

Sensory and physical properties of banana bread muffins prepared by replacing the coconut sugar with two formulations of monk fruit sweetener (50% and 100%)

Daibelis Acosta, Jenifer Barbarotto, Melina Hernandez and Robson Hidalgo
DEPARTMENT OF FAMILY, NUTRITION AND EXERCISE SCIENCES, QUEENS COLLEGE, CUNY, FLUSHING, NY 11367

Introduction

Diabetes and obesity are some of the pervasive medical issues of the contemporary population of America. According to the Centers for Disease Control and Prevention, an estimated 40.3% of people in the United States had obesity during August 2021- August 2023(CDC, 2024); this emerging epidemic has therefore called for better eating choices. Since the average intake has been above the recommended upper limit, at 17 teaspoons of added sugar per American per day, AHA 2024 also establishes dietary sugar intake as a major determinant of the disease burden of obesity-related illness.

The muffin market is projected to reach over \$16.29 billion globally by 2032(Fortune Business Insights, 2024). Furthermore, prior work by Yeung at al. (2023) showed that monk fruit sweetener is a tempting substitute for baking, as it substantially reduces calorie intake and because of its lower glycemic index compared to regular sugars.

Wang et al. established, through their research in 2023, that the usage of monk fruit sweetener in baked goods maintains desirable sensory properties and offers a healthy alternative with a low glycemic impact.

Objectives

The present study aims at the production and assessment of muffins from banana bread, using two levels of replacement of coconut sugar by monk fruit sweetener: 50% and 100%. Comparative substitution studies were conducted to determine if using substitutes could produce a product with low sugar content, pleasant flavor, and favorable sensory characteristics, texture, and overall acceptance.



Methods

Ingredients

The source of ingredients utilized in the recipe in this study consisted of Davis OK baking powder (Clabber Girl Corporation, Terre Haute, IN), Diamond Crystal Kosher salt (Diamond Crystal Brands, Savannah, GA), Eggland’s Best egg (Eggland’s Best Inc., Jeffersonville, PA), Spice Supreme vanilla extract (Tasty Spice Supreme, Passaic, NJ), Ground cinnamon (McCormick & Company, Inc., Hunt Valley, MD), Chiquita Bananas (Chiquita Brands International Inc. Fort Lauderdale, Florida, U.S.), Wholesome Organic coconut sugar (Wholesome Sweeteners Inc., Sugar Land, TX), Spectrum organic coconut oil (The Han Celestial Group Inc, Lake Success, NY), Lakanto Monk fruit golden with erythritol (Saraya, USA inc., Orem. UT), King Arthur whole wheat flour (King Arthur Baking Company, Norwich, VT). The equipment used was a Conventional Oven in Remsen 301 (Maytag Corp., Newton, IA) and an electric Hand Mixer (Cuisine Art, Stamford, CT)- (Stanley Black & Decker Inc., Towson, MD).

Sample Formulation and Preparation

Table 1: Formulations of banana bread muffin samples prepared by replacing coconut sugar with monk fruit (unit: grams).

Ingredients	Control (100% Coconut sugar)	50% Monk fruit /50% Coconut sugar (50/50)	100% Monk fruit (0/100)
Coconut sugar	94g	47g	N/A
Monk fruit	N/A	47g	94g
Coconut oil	31g	31g	31g
Cinnamon	2.8g	2.8g	2.8g
Eggs	52g	52g	52g
Salt	1.4g	1.4g	1.4g
Vanilla extract	2.8g	2.8g	2.8g
Ripe bananas	177g	177g	177g
Whole wheat flour	125g	125g	125g
Baking powder	2.8g	2.8g	2.8g

Sample Preparation

Get all the ingredients required for the two modified formulations and control recipe. Turn on the oven to 350°F (175°C). To make simple removal, either oil a 12-cup muffin tray or line it with muffin liners. Mash the bananas in a large bowl with a fork till essentially smooth. Combine in another bowl the flour, egg, vanilla extract, baking powder, salt, cinnamon, coconut oil and coconut sugar or monk fruit sweetener (adjust according to the type of sugar modification of the sample). Add these ingredients to the mashed bananas. Stir the ingredients until they get completely mixed. Spoon the batter equally between each muffin cup, filling them roughly two thirds full. Bake until a toothpick put in the center comes out clean, 25 to 28 minutes in the preheated oven. Muffins should cool in the tray for a few minutes before being moved to a wire rack.

Sensory Evaluation

The total panelists in this research experiment consisted of 10 adult volunteers, students, and related friends (n=10) who were randomly chosen on the 3rd floor of Remsen building, Queen's College, NY, to participate. This panel consisted of 3 males and 7 females; ages 19-31 years old, Mean ± SD = 22.7 ± 3.16 years old. The sensory properties evaluated were surface brownness, sweetness, aftertaste, moistness, and overall acceptability. The panelists were asked to grade the surface brownness, sweetness, aftertaste, moistness on a 9-point scale: 1=light brown, 9=dark brown for surface brownness and 1=weak and 9=strong for sweetness, aftertaste, and moistness, and on a 9-point hedonic scale the overall acceptability: 1=dislike extremely, 9=like extremely.

Nutrients Analysis

From each batch, one mini banana bread muffin was selected for sampling to compare the following characteristics: their caloric content, nutritional properties, and differences in macronutrients, dietary fiber, added sugar, total sugar, saturated fat, monounsaturated fat, cholesterol, sodium, potassium, and iron. Nutrient facts were analyzed using Nutritionist Pro software (Axxya Systems LLC, Redmond, WA, 2022).

Statistical Analysis

All results were gathered and entered SPSS for windows (version 25.0, 2017, IBM Inc, Armonk, NY) to perform statistical testing. A one-way analysis of variance (ANOVA) with Tukey HSD as a post- hoc test was implemented. The level of significance used to reject the null hypothesis was $p<0.05$.

Results

Brownness

Muffins made with 100% monk fruit received a mean score of (3.30), but the control sample containing 100% coconut sugar had a highest mean score of (7.50).

Sweetness

Muffins made with 100% monk fruit achieved the highest sweetness score of (7.10), while the control sample scored (5.20).

Aftertaste

Did not show significant differences, with scores for all three treatments ranging from (4.70) to (5.90).

Moistness

Since no significant differences in perceived moistness ($p>0.05$), the sugar substitutions did not result in moisture loss with any formulations. While monk fruit can replace sugar, care must be taken to ensure moisture is not sacrificed. When replacing the sugars with alternative sweeteners, formulations must be changed to yield similar moisture levels (McKenzie, 2022).

Overall acceptability

The overall acceptability values for all samples ranged from (6.60) to (7.60), meaning the participants had no strong preference for one formulation.

Table 3. Sensory qualities (Means*±SD) for Banana Bread Muffins were prepared by replacing coconut sugar with monk fruit

	Control 100% Coconut Sugar (Code: 239)	Modification 1 50% Coconut Sugar / 50% Monk Fruit (Code: 547)	Modification 2 100% Monk Fruit (Code: 886)
Brownness	7.50 ^b ±1.27	6.60 ^b ±1.08	3.30 ^a ±1.64
Sweetness	5.20 ^a ±1.03	5.90 ^{ab} ±1.60	7.10 ^b ±1.60
Aftertaste	4.70 ^a ±2.67	4.70 ^a ±1.83	5.90 ^a ±2.56
Moistness	6.50 ^a ±1.84	6.50 ^a ±0.85	6.20 ^a ±1.48
Overall Acceptability	6.90 ^a ±1.37	7.60 ^a ±1.35	6.60 ^a ±2.12

Mean ± Standard Deviation of 10 panelists using a 9-point scale (1: Weak, 9: Strong; Overall Acceptability- 1: dislike extremely, 9: like extremely) for Brownness the 9-point scale (1: Light Brown, 9: Dark Brown).
*Means with the same superscripts in rows indicate no significance in difference (Tukey test, $p<0.05$)
Sample formulations are found in Table 1

Nutrient Analysis

Calories decreased from 120 in the control sample to 80 calories in the 100% monk fruit muffins, indicating calories saved through sugar replacement. In particular, total sugars decreased from 9 grams to 3 grams from the control sample to the 100% monk fruit muffins. Protein, fat, saturated fat, and dietary fiber levels were comparable in all the muffin preparations. 50% coconut sugar/50% monk fruit modification and 100% monk fruit reduced cholesterol from 25 mg to 20 mg. Compared with commercial products. For example, a very famous brand of muffins, Entenmann's Little Bites Banana Muffins, is still high in calories (180) and sugars (17g). Hence, our monk fruit sample would be a super alternative for those with restrictive diets

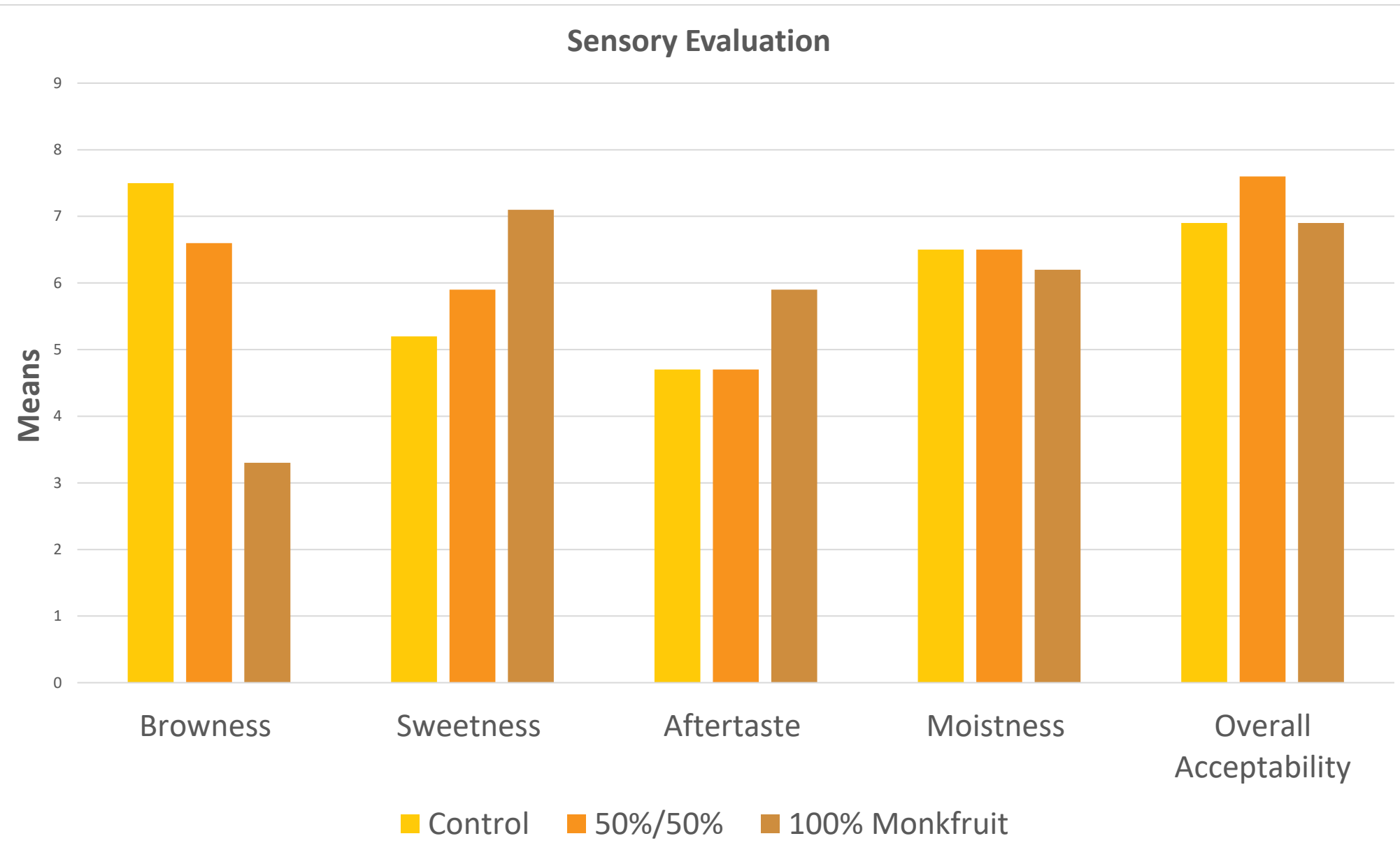
Diameter measurement

This analysis revealed that the muffin diameter significantly increased with 100% monk fruit to an average of (2.93 cm), as opposed to 50% coconut sugar/50% monk fruit modification, which had (2.80 cm), and a control sample with (2.67 cm).

Figure 4: Nutrition Facts for three clean & delicious Banana bread muffins were prepared by replacing the coconut sugar with monk fruit.

Control 100% Coconut sugar	Modification 1 50% Coconut Sugar / 50% Monk Fruit	Modification 2 100 % Monk fruit
Nutrition Facts Serving size 2 Mini Muffins (47g) Calories 120 Percent per serving Total Fat 4g 8% Saturated Fat 3g 15% Trans Fat 0g Monounsaturated Fat 0g Cholesterol 25mg 5% Sodium 180mg 8% Total Carbohydrate 18g 7% Dietary Fiber <1g 4% Total Sugars 9g 4% Includes 4g Added Sugars 8% Protein 3g Vitamin D 0.1mcg 0% Calcium 40mg 4% Iron 0.6mg 4% Potassium 170mg 4% Vitamin A 10mcg 0% Vitamin C 2mg 2%	Nutrition Facts Serving size 2 Mini Muffins (47g) Calories 100 Percent per serving Total Fat 4g 8% Saturated Fat 3g 15% Trans Fat 0g Monounsaturated Fat 0g Cholesterol 20mg 7% Sodium 170mg 7% Total Carbohydrate 19g 7% Dietary Fiber <1g 4% Total Sugars 6g 4% Includes 2g Added Sugars 4% Protein 3g Vitamin D 0.1mcg 0% Calcium 40mg 4% Iron 0.5mg 2% Potassium 150mg 4% Vitamin A 10mcg 0% Vitamin C 2mg 2%	Nutrition Facts Serving size 2 Mini Muffins (47g) Calories 80 Percent per serving Total Fat 4g 8% Saturated Fat 3g 15% Trans Fat 0g Monounsaturated Fat 0g Cholesterol 20mg 7% Sodium 170mg 7% Total Carbohydrate 19g 7% Dietary Fiber <1g 4% Total Sugars 3g 0% Includes 0g Added Sugars 0% Protein 3g Vitamin D 0.1mcg 0% Calcium 40mg 4% Iron 0.5mg 2% Potassium 120mg 2% Vitamin A 10mcg 0% Vitamin C 2mg 2%

Figure 1. Sensory Attributes for Banana bread muffins were prepared by replacing the coconut sugar with monk fruit (Means* ± SD).



Conclusion

Among the three samples analyzed, the 100% monk fruit formulation is recommended, providing a satisfactory sweetness level without compromising moistness and overall acceptability despite the lesser brownness, indicating a lack of the Maillard reaction typically provided by sugars compared with the control. This is particularly noticeable because the 100% monk fruit muffins had 80 calories instead of 120 in the control sample, which makes them a beneficial option for those trying to reduce their sugar intake.

For future research, to further validate monk fruit's versatility and effectiveness as a sugar substitute, it is recommended that research be done with various ratios of monk fruit in conjunction with other natural sweeteners.

References

- American Heart Association. (2024) How much sugar is too much?. www.heart.org. <https://www.heart.org/en/healthy-living/healthy-eating/eat-smart/sugar/how-much-sugar-is-too-much>
- Arshad, S., Rehman, T., Saif, S., Rajoka, M. S. R., Ranjha, M. M. A. N., Hassoun, A., Cropotova, J., Trif, M., Younas, A., & Aadi, R. M. (2022). Replacement of refined sugar by natural sweeteners: focus on potential health benefits. *Helveta*, 8(9), e10711. <https://doi.org/10.1016/j.helva.2022.101711>
- Axxya Systems LLC, Redmond, WA (2022). Nutritionist Pro™. Retrieved from <https://nutritionistpro.com/axxya/>
- Ban, Q., Cheng, J., Sun, X., Jiang, Y., Zhao, S., Song, J., & Guo, M. (2020). Effects of a synbiotic yogurt using monk fruit extract as sweetener on glucose regulation and gut microbiota in rats with type 2 diabetes mellitus. *Journal of dairy science*, 103(4), 2956–2968. <https://doi.org/10.3168/jds.2019.17700>
- Centers for Disease Control and Prevention. (2024). *Products - data briefs - number 508 - September 2024*. Centers for Disease Control and Prevention. <https://www.cdc.gov/nchs/products/databriefs/db508.htm>
- Fortune Business Insights. (2024). Muffins Market Size, Share & Regional. <https://www.fortunebusinessinsights.com/muffins-market-103841>
- Lee, Jong Suk; Ramalingam, Sriravanan; Jo, Il Guk; Kwon, Ye Seon; Bahuguna, Ashutosh; Oh, Young Seok; Kwon, O-Jun; Kim, Myunghee (2018). Comparative study of the physicochemical, nutritional, and antioxidant properties of some commercial refined and non-centrifugal sugars. *Food Research International*, 109:614–625. doi: 10.1016/j.foodres.2018.04.047.
- Ulu, S., Sun, H., Ma, G., Zhang, T., Wang, L., Pei, H., Li, X., & Gao, L. (2022). Insights into flavor and key influencing factors of Maillard reaction products: A recent update. *Frontiers in nutrition*, 9, 973677. <https://doi.org/10.3389/fnut.2022.973677>
- Mahato D.K., Keati R., Liem D.G., Russell C.G., Ciccone S., Ganfath S. (2021) Optimisation of natural sweeteners for sugar reduction in chocolate flavoured milk and their impact on sensory attributes *International Dairy Journal*, 115, 104922
- McKenzie, E., & Lee, S. Y. (2022). Sugar reduction methods and their application in confections: a review. *Food science and biotechnology*, 31(4), 387–398. <https://doi.org/10.1007/s10068-022-01046-7>
- Pandey AK, Chaudhary OP. (2019). Monk fruit (Siraita grosvenorii) - health aspects and food application. *Journal of Research*, 17: 191-198.
- Shivani, Thakur, B. K., Mallikarjun, C. P., Mahajan, N., Kapoor, P., Malhotra, J., Dhiman, R., Kumar, D., Pal, P. K., & Kumar, S. (2021). Introduction, adaptation and characterization of monk fruit (Siraita grosvenorii): a non-caloric new natural sweetener. *Scientific reports*, 11(1), 6205. <https://doi.org/10.1038/s41598-021-85889-2>
- Spies, D. (2024, August 17). Best healthy banana bread muffins * [Easy recipe] * Clean & delicious | Clean & Delicious. <https://cleandanddelicious.com/healthy-banana-bread-muffins/>
- Transparency Market Research. (2023). *Monk fruit sugar market (Nature: Natural and organic; and Form: Powder and liquid) - Global industry analysis, size, share, growth, trends, and forecast, 2023-2031*. <https://www.transparencymarketresearch.com/monk-fruit-sugar-market.html>
- Yeung A. W. K. (2023). Bibliometric analysis on the literature of monk fruit extract and mogrosides as sweeteners. *Frontiers in nutrition*, 10, 1252255. <https://doi.org/10.3389/fnut.2023.1252255>
- Wilks, K., Korytko, W., Pelczyńska, M., Moszak, M., & Bogdański, P. (2022). The Effect of Artificial Sweeteners Use on Sweet Taste Perception and Weight Loss Efficacy: A Review. *Nutrients*, 14(6), 1261. <https://doi.org/10.3390/nu14061261>