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Effect of butterfly pea flower (*Clitoria ternatea L.*) extract and sucrose concentrations on physicochemical and organoleptic characteristics of butterfly pea flower pastilles

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Abstract

Pastilles are confectionery-based food product that contain active ingredients to relieve sore throats, coughs, and ease breathing. As public awareness of functional foods increases, the addition of butterfly pea flower extract to pastilles can enhance their functional value through its antioxidant content. The experiment was arranged in a 3×3 factorial arrangement under a randomized complete block design (RCBD) with three replications. Factor E represents the concentration of butterfly pea flower extract, at three levels: e1 (2.5%), e2 (5.0%), and e3 (7.5%), while Factor S represents the concentration of sucrose, at three levels: s1 (30%), s2 (40%), and s3 (50%). The final products were evaluated for physicochemical and organoleptic characteristics, including hardness, melting point, color intensity, moisture content, ash content, volatile compounds, reducing sugar content, antioxidant activity, hygroscopicity, and hedonic acceptance. The results showed that the interaction between butterfly pea flower extract and sucrose concentrations significantly affected the hardness (1,847.808 to 2,357.130 gf), melting point (59.1 to 194.5 ºC), color intensity L* (9.81 to 36.31), a* (8.30 to 9.97), b* (-3.14 to -4.79), hygroscopicity (1.15 to 10.95%), moisture content (0.47 to 4.79%), ash content (1.14 to 2.19%), antioxidant activity (113.04 to 138.49 ppm), and volatile components (82.01 to 93.38%), but had no significant effect on reducing sugar content. Organoleptic responses for color and texture were significantly influenced by both extract and sucrose concentrations, whereas sucrose concentration showed no significant effect on taste, and no significant effects on aroma were observed for any factor.

Keywords: Butterfly pea flower, Functional food, Pastilles, Sucrose.

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1. Introduction

Functional foods play an important role in improving public health, particularly in preventing non-communicable diseases (NCDs) such as hypertension, diabetes, and heart disease. Functional foods rich in antioxidants significantly enhance the immune system and combat free radicals, which can damage body cells and contribute to the development of various diseases [1]. Studies have shown that public awareness of functional foods has been increasing [2]. Consumers now tend to prefer food products that provide health benefits and contribute to NCD prevention [3].

Butterfly pea flower (*Clitoria ternatea L.*) is one of the functional food-based ingredients rich in antioxidants and holds great potential for further development [4]. Previous research has revealed that it contains bioactive compounds beneficial to health, such as anthocyanins that act as antioxidants. The addition of butterfly pea flower extract to food products improves organoleptic quality and nutritional value [5]. Variations in the concentration of the extract can affect the texture and stability of the product [6]. In addition, it is known to have various health benefits, such as enhancing memory, reducing stress, and improving skin health [7].

At present, the utilization of butterfly pea flower in food products has become increasingly diverse. It is used as an ingredient in various products, including herbal teas, syrups, functional beverages, and natural food colorants for dishes such as blue rice, cakes, and jellies [8]. It has also been incorporated into yogurt, ice cream, and smoothies, providing a distinctive color without the need for artificial coloring agents [9]. In line with this, research and innovation continue to explore its potential. Therefore, there is an opportunity to diversify its use into new processed products, including pastilles.

Pastilles are confectionery-based food products that contain active ingredients to relieve sore throats, coughs, and ease breathing. They are typically made by adding essential oils as active ingredients. The addition of butterfly pea flower extract to pastilles can enhance their benefits by increasing antioxidant content. Moreover, pastilles offer a more practical and longer-lasting way to consume butterfly pea flowers as a functional food ingredient [10]. This study aimed to develop butterfly pea flower pastilles and evaluate the effects of different concentrations of butterfly pea flower extract and sucrose on their physicochemical and organoleptic characteristics. The results are expected to support the development of functional food products and serve as a reference for the food industry in creating products that are not only tasty but also beneficial to health.

2. Material and Methods

2.1. Material

Butterfly pea flowers (*Clitoria ternatea L.*) from Cicalengka, Indonesia; glucose syrup; sucrose; water; citric acid; mint essence; saturated NaCl; DPPH (2,2-diphenyl-1-picrylhydrazyl) solution; 96% methanol; universal pH indicator; glucose; and DNS (Dinitrosalicylic Acid) reagent consisting of NaOH, 3,5-dinitrosalicylic acid, Na-K tartrate, and distilled water.

3. Methods

3.1. Determination of Butterfly Pea Flower Extraction Method

The extraction treatments of butterfly pea flowers were conducted to determine the method that produced the highest antioxidant activity for use in pastille production. Only the purple petals were used, while other parts were discarded. The petals were either partially crushed or dried according to the following procedures:

1. Treatment 1: Fresh petals were crushed and macerated with 2% citric acid (1:10 w/v) for 72 h at 25°C in the dark. The extract was filtered, concentrated at 50°C to a paste, and analyzed for antioxidant activity.
2. Treatment 2: Fresh petals were crushed and squeezed to obtain the juice, then analyzed for antioxidant activity.
3. Treatment 3: Fresh petals were dried in a food dehydrator for 7 h at 30°C, then crushed and macerated with 2% citric acid (1:10 w/v) for 72 h at 25°C in the dark. The extract was filtered, concentrated at 50°C to a paste, and analyzed for antioxidant activity.

3.2. Preparation of Butterfly Pea Flower Pastilles

Butterfly pea flower pastilles were prepared by heating water, sucrose, and glucose syrup at 120°C until the sugar solution thickened. Heating was stopped and the mixture cooled to 60°C. Butterfly pea flower extract and mint essence were added and stirred until homogeneous. The mixture was quickly poured into molds measuring 1×1×1 cm. The pastilles were cooled until solidified, and their surfaces were coated with sucrose crystals. The product formulation is presented in Table 1.

Table 1.
Formulation of Butterfly Pea Flower Pastilles.

Treatment	Butterfly Pea Flower Extract (g)	Water (g)	Sucrose (g)	Glucose Syrup (g)	Mint Essence (g)
e1s1	2.5	57.484	30	10	0.016
e1s2	2.5	47.484	40	10	0.016
e1s3	2.5	37.484	50	10	0.016
e2s1	5.0	54.984	30	10	0.016
e2s2	5.0	44.984	40	10	0.016
e2s3	5.0	34.984	50	10	0.016
e3s1	7.5	52.484	30	10	0.016
e3s2	7.5	42.484	40	10	0.016
e3s3	7.5	32.484	50	10	0.016

3.3. Hardness

The hardness of the product was analyzed using a Texture Analyzer (TA XT Plus, Stable Micro Systems) by placing the sample on the instrument, then a cylindrical probe was positioned at the center to penetrate the product. The results were displayed as a curve on the computer screen, and the hardness value was expressed in gram-force (gF) [11].

3.4. Melting point

Melting point was analyzed using Differential Scanning Calorimetry (DSC) by measuring endothermic or exothermic transitions. The sample was placed in a sample pan and heated until the endothermic peak shifted due to energy absorption during melting. The thermal characteristics of the material were determined from the data presented in the thermogram [12].

3.5. Color Intensity

Color intensity was analyzed using a Chromameter by measuring color differences on the sample surface through light reflection. The results were expressed as L*, a*, and b* values from the display screen, where L* (lightness) represents brightness ranging from 0 (black) to 100 (white), a* indicates the red (+) to green (−) component, and b* indicates the yellow (+) to blue (−) component [13].

3.6. Hygroscopicity

Hygroscopicity analysis was conducted to examine the ability of the material to absorb moisture from the air under specific conditions, following the method of Aisyah, et al. [14] with some modifications. The samples were stored in a desiccator containing a desiccant of saturated sodium chloride solution. Changes in weight were observed every 24 hours for 7 days, and hygroscopicity was calculated using the following formula:

$$\% \text{ Hygroscopicity} = ((\% \text{ Wi} + \% \text{ FW}) \times 100)/(100 + \% \text{ Wi})$$

where % Wi represents (weight of absorbed water (g))/(weight of sample (g)) x 100 and % FW represents initial sample moisture content.

3.7. Moisture Content, Ash Content and Volatile Components

Thermogravimetric analysis (TGA) was performed at temperatures above 1000ºC to determine changes in sample mass during heating. Moisture content evaporated at temperatures below 120ºC, while volatile components were released at tempratures ranging from 120 to 400ºC. After all volatile components had been removed, the ash content was obtained as the final residue at temperatures above 550ºC. Approximately 2 mg of the sample was ground and placed into the TGA instrument under a nitrogen atmosphere with a gas flow rate of 20 mL/min. The sample was heated at a rate of 10ºC/min until the target temperature was reached. During heating, changes in the sample mass were recorded by the computer system [15].

3.8. Reducing Sugar Content

A glucose standard curve was prepared by dissolving 1.25 g of glucose in 25 mL of sterile distilled water. Aliquots of 8, 6, 4, and 2 mL were transferred into test tubes and diluted to a final volume of 10 mL. From each dilution, 0.1 mL was mixed with 1.5 mL of DNS reagent and homogenized. Subsequently, 0.5 mL of the mixture was heated in a boiling water bath (100ºC) for 5 min. After cooling under running water, 15 mL of sterile distilled water was added. The absorbance was measured at 540 nm using a UV-Vis spectrophotometer, and a standard curve was constructed to obtain the regression equation ($y = a + bx$).

For sample analysis, 1 g of the sample was dissolved in 20 mL of distilled water. An aliquot of 0.1 mL was mixed with 1.5 mL of DNS reagent and homogenized. The mixture was heated at 100ºC for 5 min and then cooled under running water. Subsequently, 0.5 mL of the solution was diluted with 15 mL of sterile distilled water. The absorbance was measured at 540 nm. The glucose content was calculated using the standard curve equation and divided by the sample weight. The final glucose concentration was obtained by multiplying the calculated value by 100% [16].

3.9. Antioxidant Activity

A total of 50 mg of the sample was dissolved in 50 mL of methanol (p.a.) to obtain a 1000 ppm stock solution. From this stock solution, a series of concentrations of 0, 200, 400, 600 and 800 ppm was prepared to a final volume of 25 mL. An aliquot of 2 mL from each solution was pipetted into test tubes, followed by the addition of 2 mL of 50 ppm DPPH solution. The mixtures were homogenized and incubated for 30 min under dark conditions. The absorbance was measured at 517 nm using a UV–Vis spectrophotometer. The antioxidant activity was expressed as the IC_{50} value and calculated using the following formula:

%Inhibition = ((Absorbance of blank - Absorbance of sample)/(Absorbance of blank)) x 100%

The percentage of inhibition was plotted using the linear regression equation (Y = a + bx), where Y represents the inhibition percentage (%) and x represents the concentration (ppm), following the method of Novia [17] with modifications. By substituting Y = 50 into the equation, the IC_{50} value was calculated as follows: IC_{50} = (50-a)/b.

3.10. Hedonic Acceptance

A hedonic acceptance test was conducted with 30 panelists to evaluate the product's color, texture, aroma, and taste using a hedonic scale, as presented in Table 2.

Table 2.
Hedonic Scale.

Hedonic Scale	Numeric Scale
Like very much	6
Like	5
Slightly like	4
Slightly dislike	3
Dislike	2
Strongly dislike	1

4. Results and Discussion

4.1. Determination of Butterfly Pea Flower Extraction Method

The results of the determination of butterfly pea flower extraction method showed that the concentrated extract in paste form exhibited antioxidant activity expressed as IC50 values, as presented in Table 3.

Table 3.
Results of the Determination of Butterfly Pea Flower Extraction Method.

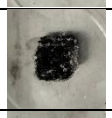
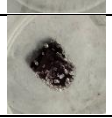
No.	Treatment Type	Antioxidant Activity (ppm)	Category
1.	Maceration of crushed fresh butterfly pea flower	158.29 ppm	Weak
2.	Butterfly pea flower juice	229.04 ppm	Very Weak
3.	Maceration of dried butterfly pea flower	61.00 ppm	Strong

Based on the analysis, extraction Treatment 3 showed the highest IC50 value (61.00 ppm), which was categorized as strong antioxidant activity. Therefore, this treatment was selected for pastille preparation.

4.2. Preparation of Butterfly Pea Flower Pastilles

The results showed that the butterfly pea flower pastilles had dimensions of 1×1×1 cm, a deep purple color, and a hard texture. The product contained anthocyanins as antioxidant compounds. Therefore, it can be categorized as a functional food.

Table 4.
Results of Physical Properties Analysis of Butterfly Pea Flower Pastilles.

Treatment	Image	Hardness (gF)	Melting Point (ºC)	Color Intensity			Hygroscopicity (%)
				*L	*a	*b	
e1s1		2141.355 ± 0.95^{g}	139.1	18.58 ± 0.95^{d}	8.68 ± 0.16^{b}	-4.16 ± 0.06^{b}	3.03 ± 0.03^{c}
e1s2		2287.855 ± 0.60^{h}	143.3	26.74 ± 0.21^{g}	8.40 ± 0.13^{a}	-4.17 ± 0.04^{b}	1.93 ± 0.03^{b}
e1s3		2357.130 ± 0.86^{i}	194.5	36.31 ± 0.24^{i}	8.30 ± 0.22^{a}	-4.79 ± 0.17^{a}	1.15 ± 0.00^{a}
e2s1		1981.476 ± 0.60^{b}	128.3	15.24 ± 0.20^{c}	8.97 ± 0.32^{d}	-3.67 ± 0.14^{cd}	6.28 ± 0.09^{e}
e2s2		2053.860 ± 0.92^{d}	128.7	21.29 ± 0.23^{f}	8.91 ± 0.21^{cd}	-3.82 ± 0.12^{c}	7.35 ± 0.01^{g}
e2s3		2127.450 ± 0.65^{f}	131.7	29.38 ± 0.23^{h}	8.73 ± 0.33^{bc}	-4.13 ± 0.09^{b}	3.82 ± 0.01^{d}
e3s1		1847.808 ± 0.80^{a}	122.3	9.81 ± 0.13^{a}	9.97 ± 0.23^{g}	-3.14 ± 0.09^{e}	8.20 ± 0.12^{h}
e3s2		2013.584 ± 0.89^{c}	126.2	13.58 ± 0.33^{b}	9.61 ± 0.21^{e}	-3.47 ± 0.14^{d}	6.74 ± 0.16^{f}
e3s3		2107.989 ± 0.60^{e}	59.1	19.46 ± 0.33^{e}	9.31 ± 0.16^{f}	-3.55 ± 0.15^{d}	10.95 ± 0.06^{i}

Note: Indicates a significance level of 5%.

4.3. Hardness

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the hardness of the pastilles. The lowest hardness value was observed in sample e3s1 (1847.808 gf ± 0.80^{a}), while the highest value was found in sample e1s3 (2357.130 gf ± 0.86^{i}). Increasing sucrose concentration raised the hardness due to the formation of a glassy solid matrix. Increasing extract concentration decreased the hardness because the anthocyanin contains polar functional groups that can interact with water, resulting in higher moisture content and a softer texture.

4.4. Melting point

The melting enthalpy (ΔH) indicates the amount of energy required to disrupt the intermolecular bonds within the sugar matrix of the pastilles. Increasing ΔH corresponds to a greater amount of energy needed to melt the sample, reflecting a denser structure and higher thermal stability. Sample e1s3 exhibited the highest melting point (194.5ºC) and the largest ΔH value (146.9 J/g), whereas sample e3s3 showed the lowest melting point (59.1ºC) and a relatively low ΔH value (47.07 J/g), indicating weaker intermolecular interactions and a greater tendency to undergo phase transition from solid to liquid.

4.5. Color Intensity

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the color intensity (L*, a*, b*) of the pastilles. L* values ranged from 9.81 ± 0.13^{a} to 36.31 ± 0.24^{i}, a* from 8.30 ± 0.22^{a} to 9.97 ± 0.23^{g}, and b* from -3.14 ± 0.09^{e} to -4.79 ± 0.17^{a}. Negative b* values indicate a blue component. But, visually the pastilles appeared reddish-purple due to the dominance of red-purple pigments at pH 2.

Increasing sucrose concentration raised L* and lowered a*, producing a lighter color with less, while b* increased toward blue. Increasing extract concentration had the opposite effect, decreasing L* and b*, and raising a*. Resulting in a darker, more intense red-purple color as the bluish component weakened.

4.6. Hygroscopicity

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the hygroscopicity of the pastilles. Sample e1s3 showed the lowest moisture content (1.15 % ± 0.00^{a}), while sample e3s3 (10.95 % ± 0.06^{i}) had the highest. Increasing sucrose concentration reduced hygroscopicity, as sucrose binds water within

its solid matrix, limiting the absorption of external moisture. This effect is due to the polyhydroxyl groups in sucrose, which can form hydrogen bonds.

Table 5.
Results of Chemical Analysis of Butterfly Pea Flower Pastilles.

Treatment	Moisture Content (%)	Ash Content (%)	Volatile Components (%)	Reducing Sugar Content (%)	Antioxidant Activity (ppm)
e1s1	1.73 ± 0.11^{c}	1.50 ± 0.09^{bs}	90.46 ± 0.60^{d}	2.11 ± 0.05^{a}	133.08 ± 0.89^{g}
e1s2	1.25 ± 0.11^{b}	1.34 ± 0.05^{ab}	92.76 ± 0.59^{e}	2.11 ± 0.09^{a}	135.81 ± 0.83^{h}
e1s3	0.47 ± 0.10^{a}	1.14 ± 0.04^{ab}	93.38 ± 0.56^{e}	2.13 ± 0.05^{a}	138.49 ± 0.87^{i}
e2s1	3.49 ± 0.17^{g}	1.86 ± 0.05^{f}	85.85 ± 0.55^{b}	2.12 ± 0.04^{a}	125.62 ± 0.95^{d}
e2s2	2.56 ± 0.14^{e}	1.62 ± 0.05^{cde}	87.18 ± 0.76^{c}	2.11 ± 0.06^{a}	127.27 ± 0.93^{e}
e2s3	2.00 ± 0.19^{d}	1.59 ± 0.06^{cd}	87.13 ± 0.70^{c}	2.12 ± 0.05^{a}	129.03 ± 0.90^{f}
e3s1	4.79 ± 0.13^{h}	2.19 ± 0.08^{g}	82.01 ± 0.59^{a}	2.13 ± 0.05^{a}	113.04 ± 0.99^{a}
e3s2	2.86 ± 0.12^{f}	1.83 ± 0.09^{ef}	82.54 ± 0.60^{a}	2.13 ± 0.06^{a}	115.24 ± 0.97^{b}
e3s3	2.23 ± 0.19^{d}	1.73 ± 0.07^{def}	82.51 ± 0.56^{a}	2.12 ± 0.07^{a}	118.69 ± 1.12^{c}

Note: Indicates a significance level of 5%.

4.7. Moisture Content

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the moisture content of the pastilles. Sample e1s3 showed the lowest moisture content ($0.47\ \% \pm 0.10^{a}$), while sample e3s1 ($4.79\ \% \pm 0.13^{h}$) had the highest. Increasing sucrose concentration reduced the moisture content, as sucrose binds free water within its dense matrix. Increasing extract concentration raised the moisture content, since butterfly pea flower extract contains water and anthocyanins that are hydrophilic, with polar hydroxyl groups that attract and bind water molecules.

4.8. Ash Content

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the ash content of the pastilles. The lowest ash content was observed in sample e1s3 ($1.14\% \pm 0.04^{ab}$), while the highest value was recorded in sample e3s1 ($2.19\% \pm 0.08^{g}$). Increasing sucrose concentration reduced the ash content because sucrose is an organic compound that is completely decomposed during the incineration process. Increasing the concentration of butterfly pea flower extract raised the ash content, since the extract contains natural minerals such as calcium, potassium, magnesium, and other elements classified as inorganic substances that remain as residue after combustion.

4.9. Volatile Components

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the volatile components of the pastilles. The lowest value was observed in sample e3s1 ($82.01\% \pm 0.59^{a}$), while the highest value was recorded in sample e1s3 ($93.38\% \pm 0.56^{e}$). Increasing the concentration of butterfly pea flower extract reduced the volatile components of the product because the extract contains minerals that are relatively stable during heating, thereby suppressing the formation of volatile compounds. Increasing sucrose concentration increased the volatile components of the product because sucrose undergoes thermal degradation at high temperatures, producing compounds that evaporate during heating.

4.10. Reducing Sugar Content

The results showed that the interaction between the concentration of butterfly pea flower extract and sucrose had no significant effect on the reducing sugar content of the pastilles. The reducing sugar content ranged from 2.11 to 2.12%, with relatively similar values across all treatments because the main source of reducing sugars originated from glucose syrup, which was used at a constant level in each formulation. Therefore, variations in sucrose and extract concentrations did not affect the reducing sugar content.

4.11. Antioxidant Activity

The results showed that the interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the antioxidant activity of the pastilles. The lowest antioxidant activity was observed in sample e1s3 ($138.49\ \text{ppm} \pm 0.87^{i}$), while the highest antioxidant activity (lowest IC_{50} value) was recorded in sample e3s1 ($113.04\ \text{ppm} \pm 0.99^{a}$). Increasing the concentration of butterfly pea flower extract enhanced the antioxidant activity due to the presence of bioactive compounds, namely anthocyanins and flavonoids. Increasing sucrose concentration reduced the antioxidant activity because sucrose does not possess antioxidant properties and decreases the proportion of the extract in the formulation.

Table 6.
Results of Hedonic Acceptance Analysis of Butterfly Pea Flower Pastilles.

Treatment	Color	Texture	Taste	Flavors
e1s1	4.78 ± 0.06^{d}	4.31 ± 0.03^{c}	4.67 ± 0.07^{c}	4.38 ± 0.23^{a}
e1s2	4.80 ± 0.03^{cd}	4.49 ± 0.01^{c}	4.71 ± 0.07^{c}	4.30 ± 0.09^{a}
e1s3	4.47 ± 0.02^{ab}	3.71 ± 0.02^{a}	4.27 ± 0.04^{b}	4.30 ± 0.03^{a}
e2s1	4.69 ± 0.01^{bcd}	4.32 ± 0.04^{c}	4.08 ± 0.18^{ab}	4.23 ± 0.12^{a}
e2s2	4.81 ± 0.02^{cd}	4.50 ± 0.02^{c}	4.26 ± 0.21^{b}	4.41 ± 0.07^{a}
e2s3	4.91 ± 0.01^{cd}	4.72 ± 0.01^{d}	4.74 ± 0.12^{c}	4.34 ± 0.15^{a}
e3s1	4.68 ± 0.03^{bcd}	4.07 ± 0.04^{b}	4.29 ± 0.02^{b}	4.32 ± 0.02^{a}
e3s2	4.63 ± 0.07^{bc}	4.49 ± 0.03^{c}	4.18 ± 0.05^{b}	4.22 ± 0.09^{a}
e3s3	4.39 ± 0.01^{a}	4.43 ± 0.01^{c}	3.90 ± 0.24^{a}	4.19 ± 0.07^{a}

Note: Indicates a significance level of 5%.

4.12. Hedonic Acceptance

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the moisture content of the pastilles. Sample e1s3 showed the lowest moisture content ($0.47\ \% \pm 0.10^{a}$), while sample e3s1 ($4.79\ \% \pm 0.13^{h}$) had the highest. Increasing sucrose concentration reduced the moisture content, as sucrose binds free water within its dense matrix. Increasing extract concentration raised the moisture content, since butterfly pea flower extract contains water and anthocyanins that are hydrophilic, with polar hydroxyl groups that attract and bind water molecules.

5. Conclusion

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the moisture content of the pastilles. Sample e1s3 showed the lowest moisture content ($0.47\ \% \pm 0.10^{a}$), while sample e3s1 ($4.79\ \% \pm 0.13^{h}$) had the highest. Increasing sucrose concentration reduced the moisture content, as sucrose binds free water within.

6. Discussion

The interaction between the concentration of butterfly pea flower extract and sucrose had a significant effect on the moisture content of the pastilles. Sample e1s3 showed the lowest moisture content ($0.47\ \% \pm 0.10^{a}$), while sample e3s1 ($4.79\ \% \pm 0.13^{h}$) had the highest. Increasing sucrose concentration reduced the moisture content, as sucrose binds free water within.

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