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Effect of Low Glycemic Index Stevia-Benefiber Sweetener on the Physical, Textural and Sensory Qualities of Oatmeal Raisin Cookies

Karen F Bukolt, Nicole Ramirez, Andrea Saenz, Kaiwan Mirza, Sikha Bhaduri and Khursheed Navder*

School of Urban Public Health, Hunter College, CUNY, New York, NY 10035, USA

Abstract

This study was conducted to test the effectiveness of a 33%, 50%, 66% and 100% substitution of white and brown sugar with a zero calorie sweetener (Stevia) and a bulking agent (Benefiber). As Stevia and Benefiber increased, %Δ weight, %Δ height and pH did not differ significantly between variations and control samples. Compared to control, moisture decreased significantly with all substitutions ($p<0.05$). Water activity decreased significantly with 66% and 100% substitutions. Area and diameter also significantly decreased with the replacement of sugar. Hunter colorimeter showed significantly increased crust lightness at 66% and 100% while the crumb lightness decreased significantly with all substitutions. Texture analysis measured using a TA.XT Plus Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) indicated a significant increase in fracturability at 66% and 100% substitution. Hardness was found to significantly increase by 50%, 66% and 100% ($p<0.05$). Sensory evaluations indicated that substitutions at 50%, 66%, and 100% were significantly different ($p<0.05$) in color, texture, taste and overall acceptability compared to control. Substitutions at 33%, 50% and 66% all ranked above 3 (acceptable) in appearance, color, taste, texture and overall acceptability. The nutrient analysis showed that the 66% variation increased in fiber by 3 grams (289.09%), and decreased in sugar content by over 4 grams (-48.70%) per 27 grams serving compared to control. Improved nutritional content and acceptability make Stevia and Benefiber a viable sugar replacement at 66% substitution for oatmeal cookies.

Keywords: Stevia; Sugar replacement; Benefiber; Oatmeal cookies

Introduction

Obesity and diabetes are diseases on the rise. In 2012, 9.3% of the population in the United States of America had diabetes [1]. Diabetes affects people of all ages and finding appropriate alternatives for these populations is vital to their health. In addition, more than 66.8% of adults are overweight or obese. Just as with diabetes, obesity affects people of all ages [2]. High sugar diets affect rates of obesity and diabetes. Sugar has no other property that appears to contribute to our nutritional well-being, it is not an essential food and is used mainly for sweetness and flavor. The pursuit for a natural sugar substitute that has few or no calories, has no effect on blood glucose levels and can be used in home baked products has been underway for a long time.

Scientific research has shown that sugar is detrimental to health. Sugar is an abused substance in the world, especially in the United States. The consumption of sugar has tripled since 1960 [3], which correlates with the obesity epidemic. White granulated sugar is an empty calorie, overly processed, the non-nutritive sweetener used in many baked goods. It is high on the glycemic index and some studies have also shown its addictive properties [4]. Sugar contains fructose, which has also been shown to affect chronic diseases [3].

Cookies are widely consumed by many populations. A cookie has low nutrient density, high sugar, and low fiber content. This snack item can contribute to obesity making it necessary to create a way to eliminate or reduce sucrose in cookie formulation.

Sucrose provides the most important sensory characteristic in cookies sweetness [5]. Obtaining the same sweetness level with minimal taste, color, mouthfeel and odor alteration is key [5,6]. The high sucrose content of cookies impacts not only the sweetness and flavor but the dough formation, viscosity, moisture control, cookie spread, structure formation, browning and crispness [6,7]. Since other sweeteners have different chemical compositions than sugar, replacement affects the structural and textural properties of cookies [6,7]. Sucrose concentrations of less than 25% are dry and crumbly, while sugar concentrations higher than 50% create overly soft and sticky doughs [6]. The replacement sweetener needs to have similar properties of sucrose which is why it has been challenging to find an ideal sugar replacement.

Fluctuation in blood glucose level was noticed after ingestion of sugar and sucralose-based products whereas, on replacement with Stevia powder in products uniformity was noticed in blood glucose level resulting in low glycemic index. Stevia is natural sweetener, 300-400 times sweeter than sugar, derived from the Stevia plant [8]. The incorporation of Stevia powder instead of sucralose and sugar was found to be a good alternative for deprived obese and diabetic patients [9]. This study was undertaken to determine the applicability, functionality and consumer acceptability of Stevia and Benefiber as a substitution for sugar in oatmeal raisin cookies on physical, textural, and nutritional properties.

Materials and Methods

Material

All modified cookie recipes were made with unbleached all-purpose flour (Gold Medal Flour, Minneapolis, MN, USA), granulated white sugar (Domino Foods Inc., Yonkers, NY, USA), dark brown sugar (Domino Foods Inc., Yonkers, NY, USA), vanilla extract (McCormick and Company, Sparks, MD, USA), butter (Breakstone's, Dairy Farmers of America, Kansas City, MO, USA), iodized salt (Diamond Crystal,

***Corresponding author:** Dr. Khursheed Navder, School of Urban Public Health, Hunter College, CUNY, New York, NY 10035, USA, Tel: +2123967775; Fax: +2123967644; E-mail: knavder@hunter.cuny.edu

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Minneapolis, MN, USA), eggs (Cherry Valley, Mitlitsky Eggs, Lebanon, CT, USA) and baking soda (Arm and Hammer, Church and Dwight Co., Inc., Princeton, NJ, USA), cinnamon (Lisy Corp, Miami, FL, USA), oatmeal (Quaker Oats Company, Chicago, IL, USA), raisins (Sun-Maid Growers of California, Kingsburg, CA, USA), Stevia (In the Raw, Brooklyn, NY, USA), Benefiber (Novartis Consumer Health, Inc., Parsippany, NJ, USA). The modified cookie recipe was made with a combination of Stevia and Benefiber replacing 33%, 50%, 66%, and 100% sugar.

Stevia: Stevia in the raw form is a zero calorie sweetener, which consists of Stevia extract and a bulking agent, maltodextrin [8]. Stevia is extracted from the sweetest part of the Stevia plant leaf (Stevia Rebaudiana Bertoni). It is then purified to create a sweetener that is 300 to 400 times sweeter than cane sugar. Because the Stevia leaf extract is so pure and sweet, it requires blending with a bulking agent so that it can be conveniently measured, poured and used as a substitute for sugar or other caloric sweeteners. Maltodextrin is a carbohydrate derived from corn, to produce a zero calorie sweetener that matches the sweetness and measurement of sugar [8].

Benefiber: Benefiber is a clear, taste-free and completely soluble, natural prebiotic fiber that contains wheat dextrin [10].

Cookie preparation

The cookies were prepared using the recipe provided on the container of Quaker Oats since this would be readily available to consumers. Table 1 provides the original recipe and the revised brown and white granulated sugar amounts along with the substitution amounts of Stevia and Benefiber, converted to grams. The oven was heated to 350 degrees Fahrenheit. The butter and eggs were set out at room temperature for thirty minutes prior to use. The ingredients were individually measured using an electronic scale. The granulated and brown sugar was replaced with a 9:1 ratio of Benefiber to Stevia for the 33%, 50%, 66%, and 100% variations. In a large bowl, butter and sugar/Stevia/Benefiber were blended on medium speed with an electric mixer until creamy. The control took 2:30 minutes. As more Benefiber was added, the mixing time increased to 4:00 minute. At 2:00 minutes, a rubber spatula was used to manually manipulate the ingredients. After beating the butter and sugar/Stevia/Benefiber, eggs and vanilla were added and blended for 30 seconds. The sifted flour, baking soda, and cinnamon were added with the salt to the dough and blended for 30 seconds. Finally, oats and raisins were added and blended all together on low for 10 seconds. The cookie dough was weighed to 30 grams of dough for each cookie. On a parchment lined cookie sheet, the dough was placed in a round mold and pressed down to evenly fill. Baking time was 11-14 minutes until they reached a pleasing golden-brown color. Following a five-minute set period out of the oven, cookies were removed from the pans and allowed to cool on wire racks for one hour after which analyses were performed.

Analysis of cookie

Physical measurements: All tests were performed in triplicate. An electronic balance was used to determine any change in the weight of the product after baking. pH was measured on cookie batter solutions with an electronic pH tester (Ohaus ST20 EC/pH Pen Meter, Pinebrook, NJ, USA). A Vernier caliper (United Scientific Supplies, Inc., Waukegan, IL) was used to measure both height and diameter which were used to calculate cookie spread. The area was calculated by a planimeter (Planix 5 Digital Planimeter, Japan). Percent moisture was determined by a moisture analyzer (OHAUS Explorer, MB 45, Pinebrook, NJ, USA). Water activity was measured with a water activity meter (Aqua Lab CX-1, Decagon Devices, Inc., Pullman, WA, USA).

Color analysis: A Hunter colorimeter (Hunter Color-Flex, CFLX 45-2, Hunter Associates Laboratory Inc., Reston, VA) was used to determine the crust and crumb color of oatmeal cookies. Measurements were done in triplicate and color values L^* were recorded on the crust and crumb; L^* value represents lightness (black (0)/white (100)). Calibration of instrument was done by using both black and white color standards supplied by the manufacturer.

Texture analysis: Hardness and fracturability were measured using a three-point bending test employing an HDP/3PB probe. The hardness (force in grams) of cookies was indicated by the maximum peak force [11,12] required to break them, while fracturability was determined by the distance in mm of the first significant break peak in the Texture Profile Analysis (TPA) curve. The texture analyzer was fitted with the sharp-blade probe, 6 cm long and 1 mm thick, and was set to 'return to start' cycle, a pretest speed of 1.0 mm/s, test speed of 2.0 mm/s, post-test speed of 10 mm/s and a distance of 5.0 mm. Three cookies from each formulation were used to evaluate textural parameters.

Sensory evaluation: The Hunter College Institutional Review Board approved the study, granting it an exemption from review since the research involved tasting and food quality evaluation. According to the FDA, CFR-Code of Federal Regulations Title 21, food quality and consumer acceptance studies are exempt from review [13]. Oatmeal cookies were evaluated by a consumer panel (n=100) using a 5-point hedonic scale (1=dislike extremely, 3=neither like nor dislike and 5=like extremely). This number of panelists is considered adequate for rough product screening and for evaluating the acceptance and/or preference [14]. Panel participants consisting of students, staff, and faculty were recruited from the Hunter College School of Urban Public Health campus. Selection criteria of consumer panelists in this study included at least 18 years of age, not allergic to products and consumers of cookies. Oatmeal cookies were sliced cut into an approximately 1 × 1 inch sample size and were coded with a random 3-digit number. Samples were presented to participants at random and served in white plates under white light. General appearance, color, taste, texture, and overall acceptability were all evaluated on a 5-point hedonic scale with 1 for "Dislike extremely, 3 for "Neither like nor dislike" and 5 for "Like extremely". The cookies were also ranked from 1 for "least liked" to 5 for "most liked".

Nutrient analysis

Nutritional analysis was conducted using Nutritionist Pro software (Axxya Systems, Woodinville, WA). The analysis represents nutrient values for one serving, equivalent to a single cookie of 30 grams, pre-baked weight.

Statistical analysis

Three cookies from each of the six batches for each type (control and variations) were used for all measurements. Objective data (n=18) was analyzed using SPSS (IBM, Armonk, NY) and subjected to analysis of variance with 0.05 level of probability. Sensory data (n=100) was analyzed using FIZZ (Biosystems, Couternon France) using a hedonic scale of 1 to 5. The data were subjected to analysis of variance with 0.05 level of probability with LSD post hoc, and Friedman's sum of ranks.

Results and Discussion

Physical properties

Table 2 shows a summary of the physical measurements taken. The variations did not show a significant change in pH and percent weight change. The hygroscopic nature of sugar influences both the moisture and texture of baked products. Sugar tends to bind water and can also draw moisture into the mix affecting its quality. With a reduction in sucrose, moisture and water activity typically decrease [15]. While a significant decrease in moisture was observed in this study, percent weight change was not affected. This may be due to the ability of the flour and Benefiber to absorb more water when sucrose is reduced, thus preventing any significant change in weight due to moisture loss. The reduction in area and percent decrease in diameter were found in all variations with a significant decrease in the 100% variation. The higher hygroscopicity of Benefiber and the ability of flour to bind more water in the absence of sucrose could have inhibited cookie spread [16].

Moisture and water activity are important physical properties affecting not only product quality but also shelf life. These tests were done with and without raisins to account for the extra water found in raisins. There was a significant decrease in percent moisture at all levels of Stevia substitution compared to the control. The control oatmeal cookie was not a soft, chewy cookie nor hard and brittle. It had some resistance but was not crumbly. The decrease in percent moisture is beneficial as the higher moisture content make the cookies softer resulting in lower texture acceptability by consumers [17]. Additionally, the water activity of all variations decreased, with significant decreases at 66% and 100% substitutions compared to the control sample. This was expected since Benefiber, composed of wheat dextrin, has a higher hygroscopic property than sugar leading to the decreased water activity and moisture %. As the concentration of Stevia/Benefiber soluble fiber increased, water absorption percentage increased, water activity decreased, and consequently the diameter and area of cookie decreased [18].

Water activity is a measure of the availability of water in the cookie able to support microbial growth. Water activity decreased consistently with a significant decrease between the control and 66% and 100% substitution levels. These results indicate that there would be a decrease in the susceptibility of microbial growth and improved shelf life.

Textural properties: Table 2 shows the texture properties of Stevia/Benefiber cookies and control. The fracturability did change significantly with 66% and 100% variations. Fracturability is an important textural characteristic of brittle and crunchy snack item such as cookies. Fracturability is the progressive indication of structural failure that occurs as a result of strain due to the sequential breakage of small structural subunits [15]. These individual structural units can independently collapse while leaving the rest of the sample intact, as occurs when a snack sample is compressed with the teeth [15]. Fracturability and hardness are highly susceptible to changes in humidity and moisture absorption, it is typical for fracturability to decrease with an increase in humidity and moisture absorption [15]. This can explain the significant increase in fracturability and hardness as moisture decreased by 50%, 66%, and 100% variations. The 33% variation resembled the control in hardness most out of all variations without a significant increase while all other variations were significantly different.

Color properties: The color of food perceived by consumers is the first and most critical parameter evaluated and may greatly affect the overall acceptability of the product even before it is consumed. The color of baked products is affected by several factors such as fat, sugar and protein content which contribute to the Maillard browning reactions. Sucrose inverts to glucose and fructose at a higher temperature allowing both monosaccharides to participate in Maillard reactions with amino acids, which result in the development of important flavor components and browning compounds [6]. Table 2 represents the changes in color values L (lightness) for control and Stevia variations after baking.

The substituted oatmeal cookies at the 33%, 50% and 66% levels were significantly lower in crumb lightness, as evidenced by L^*, than the control cookie. The 100% variation was comparable to the control. As the substitution level of Stevia/Benefiber increased, the baking time had to be increased to try and achieve similar browning. All cookies were baked on parchment paper at 350°Fahrenheit. The crust lightness, as evidenced by L^* score, had a decreasing trend through all substitutions, compared to the control sample, however only the 66% and 100% variation changes were significant. Although Stevia is relatively heated stable, it is unable to undergo browning or caramelization when heated [19]. The overall decrease in the lightness of the crumb may be due to divergences in baking times as well as the use of bulking agent wheat dextrin, which could have promoted the progression of the browning reactions. Table 1 shows the variations in baking time to try and reach the desired color. The 66% and 100% variations had the longest baking times, 13:00 and 12:20 respectively, yet still had the highest L values. Similar results were found by Garcia Serna et al. where the substitutions of sucrose by 15%, 30%, 60%, and 100% Stevia significantly reduced ($p<0.05$) the L^* parameter [17].

Sensory properties: Hedonic rating for product characteristics and overall acceptability of each variation are presented in Table 2. Based on the LSD posthoc test, 33% and 50% levels did not affect the appearance of oatmeal cookies and were not significantly differ from the control sample. The 50%, 66%, and 100% variation were significantly different from the control in color. This may be due to the lower content of reducing sugar to act with the amino acids and promote the Maillard reaction. Therefore, crumb and crust for 100% Stevia substituted are lighter in color compared to other variations. This was observed in previous studies where Stevia replaced some or all of the sugar in recipes without drastically affecting the visual acceptability of the food product [20]. This result is also supported by the L^* value of the crust of the oatmeal cookie increasing as the substitution level of Stevia increased, as indicated in Table 2.

Although there was a significant difference in taste texture and

Ingredients- 1 dozen	control	33%	50%	66%	100%
Butter (g)	50	50	50	50	50
Brown sugar (g)	30	20	15	10	0
Stevia substitution for brown sugar (g)	-	1	1.5	2	3
Granulated sugar (g)	22.5	15	11.25	7.5	0
Stevia substitution for granulated sugar (g)	-	0.75	1.13	1.5	2.25
Total stevia (g)	-	1.75	2.63	3.5	5.25
Benefiber (g)	-	15.75	23.63	31.5	47.25
Eggs-large (g)	24.5	24.5	24.5	24.5	24.5
Vanilla (g)	0.35	0.35	0.35	0.35	0.35
All-purpose flour (g)	43.5	43.5	43.5	43.5	43.5
Baking soda (g)	0.85	0.85	0.85	0.85	0.85
Ground cinnamon (g)	0.5	0.5	0.5	0.5	0.5
Salt (g)	0.3	0.3	0.3	0.3	0.3
Quaker Oats (g)	73.5	73.5	73.5	73.5	73.5
Raisins (g)	36	36	36	36	36
Total weight (g)	282	282	282	282	282
Cooking time (minutes:seconds)	10:50	12:00	11:00	13:00	12:20

Table 1: Original recipe-quaker oats vanishing oatmeal raisin cookies [11].

overall acceptability in the 50%, 66%, and 100% substitutions, the 50% and 66% were still rated above 3 on the hedonic scale. The number "3" represents a neither like nor a dislike, thus despite the significant differences in objective values from the control, 50% and 66% substitutions remain acceptable. The 100% Stevia substitution had the lowest appearance, color, taste, texture and overall acceptability ranking. This could be due to the presence of a slightly bitter aftertaste and an extremely pale crust appearance. The 100% Stevia variation showed a significant weight increase due to the hygroscopic nature of wheat dextrin from the Benefiber and area/diameter decrease compared to others [21]. Hardness increased as the amount of Stevia and Benefiber replacement increased. The hardness could have increased as the amount of moisture decreased due to the increased hygroscopic nature of Benefiber.

The substitutions at 33%, 50%, 66%, and 100% levels were significantly different ($p<0.0001$) in the sensory attributes when compared to the control. Friedman's rank test (Figure 1) showed no significant difference in ranking based on liking among control and

Characteristic	Control	33% Stevia	50% Stevia	66% Stevia	100% Stevia
Physical Measurements					
pH	7.20 ± 0.22	7.25 ± 0.14	7.21 ± 0.07	7.25 ± 0.08	7.24 ± 0.04
Weight loss (%Δ)	8.91 ± 3.29	9.21 ± 1.84	9.58 ± 2.97	9.90 ± 2.03	10.10 ± 1.32
Area (cm²)	55.92 ± 3.57	55.03 ± 3.91	54.59 ± 5.14	53.71 ± 2.63	47.97 ±4.91[a]
Diameter (%Δ)	27.94 ± 5.95	27.79 ± 5.21	27.12 ± 4.63	26.29 ± 2.52	22.34 ± 4.62 [a]
Moisture (%)	10.64 ± 0.73	9.71 ± 0.92[a]	9.32 ± 1.27[a]	9.16 ± 1.25[a]	8.94 ± 0.60[a]
Water activity (A_w)	0.60 ± 0.02	0.59 ± 0.04	0.57 ± 0.04	0.56 ± 0.02[a]	0.55 ± 0.01[a]
Texture Analysis					
Fracturability (g)	25.48 ± 11.11	28.28 ± 9.06	29.09 ± 7.71	32.88 ± 1.10[a]	35.48 ± 1.27[a]
Hardness (N)	472.28 ± 211.91	719.09 ± 245.97	2005.34 ± 960.26[a]	4076.21 ± 874.02 [a]	4413.48 ± 1140.12 [a]
Color Analysis					
Crumb L	44.91 ± 2.53	40.37 ± 2.07[a]	39.57 ± 1.03[a]	39.77 ± 1.61[a]	44.03 ± 2.15
Crust L	48.98 ± 2.12	49.27 ± 2.36	49.92 ± 2.16	51.69 ± 2.90[a]	52.88 ± 2.29[a]
[a] Statistical difference with control group at p<0.05					

Table 2: Physical, textural and color measurements for control and Stevia/Benefiber substitutions in oatmeal raisin cookies.

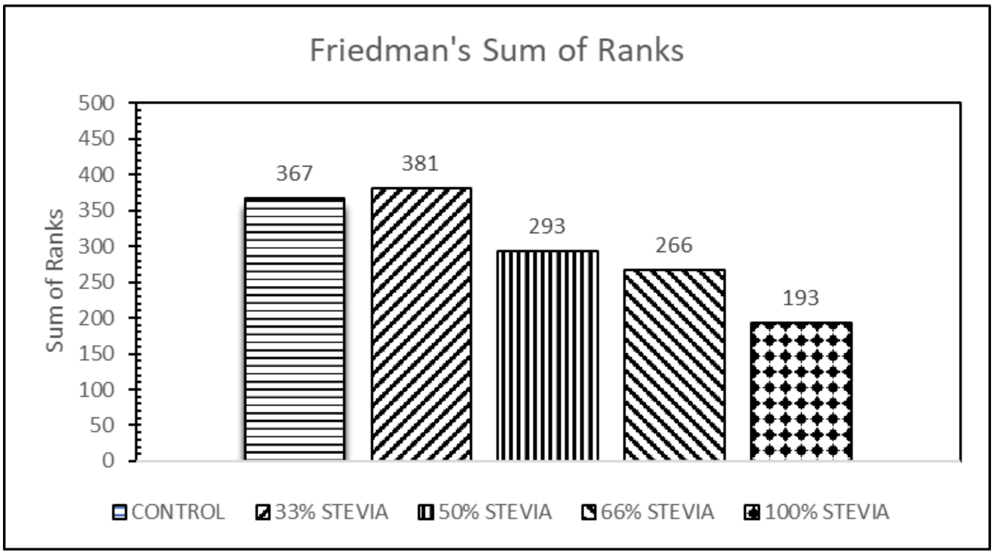

Figure 1: Friedman's sum of ranks test for control and Stevia/Benefiber substitutions in oatmeal raisin cookies.

Sensory Measures					
Appearance	3.63 ± 0.77	3.60 ± 0.90	3.39 ± 0.83	3.18 ± 0.82[a]	3.02 ± 1.04[a]
Color	3.70 ± 0.73	3.63 ± 0.79	3.40 ± 0.83[a]	3.24 ± 0.75[a]	2.95 ± 0.91[a]
Taste	3.90 ± 0.92	3.73 ± 0.97	3.28 ± 1.07[a]	3.34 ± 1.05[a]	2.59 ± 1.16[a]
Texture	3.79 ± 0.74	3.60 ± 0.79	3.41 ± 0.82[a]	3.25 ± 0.85[a]	2.79 ± 0.94[a]
Overall acceptability	3.86 ± 0.89	3.71 ± 0.86	3.35 ± 0.99[a]	3.27 ± 0.93[a]	2.62 ± 1.08[a]
Friedman's sum of ranks	367	381	293	266	193
[a] Statistical difference with control group at p<0.05					

Table 3: Sensory measurements for control and Stevia/Benefiber substitutions in oatmeal raisin cookies.

Figure 2: Color and spread for control and Stevia/Benefiber substitutions in oatmeal raisin cookies.

Macronutrient	Control	33%	50%	66%	100%
Kilocalories (kcal)	120.47	119.98	119.72	119.47	118.98
% (Decrease) in kcal		(0.41)%	(0.62)%	(0.83)%	(1.24)%
Dietary fiber, total (g)	1.03	2.51	3.25	4.00	5.48
% Increase in fiber		144.60%	216.85%	289.09%	433.69%
Sugar, Total (g)	8.86	6.71	5.63	4.55	2.39
% (Decrease) in sugar		(24.33)%	(36.52)%	(48.70)%	(73.03)%

Table 4: Nutrient Analysis for control and Stevia/Benefiber substitutions in oatmeal raisin cookies.

33% variation of the oatmeal raisin cookie (Table 3). The 50% and 66% variations were not significantly different from each other, but lower than the previous two, while the 100% variation was ranked the lowest ($p<0.00001$). Figure 2 shows a comparison between the sum of ranks for the variations of Stevia/Benefiber substitution. The 33% variation ranked even higher than the control. Since the 66% substitution variation was satisfactory for sensory criteria, Stevia can be a successful substitute in oatmeal cookies at 66%.

Nutrient content: Based on the nutrient analysis, the decrease in kilocalories of the cookies was minimal. Sucrose and Benefiber are both carbohydrates with kcal of approximately 4 kcal/gram. Table 4 shows the nutrient analysis of each cookie. The nutritional benefit comes from the lowered sugar and higher fiber. Fiber increased from 1.03 grams in the control to 5.48 grams in the 100% replacement, a 433.69% increase. This was expected with the inclusion of the Benefiber. Sugar reduced from 8.86 grams in the control to 2.39 grams in the 100%, a 73.03% decrease.

Conclusion

The substitution of sugar with Stevia and Benefiber, as demonstrated in this study, represents a nutritional improvement in oatmeal raisin cookies with similar textural and sensory properties. In the objective tests, the 33% variation was most similar to the control cookie, with 50% and 66% variations having fewer significant differences than the 100%. The substitutions improved the nutritional content by increasing fiber and reducing sugar. In the sensory tests, many commented on the different texture of the cookies. The 100% variation was the hardest and the control was the softest. The similarity in taste, texture and overall liking demonstrated 33%, 50% and 66% variations were desirable variations with a hedonic score above 3, neither like nor dislike. Based on the objective and sensory results, the 66% variation is a viable substitution for consumers. Thus, improved nutritional content and acceptability make Stevia and Benefiber a viable sugar replacement for oatmeal raisin cookies.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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