Physiochemical properties and sensory characteristics of resistant starch enriched cookies

Arezoo Rojhani
Department of Family and Consumer Sciences, Western Michigan University, Kalamazoo, Michigan, USA

Joshua Naranjo
Department of Statistics, Western Michigan University, Kalamazoo, Michigan, USA, and

Ping Ouyang
Department of Family and Consumer Sciences, Western Michigan University, Kalamazoo, Michigan, USA

Received 27 July 2021
Revised 21 September 2021
25 October 2021
Accepted 25 October 2021

Abstract

Purpose – The purpose of this study was to examine sensory attributes, physiochemical characteristics and consumer preference of drop sugar cookies prepared using high-amylose maize resistant starch (HAMRS) as a replacement for 10%, 20% and 30% of all-purpose (AP) flour as compared to a control made with 100% AP flour.

Design/methodology/approach – A balanced complete block experimental design was used to evaluate the eating quality of the resistant starch enriched cookies using a consumer panel. Consumer preference for the appearance, flavor, texture, moistness and overall acceptability of cookies was assessed. Diameter, height, spread ratio, hardness, moisture, pH, density, surface color and nutrient composition of cookies were analyzed.

Findings – Compared with the control cookies, the HAMRS cookies had lower diameters, higher, heights, reduced spreads, reduced % moisture losses and lower densities ($p < 0.001$). TA.XT Plus Texture Analyzer showed the HAMRS cookies had a softer texture than the control cookies ($p < 0.0001$). Evaluation of surface color showed no significant difference in lightness between the control and the HAMRS cookies. The HAMRS cookies were preferred over the control for appearance, texture and moistness in sensory evaluation with 42.5% of panelists choosing the 20% HAMRS replaced cookies as their overall preference. The 20% and 30% HAMRS replaced cookies qualify to be labeled as a "good source" and "excellent source" of fiber, respectively.

Practical implications – This data demonstrates that replacement of up to 30% of AP flour with HAMRS improves eating quality and dietary fiber content of sugar cookies. Our results show that HAMRS has good potential for developing high fiber cookies with minimal adverse impact on physical characteristics and notable improvements in sensory attributes and nutritional value.

Originality/value – To the best of the authors' knowledge, this is the first study that has reported on the functionality, consumer preference and nutritional value of cookies enriched with a HAMRS that is available to consumers in the form of flour.

Keywords Cookies, Sensory attributes, Dietary fiber, Cookie texture, High-amylose maize resistant starch, Spread ratio, cookie color, cookie density, cookie moisture, sensory evaluation

Paper type Research paper

Background

Adequate fiber intake is considered to be an important component of a healthy diet because of ample evidence linking high fiber intake with a low incidence of many chronic diseases

Nutrition & Food Science
© Emerald Publishing Limited
0034-6659
DOI 10.1108/NFS-07-2021-0231

(Academy of Nutrition and Dietetics, 2015). Despite the well-established connection between adequate fiber intake and lower risk for chronic degenerative diseases, the fiber intake of the average American remains woefully low. The fiber content of the typical American diet is 15 g/d, considerably lower than the recommended intake of 25 g/d for women and 38 g/d for men, or 14 g/1,000 kilo calories consumed. Increased consumption of processed and convenience foods and decreased intake of fiber-rich plant food sources have been identified as the major culprits for the gap in fiber intake (Cordain *et al.*, 2005).

Resistant starch (RS) is a form of dietary fiber and is the fraction of starch that escapes digestion in the small intestine and hence is not hydrolyzed to D-glucose within 2 h of being consumed but is fermented in the colon (Raigond *et al.*, 2015). Five subtypes of RS have been identified based on structure or source (Murphy *et al.*, 2008; Raigond *et al.*, 2015). RS1 is physically trapped starch that is found in whole or partly milled grains, seeds and legumes. Starch that is present in foods in its natural granular form is RS2. This type of starch is primarily found in raw potatoes, unripe bananas, some legumes and in high-amylose starches such as high-amylose corn. RS3 also known as retrograde starch can be generated through the process of moist-heat cooking followed by cooling. This includes cooked and cooled rice, potatoes, bread and ready-to-eat cereals. RS4 is the result of the chemical modification of native starch. These are not found in foods naturally. RS5 is the result of the formation of amylose-lipid complexes during food processing and is generally formed from high-amylose starches.

By definition, functional foods either contain (or add) a component with a specific health benefit or eliminate a component with a negative one (Fuentes-Zaragoza *et al.*, 2010). RS can be added to foods as a functional ingredient because of its many positive physiological benefits. Evidence from animal and human studies suggests that the benefits of RS go beyond improving digestive health and include a metabolic role (Birkett and Brown, 2008). Much of the digestive health benefits attributed to RS are directly linked to the generation of short-chain fatty acids (SCFAs) during fermentation, which positively influences the large intestine environment (Murphy *et al.*, 2008). These acids lower the lumen pH interfering with the growth of pathogenic bacteria and inhibit the absorption of compounds with toxic or carcinogenic potential thus preventing colonic cancer. SCFAs also stimulate colonic blood flow, provide nutrients and energy for cells of the colon, promote colonocyte proliferation and reverse atrophy associated with low-fiber diets. Because RS functions as a prebiotic fiber, it encourages the growth of beneficial bacteria, promoting regularity with a mild laxative effect (Fuentes-Zaragoza *et al.*, 2010; Murphy *et al.*, 2008).

Studies have shown that RS plays an important role in glycemic management by lowering postprandial glucose levels and insulin response when partially substituted for flour in recipes (Birkett and Brown, 2008). It can also be beneficial in energy management by reducing caloric load and increasing energy wastage because of increased fecal nutrient excretion (Fuentes-Zaragoza *et al.*, 2010) There is evidence that RS can lower total and regional body fat accumulation and lower fat cell volume. Furthermore, RS appears to increase lipid oxidation over carbohydrate oxidation when substituted for digestible carbohydrates (Birkett and Brown, 2008). Based on the glycemic and energy management benefits of RS, in 2016, the US Food and Drug Administration authorized a qualified health claim for high-amylose maize RS (HAMRS), a Type 2 RS stating there is limited evidence available that it may reduce the risk of Type 2 diabetes. To reap the health benefits of RS, it is recommended to consume 15–20 g/d of RS (Birkett and Brown, 2008). Most contemporary western diets supply only about 5 g/d of RS. Achieving the recommended intake levels requires major dietary modifications that may prove difficult to implement for most people.

Therefore, other means of increasing RS intake, such as adding RS as a food ingredient to recipes, must be explored (Fuentes-Zaragoza *et al.*, 2010)

Cookies are one of the most popular snack foods consumed because of their low cost, convenience and shelf life. Most varieties of cookies are fairly low in fiber and supply little nutrients. Because of their long shelf life, cookies can be used as a medium for the incorporation of nutritionally rich ingredients such as RS. Typically, high fiber cookies are coarser, denser and are perceived as less palatable than those made from refined grains. RS is a desirable alternative because it does not negatively impact sensory characteristics of food, such as appearance, taste and texture because of its small particle size, bland flavor and white color (Sajilata *et al.*, 2006). Therefore, RS has great potential for functional food development and has become a popular ingredient in baked goods such as cakes, muffins, waffles and bread (Baghurst *et al.*, 1996; Premavalli *et al.*, 2006). HAMRS is the focus of this study because it is available to the consumers in the form of flour (Murphy *et al.*, 2008). Currently, there are no published studies on the use of HAMRS ingredients that are available to consumers for use in sugar cookies or comparable products. The purpose of this study was to examine sensory attributes, physiochemical characteristics and consumer preference of sugar cookies prepared using HAMRS as a replacement for 10%, 20% and 30% of all-purpose (AP) flour as compared to a control made with 100% AP flour.

Materials and methods

Cookie preparation

Hi-maize© natural fiber (King Arthur Flour Company), a HAMRS Type 2 product, was substituted for 10%, 20% and 30% of AP flour in sugar cookies. Cookies were prepared using a basic sugar cookie recipe (cooks.com) with slight modification (Table 1). Shortening and sugar were creamed together at speed 2 for 2 min with an electric hand mixer (Kitchen Aid Ultra Power 5, Benton Harbor, MI, USA). Eggs were then added followed by flavorings. The dry ingredients were sifted and added to the mixture, and all ingredients were thoroughly mixed for an additional 3 min. Cookies were prepared by rolling the dough and cutting it with a round cutter with a diameter of 35 mm and thickness of 8 mm and subsequently baked on greased aluminum pans. All cookies were baked for 8 min at 177°C. After baking, the cookies were cooled on wire racks at 27°C for 60 min before packing in airtight containers in preparation for evaluation.

Ingredients	Control (g)	10% RS[ab] (g)	20% RS[ab] (g)	30% RS[ab] (g)
Shortening	180	180	180	180
Sugar	395	395	395	395
Eggs	101	101	101	101
Vanilla extract	4.9	4.9	4.9	4.9
Almond extract	4.6	4.6	4.6	4.6
Salt	5.9	5.9	5.9	5.9
Baking powder	7.6	7.6	7.6	7.6
All-purpose flour	379	343	305	267
Hi-maize natural fiber[c]	0	37.9	75.8	115

Notes: [a]RS = resistant starch; [b]Source of RS was Hi-maize© natural fiber (King Arthur Flour Company); [c]Quantity calculated based on dry weight of flour

Table 1. Sugar cookie formulations

Physical and chemical measurements

Cookie diameter, height and spread ratio. The AACC (1983) Method 10–50 D was used to evaluate cookie diameter, height and spread ratio. The diameter and height of the cookies were measured with a vernier caliper (Mitutoyo Co., Kawasaki, Japan). Cookie diameter was measured by placing six cookies edge to edge, measuring their diameter and then rotating the cookies 90° and re-measuring the diameter. The mean diameter of the cookies was determined by averaging the two readings and dividing by six. The height of the cookies was calculated by stacking six cooking on top of each other and measuring the thickness then restacking the cookies in a different order and re-measuring them. The mean height of the cookies was the average of the two readings divided by six. The spread ratio, which is the ratio of average diameter to average height, was calculated. All measurements were taken on three sets of cookies from the same batch for each formulation.

Density. Six cookies from each variation were weighed, and their volume was measured with rapeseed displacement. Density was calculated by dividing the weight of the cookies by their volume.

Moisture analysis. The moisture of cookies was measured in three replicates of each formulation using an HE53 halogen moisture analyzer (Mettler, Toledo, Columbus, OH, USA) set at 120°C using a 3 g crushed sample.

Color evaluation. The surface color of cookies was assessed using a Labscan XE Hunter Colorimeter (Hunter Associate Laboratories Inc., Reston, VA, USA). Nine replicates of each formulation were measured. The CIE1abv 10°/C scale was used to obtain the values for *L*, *a* and *b*.

pH measurement. In total, 10 g of ground sample was mixed with 90 g of distilled deionized water. The mixture was vortexed for 10 min and held at room temperature for 1 h to separate solid and liquid phases. After carefully removing the supernatant layer, the pH of the cookies was measured using a calibrated pH meter (Symphony SB70P, VWR International, Radnor, PA, USA). Three replicates of each formulation were used for pH measurements.

Texture evaluation. Cookie hardness was assessed with a three-point bend test using a TA.XT Plus Texture Analyzer (Texture Technologies Corp., Scarsdale, NY, USA) equipped with a 30-kg load cell and calibrated to a force sensitivity of 1 g. The cookies were placed on an adjustable bridge (TA-92, Texture Technologies Corp., Scarsdale, NY, USA). The end of the probing knife (TA-42, Texture Technologies Corp., Scarsdale, NY, USA) descended at a speed of 2 mm/s until a 10 g force was detected and then traveled a distance of 20 mm through the cookies. The peak breaking force (g), an indication of the hardness of cookies, was measured for 20 cookies each from the control and the experimental variations.

Sensory evaluation. In total, 115 sensory panelists, all college students at a state university in the mid-western USA used a seven-point hedonic descriptive scale to rate each cookie variation for appearance, flavor, texture, moistness and overall acceptability. Each point on the hedonic scale was assigned a value ranging from 1 (dislike extremely) to 7 (like extremely). Each panelist evaluated all four cookie variations. The cookies were coded using randomly selected three-digit numbers and were presented to the panelists in a randomized order. The study was granted exemption from review by the university's institutional review board.

Statistical analyses. Data were analyzed with Statistical Analysis System version 9.4 (SAS Institute Inc., Cary, NC, USA). One-way analysis of variance (ANOVA) was used to test the differences between the four cookie types for all quantitative variables (diameter, height, spread, hardness, moisture, pH, density and color). When ANOVA was significant, separation of means was tested using Tukey's pairwise comparison procedure.

The appearance, flavor, texture, moisture and overall preference of each cookie variation were compared against control using a paired *t*-test and were considered significant if $p \leq 0.05$.

Results and discussion

Cookie diameter, height and spread ratio

Larger diameter and higher spread are considered desirable attributes in cookies (Handa *et al.*, 2012). The viscosity of the dough plays an important role in the spread of the cookie (Yamazaki, 1959; Hoseney and Rogers, 1994). When there is sufficient water in the dough that is free and can act as a solvent, more sucrose is dissolved during baking (Handa *et al.*, 2012). This decreases the initial dough viscosity and allows the dough to spread at a faster rate while baking (Hoseney and Rogers, 1994). Flour or any ingredient that absorbs water during dough mixing has been shown to limit the amount of water available to dissolve sugar during baking, resulting in reduced spread (Miller and Hoseney, 1997).

In this study, the control cookies had the largest diameter, the lowest height and the most spread (Table 2). As the amount of HAMRS in the cookie formulation increased, the diameter decreased ($P < 0.001$), the height increased ($p < 0.001$) and the spread ratio decreased ($p < 0.001$). In essence, the cookies became smaller. The lower spread was also reported for cookies made with 20%, 40% and 60% replacement of flour with Hi-maize 260, a Type 2 RS (Laguna *et al.*, 2011), and sugar snap cookies made with replacement of 43% and 50% of cookie flour with high-amylose corn starch and heat–moisture-treated high-amylose corn starch (Yeo and Seib, 2009). Laguna *et al.* (2011) attributed the lower spread of the cookies made with Hi-maize 260 to the lower moisture level and higher alkaline water retention capacity of doughs made with this RS, which resulted in the retention of a portion of the water by RS and less dissolution of sucrose. The fact that RS bounds a portion of the water in the dough is further supported by the higher moisture content of RS enriched cookies compared to the control ($p < 0.001$) in this study (Table 3) and that reported by Laguna *et al.* (2011).

Cookie density and texture

Cookie density is an indicator of the amount of air incorporated into the dough prior to baking. The cookies with added HAMRS had a lower density than the control cookies ($p < 0.001$). No significant differences were found in the density of the cookies made with different proportions of flour replacement with HAMRS (Table 3). This means that the RS containing cookie doughs retained more air prior to baking and that the latter was not

Cookie variation	Diameter (mm) means ± SD[ce]	Height (mm) means ± SD[ce]	Spread ratio means ± SD[ce]	Hardness (kg) means ± SD[de]
Control	33.4 ± 0.15[a]	6.8 ± 0.09[c]	4.9 ± 0.30[a]	11.3 ± 0.95[a]
10% RS[ab]	32.7 ± 0.47[b]	7.9 ± 0.36[b]	4.6 ± 0.28[b]	10.1 ± 0.9[b]
20% RS[ab]	32.0 ± 0.15[b]	8.4 ± 0.2[b]	3.9 ± 0.23[c]	8.9 ± 0.68[c]
30% RS[ab]	32.2 ± 0.06[b]	9.5 ± 0.17[a]	3.4 ± 0.15[c]	8.4 ± 0.46[c]
Pr > *F*	<0.001	<0.001	<0.001	<0.001

Notes: [a]RS = resistant starch; [b] = source of RS was Hi-maize© natural fiber (King Arthur Flour Company); [c]Data are mean values of three replicates; [d] = data are mean values of 20 replicates; [e] = means ± standard deviation (SD) followed by the same letter superscript within a column are not significantly different ($p \leq 0.05$) according to the ANOVA and Tukey's adjusted pairwise comparisons

Table 2. Physical evaluation of sugar cookies

sufficiently compensated by more moisture retention after baking because of the presence of RS. This makes sense, as the formulation used in this study contained little liquid with the only source of liquid being the egg white. Laguna *et al.* (2011) reported no difference in density of short-dough cookies prepared with 20%, 40% and 60% replacement of soft wheat flour with Hi-maize 260 compared to the control cookies made with 100% flour. However, their cookie formulation had more liquid, as it contained powdered milk that was reconstituted with water.

Ensuring that cookies remain moist and soft after packaging and during storage is important in developing cookie formulations for consumer usage and commercial purposes. From a sensory standpoint, cookies become drier and more crumbly with storage, even with proper packaging (Belcourt and Labuza, 2007). In the present work, the control cookies made with 100% AP flour were harder as evidenced by the higher peak force of 11.3 ± 0.95 kg than the HAMRS substituted cookies (Table 2). The degree of hardness of cookies made with HAMRS progressively decreased as the amount of RS used in the cookie formulations increased ($P < 0.001$). The lower force required to snap the HAMRS substituted cookies is further supported by the lower density of these cookies compared to the control cookies. This is indicative of the softer texture of these cookies and can be attributed to the lower level of wheat proteins in the HAMRS substituted samples resulting in a less structured gluten matrix. Despite the earlier notion that proteins do not aggregate and hydrate enough to form a gluten network in cookies (Chevallier *et al.*, 2002), Pareyt *et al.* (2008) have shown a decrease in extractability of both glutenin and gliadin during baking, confirming that gluten is not functionally inert during cookie baking and that protein aggregation that results in the formation of gluten network takes place.

Cookie color

A desirable attribute of cookies is the golden-brown exterior, which is thought to be the result of the Maillard reaction (MR). MR is a type of non-enzymatic browning (NEB) that consists of a series of reactions involving condensation of a reducing sugar and an amine (McWilliams, 2017). The results of instrumental analysis of the surface color of cookies are presented in Table 4. The L values are an indicator of lightness and extent of NEB of the samples, i.e. low L values indicate darker color and more browning. Based on the L values, all cookie variations were light in color. There was no significant difference in the extent of browning among the four cookie variations. The b values (yellowness) showed similarity among the different cookie variations. There was some yellowness in cookies from all variations, albeit, it was slight. However, there was a significant difference in the a values

Table 3. Moisture, pH and density of sugar cookies

Cookie variation	Moisture (%)[cd] means ± SD	pH[cd] means ± SD	Density (g/cm^3)[cd] means
Control	3.4 ± 0.07[c]	7.0 ± 0.12[a]	0.67[a]
10% RS[ab]	3.7 ± 0.08[b]	6.9 ± 0.11[a]	0.53[b]
20% RS[ab]	3.9 ± 0.06[a]	6.9 ± 0.13[a]	0.53[b]
30% RS[ab]	4.0 ± 0.09[a]	6.9 ± 0.10[a]	0.55[b]
$Pr > F$	<0.001	0.21	<0.001

Notes: [a]RS = resistant starch; [b] = source of RS was Hi-maize© natural fiber (King Arthur Flour Company); [c] = data are mean values of three replicates; and [d] = means ± standard deviation (SD) followed by the same letter superscript within a column are not significantly different ($p \leq 0.05$) according to the ANOVA and Tukey's adjusted pair-wise comparisons (redness) of the cookies. The HAMRS containing cookies were redder than the control. This was more pronounced at the 30% flour replacement level. Despite this based on the low positive *a* values, none of the cookie variations were noticeably red. Overall, cookies made from all four formulations had a pale appearance. This is primarily because of the colorless nature of RS used in the formulation.

Although NEB can have a positive impact on the sensory attributes of cookies, it can also lead to the formation of undesirable MR reaction products, namely, hydroxymethylfurfural (HMF), a possible mutagen, and acrylamide, a mutagenic and carcinogenic compound (Capuano *et al.*, 2008). Leiva-Valenzuela *et al.* (2018) have shown that bake time can affect the development of NEB in cookies. In their study, the largest decrease in the *L* values happened in the cookie samples that were baked between 13 and 19 min. The cookies in the present study were baked for only 8 min. Another factor that can influence the extent of NEB is the pH (Ames, 1998). In general, as the pH increases, so does browning. The pH of all four cookie variations in this study was less than 7.0. To address inadequate surface browning, the recipe can be modified by replacing baking powder with sodium bicarbonate and an acid salt to increase the pH, while keeping the bake time the same. Previous research has shown that when ammonium bicarbonate is replaced with sodium bicarbonate, the pH of the cookies increased to greater than 9 and significantly less HMF is formed in the cookies (Gökmen *et al.*, 2008).

Sensory evaluation

The results of the sensory evaluation revealed that the control cookies received a lower rating on all attributes evaluated when compared to the HAMRS containing cookies (Table 5). These differences were statistically significant for appearance, texture and moistness at all replacement levels and for flavor at 30% replacement level. There was no significant difference in the preference ratings for appearance and flavor of the cookies when the 10%, 20% and 30% HAMRS replaced cookies were compared to each other. However, mean ratings for texture and moistness of the cookies progressively increased as the amount of RS incorporated in the cookies increased. The sensory data correlated well with the objective data, as texture analysis showed that there was a concomitant decrease in the hardness of cookies as the amount of HAMRS incorporated in the cookies increased. The HAMRS cookies were less hard and were moister, thus had higher acceptability scores. A large percentage of sensory panelists (42.5%) chose the 20% HAMRS cookies as their overall preference.

Table 4. Instrumental color assessment of top surface of sugar cookies

Cookie variation	L^c, means ± SD[fg]	a^d, means ± SD[fg]	b^e, means ± SD[fg]
Control	70.5 ± 6.8[a]	0.73 ± 0.17[b]	15.4 ± 0.43[a]
10% RS[ab]	66.8 ± 1.0[a]	1.3 ± 0.13[ab]	15.7 ± 0.30[a]
20% RS[ab]	68.0 ± 0.36[a]	0.99 ± 0.09[ab]	15.8 ± 0.34[a]
30% RS[ab]	64.6 ± 1.0[a]	1.5 ± 0.04[a]	15.2 ± 0.60[a]
$Pr > F$	0.44	0.04	0.50

Notes: [a]RS = resistant starch; b = source of RS was Hi-maize© natural fiber (King Arthur Flour Company); [c]*L* = lightness scale, where 0 = black and 100 = white; [d]*a* (where + = red, − = green and 0 is neutral); [e]*b* (where + = yellow, − = blue and 0 is neutral); [f] = data are mean values of nine replicates; [g] = means ± standard deviation followed by the same letter superscript within a column are not significantly different ($p \leq 0.05$) according to the ANOVA and Tukey's adjusted pair-wise comparisons

Nutrient composition

Although replacement of AP flour with HAMRS resulted in only a modest decrease in energy, it had a noticeable improvement on the fiber content of cookies (Table 7). Similar results have been reported for partial replacement of AP flour with potato flour in yogurt pie bread (Kumar, *et al.*, 2020). The daily value (DV) for dietary fiber is 28 g (Whitney and Rady Rolfes, 2019). For a food to be labeled as a "good source" of fiber, it must supply 10%–19% of the DV or a minimum of 2.8 g of fiber per serving. A food is considered an "excellent source" of fiber if it provides 20% or more or 5.6 g of fiber per serving

Table 5.
Sensory evaluation of sugar cookies[ABC]

	Appearance	Flavor	Texture	Moistness
Control	5.0 (± 1.5)[b]	5.0 (± 1.3)[b]	3.7 (± 1.6)[d]	2.8 (± 1.4)[c]
10% RS[DE]	5.8 (± 1.0)[a]	5.2 (± 1.2)[ab]	4.0 (± 1.7)[c]	3.4 (± 1.6)[b]
20% RS[DE]	5.7 (± 1.2)[a]	5.2 (± 1.1)[ab]	4.4 (± 1.5)[b]	4.1 (± 1.7)[a]
30% RS[DE]	5.7 (± 1.1)[a]	5.4 (± 1.2)[a]	4.8 (± 1.5)[a]	4.3 (± 1.6)[a]

Notes: [a]All sensory characteristics were evaluated using a seven-point hedonic scale, where 1 = dislike extremely and 7 = like extremely; [B] = Data is based on responses of randomly selected, untrained college student panelists (n = 115); [C] = means ± standard deviation followed by the same letter superscript within a column are not significantly different ($p \leq 0.05$) according to the paired t-tests; [D]RS = resistant starch; [E] = source of RS was Hi-maize© natural fiber (King Arthur Flour)

Table 6.
Overall consumer preference of sugar cookies[ab]

Sample	Frequency	Percent	Pr > χ^2
Control	13	14.5	0.007
10% RS[cd]	23	26.4	
20% RS[cd]	37	42.5	
30% RS[cd]	14	16.1	

Notes: [a] = In total, 87 of the 115 panelists indicated which cookie sample they overall preferred; [b] = chi-squared test was used to determine differences in preference of panelists for cookie variations; [c]RS = resistant starch; [d] = source of RS was Hi-maize© natural fiber (King Arthur Flour Company)

Table 7.
Nutrient composition of cookies[a]

Nutrient	Control	10% RS[bc]	20% RS[bc]	30% RS[bc]
Energy (kcal)	432	423	415	407
Protein (g)	4.6	4.3	4.0	3.6
Carbohydrate (g)	63.3	63.8	64.3	64.8
Total fat (g)	17.6	17.6	17.7	17.7
Saturated fat (g)	4.8	4.8	4.5	4.5
Dietary fiber (g)	0	2.3	4.6	6.9
Calcium (mg)	47.3	47.9	48.6	49.2
Sodium (mg)	306	306	307	307

Notes: [a] = Nutrient composition values provided per 100 g or two cookies; [b]RS = resistant starch; [c] = source of RS was Hi-maize© natural fiber (King Arthur Flour Company)

(Whitney and Rady Rolfes, 2019). Based on this, one serving of the 20% HAMRS cookies can be considered a "good source" of fiber, while the 30% HAMRS cookies are an "excellent source" of fiber. The latter is significant, as eating one serving or two sugar cookies enriched with HAMRS can help bridge the gap in dietary fiber intake, while slightly lowering the energy density of the diet.

Conclusions

This study has shown that Hi-maize© natural fiber is a viable option that can increase the fiber content of cookies without negatively affecting their sensory attributes. Although substituting part of the flour with the RS decreased cookie spread, it did not adversely affect any of the other physical characteristics of the cookies. The HAMRS cookies were less hard and had a softer texture, which are among desired cookie characteristics. Replacing up to 30% of the AP flour with the RS improved the appearance, texture and moistness of the cookies with no negative impact on flavor. Overall consumer acceptance of the HAMRS substituted cookies was good, especially at the 20% replacement level.

References

AACC (1983), *Method 10-50D*, American Association of Cereal Chemists, St. Paul, MN.

Academy of Nutrition and Dietetics (2015), "Position of the academy of nutrition and dietetics: health implications of dietary fiber", *Journal of the Academy of Nutrition and Dietetics*, Vol. 115 No. 11, pp. 1861-1870.

Ames, J.M. (1998), "Applications of the Maillard reaction in the food industry", *Food Chemistry*, Vol. 62 No. 4, pp. 431-439.

Baghurst, P.A., Baghurst, K.I. and Record, S.J. (1996), "Dietary fiber, non-starch polysaccharides and resistant starch: a review", *Food Australia*, Vol. 48 No. 3, pp. S3-S35.

Belcourt, L.A. and Labuza, T.P. (2007), "Effect of raffinose on sucrose recrystallization and textural changes in soft cookies", *Journal of Food Science*, Vol. 72 No. 1, pp. C65-C71.

Birkett, A.M. and Brown, I.L. (2008), "Resistant starch and health", in Hamaker, B.R. (Ed.), "*Technology of Functional Cereal Products*, CRC Press, Boca Raton, FL, pp. 63-85.

Capuano, E., Ferrigno, A., Acampa, I., Ait-Ameur, L. and Fogliano, V. (2008), "Characterization of the maillard reaction in bread crisps", *European Food Research and Technology*, Vol. 228 No. 2, pp. 311-319.

Chevallier, S., Della Valle, G., Colonna, P., Broyart, B. and Trystram, G. (2002), "Structural and chemical modifications of short dough during baking", *Journal of Cereal Science*, Vol. 35 No. 1, pp. 1-10.

Cordain, L., Eaton, S.B., Sebastian, A., Mann, N., Lindeberg, S., Watkins, B.A., O'Keefe, J.H. and Brand-Miller, J. (2005), "Origins and evolution of the Western diet: health implications for the 21st century", *The American Journal of Clinical Nutrition*, Vol. 81 No. 2, pp. 341-354.

Fuentes-Zaragoza, E., Riquelme-Navarrete, M.J., Sánchez-Zapata, E. and Pérez-Álvarez, J.A. (2010), "Resistant starch as a functional ingredient: a review", *Food Research International*, Vol. 43 No. 4, pp. 931-942.

Gökmen, V., Açar, Ö.Ç. and Serpen, A. and Morales, F. (2008), "Effect of leavening agents and sugars on the formation of hydroxymethylfurfural in cookies during baking", *European Food Research and Technology*, Vol. 226 No. 5, pp. 1031-1037.

Handa, C., Goomer, S. and Siddhu, A. (2012), "Physiochemical properties and sensory evaluation of fructoligosaccharide enriched cookies", *Journal of Food Science and Technology*, Vol. 49 No. 2, pp. 192-199.

Hoseney, R.C. and Rogers, D.E. (1994), "Mechanism of sugar functionality in cookies", in Faridi, H. (Ed.), *The Science of Cookie and Cracker Production*, Avi, New York, NY, pp. 203-226.

Kumar, D., Mu, T. and Ma, M. (2020), "Effects of potato flour on dough properties and quality of potato-wheat-yogurt pie bread", *Nutrition and Food Science*, Vol. 50 No. 5, pp. 885-901.

Laguna, L., Salvador, A., Sanz, T. and Fiszman, S.M. (2011), "Performance of a resistant starch rich ingredient in the baking and eating quality of short-dough biscuits", *Lwt – Food Science and Technology*, Vol. 44 No. 3, pp. 737-746.

Leiva-Valenzuela, G.A., Quilaqueo, M., Lagos, D., Estay, D. and Pedreschi, F. (2018), "Effect of formulation and baking conditions on the structure and development of non-enzymatic browning in biscuit models using images", *Journal of Food Science and Technology*, Vol. 55 No. 4, pp. 1234-1243.

McWilliams, M. (2017), *Foods: Experimental Perspective*, Prentice Hall Inc., Upper Saddle River, NJ.

Miller, R.A. and Hoseney, R.C. (1997), "Factors in hard wheat flour responsible for reduced cookie spread", *Cereal Chemistry Journal*, Vol. 74 No. 3, pp. 330-336.

Murphy, M.M., Spungen Douglass, J. and Birkett, A. (2008), "Resistant starch intakes in the United States", *Journal of the American Dietetic Association*, Vol. 108 No. 1, pp. 67-78.

Pareyt, B., Wilderjans, E., Goesaert, H., Brijs, K. and Delcour, J.A. (2008), "The role of gluten in a sugar-snap cookie system: a model approach based on gluten–starch blends", *Journal of Cereal Science*, Vol. 48 No. 3, pp. 863-869.

Premavalli, K.S., Roopa, S. and Bawa, A.S. (2006), "Resistant starch – a functional dietary fiber", *Indian Food Industry*, Vol. 25 No. 2, pp. 40-45.

Raigond, P., Ezekiel, R. and Raigond, B. (2015), "Resistant starch in food: a review", *Journal of the Science of Food and Agriculture*, Vol. 95 No. 10, pp. 1968-1978.

Sajilata, M.G., Singhal, R.S. and Kulkarni, P.R. (2006), "Resistant starch – a review", *Comprehensive Reviews in Food Science and Food Safety*, Vol. 5 No. 1, pp. 1-17.

Whitney, E. and Rady Rolfes, S. (2019), *Understanding Nutrition*, Cengage Learning Inc., Boston, MA.

Yamazaki, W.T. (1959), "The application of heat in the testing of flours for cookie quality", *Cereal Chemistry*, Vol. 36 No. 1, pp. 59-69.

Yeo, L.L. and Seib, P.A. (2009), "White pan bread and sugar-snap cookies containing wheat starch phosphate, a cross-linked resistant starch", *Cereal Chemistry Journal*, Vol. 86 No. 2, pp. 210-220.

Further reading

Conrad, A.M., Munro, D. (2008). Relationships Between Computer Self-Efficacy, Technology, Attitudes and Anxiety: Development of the Computer Technology Use Scale (CTUS), *Journal of Educational Computing Research*, Vol., 39, No. 2, pp. 51-73, doi: 10.2190/EC.39.1.d

About the authors

Arezoo Rojhani, PhD, RD, is Associate Professor and Director of the Undergraduate Program in Dietetics in the Department of Family and Consumer Sciences at Western Michigan University. Arezoo Rojhani is the corresponding author and can be contacted at: arezoo.rojhani@wmich.edu

Joshua Naranjo, PhD, is Professor in the Dietetics Program in the Department of Statistics at Western Michigan University.

Ping Ouyang is Assistant Professor and Director of the Graduate Program in Nutrition and Dietetics in the Department of Family and Consumer Sciences at Western Michigan University.