Food Research 7 (2) : 11 - 18 (April 2023)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Optimization of the recipe for composite flour-based sugar-free biscuits

[1]Khan, S., [2]Rustagi, S., [1]Kumari, A. and [1,*]Singh, A.

[1]Warner School of Food and Dairy Technology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (Allahabad), India- 211007
[2]Amity Institute of Food Technology, Amity University, India- 201313

Article history:
Received: 4 December 2021
Received in revised form: 20 January 2021
Accepted: 3 March 2022
Available Online: 8 March 2023

Keywords:
Composite flour,
Bakery product,
Sugar-free biscuit,
Polydextrose,
Guar-gum,
Design expert

DOI:
https://doi.org/10.26656/fr.2017.7(2).982

Abstract

Biscuits are widely consumed bakery products around the globe. Its excess consumption has led to many health problems such as diabetes, obesity, and cardiovascular diseases. Although sugar replacement may be a step in solving most health-related issues, the complication is in its formulation. It is tedious to replace sugar and prepare biscuits with quality attributes, including aeration, texture, and mouthfeel. The present study aimed to formulate composite flour-based sugar-free biscuits. A composite flour, millet-legume-based mixture, was used for biscuit preparation. The central composite design of response surface methodology (RSM) (Design Expert 11 version) was used to analyse the effect of eliminating sugar using polydextrose (A) (10-15%) and guar-gum (B) (0-1.5%) at different levels on physical (thickness and spread ratio) and textural (hardness and fracturability) attributes. The optimized biscuit was prepared, and the precision of the optimized biscuit was determined using a one-sample T-test in SPSS Statistics version 22. The optimization with the design expert resulted in the best solution, i.e., polydextrose (12.488%) and guar-gum (0.921%) with the highest desirability value of 0.993. The ANOVA, R^2, and R^2 adjusted values for thickness, spread ratio, hardness and fracturability showed that the formulated sugar-free biscuits were statistically significant. Sugar elimination from the control biscuits noticeably affects its physical and textural attributes. Biscuits prepared were of lesser diameter, spread ratio, comparable hardness and fracturability than control biscuits, mainly due to the composite flour used in the formulation of experimental biscuits. The protein present in the flour restricts the spread of sugar-free biscuits because of its higher binding capacity. However, the addition of polydextrose and guar-gum resulted in the preparation of accepted quality sugar-free biscuits. To conclude, the proposed sugar-free biscuits may be a solution to the present dietary recommendations and an alternative to healthy options for health management.

1. Introduction

Biscuits are convenient food products consumed globally as snacks for nutritional requirements, enjoyment, or gifts (Srivastava, 2010). Due to its low cost and longer shelf-life, it is preferred among rural and urban populations (Banerjee *et al.*, 2014). In biscuit preparation, the principal ingredients included wheat flour, sugar, fat, water, and salt which are mixed with other co-ingredients (baking powder, skimmed milk, emulsifier, and sodium metabisulphite) to form the dough containing a gluten network (Chevallier *et al.*, 2000). Although nutritionally rich and appealing, biscuits are not healthy due to their higher fat and sugar content. Consumption of a high quantity of fat and sugar is among the main reasons behind current health problems such as obesity, diabetes, and coronary heart diseases (Rippe and Angelopoulos, 2016; Cercato and Fonseca, 2019). Despite numerous health issues, the replacement of fat and sugar is difficult in biscuits as both are essential for physical and textural attributes. Fat provides flavour, and mouthfeel and contributes to appearance, palatability, texture, and lubricity, whereas sucrose is responsible for sweetness, volume and texture (Zoulias *et al.*, 2002). With increasing awareness, the demand for healthy products like low-fat, sugar-free, and high-fibre is growing. Of late, several researchers worked on reducing the fat and sugar content using different fat replacers and sugar-free in food products (Ho and

*Corresponding author.
Email: *avinash.singh@shiats.edu.in*

eISSN: 2550-2166
Published by Rynnye Lyan Resources

Pulsawat, 2020; Di Cairano *et al*., 2021).

Polydextrose is a low glycaemic index, a non-digestible polysaccharide composed of randomly cross-linked glucose and an energy value of only one kcal/g (do Carmo *et al*., 2016). It has been approved as a direct food additive by the US Food and Drug Administration for use as a nutrient supplement, texturizer, stabilizer or thickener, formulation aid, and humectant (Burdock and Flamm, 1999). It provides the bulk, appropriate textural, and mouthfeel qualities usually associated with sugar while lacking the sweet taste and caloric value connected with the conventional food ingredient (Aidoo *et al*., 2015). Polydextrose intake reduces glucose absorption in the small intestine and improves bowel function (Allingham, 1982). Due to its good processing performance and potential health benefits, it is widely used as a low-calorie bulking agent in various foods and a partial replacement for fat and sugar (Veena *et al*., 2015).

Guar gum is a natural non-ionic, water-soluble polysaccharide obtained from the guar plant. Guar gum is an essential non-calorie source of dietary fibre and one of the cheapest hydrocolloids in the food industry (BeMiller, 2009). It is used for increasing the dough yield in baked goods (Gujral *et al*., 2002). The addition of guar gum in cake and biscuit dough improves the machinability of the dough, easily removed from the mould, and can be easily sliced without crumbling (Mudgil *et al*., 2014).

The present research intended to prepare composite flour-based sugar-free biscuits with specific ingredient replacements, i.e., refined flour with millet-legume-based composite flour, to increase the fibre content of biscuits, sugar with sugar-free, and a slight reduction in fat with the carbohydrate-based fat replacer, i.e., polydextrose and guar-gum.

2. Materials and methods

2.1 Source of materials

A composite flour mixture used for biscuit preparation was obtained from our previous research (Khan *et al*., 2021). Litesse 2 (polydextrose) was procured from Danisco India Pvt Ltd. as the sample. Sugar-free Natura, Delicious cholesterol-free butter was obtained from the local market and Urban Platter guar-gum powder from an online purchase. Baking powder, baking soda, and ammonia were used from the bakery production laboratory (Assocom institute of bakery technology and management AIBTM, New Delhi, India).

2.2 Experimental design

The central composite design of response surface methodology (RSM) (Design Expert 11 version) was used to analyze the effect of eliminating sugar and using polydextrose (A) (10-15%) and guar-gum (B) (0-1.5%) at different levels (Table 1) of its weight percentage on physical and textural attributes of formulated sugar-free biscuits with 13 random treatments (Table 2). The range of the independent variables was based on previous literature (Chugh *et al*., 2013; Banerjee *et al*., 2014; Rana *et al*., 2020; Di Cairano *et al*., 2021) and preliminary trials. The physical and textural attributes of biscuits, i.e., thickness, spread ratio, hardness, and fracturability were the dependent variables.

Table 1. Experimental design using optimal mixture model of RSM for sugar-free biscuit.

S. no.	Independent variables	Symbol	Minimum (%)	Maximum (%)
1.	Polydextrose	A	10	15
2.	Guar-gum	B	0	1.5

2.3 Biscuit preparation

Control biscuits were prepared using refined flour (100%), butter (60%), sugar (50%), milk (15%), refined oil (4%), custard powder (2.5%), milk powder (2.5%), glucose powder (2.5%), baking powder (1.3%), baking soda (0.5%), ammonia (0.5%), essence (0.5%) (Table 3). KitchenAid stand mixer was used to prepare biscuits. Initially, creaming was done (mixing butter and sugar) at a medium speed, followed by gradually adding milk and oil into it, and lastly, all the dry ingredients were mixed to formulate dough. The dough was sheeted on a platform and cut into a round shape. Biscuits were placed on an oven tray and baked at 160°C for 14-16 mins. For the experimental biscuits (sugar-free biscuits) preparation, refined flour was replaced by composite flour comprising millets, legumes, and wheat (Khan *et al*., 2021), sugar-free (3%), butter (50%), milk powder (5%), milk (20%), water (15%), oil (2%) and baking powder (1.5%) (Table 3) standardized through trials, polydextrose, and guar-gum were mixed in the required proportion according to the response surface design (Table 2). Baking soda and ammonia were in constant quantity. Experimental biscuits were baked at 160°C for 22-24 mins. After baking, both biscuits were cooled, packed, and stored for further analysis.

2.4 Physical attributes

The diameter and thickness of the biscuits were measured using a vernier calliper. The average value of six biscuits from each treatment batch was taken to calculate the spread ratio (McWatters *et al*., 2003).

https://doi.org/10.26656/fr.2017.7(2).982

Table 2. Effect of independent variables on biscuits physical attributes and texture

Treatment	A (%)	B (%)	Diameter (mm)	Thickness (mm)	Spread Ratio (mm)	Hardness (g)	Fracturability (mm)
1	10	0	55.26	11.03	5.01	1382.08	15.33
2	15	0	55.35	9.8	5.75	1366.25	10.84
3	10	1.5	53.23	8.67	6.14	1948.4	7.93
4	15	1.5	52.9	8.92	5.93	2279.5	8.61
5	10	0.75	53.35	7.88	6.77	1696.5	7.19
6	15	0.75	54.23	8.33	6.51	2333.56	8.08
7	12.5	0	56.72	8.44	6.72	876.04	8.38
8	12.5	1.5	53.11	7.72	6.88	2715.84	7.19
9	12.5	0.75	51.37	7.37	6.97	1224.34	6.01
10	12.5	0.75	51.36	7.39	6.95	1216.11	6.25
11	12.5	0.75	51.38	7.01	7.33	1202.26	5.25
12	12.5	0.75	51.36	7.62	6.74	2221.34	6.64
13	12.5	0.75	51.32	7.47	6.87	1233.34	6.98
Control	0	0	57.84	6.11	9.466	1757.2	7.69

Independent variables A: Polydextrose, B: Guar-gum

$$\text{Spread ratio} = \text{diameter}/\text{thickness}$$

Table 3. Cookie formulation

S.no.	Ingredients	C (%)	SFB (%)
1	Refined flour	100	-
2	Composite flour	-	100
3	Butter	60	50
4	Sugar	50	-
5	Sugar-free	-	3
6	SMP	2.5	5
7	Custard powder	2.5	-
8	Glucose powder	2.5	-
9	Baking powder	1.3	1.5
10	Baking soda	0.5	0.5
11	Ammonia	0.5	0.5
12	Essence	0.5	0.5
13	Refined oil	4	2
14	Milk	15	15
15	Water	-	15

SMP: skim milk powder, C: control biscuit, SFB: sugar-free biscuits

2.5 Texture analysis

Texture Analyzer TA. HD Plus (Stable Micro Systems, Surrey, England) was used for the texture analysis of formulated biscuits. Six replicates from each treatment batch were picked to calculate the hardness and fracturability of the formulated biscuits as per the AACC method 74-09 (AACC, 2010). The mode of the test was compression, and the analyser was set to 'return to start' cycle with the following test conditions: pre-test speed of 1.00 mm/s, test speed of 3.00 mm/sec, post-test speed of 10 mm/s, a distance of probe was 5 mm, automatic trigger type force of 50 g was used, and method settings were maintained by adjusting data acquisition rate at 400 pps.

2.6 Statistical analysis

The obtained data were assessed for analysis of variance (ANOVA) and regression models using the Response Surface Methodology (Design-Expert software version 11, Stat-Ease Inc. Minneapolis, USA) to understand the effect of polydextrose (A) and guar-gum (B) on the physical and textural characteristics of the experimental biscuits. Second-order mixture polynomial was fitted to the data to get the regression equations. The statistical significance of the model was assessed using model analysis, lack of fit F- value, model F- value and coefficient of determination (R^2) (Weng, Liu, and Lin 2001). The linear, quadratic, and interactive effect of variables on the response was described at 1% and 5% levels of confidence.

2.7 Optimization

The optimization process was executed using the numerical method with the Design-Expert software (version 11, Stat-Ease Inc. Minneapolis, USA). The optimization objective was to find the best combination of polydextrose and guar-gum with desired physical and textural characteristics. In the optimization process, both the independent variables, namely polydextrose and guar -gum, were kept in range while within the responses, only the spread ratio was maximized, and the remaining parameters, i.e., thickness, hardness, and fracturability were kept in range. These parameters are a key index to measure the desirability function, a technique primarily employed in process optimization with multiple responses where desirability varies from 0 (lowest) to 1 (highest) (Myers *et al.*, 1995). The solution with the maximum desirability was selected for further experiments. Response surface graphs were generated showing the effect of different independent variables on responses. Experiment biscuits were prepared with optimal conditions of polydextrose and guar-gum, and their physical and textural attributes were analysed. The

https://doi.org/10.26656/fr.2017.7(2).982

experimental results were comprehended with predicted values from the fitted model. The precision of the model was established with a two-tailed, one-sample T-test using SPSS Statistics version 22 (IBM).

3. Results

3.1 Physical attributes

The thickness of the experimental biscuits ranges from 7.01 mm to 11.03 mm and the spread ratio from 5.007 mm to 7.325 mm (Table 2). Thickness is maximum for treatment 1 (polydextrose 10 %, guar gum 0) and minimum for treatment 11 (polydextrose 12.5%, guar gum 0.75%) in contrast to spreading ratio as a maximum is for treatment 11 (polydextrose 12.5% and guar gum 0.75%) and minimum for treatment 1 (polydextrose 10%, guar gum 0%) establishing an inverse relationship between both the physical attributes. The thickness and spread ratio of the control biscuit is 6.11 mm and 9.466 mm, respectively. The coefficient of thickness estimation shows that increasing levels of factor A and factor B are inversely proportional to the thickness of the biscuit. In contrast, the synergistic effect of both factors is positive (Table 4).

In contrast, the coefficient of estimation of the spread ratio displays increasing levels of factor A and factor B are directly proportional to the spread ratio of biscuits. However, the interactive effect of both factors is negative. The ANOVA reveals that model (quadratic) and model terms (A, B, AB, A^2, B^2) are significant for thickness ($p<0.01$) and spread ratio ($p<0.05$) of the biscuit establishing both the factors have a positive effect on thickness along with spread ratio. The 3D plots showing the impact of both factors on the thickness and spread ratio are shown in Figure 1. The R- squared and adjusted R-squared values for thickness are 0.9214 and 0.8652, and the spread ratio is 0.8407 and 0.7269, respectively (Table 4).

3.2 Textural analysis

The hardness of the biscuit ranges from 876.04 g to 2715.84 g. Maximum hardness is for treatment 8 (polydextrose 12.5%, guar gum 1.5%) and minimum for treatment 7 (polydextrose 12.5%, guar gum 0.0 %) (Table 2). The hardness of the control biscuit is 1757.2 g. The coefficient of estimation for hardness shows a linear positive effect of both factors on hardness. The ANOVA shows that the model (linear) and model terms (A and B) are significant ($p<0.05$) (Table 4), indicating a significant effect of both factors on the hardness of biscuits. The 3D plots showing the effect of factor A and factor B on the hardness of the biscuit are shown in Figure 1. The R- squared and adjusted R-squared values are 0.5087 and 0.4104 (Table 4), respectively.

Fracturability of the biscuit ranges from 5.25 mm to 15.33 mm. Maximum fracturability is for treatment 1 (polydextrose 10%, guar gum 0%) and minimum for treatment 11 (polydextrose 12.5%, guar gum 0.75%) (Table 2). The Fracturability of the control biscuit is 7.69 mm. The coefficient of estimation for fracturability shows that increasing levels of factor A and factor B are inversely proportional to fracturability while the interactive effect is positive. The ANOVA explains that the model (quadratic) and model terms (A, B, AB, A^2, B^2) are significant for fracturability ($p<0.01$) (Table 4). This indicates that both factors have a positive effect on fracturability. The 3D plots showing the effect of factor A and factor B on the fracturability of the biscuit are shown in Figure 1. The R- squared and adjusted R-squared values are 0.8737 and 0.7834 (Table 4), respectively.

Table 4. Coefficient of analysis and ANOVA model

Factor	Thickness	Spread ratio	Hardness	Fracturability
Intercept	7.26	7.08	1668.89	6.02
A	-0.0883	0.0468	158.72	-0.4867
B	-0.6600	0.2438	553.23	-1.80
AB	0.3700	-0.2380		1.29
A^2	1.12	-0.6988		2.13
B^2	1.09	-0.5388		2.28
Model				
Type	quadratic	quadratic	linear	quadratic
F- value	16.41	7.39	5.18	9.68
p- value	0.0010**	0.0103*	0.0286*	0.0048**
Lack of fit	ns	ns	ns	ns
R^2	0.9214	0.8407	0.5087	0.8737

ns: non-significant, s: significant, * significant at 5% ($p<0.05$); ** significant at 1 % ($p<0.01$)

https://doi.org/10.26656/fr.2017.7(2).982

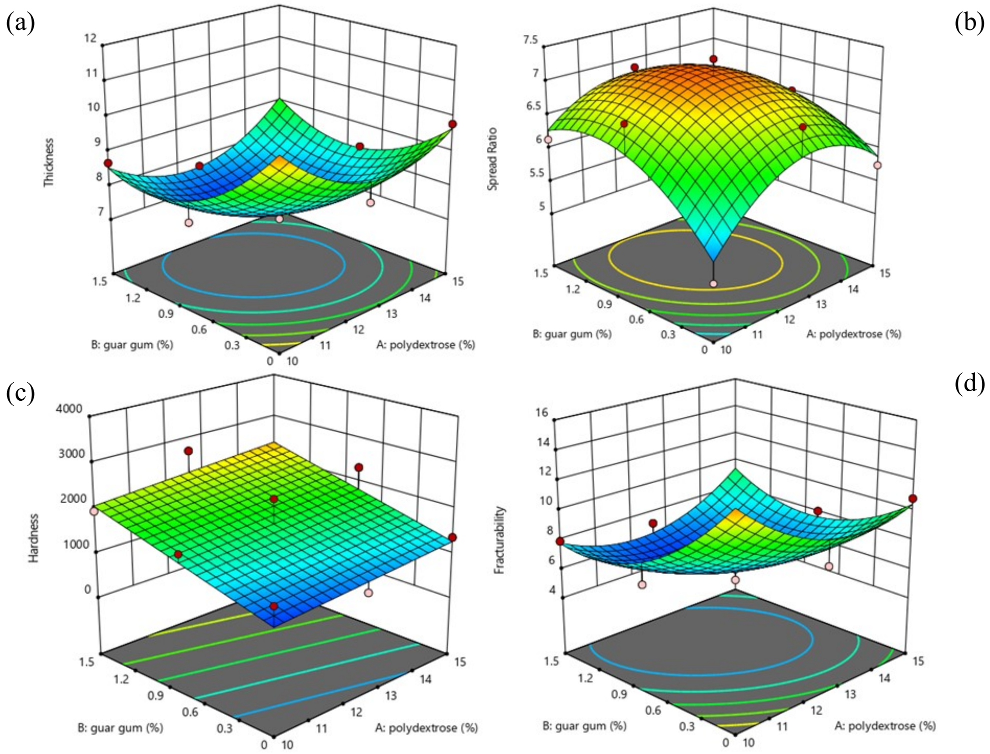

Figure 1. 3D plots showing the effect of polydextrose and guar-gum on (a) thickness (b) spread ratio (c) hardness and (d) fracturability of biscuits/cookies.

4. Discussion

4.1 Effect of independent variables on physical attributes of biscuits

The physical attributes of biscuits are the primary and significant parameters that appeal to consumers. In general, biscuits with a higher spread ratio are preferred (Igbabul *et al*., 2018). This is achieved by the sucrose present in the biscuit. Control biscuits containing soft flour and sucrose had the highest diameter (57.84 mm), lesser thickness (6.11 mm), and more excellent spread ratio (9.466 mm). The presence of high sugar and fat is the primary reason for the greater diameter and spread ratio. During baking, sugar left undissolved melts, decreasing the dough's viscosity, leading to the larger diameter and spread ratio of control biscuits. During the mixing of ingredients, sugar hinders gluten development in dough. It competes with gluten protein over water, resulting in lesser biscuit thickness (Handa *et al*., 2012; Ho and Pulsawat, 2020).

Experimental biscuits have less diameter, spread ratio, and thickness in comparison with control biscuits which might be attributed to the use of composite flour in the formulation of experimental biscuits. The higher binding capacity of protein present in the flour restricts the spread of the experimental biscuits. AL-Ansi *et al.* (2018) also established a low spread ratio and increased thickness of cookies on replacing wheat flour with millet flour, lentil flour, and whole wheat flour. Akter *et al.* (2020) also reported a decrease in the spread ratio of biscuits on incorporating protein concentrate in flour. A similar reduction in spread ratio was also recognized by Chugh and Kumbhar (2016) on the increasing quantity of sugar and fat replacer. Apart from composite flour used in biscuit making, the absence of sugar is another factor influencing dough viscosity and resulting in a low spread ratio.

The 3D plot of Figures (a) and (b) show the effect of polydextrose (factor A) and guar-gum (factor B) on the thickness and spread ratio of biscuits simultaneously. Figure 1 (a) illustrated the maximum thickness at starting of the graph when both factors were at minimum levels. As the levels of both factors increase, thickness also increases and falls in the end. This indicates thickness decreases with an increase in both factors, and a non-significant increase was observed at the end of the graph. In Figure 1 (b) spread ratio increases as the level of both factors increases, and reaches a maximum level, with subsequent fall.

4.2 Effect of independent variables on the texture of biscuits

Textural qualities are essential attributes that determine the eating quality of a product. Among the various textural parameters for biscuits, hardness is considered an important characteristic measured as the peak force needed to snap the biscuit (Cheng and Bhat, 2016). The breaking strength of biscuits is a factor that defines how they work when placed in the mouth and pressed in between the teeth; moderate crackling strength and crisp mouthfeel are the key elements that verify the level of acceptability by consumers. The average intensity of breaking strength is the practical

https://doi.org/10.26656/fr.2017.7(2).982

characteristic operated through the percentage of fat proportion and moisture utilized in biscuit preparation before baking. Later on, acquired moisture during storage resulted in sogginess, which alters mouthfeel, lower breaking strength values, and acceptability (Park *et al*., 2015; Parul *et al*., 2015; AL-Ansi *et al*., 2018).

The texture profile of cookies was analysed for hardness and fracturability. Sucrose acts as a hardening agent, it makes the biscuit crisp by crystallisation (Chevallier *et al*., 2000). There was a significant difference in hardness and fracturability of 100% sucrose and sugar-free cookies (Handa *et al*., 2012). In this study, the complete removal of sugar from the experimental biscuits resulted in a comparable hardness and fracturability with control biscuits due to the high protein content and strong binding of starch present in the composite flour. This is in line with previous studies, where the use of composite flour resulted in higher hardness of biscuits in sucrose-containing cookies (Park *et al*., 2015; Parul *et al*., 2015; AL-Ansi *et al*., 2018).

The 3D plots of Figures 1 (c) and (d) show the effect of both factors on the hardness and fracturability of biscuits simultaneously. Figure 1(c) shows the linear effect of both factors on hardness indicating as the level of both factors increases, hardness also increases whereas figure 1(d) shows the highest fracturability at initial levels of both factors which decreases with increasing levels of both the factors and a non-significant increase is recorded towards the end.

4.3 Optimization of sugar-free biscuits

Optimization of sugar-free biscuits resulted in a desirability value of 0.993. This desirability value corresponds to the conditions: polydextrose 12.485% and Guar-gum 0.921% with predicted value by design for thickness 7.17 mm, spread ratio 7.10 mm, hardness 1794.22 g, and fracturability 5.73 mm (Table 5). A desirability value > 0.7 is considered to be excellent (Carrera 1998). The experiment is carried out with the optimal conditions of biscuit. The physical and textural attributes were analysed and compared with the predicted values to validate the model obtained. There is no significant difference between the predicted values and the validated values. (Table 5). Therefore, the model used in each response resonates with the optimal level of polydextrose and guar-gum to formulate composite flour -based sugar-free biscuits.

Table 5. Comparison of observed and predicted values of optimized sugar-free biscuits.

Response	Predicted value	Actual value±SD
Thickness (mm)	7.17	7.14±0.015
Spread ratio (mm)	7.10	7.09±0.015
Hardness (g)	1793.58	1793.56±0.01
Fracturability (mm)	5.73	5.71± 0.01

5. Conclusion

Replacement of sugar from bakery products is challenging because it gives taste to the product and determines the physical and textural attributes. At the same time, the adverse effects of sugar on health cannot be ignored, which brings a need for its replacement. This study efficaciously prepared sugar-free biscuits with accepted physical and textural attributes. Polydextrose and guar-gum have a significant effect on these attributes. The results show a decrease in the spread ratio of the biscuits in comparison to the control, which is not desirable. Apart from complete sugar replacement, this study successfully replaced 10% fat from the control biscuits without sacrificing the textural quality of the experimental biscuits. The use of composite flour containing millets and legumes further adds sugar-free biscuits as a healthy choice for diabetic and health-conscious consumers. Together these shifts may help the bakery industry achieve a healthy outlook from customers and hopefully improve the health infrastructure affected by the consumption of bakery products.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors duly acknowledge Er. Saumya Choudhary, Scientist B, ICMR-National Institute of Pathology, New Delhi, for editing the manuscript.

References

AACC. (2010). American Association of Cereal Chemists International Approved Method of Analysis 11th ed. Minnesota, USA: AACC.

Aidoo, R.P., Afoakwa, E.O. and Dewettinck, K. (2015). Rheological properties, melting behaviours and physical quality characteristics of sugar-free chocolates processed using inulin/polydextrose bulking mixtures sweetened with stevia and thaumatin extracts. *LWT - Food Science and Technology*, 62(1), 592–597. https://doi.org/10.1016/j.lwt.2014.08.043

Akter, D., Begum, R., Rahman, M.N., Talukder, N. and Alam, M.J. (2020). Optimization of Extraction Process Parameter for Rice Bran Protein Concentrate and its Utilization in High Protein Biscuit Formulation. *Current Research in Nutrition* and

Food Science Journal, 8(2), 596–608. https://doi.org/10.12944/CRNFSJ.8.2.25

AL-Ansi, W., Ali Mahdi, A., Li, Y., Qian, H. and Wang, L. (2018). Optimization and Acceptability Evaluation of Shapporah Biscuits Formulated by Different Ingredients: Using Response Surface Methodology (RSM). *Journal of Food* and *Nutrition Research*, 6(3), 192–199. https://doi.org/10.12691/jfnr-6-3-9

Allingham, R.P. (1982). Polydextrose—A new food ingredient: Technical aspects. Vol. 293. New York, USA: Academic Press. https://doi.org/10.1016/B978-0-12-169080-9.50019-4

Banerjee, C., Singh, R., Jha, A. and Mitra, J. (2014). Effect of inulin on textural and sensory characteristics of sorghum based high fibre biscuits using response surface methodology. *Journal of Food Science* and *Technology*, 51(10), 2762–2768.

BeMiller, J.N. (2009). One hundred years of commercial food carbohydrates in the United States. *Journal of Agricultural* and *Food Chemistry*, 57(18), 8125–8129. https://doi.org/10.1021/jf8039236

Burdock, G.A. and Flamm, W.G. (1999). A review of the studies of the safety of polydextrose in food, *Food* and *Chemical Toxicology*, 37(2–3), 233–264. https://doi.org/10.1016/S0278-6915(98)00113-6

Carrera, G.F. (1998). *Diseño y análisis de experimentos industriales*. Mexico: Universidad Iberoamericana. [In Spanish].

Cercato, C. and Fonseca, F.A. (2019). Cardiovascular risk and obesity. *Diabetology and Metabolic Syndrome*, 11(1) 74. https://doi.org/10.1186/s13098-019-0468-0

Cheng, Y.F. and Bhat, R. (2016). Functional, physicochemical and sensory properties of novel cookies produced by utilizing underutilized jering (*Pithecellobium jiringa* Jack.) legume flour. *Food Bioscience*, 14, 54–61. https://doi.org/10.1016/j.fbio.2016.03.002

Chevallier, S., Colonna, P., Della, V.G. and Lourdin, D. (2000). Contribution of major ingredients during baking of biscuit dough systems. *Journal of Cereal Science*, 31(3), 241–252. https://doi.org/10.1006/jcrs.2000.0308

Chugh, B., Singh, G. and Kumbhar, B.K. (2016). Optimization of ingredients for development of low-fat biscuits using response surface methodology. *Journal of Food Industrial Microbiology*, 2(1), 1000110.

Chugh, B., Singh, G. and Kumbhar, B.K. (2013). Development of low-fat soft dough biscuits using carbohydrate-based fat replacers. *International Journal of Food Science*, 2013, 576153. https://doi.org/10.1155/2013/576153

Di Cairano, M., Caruso, M.C., Galgano, F., Favati, F., Ekere, N. and Tchuenbou-Magaia, F. (2021). Effect of sucrose replacement and resistant starch addition on textural properties of gluten-free doughs and biscuits. *European Food Research* and *Technology*, 247(3), 707–718. https://doi.org/10.1007/s00217-020-03659-w

do Carmo, M.M.R., Walker, J.C.L., Novello, D., Caselato, V. M., Sgarbieri, V. C., Ouwehand, A.C., Andrello, N.A., Hiane, P.A. and Dos Santos, E.F. (2016). Polydextrose: Physiological function, and effects on health. *Nutrients*, 8(9), 553. https://doi.org/10.3390/nu8090553

Gujral, H.S., Sharma, A. and Singh, N. (2002). Effect of Hydrocolloids, Storage Temperature, and Duration on the Consistency of Tomato Ketchup, *International Journal of Food Properties*, 5(1), 179–191. https://doi.org/10.1081/JFP-120015600

Handa, C., Goomer, S. and Siddhu, A. (2012). Physicochemical properties and sensory evaluation of fructoligosaccharide enriched cookies. *Journal of Food Science* and *Technology*, 49(2), 192–199. https://doi.org/10.1007/s13197-011-0277-4

Ho, L.H. and Pulsawat, M.M. (2020). Effects of partial sugar replacement on the physicochemical and sensory properties of low sugar cookies. *International Food Research Journal*, 27 (3), 557-567.

Igbabul, B., Ogunleye, R. and Amove, J. (2018). Quality Characteristics of Cookies Prepared from Wheat and Fermented Afzelia Africana Flour. *American Journal of Food Science* and *Technology*, 6(6), 247-252. https://doi.org/10.12691/ajfst-6-6-3

Khan, S., Rustagi, S., Singh, A. and Devi, P. (2021). Optimization of Millet-Legume Based Composite Flour, Its Rheology and Use as Pro-Health Ingredient in Bakery Industry. *Plant Archives,* 21(2), 35-43. https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no2.006

McWatters, K.H., Ouedraogo, J.B., Resurreccion, A.V.A., Hung, Y.-C. and Phillips, R.D. (2003). Physical and sensory characteristics of sugar cookies containing mixtures of wheat, fonio (*Digitaria exilis*) and cowpea (*Vigna unguiculata*) flours. *International Journal of Food Science* and *Technology*, 38(4), 403–410. https://doi.org/10.1046/j.1365-2621.2003.00716.x

Mudgil, D., Barak, S. and Khatkar, B.S. (2014). Guar gum: processing, properties and food applications—A Review. *Journal of Food Science* and *Technology*, 51(3), 409–418. https://doi.org/10.1007/s13197-011-0522-x

Myers, H.R., Montgomery, D.C. and Anderson-Cook, C.M. (1995). Response Surface Methodology: Process and Product Optimization Using Designed Experiments. 4th Ed. Wiley.

Park, J., Choi, I. and Kim, Y. (2015). Cookies formulated from fresh okara using starch, soy flour and hydroxypropyl methylcellulose have high quality and nutritional value. *LWT – Food Science* and *Technology*, 63(1), 660–666. https://doi.org/10.1016/j.lwt.2015.03.110

Parul, S., Rakhi, S., Alok, J., Prasad, R. and Ak, G. (2015). Optimization of a process for high fibre and high protein biscuit. *Journal of Food Science* and *Technology*, 52(3), 1394-1403. https://doi.org/10.1007/s13197-013-1139-z

Rana, S., Chandra Das, P., Yeasmin, F. and Islam, M. (2020). Effect of polydextrose and stevia on quality characteristics of low-calorie biscuits. *Food Research*, 4(6), 2011–2019. https://doi.org/10.26656/fr.2017.4(6).223

Rippe, J.M. and Angelopoulos, T.J. (2016). Sugars, obesity, and cardiovascular disease: results from recent randomized control trials. *European Journal of Nutrition*, 55(2), 45–53. https://doi.org/10.1007/s00394-016-1257-2

Srivastava, Y. (2010). Effect of Virgin Coconut Meal (VCM) on the Textural, Thermal and Physico Chemical Properties of Biscuits. *Food* and *Nutrition Sciences*, 1(2), 38–44. https://doi.org/10.4236/fns.2010.12007

Veena, N., Nath, S. and Arora, S. (2016). Polydextrose as a functional ingredient and its food applications: a review. *Indian Journal of Dairy Science*, 69(3), 239-251.

Weng, W.-L., Liu, Y.-C. and Lin, C.-W. (2001). Studies on the Optimum Models of the Dairy Product Kou Woan Lao Using Response Surface Methodology. *Asian-Australasian Journal of Animal Sciences*, 14 (10), 1470–1476. https://doi.org/10.5713/ajas.2001.1470

Zoulias, E.I., Oreopoulou, V. and Tzia, C. (2002). Textural properties of low-fat cookies containing carbohydrate- or protein-based fat replacers. *Journal of Food Engineering*, 55(4), 337–342. https://doi.org/10.1016/S0260-8774(02)00111-5

