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Development and evaluation of spray-dried Illinois mulberry *(Morus rubra)* fruit juice

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ABSTRACT

The study developed Illinois mulberry *(Morus rubra)* as a fruit juice through a spray drying method with maltodextrin as the carrier agent. *M. rubra* was prepared and underwent a spray drying method to develop three treatments of the powdered product. Among the three treatments (Treatment 1 with 16% maltodextrin, Treatment 2 with 18% maltodextrin, and Treatment 3 with 20% maltodextrin), the most acceptable *M. rubra* fruit juice was determined through sensory evaluation (consumer acceptability test) and the degree of difference test. The result yielded Treatment 3 as the most favourable sample which was rated as Liked Moderately with mean values ranging from 6.98 - 7.58 for all sensory properties. Likewise, the degree of difference in terms of flavor gave a computed average of 4.86 which indicates that there was a slight difference between fresh mulberry fruit juice (control) and the sample product from all treatments. Treatment 3 was further subjected to various tests to determine the physicochemical properties and microbiological properties. The findings showed the proximate composition as 9.92% moisture, 1.59% ash, 0.06% crude fat, 0.82% crude fiber, 1.77% crude protein, and 88.57% nitrogen-free extract. In addition, the pH level, phenolic content, total soluble solids, particle size, and bulk density were determined to be 4.77, 33.01 ± 0.55 mg GAE/g dry sample, 17 °Brix, 33.40% in sieve no. 20 and 24.84% in sieve no. 40, and 44.66 g/L, respectively. In terms of microbiological properties, the results showed 735 CFU/g for the Standard Plate Count (SPC)/ Aerobic Plate Count (APC) while <10 CFU/g for the total coliform count. Hence, the *M. rubra* has high potential to be developed as a powdered fruit juice based on the sensory evaluation and laboratory analyses conducted. Data showed acceptable results as compared with the standard values; however, further tests are warranted to ensure the overall food safety and quality of the product.

Keywords: Illinois mulberry *(Morus rubra)*, intermediate raw material, spray-dried fruit juice

1. Introduction

A higher intake of fruits and vegetables is generally linked to lowering the risk of developing serious illnesses. Study shows that fruit juice consumption is directly associated towards a better diet quality [1]. They play a significant role in improving human nutrition and health due to its high source of various vitamins and minerals. Thus, several juices from fruits and vegetables have been successfully introduced in the market throughout the years.

In the Philippines, there is another berry commonly known aside from strawberries [2]. Certain mulberry species are widely grown in Batan Island of Batanes province, and Cagayan Valley as a backyard plant [3]. Similarly, [4] stated that the Cordillera region in the northern Philippines has seen an extensive growth of white mulberry trees on its mountain slopes which are used in the silkworm operations.

Mulberries have been connected in reducing blood sugar, cholesterol, and cancer risks. They are also a good source of iron and vitamin C. Although there is little evidence to support their efficacy, these berries have also been used for thousands of years in Chinese herbal medicine to cure a variety of ailments. Mulberries are a great addition to any diet because of their sweet, delectable flavor, high vitamin content, and numerous possible health advantages [5].

However, mulberry trees can only bear fruit within 1 to 2 years, and their harvest season is every three months. Mulberry fruit should be thoroughly ripened on the tree before harvesting for the best quality and flavor of it. Furthermore, it has a short harvesting period, and it is susceptible to spoilage. It has a shelf life of 1 to 2 days after harvest; it becomes yellow and mildew after leaving at room temperature in just a day, due to its high-water content of more than 80%. As a result, mulberry fruit is difficult to store and preserve if not directly consumed, and unfortunately, it will become a food waste even if it has significant functions [6]. Subsequently, it is a common issue for farmers and researchers to conduct a study using this fruit as the main raw material.

Due to its limited shelf life, this study developed a new product from the *M. rubra* fruit. Using a spray drying method, the extracted juice from mulberry fruit is converted into powdered form with maltodextrin as the carrier agent. This development will expand the use of mulberry fruits providing health and nutritional properties, thus boosting the immune system. It may also serve as an intermediate raw material which can be applied to different food and beverage products such as bread and pastries, flavored products, and juices.

2. Materials and methods

The fruit of *M. rubra* fruit were collected at the end of February 2022 and in the third week of March from Fork & Spades, Ibaan, Batangas.

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After collection, the mulberry fruits were sorted, washed, blended thru an electric juicer/ blender, and filtered using a cheesecloth to extract the juice before proceeding to spray drying. The parameters used were 150°C, inlet temperature; 90-98°C, outlet temperature; and 4 rpm, pump speed. To determine the drying yield of the sample, the formula, % yield of mulberry = [(W2/ W1)] x 100, was used where W2 is the weight of the spray-dried mulberry and W1 is the weight of the liquid mulberry. From this, three treatments were formulated on which Treatment 1, 2 and 3 have 16%, 18%, and 20% maltodextrin concentration, respectively.

2.1. Sensory evaluation and degree of difference test

To establish the most acceptable treatment, sensory evaluation and degree of difference test of the samples were conducted. Fifty untrained panelists, from the Chemical and Food Engineering Department, were randomly selected to assess the attributes such as appearance, aroma, mouthfeel, taste, and overall acceptability of the three treatments. Four coded samples were prepared to test the level of acceptability using the 9-point hedonic scale (Table 1). Moreover, fifteen semi-trained panelists, which constitute faculty, employees and alumni and farm owners, were chosen to compare and rate in terms of flavor the fresh mulberry juice (labeled as control) from the spray-dried mulberry fruit juice (most acceptable treatment labeled using three-digit code). The responses were recorded and evaluated based on the degree of difference scale (Table 1).

Table 1. The 9-point hedonic scale and the degree of difference scale.

Score	9-point hedonic scale	Degree of difference scale
9	Like extremely	Very large difference
8	Like very much	Large difference
7	Like moderately	Large difference
6	Like slightly	Slight/ moderate difference
5	Neither like nor dislike	Slight/ moderate difference
4	Dislike slightly	Slight difference
3	Dislike moderately	Slight difference
2	Dislike very much	Very slight difference
1	Dislike extremely	Very slight difference
0	-	No difference

2.2. Physicochemical and microbiological properties

The most acceptable treatment was then analyzed to measure the physicochemical and microbiological properties. The proximate composition analysis of the powdered *M. rubra* fruit juice was carried out as prescribed in the Association of Official Analytical Collaboration (AOAC) International methods. It includes determination of ash content (AOAC 942.05), crude fat content (AOAC 954.02), crude fiber content (AOAC 978.10), crude protein content (AOAC 984.13), moisture content (AOAC 934.01). Other physicochemical properties that were analyzed are pH (AOAC 973.41), phenolic content using the Folin-Ciocalteu method [7], total soluble solids using hand-held refractometer and expressed in °Brix, bulk density (g/mL), and particle size using particle size analyzer (Cilas 10640). For the microbiological properties, the pour plate technique was used to identify and count the viable microorganisms that are present in a liquid specimen [8]. The specific guidelines issued by the Philippines' Food and Drug Administration provides the reference criteria in determining the microbiological requirements and assessment of processed foods [9].

2.3. Statistical analysis

A Scheffe post hoc test under the one-way analysis of variance (ANOVA) was employed to analyze sensory evaluation data, and the data obtained from hedonic scale rank testing was plotted using the SPSS Statistics data (IBM, Armonk, NY, USA). The statistical significance of all experiment data was assessed at a probability level of less than 0.05.

3. Results and discussion

3.1. Drying yield of the Illinois mulberry *M. rubra*

Figure 1 shows the effects of increasing the carrier agent concentration on the yield of spray-dried powdered juice of *M. rubra*. After the spray drying process, the data showed that adding 16%, 18%, and 20% of maltodextrin to the extracted *M. rubra* fruit juice gave 8.55%, 9.44%, and 10.44% drying yield, respectively. Comparing the results, it was observed that 20% of maltodextrin received the highest drying yield among all treatments. Similarly in the study of [10], the drying yield was significantly increased upon increasing the concentration of maltodextrin in the spray-dried feed.

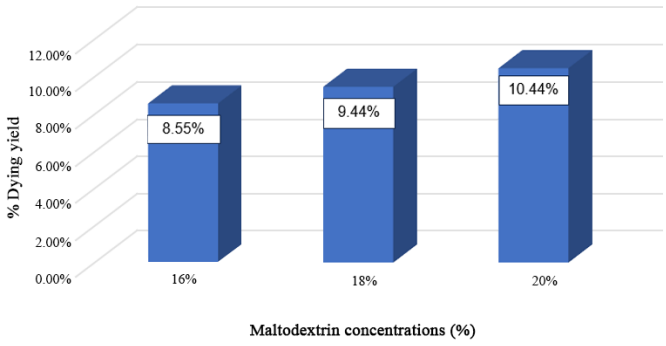

Figure 1. Drying yield of *M. rubra* juice with different percentages of maltodextrin.

3.2. Acceptability level of spray-dried *M. rubra* fruit juice

In every product development, sensory evaluation is an important analytical tool to understand what individuals perceive in a certain product. In line with this, consumer-based sensory evaluation/ consumer acceptability test is important to measure the marketability of a specific product.

Table 2 shows the results of the sensory evaluation conducted on fifty untrained panelists. Similar to all treatments, 1 L of water for every 25 g of spray-dried *M. rubra* fruit juice was prepared. Thus, it can be observed that the amount of water used for the dilution has no effect on the appearance, aroma, mouthfeel, taste, and the powder's overall acceptability.

Table 2. Sensory evaluation of the sample spray-dried *M. rubra* fruit juice with varying concentrations of maltodextrin.

Properties	Treatment		
	1 (16%)	2 (18%)	3 (20%)
Appearance	7.46	7.38	7.52
Aroma	6.80	6.74	6.98
Mouthfeel	7.40	7.22	7.64
Taste	7.44	7.20	7.54
Overall acceptability	7.50	7.48	7.58
Verbal	Like Moderately	Like Moderately	Like Moderately

The data showed that the 20% maltodextrin concentration has the highest mean values in terms of appearance, aroma, mouthfeel, taste, and overall acceptability among the three treatments.

With its African violet (Pantone 16-3520 TCX) color, Treatment 3 (20% maltodextrin) with computed mean value of 7.52 (Like Moderately) exhibits a good appealing appearance according to most of the panelists. For the aroma, the result indicates a value of 6.98 (Like Slightly) which is because of a mixture of sweet and slightly tart smell as observed. A mean value of 7.64 (Like Moderately) was computed for mouthfeel and was described by some panelists as not having the same smoothness as compared to existing fruit juices in the market. In terms of taste, the mean value 7.54 (Like Moderately) was computed which gives a balanced mixture of sweet and tangy flavor. For the overall acceptability, Treatment 3 was considered as the most favorable receiving the highest mean value of 7.58 (Like Moderately) which signifies that the spray-dried *M. rubra* fruit juice can be considered as acceptable for consumption.

3.3. Significant difference between all treatments in terms of sensory evaluation

Table 3 shows the level of significance of all the treatments of spray-dried *M. rubra* fruit juice using different concentrations of maltodextrin.

Table 3. Significant difference of all treatments in terms of overall acceptability.

Properties	p values	Computed f values	Decision on H_o	Verbal interpretation
Appearance	0.8350	0.1810	Failed to reject	Not significant
Aroma	0.2840	1.2700	Failed to reject	Not significant
Mouthfeel	0.1960	1.6470	Failed to reject	Not significant
Taste	0.6280	0.4670	Failed to reject	Not significant
Overall acceptability	0.8660	0.1440	Failed to reject	Not significant

**Significant, $p<0.05$*

The appearance of the spray-dried *M. rubra* fruit juice plays a pivotal role in the acceptance of the product. The computed p-value for the appearance is 0.8350 greater than 0.05, thus indicating no significant difference among all treatments. It was perceived that maltodextrin does not affect the samples, specifically its overall characteristic if it is used in moderate/proportional amounts. The rest of the values also gave a p-value greater than 0.05; thus, denoting no significant difference among all treatments. A proportional amount of the maltodextrin concentration as well as the equal volume of water used in the dilution suggest that there is no significant difference in aroma, mouthfeel, taste, and overall acceptability. Moreover, the 20% maltodextrin concentration is lower compared to the 30% maltodextrin in the study of [11] which also did not negatively influence the sensory evaluation of the samples.

3.4. Degree of difference in terms of flavor between control and Treatment 3 (most acceptable maltodextrin concentration)

For the degree of difference, the computed mean value is 4.86 which indicates that the Treatment 3 is slightly different in terms of flavor with the control. With this, the spray-dried *M. rubra* fruit juice produced may be considered similar in taste with fresh mulberry fruit juice as perceived by the semi-trained panelists. Knowing this result, the product produced can be considered as market competitive as it is comparable with fresh mulberry fruit juice.

3.5. Physicochemical properties of Treatment 3

Table 4 presents the results of the analyses in determining physicochemical properties of Treatment 3 with 20% maltodextrin concentration.

Table 4. Physicochemical properties of Treatment 3.

Physicochemical properties	Values
Proximate composition	
Moisture, %	9.92
Ash, %	1.59
Crude fat, %	0.06
Crude fiber, %	0.82
Crude protein, %	1.77
Nitrogen free extract, %	88.57
pH	4.77
Phenolic content, mg GAE/g dry sample	33.01
Total soluble solid, ^{o}Brix	17
Particle size	
Sieve no. 20, %	33.40
Sieve no. 40, %	24.84
Bulk density, g/L	44.66

Based on the analyses, the 9.92% moisture content is comparable to [12] as both use the same drying process and related raw materials. In addition, a moisture level greater than 18% enables some microbes to grow while those with less than 10% is considered ideal for dried products particularly instant powdered drinks [13]. The ash content of the sample is 1.59% which confirms a general connotation of its inverse relationship with moisture content. Accordingly,

the minerals and inorganics that remain after a food sample has been heated to an extremely high temperature, eliminating moisture, volatiles, and organics, are referred to as the food's ash content [14]. The crude fiber of 0.82% obtained from the sample is similar to the study of [15] with 0.85 ± 0.01 value using spray drying in determining the physicochemical properties of mango powder. With inlet temperature of 150°C in the spray drying process, the crude protein content from the sample is similar with the findings of [16] where the *Morus alba* L. has been subjected to 147°C in the development of instant powdered tea. Along with crude fat with 0.06%, most of the proximate compositions were comparatively low for spray-dried powders as elevated temperature (150°C) reduces the quality of these heat-sensitive parameters [15]. Finally, the nitrogen-free extract in the sample is 88.57% since it is determined by subtraction, i.e., 100 - (moisture + crude protein + crude fat + crude fiber + ash) [17].

The computed pH of the sample is 4.77 which is similar with the pH of 4.76 of the fresh mulberry fruit juice which shows that it is not affected by the concentration of maltodextrin. On the other hand, the phenolic content is 33.01 ± 0.55 mg GAE/g dry sample for Treatment 3 may be considered as a good indicator of its health benefits. Fruit juices containing high phenolic contents have been found to exert high antioxidant potential [18]. The total soluble solid of the sample is 17 °Brix which is comparable with the 16.40 °Brix of fresh black mulberry juice and is expected to gradually increase during the storage period [19]. The particle size of the spray-dried mulberry fruit juice is found to have a measure of 33.40% in sieve no. 20 and 24.84% in sieve no. 40 after conducting sieve analysis while the bulk density is 44.66 g/L. Relative to the study of [20], both particle size and bulk density are affected by the inlet temperature as an increase can lead to higher swelling which cause increase in particle size while rapid formation of dried layer on the droplet surface causes the bulk density to increase.

3.6. Microbiological properties of Treatment 3

The spray-dried *M. rubra* fruit juice falls under the category of powdered beverages and were tested for the microbial load through the Standard Plate Count (SPC)/ Aerobic Plate Count (APC) and Total Coliforms. While the latter is a broad indication of the state of sanitation in the area where food is processed, the former is a standard test that gives an estimate of the total number of mesophilic aerobic bacteria [9].

Table 5 presents the results of the analyses in determining the microbiological properties of Treatment 3 with 20% maltodextrin.

Table 5. Microbiological properties of Treatment 3.

Microbiological test (CFU/g)	Acceptable value	Measured value
SPC/APC	$3x10^3$	735
Total Coliforms	10	<10

Legend: <10 – No growth observed, CFU/g – Colony Forming Unit per gram

The computed value 735 is considered permissible as it is within the allowable range which is $3x10^3$. It indicates that although there is a presence of mesophilic aerobic bacteria, the spray-dried *M. rubra* fruit juice maybe considered as marginally acceptable quality. On the other hand, the <10 computed value for the coliform test denotes that it is within the allowable range. The detection of coliforms implies the unsanitary condition in the food-processing environment; thus, the product was proved to be prepared in a clean and sanitized manner.

4. Conclusions

As the concentration of the maltodextrin was increased, the drying yield of spray-dried *M. rubra* fruit juice also increased. Likewise, Treatment 3 with 20% maltodextrin was considered the most favorable according to the sensory evaluation (consumer acceptability test) conducted with "Like Moderately" as the overall interpretation. Notably, variations in maltodextrin concentration did not yield any significant differences among treatments as it failed to reject the null hypothesis. Furthermore, it was confirmed through the degree of difference test in terms of flavor that Treatment 3 is slightly different as compared to the fresh mulberry juice. Moreover, the product's moisture content met standard levels for powdered or dried food products, as well as its ash, crude fat, crude fiber, crude protein, and nitrogen-free extract content proved favorable when compared to related studies. Other physicochemical properties such as pH, phenolic content, total soluble solids, particle size, and bulk density, along with the microbiological properties presented competitive values; however, further tests are warranted to ensure the overall food safety and quality of the product.

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