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"Extending Shelf Life of Mulberry Fruit Through Dehydration: Chemical, Microbial, and Sensory Evaluation"

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Abstract

Dehydrated candied mulberry fruits were developed to process underutilized mulberry fruit with very short shelf life and to specifically investigate the chemical compositions, water activity, microbiological and sensory qualities of mulberry fruits. Dehydration using Multi-Commodity Solar Tunnel Dryer (MCSTD) and sugar preservation methods were used to extend the shelf life of the mulberry fruits. Slightly ripe and fully ripe fruits were processed into dehydrated candy. The chemical compositions, water activity, microbiological, and sensory qualities were studied. The results showed that the dehydrated candied mulberry fruits both fully ripe and slightly ripe were good sources of protein (2.42 and 2.27 g per 100g), ash (0.69 and 1.20 g per 100g), and carbohydrates (81.45 and 91.44g per 100g). Water activity values were 0.47 and 0.62. Results on microbiological analyses particularly on aerobic plate count and yeast and mold count were within safety levels. The degree of ripeness of the fruit showed significant differences in color, taste, hardness, and fracturability. The developed dehydrated candied mulberry can be considered in the human diet with abundant nutrients.

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Introduction

Food waste is produced worldwide on a large scale at different stages of food production, processing, marketing, and consumption. The total food waste produced worldwide is almost 1.3 billion tons per year which explains that 30%–50% of the food produced globally gets discarded. Among the food waste, 50% is produced from fruits, vegetables, and root crops (Bellemare *et al.,* 2017). Fruit wastage is mainly due to its perishable nature and being underutilized. Fruits are available as seasonal surpluses during certain parts of the year in different regions and are wasted in large quantities due to absence of facilities and know-how for proper handling, distribution, marketing, and storage. Furthermore, massive amounts of the perishable fruits produced during a particular season result in oversupply in the market and become scarce during other seasons. Food preservation has an important role in the conservation, better utilization of fruits and utilize the surplus during the off-season. It is necessary to employ methods to extend storage life for better distribution and processing techniques to preserve them for utilization during off-season in both large and small scale. Mulberry (*Morus alba*) is widely known because of its importance in silk production. The leaves are the sole food of silkworm while its fruits contain high nutrient profile including minerals, amino acids, polyphenols, and polysaccharides (Jiang & Nie, 2015; Sanchez *et al.*, 2015; Wei *et al.*, 2007). Because of these bioactive compounds, antioxidant, antiatherosclerosis, immunomodulative, anticancer, antihyperglycemic, hypolipidemic, and neuroprotective activities, other therapeutic uses of mulberry fruit have been found (Zhang *et al.*, 2018). The fruit can be eaten fresh, dried, and processed products (Yuan & Zhao, 2017). In some other countries like Vietnam, mulberry fruits were processed into syrup (Trung *et al.,* 2018), "pestil" and "köme", traditional Turkish food prepared from mulberry, honey, walnut, hazelnut, and flour mixture (Yildiz, 2013), jams, marmalades, jellies, juices, liquors, natural dyes, and even cosmetics (Nayab *et al.,* 2020). Mulberry fruit is perishable in nature, softer, more susceptible to mold growth causing their quality to deteriorate and prone to bruising during storage and distribution (Hamid and Thakur, 2018; Park *et al.*, 2013). These are major factors that necessitate developing a cheap and efficient preservation process or value-addition for growers of this fruit and dehydration using Multi-Commodity Solar Tunnel Dryer (MCSTD) and sugar preservation were used on this study as methods in extending the shelf life of the mulberry fruit. Dehydration is a valuable food preservation method because it offers several advantages compared to other methods such as freezing or canning. By removing moisture, dehydration inhibits the growth of bacteria, yeasts, and molds that need water to thrive, thus extending shelf life. Dehydrated foods are also lightweight and compact, making them easier to store and transport, unlike frozen foods that require continuous refrigeration or canned goods that are bulky due to liquid content, dehydrated foods can be stored at room temperature in airtight containers, saving on energy costs and storage space. Nutritionally, dehydration preserves many vitamins and minerals, with only minimal loss of heat-sensitive nutrients, making it more advantageous than canning, which often uses high temperatures that can degrade nutritional content. Additionally, dehydration tends to retain flavors. In contrast, freezing can alter texture due to ice crystal formation, and canning can result in softer or altered-tasting foods due to the high heat involved. Furthermore, dehydration is a low-cost, energy-efficient process, making it an accessible and effective method for long-term food preservation.

The main objective of this study is to process mulberry into dehydrated candied mulberry fruit. Furthermore, the chemical compositions, water activity, microbiological, and sensory qualities were investigated.

Methodology

Sample Preparation

Slightly ripe and fully ripe mulberry fruits (Figure 1) were manually harvested at GLBR Farm, Pangasinan, Philippines. Fruits were immediately inspected and sorted according to the degree of ripeness. Defects and damaged fruits were also discarded to ensure quality finished product, washed with potable water to minimize contamination, and drained prior to processing.

Processing of Dehydrated Candied Mulberry Fruit

Processing was done in Food Laboratory, Don Mariano Marcos Memorial State University- La Union, Philippines. Fruits and other ingredients were weighed in a calibrated weighing scale. Syrup was prepared (1:1 ratio) and pasteurized at 80 °C for 10-15 minutes. Washed fruits were added into the syrup and stirred occasionally to ensure thorough penetration of the syrup. Fruits were thoroughly immersed in syrup. The mixture was then transferred into a clean, well-covered container and soaked in syrup overnight to attain equilibrium of fruit and sugar concentration. Fruits were drained immediately for 5 to 10 minutes, arranged in trays using tong and hygienically dried in MCSTD for 10 hours at 60°C. Candied fruits were packed in nylon polyethylene plastic, labelled, and stored in cool, dry place. The same processing procedure was used on both fully ripe and slightly ripe mulberry fruits.

Chemical Composition and Water Activity of the Dehydrated Candied Mulberry Fruits

Chemical compositions including ash, moisture, crude protein, crude fat, and total carbohydrates were analyzed according to AOAC method (2016) as shown in Table 2. Water activity was analyzed using the Water Activity Lab-Master-aw Meter. Analyses were carried out at the Department of Science and Technology- Regional Science and Technology Testing Laboratory- Region I, San Fernando City, La Union, Philippines.

Microbiological Qualities of the Dehydrated Candied Mulberry Fruit

Aerobic plate count (APC) and yeast and mold count (YM) were analyzed following the pour plate method by Maturin and Peeler (2001) and Tournas *et al.* (2001), respectively. Analyses were performed at the Department of Science and Technology- Regional Science and Technology Testing Laboratory- Region I, San Fernando City, La Union, Philippines.

Sensory Qualities of The Dehydrated Candied Mulberry Fruit

The descriptive test of the two samples of dehydrated candied mulberry fruit was performed at the Food Laboratory, DMMMSU-La Union, Philippines. The coded samples were presented to eight trained panelists and descriptive attributes were evaluated in terms of color, taste, flavor, texture, fracturability, toothpacking and moisture absorption. Scoresheets were also provided based on Meilggard *et al.* (2000).

Statistical Analysis

All measurements and analyses were conducted in three replications. Sensory evaluation data were consolidated and summarized. Wilk Shapiro test was used to determine normality of the data and paired t-test was used to assess significant differences in experimental mean values of the descriptive sensory characteristics ($\alpha=0.05$) between the two types of candied mulberry. All statistical computations and analyses were conducted using IBM SPSS Statistic (Version 20).

Results and discussion

Results

Chemical Compositions and Water Activity Values of Dehydrated Candied Mulberry Fruit

The chemical compositions of dehydrated candied mulberry both from fully ripe and slightly ripe fruit are revealed in Table 3. The major compositions were total carbohydrates (81% and 91%), moisture (15 % and 5%), and crude protein (2%). Moreover, the water activity values were 0.47 (fully ripe) and 0.62 (slightly ripe).

Microbiological Qualities of Dehydrated Candied Mulberry Fruit

The microbiological qualities of dehydrated candied mulberry fruit is presented in Table 4. Aerobic plate count and yeast and mold count of dehydrated candy from slightly ripe fruit has lower values than the fully ripe fruit with 480 cfu/g and 100 cfu/g, respectively.

Sensory Qualities of Dehydrated Candied Mulberry Fruit

Table 5 shows the mean scores on the descriptive attributes of dehydrated candied mulberry fruit. There is a significant difference between the mean scores obtained by the fully ripe and slightly ripe candied mulberry fruits on sensory attributes such as color, taste, hardness, and fracturability.

Table 1. Formulation used on the processing of dehydrated candied mulberry fruit.

Treatment	Quantity	Materials
T_1 (Fully ripe)	1kg	Fully ripe mulberry fruit
	1 kg	Sugar
	1L	Distilled water
T_2 (Slightly ripe)	1kg	Slightly ripe mulberry fruit
	1 kg	Sugar

Discussion

The data show the chemical compositions of dehydrated candied mulberry fruit. Mulberry fruit contains abundant protein, lipids, carbohydrates, fiber, minerals, and vitamins but low calories as reviewed by Yuan and Zhao, 2017. The protein content of dehydrated candied mulberry fruit was comparable to the previous study by Jiang and Nie (2015) ranging from 1.17% to 2.25%. It is noticeable that total carbohydrates recorded the highest content which is generally close to the study of Chen *et al.* (2015) wherein the researchers characterized and examined the chemical composition of polysaccharide fractions in mulberry fruits that ranged from 76-88%. Carbohydrates are sugars.

The principal sugars in mulberry are glucose and fructose (Gundogdu *et al.*, 2011). Carbohydrate composition in fruits showed that total soluble carbohydrates were 3.4 g/100 g fw, reducing sugars 1.7 g/100 g fw, monosaccharides fructose 3.0 g/100 g fw, glucose 3.1 g/100 g fw, fructooligosaccharides 1-ketose 0.1 g/100 g fw, nystose 0.01 g/100 g fw and inulin 0.04 g/100 g fw (Dimitrova, *et al.*, 2015).

Table 2. Test method used in the determination of chemical compositions of dehydrated candied mulberry fruit.

Test	Method
Ash	Gravimetric Method (AOAC 925.49.C)
Moisture	Loss in Drying (AOAC 925.49.B)
Crude protein	Kjeldahl Method (AOAC 925.49.H)
Crude fat	Soxhlet Method (AOAC 920.177)
Total carbohydrates	Computed by difference

The low moisture content of the dehydrated candy was observed, and this can be attributed to osmotic dehydration. Drying the food reduces the amount of moisture available to support microbial growth, thereby increasing the product's shelf life. Osmotic dehydration, a phenomenon of removal of water from a lower concentration of solute to a higher concentration through a semi-permeable membrane results in the equilibrium condition on both sides of the membrane. In this process, the water flows from fruits to the sugar solution and eventually lowers water activity (Yadav and Singh, 2012). To avoid microbial growth, the water activity must be kept below approximately 0.60–0.65 (Mercer, 2008) thus, the results show that it is below the limit where bacteria, yeast, and molds could not easily grow if packed and stored in an appropriate packaging film. Dehydrated candy also contains ash, which is a good indication of mineral content that supports the previous study of Salcedo *et al.*, 2015. The content of macro-elements on dry weight basis were N (1.62-2.13 g/100 g), P (0.24-0.31 g/100 g), K (1.62-2.13

g/100 g), Ca (0.19-0.37 g/100 g), Na (0.01 g/100 g), Mg (0.12-0.19 g/100 g), S (0.08-0.11 g/100 g); and micro-elements were Fe (28.2-46.74 mg/kg), Cu (4.22-6.38 mg/kg), B (13.78-19.48 mg/100 g), Mn (12.33-19.38 mg/kg), Zn (14.89-19.58 mg/kg) and Ni (1.40-2.62 mg/kg).

Table 3. Chemical compositions of dehydrated candied mulberry fruit.

Chemical compositions	Value (g/ 100 g)	
	T_1 (Fully ripe)	T_2 (Slightly ripe)
Ash	0.69 g	1.20 g
Moisture Content	14.98 g	4.53 g
Crude Protein	2.42 g	2.27 g
Crude Fat	0.46 g	0.56 g
Total Carbohydrates	81.45 g	91.44 g

In terms of microbiological qualities, knowing allowable limit of microbial load in food is very important because this represents the level above which action is required for food safety concerns.

Consumption of unsafe food products can cause adverse health effects, but it can be prevented through food safety practices among processors and handlers to eventually reduce the risk of foodborne illnesses (Fung *et al*., 2018). Low values of microbial load were observed considering it has low moisture, low water activity and hygienically processed in the Multi-Commodity Solar Tunnel Dryer (MCSTD). Research has shown that drying or dehydration can decrease microbial growth due to low water activity. Drying or dehydration of fruits, vegetables, herbs, and spices significantly inactivates microorganisms with a focus on foodborne pathogens and viruses as reported by Bourdoux, S. (2016). Studies on mushroom have shown dehydration can decrease microbial growth in stored mushroom slices, with negligible growth observed after three weeks of storage (Brahmini, B. *et al*., 2021). Additionally, on edible bolete mushrooms (*Boletus* spp.) it was reported that drying does not significantly affect their bacterial counts, even after six months of storage at room temperature (Popa, M, *et al*., 2022). Final product with sufficient low water activity is safe from enzymatic spoilage in general because active water is not available for microbial growth (Omolola, A. O. *et al*.,2015). Furthermore, a water activity level below 0.6 is generally recommended for the safe storage of dried foods.

Table 4. Microbiological qualities of dehydrated candied mulberry fruit.

Test Method	Result (cfu/g)	
	T_1 (Fully ripe)	T_2 (Slightly ripe)
Aerobic Plate Count	960	480
Yeast and Molds Count	190	100

At this level, the growth of bacteria, yeasts, and molds is significantly inhibited, thereby extending shelf life and ensuring safety (Ongun, G. *et al.,* 2023). MCSTD is used as an alternative to sun-drying practice for agricultural and fishery products and was already adopted by micro-enterprises (Martinez, 2014). Concerning food safety, MCSTD prevents insects, bacteria, and other external factors during drying, upgrading the quality of products compared to traditional sun drying. Moreover, with the sugar solution used in the processing may also be attributed to the low microbial load of the dehydrated candied mulberry fruit.

On the sensory qualities of dehydrated candied mulberry fruit, there is a significant difference between the mean scores obtained by the fully ripe and slightly ripe candied mulberry fruits on the sensory attributes such as color, taste, hardness, and fracturability. Anthocyanin, as the responsible pigment of the fruit color. Fresh mulberry fruit changes color from green to black-purple.

Table 5. Mean scores on the descriptive attributes of dehydrated candied mulberry fruit.

Descriptive attributes	Mean Scores		Description	
	T_1 (Fully Ripe)	T_2 (Slightly ripe)	T_1 (Fully Ripe)	T_2 (Slightly ripe)
Color	150^a	120^b	Dark brown	Slightly brown
Sweet	40^a	20^b	Perceptible	Very low
Sour	20^a	50^b	Very low	Perceptible
Mulberry Flavor	50^a	90^a	Perceptible	Distinct
Hardness	80^a	95^b	Moderate	Moderate
Roughness	100^a	100^a	Moderate	Moderate
Fracturability	80^a	100^b	Slightly brittle	Moderately brittle
Toothpacking	50^a	35^a	Low	Low
Moisture absorption	85^a	110^a	Moderate	Moderate

$^{a\text{-}b}$ Mean values with different letters in each column are significantly different ($p \leq 0.05$).

The stabilization of anthocyanin affects in different factors such as light, temperature, processing, pH, and enzymes (Pornanong *et al.*, 2010). The dark brown color of the dehydrated candied mulberry fruit can be attributed to the degradation of anthocyanin upon processing. The dehydration process often affects color quality of foods (Hojjatpanah *et al.*, 2011). In terms of taste, low concentrations of sourness and sweetness were perceived by the panelists.

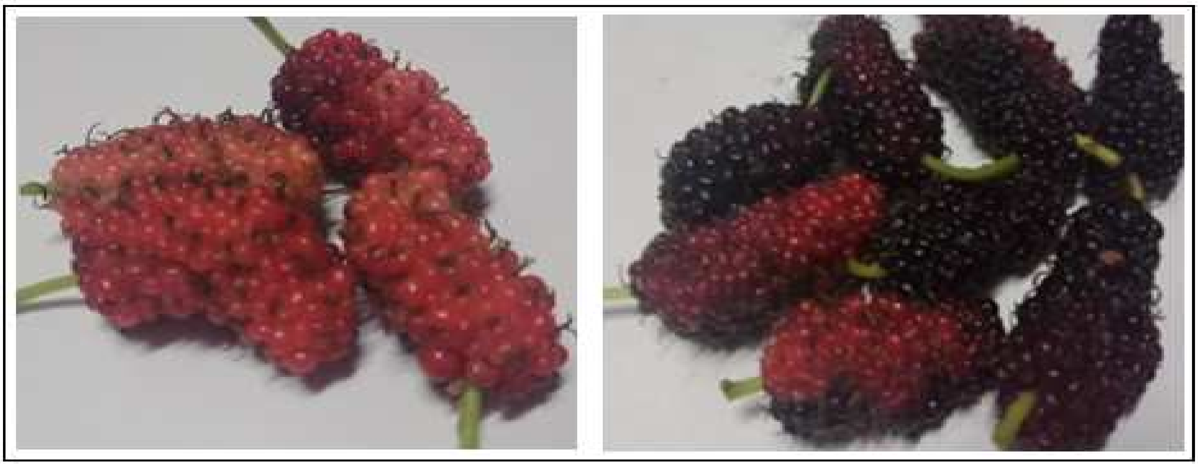

Fig. 1. Collected mulberry fruits: slightly ripe (A) and fully ripe (B).

The sour taste of dehydrated candy may be due to the organic acid present in the fruit. Bozhuyuk *et al.*, (2015) reported that mulberry contains citric acid, tartaric acid, malic acid, succinic acid, lactic acid, fumaric acid and acetic acid. For fracturability, the dehydration and sugar solution affect the texture of dehydrated candy specifically, brittleness was observed. During dehydration, moisture loss occurs, causes shrinkage and eventually, the texture of the fruit becomes hard (Hasanuzzaman *et al.*, 2014).

Conclusion

The study successfully developed a functional food product by processing fully ripe and slightly ripe mulberry fruits into dehydrated candy. The findings show that the product has high carbohydrate content, low water activity, and safe microbial levels, making it a viable option for extended shelf life. Significant differences in sensory attributes like color, taste, hardness, and fracturability between fully ripe and slightly ripe fruits were also observed. These differences should be considered when targeting specific markets or consumer preferences.

Recommendation(s)

1. The dehydrated candied mulberry fruit shows great potential as a functional food. It is recommended that further research focus on optimizing packaging and storage conditions to maximize the shelf life and maintain the product's quality over time.
2. Additionally, the market potential of the product should be explored, particularly in the functional foods and healthy snacks segments. Further development of product variants, such as flavor enhancements or different sugar levels, could cater to different consumer preferences.
3. Lastly, more studies should be conducted on the economic feasibility of scaling up production, especially for local farmers and small enterprises interested in diversifying their product lines with value-added mulberry products.

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