significantly different at 0.5 level (HSD)

However, ash content during the wet season, two varieties viz; Alf-004 and Alf-058 performed comparably with respective means of 1.14 and 1.12g/100g and the lowest ash content was also determined as 0.68g/100g in Alf-025 variety.

Similarly, Gani and Kumar (2013) reported that ash content is an organic content residue which remains after removal of water and organic matter and most could not be decreased during storage.

Moisture Content (g/100g)

As shown in Table 3, the moisture content was determined between 22.60-28.76g/100g (dry season) and 37.64 - 44.88g/100g (wet season). Alf-023 fruits gathered during the dry season showed the highest MC with a mean of 28.76g/100g followed by fruits of Alfonso (28.56g/100g). Alf-004 fruits recorded the lowest MC of 22.60g/100g. However, during the wet season, the same trend was observed that fruits of Alf-023 produced the highest MC of 44.88g/100g which was significantly different from the rest of the varieties. Alfonso berries recorded the lowest MC at 29.93g/100g.

Table 3. Moisture Content of the different fruiting mulberry varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	22.60 e	42.68 b
V ₂ -Alf-025	23.73 d	37.08 d
V ₃ -Alf-023	28.76 a	44.88 a
V ₄ -Alf-058	25.85 c	37.64 c
V ₅ -Alfonso	28.56 b	29.93 e

*Means with the same letter in a column are not significantly different

Moisture content is the quantity of water contained in a food material. It is a fact that helps to explain the refreshing character of the food.

Mulberry fruit has a high moisture level therefore this fruit is regarded as highly perishable according to Muhammad *et al.* (2010) as cited by Ali (2016). Due to high production and potential uses in food and pharmaceutical applications, this fruit is dried either for consumption as dried fruit or further use for industrial products. <https://www.britannica.com/topic/moisture-content-foodstuffs#>

Crude protein (g/100g)

Significant variations were observed as to crude protein during the dry and wet seasons (Table 4). Crude protein was determined at the highest level of 1.62g/100g in Alf-004 cultivar, the lowest level of 0.92g/100g was determined in Alf-025 cultivar during dry season. However, Alf-004 berries harvested during the wet season found significantly higher CP content (2.60g/100g) followed by Alfonso berries at 1.90g/100g. The lowest CP level of 1.53g/100g was determined in Alf-058 berries

Table 4. Crude protein of the different fruiting mulberry varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	1.62 a	2.60 a
V ₂ -Alf-025	0.92 e	1.76 c
V ₃ -Alf-023	1.25 c	1.64 d
V ₄ -Alf-058	1.45 b	1.53 e
V ₅ -Alfonso	1.11 d	1.90 b

*Means with the same letter in a column are not significantly different

Crude fat (g/100g)

Considerable variation existed among the different mulberry varieties with respect to crude fat (Table 5.) During the dry season, Alfonso berries produced the highest value of crude fat (0.69g/100g) followed by Alf-025 fruits with 0.52g/100g however, it was comparable with two other varieties with both means of 0.50g/100g. Significantly lower CF content was found in Alf-023 (0.48 g/100g). However, during wet season, fruits of Alf-004 recorded the highest value of 0.67g/100g which was significantly different from the rest of the varieties. Lower crude fat was produced by Alf-023 berries (0.17g/100g).

Table 5. Crude fat of the different fruiting mulberry varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	0.50 bc	0.67 a
V ₂ -Alf-025	0.52 b	0.26 d
V ₃ -Alf-023	0.48 c	0.17 e
V ₄ -Alf-058	0.50 bc	0.36 c
V ₅ -Alfonso	0.69 a	0.39 b
V ₁ -Alf-004	0.50 bc	0.67 a

*Means with the same letter in a column are not significantly different

Research indicated that the crude fat contents from mulberry are 1.23-2.23%. The major fatty acids in mulberry fruits were linoleic acid (C_{18:2}) and palmitic acid (C_{16:0}), 26.40-74.77% and 9.29-22.26%, respectively (Liang *et al.*, 2012)

Total carbohydrates (g/100g)

As portrayed in Table 6. Alfonso had the highest total carbohydrates in its fruits at 74.40g/100g(Alf-004), while Alf-023 had the lowest value of 68.84g/100g harvested during the dry season. However, Alfonso fruits harvested during the wet season showed a significantly higher TC content of 66.76g/100g which was significantly different among the varieties. The lowest TC content was recorded in Alf-023 berries at 52.29g/100g.

Table 6. Total carbohydrates of the different fruiting mulberry varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	74.40 a	52.91 d
V ₂ -Alf-025	74.25 b	60.23 b
V ₃ -Alf-023	68.84 e	52.29 e
V ₄ -Alf-058	71.42 c	59.35 c
V ₅ -Alfonso	68.97 d	66.76 a

*Means with the same letter in a column are not significantly different

Fresh mulberries consist of 9.8% carbs or 14 grams per cup (140 grams). These carbs are mostly simple sugars, such as glucose and fructose, but also contain some starch and fiber. <https://www.healthline.com/nutrition/foods/mulberries#>

Sodium (mg/100g)

As presented in Table 7, sodium content determined from the varieties evaluated ranged from 9.00 to 16mg/100g (dry season) and sodium content ranged from 28-36g/100g (wet season). Alf-058 fruits harvested during the dry season recorded the highest sodium

content at 16mg/100g followed by Alf-023 berries (12.00mg/100g) however, it was comparable with two other mulberry varieties Alf-025 (10m/100g) and Alf-004 (11mg/100g). Lowest sodium content was observed in Alfonso fruits with 9.00mg/100g. Whereas fruits harvested during the wet season, two mulberry varieties viz; Alf-004 and Alf-025 produced significantly higher sodium content with a respective means of 36 and 35mg/100g while the lowest sodium level of 28mg/100g was recorded by Alfonso berries.

Table 7. Sodium content of the different mulberry fruiting varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	11.00 bc	36.00 a
V ₂ -Alf-025	10.00 bc	35.00 a
V ₃ -Alf-023	12.00 b	32.00 b
V ₄ -Alf-058	16.00 a	32.00 b
V ₅ -Alfonso	9.00 c	28.00 c

*Means with the same letter in a column are not significantly different

Sugar (g/100g)

The concentrations of glucose, fructose, and sucrose, essential sugars in mulberry fruits were determined and the variation between the different mulberry varieties revealed significant results (Table 8). The sugar content of the five varieties ranged from 9.00–17.50g/100g (dry season) and ranged from 6.00 - 11g/100g (wet season). During the dry season, the highest value in terms of sugar was from Alfonso variety with 17.50g/100g followed by fruits of Alf-058(17.00g/100g). The third highest level of 15g/100g was recorded by Alf-025 and Alf-023 berries. The lowest sugar content was also determined as 9.00g/100g in Alf-004 variety. The same trend was observed during wet season. Alfonso berries produced the highest sugar content at 11g/100g which was significantly different from the rest of the varieties.

Table 8. Sugar content of the different mulberry fruiting varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	9.00 d	10.17 b
V ₂ -Alf-025	15.00 c	8.73 d
V ₃ -Alf-023	15.00 c	6.00 e
V ₄ -Alf-058	17.00 b	9.00 c
V ₅ -Alfonso	17.50 a	11.00 a

*Means with the same letter in a column are not significantly different

The result is in consonance with the study of Mahmood *et al.* (2012) who measured the glucose and fructose contents of black mulberries harvested when fully ripe as 2.50 and 5.36g/100g and the glucose and fructose contents of white berries as 3.21 and 4.97g/100g respectively. In another study, Ozgen *et al.* (2009) stated that fructose and glucose contents of fourteen black and red mulberry genotypes ranged from 5.50 to 17.2g/mL and from 4.86 to 6.41g/100mL respectively.

pH

As shown in Table 9, significant variations existed in the different varieties in terms of pH content. pH content ranged from 4.33g/100g (Alf-025) to 5.10g/100g (Alf-058) during the dry season while during the wet season harvested fruits recorded pH content ranging from 3.23g/100g(Alf-023)-4.43g/100g (Alfonso). Higher pH was recorded from fruits of Alf-058 while the lowest pH was obtained by variety Alf-025 with 4.33 during the dry season. Whereas during the wet season, two varieties; Alfonso (4.43g/100g) and Alf-004 (4.33g/100g) were comparable in terms of pH which were significantly different from the rest of the varieties. Fruits of Alf-023 recorded the lowest pH value of 3.23g/100g. These findings coincide with that of Liang *et al.* (2012) that pH varies depending on the varieties of mulberry that can range from 3.37 to 5.33.

Table 9. pH content of the different mulberry fruiting varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	4.50 cd	4.33 a
V ₂ -Alf-025	4.33 d	3.50 c
V ₃ -Alf-023	4.80 b	3.23 d
V ₄ -Alf-058	5.10 a	3.80 b
V ₅ -Alfonso	4.57 c	4.43 a

*Means with the same letter in a column are not significantly different

Anthocyanin (g/100g)

Mulberries have significantly high amounts of phenolic flavonoid phytochemicals called anthocyanin. Scientific studies have shown that consumption of berries has potential health effects against cancer, aging and neurological diseases, inflammation, diabetes, and bacteria (<https://www.nutrition-and-you.com/mulberries.html>).

In the study, the anthocyanin content of the different mulberry varieties showed significant variations during the wet and dry seasons (Table 10). Anthocyanin content ranged from 4.84g/100g (Alf-058) to 64.45g/100g (Alf-025) during the dry season while during the wet season, anthocyanin content ranged from 15.37g/100g (Alf-058) to 39.80 g/100g (Alfonso). During the dry season, fruits of Alf-025 obtained the highest amount of anthocyanin at 64.45g/100g which was significantly different from the rest of the varieties followed by Alfonso with a mean of 51.56. Lower anthocyanin content of 4.84g/100g was recorded from Alf-058 berries. On the other hand, during the wet season, two varieties showed comparable anthocyanin contents of 39.40g/100g (Alfonso) and 38.65g/100g (Alf-004). Berries of Alf-058 produced the lowest level of anthocyanin. Alf-025 berries are characterized by having a dark purple fruit when it is ripe. This confirms the findings of Ercisli and Orhan (2008), that mulberries, especially the black and purple colored ones are a very rich source of anthocyanin.

Table 10. Anthocyanin content of the different mulberry fruiting varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	42.12 c	38.65 a
V ₂ -Alf-025	64.45 a	30.25 b
V ₃ -Alf-023	31.64 d	17.55 c
V ₄ -Alf-058	4.84 e	15.37 d
V ₅ -Alfonso	51.56 b	39.80 a

*Means with the same letter in a column are not significantly different

Vitamin C (Ascorbic Acid)

Vitamin C is a monosaccharide antioxidant found in both plants and animals and as an essential nutrient, which can be obtained from citrus fruits and vegetables. As portrayed in Table 11, during dry season, the highest Vitamin C content was measured as 0.11g/100g in variety Alfonso however; it was comparable with Alf-004 variety (0.09g/100g). Alf-025 recorded the lowest at 0.07g/100g but comparable with Alf-023 and Alf-058 with respective means of 0.07 and 0.8g/100g. The comparable results showed in Vitamin C content on all the mulberry varieties evaluated which ranged from 0.10-0.12 g/100g during the wet season.

Iqbal *et al.* (2008) affirmed that Vitamin C or ascorbic acid, a very useful constituent for the redox mechanism, is used in medicine and food to prevent oxidation. The presence of a high amount of vitamin C in medicinal plants than in fruits and their juices is due to its higher stability in these media, as Vitamin C is usually highly sensitive to heat, light, pH, time, oxygen, temperature, and in aqueous solution, etc. Imran *et al.* (2010) reported that white and black mulberries contained vitamin C in the amount of 15.20 and 15.37mg/100g respectively. In another study conducted by Eyduran *et al.* (2015), the fruits of white and black mulberries were analyzed and Vitamin C content ranged from 10.12 to 18.22mg/100g, as cited by Gundogha (2017).

Table 11. Vitamin C content of the different mulberry fruiting varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	0.09ab	0.010 a
V ₂ -Alf-025	0.07c	0.010 a
V ₃ -Alf-023	0.08bc	0.012 a
V ₄ -Alf-058	0.08c	0.012 a
V ₅ -Alfonso	0.11a	0.010 a

*Means with the same letter in a column are not significantly different

Titrateable acidity (g/100g)

There were no significant differences observed among the varieties in terms of TA during dry season (Table 12). The observed TA content ranged from 0.003g/100g to 0.004g/100g. On the other hand, TA content of the different fruits during the wet season ranged from 0.008g/100g to 0.039g/100g and revealed significant differences among the varieties. Alf-004, Alf-058, Alf-025, Alf-023 and Alfonso garnered 0.039, 0.019, 0.013, 0.011 and 0.008 g/100g respectively. Titrateable acidity (TA) is a measurement of total titrateable acids in a sample expressed as a concentration of the predominant acid present in the sample (i.e. citric acid in orange juice). The titrateable acidity of black mulberry cultivars was between 1.45% (13-BIT-1) and 1.85% (13-BIT-4). The average titrateable acidity of black mulberry cultivars was 1.63%, which is a negligibly compared to those reported for red and white mulberries (Ercisli *et al.*, 2010) and black mulberry (Iqbal *et al.*, 2010). <http://horticulturejournal.usamv.ro/pdf/2016/Art4.pdf>

Table 12. Titratable acidity content of the different mulberry fruiting varieties during dry and wet seasons.

Variety/Season	S ₁ (Dry)	S ₂ (Wet)
V ₁ -Alf-004	0.003 a	0.039 a
V ₂ -Alf-025	0.004 a	0.013 c
V ₃ -Alf-023	0.003 a	0.011 d
V ₄ -Alf-058	0.003 a	0.019 b
V ₅ -Alfonso	0.003 a	0.008 e

*Means with the same letter in a column are not significantly different.

Conclusion

Based on the results of the study, during dry season, Alf-004 berries were determined high in ash, crude protein, total carbohydrates and Vitamin C, while high sodium and pH value were seen in Alf-058 fruits. On the other hand, Alf-025 berries had high anthocyanin content. Alfonso berries were seen high in CF, sugar and Vitamin C.

Similarly, during wet season, Alf-004 berries had high ash, crude protein, and Vitamin C. Moreover, Alf-004 was also high in CF, sodium, anthocyanin and TA contents. On the other hand, Alfonso berries were also high in ash, TC, sodium, sugar, pH, and anthocyanin, while Alf-023 berries had highmc in both dry and wet seasons.

Overall, Alf-004 and Alfonso varieties were identified with higher biochemical components and appeared to be promising for further exploitation besides being identified as high-leaf-yielding varieties for silkworm rearing and cocoon production.

Recommendation

Based on the findings of the study, Alf-004 and Alfonso varieties can be subjected to further studies in order to validate their potential as good sources of higher bioactive compounds.

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