Journal of
Food Chemistry & Nanotechnology

https://doi.org/10.17756/jfcn.2024-s1-001

Research Article

Open Access

Effect of Flaxseed Gel as an Egg Substitute on the Functional Properties of Cake: A Comparative Analysis

Vishal Sharma[1], Monica Premi[2], Vikas Bansal[3], Ajay Bhardwaj[1], Narendra Tripathi[4] and Naveen Kumar[5*]

[1]*Amity University, Jaipur, Rajasthan, India*
[2]*School of Life Sciences, Manipal Academy of Higher Education, Dubai*
[3]*Jaipur National University, Jaipur, Rajasthan, India*
[4]*BACFO Pharmaceutical (India) Ltd., Noida, India*
[5]*Chitkara University Research and Innovation Network (CURIN), Chitkara University, Punjab, India*

***Correspondence to:**
Naveen Kumar
Chitkara University Research and Innovation Network (CURIN),
Chitkara University,
Punjab, India.
E-mail: nkft87@gmail.com

Received: November 23, 2023
Accepted: March 01, 2024
Published: March 06, 2024

Citation: Sharma V, Premi M, Bansal V, Bhardwaj A, Tripathi N, et al. 2024. Effect of Flaxseed Gel as an Egg Substitute on the Functional Properties of Cake: A Comparative Analysis. *J Food Chem Nanotechnol* 10(S1): S1-S6.

Copyright: © 2024 Sharma et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY) (https://creativecommons.org/licenses/by/4.0/) which permits commercial use, including reproduction, adaptation, and distribution of the article provided the original author and source are credited

Published by United Scientific Group

Abstract

Eggs are the primary ingredient responsible for the nutritional value and textural properties of bakery products. However, some consumers nowadays are more interested in health benefits and healthy vegan alternatives. The study's main goal was to assess the qualities of baked cakes using flaxseed gel (FSG) in varied proportions in place of eggs. The cake was made using the original egg composition as the control sample, and other cake formulations were made using FSG in place of fresh eggs (w/w) at replacement levels of 20%, 40%, 50%, 60%, 80%, and 100%. All cakes were evaluated for cake height, volume, moisture content, texture characteristics (toughness, cohesiveness, springiness, and adhesion), and consumer acceptance. The use of FSG in place of fresh eggs had a statistically significant impact, according to present investigation of the physico-textural properties and overall acceptability. When compared to a control sample, FSG had no detrimental effects on the overall nutritional value of cake recipes. Cake height and textural qualities (such as hardness, cohesiveness, springiness, and stickiness) were not significantly different; however, FSG increased the cake's total fiber content to a level of 50% replacement. It proves that cakes formulated with FSG as a fresh egg replacement are comparable to the control cake in terms of moisture and texture, can be used successfully as an egg substitute in cake compositions up to 50%, and provide a sustainable alternative for egg replacement.

Keywords

Cake, Egg replacement, Flaxseed gel, Physical properties, Sensory properties

Introduction

Cakes represent a distinct culinary category that is well-recognized and appreciated in a variety of cultures around the world, demonstrating a substantial increase in the international market. Cakes come in a variety of categories and forms, but they are all made with the same basic ingredients: wheat flour, fats, sugar, milk powder, and eggs. Eggs are mainly responsible for imparting the cake's textural characteristics as well as maintaining the batter's foaming and emulsifying capacity [1].

Nowadays, a lot of people eat muffins, cream cakes, and sponge cakes. Research has shown that eggs have perishable qualities, which is why the food industry is reluctant to use egg applications in bread goods. Additionally, a specific customer has objections to consuming eggs because of their religious beliefs and health issues related to an egg allergy or personal lifestyle choices [2].

Egg white protein contributes to the texture of bakery items by producing

emulsions, stabilizing foams, and forming gels. Fresh eggs are protein-rich and contain high quality nutrients; they have long been regarded as foods fit for humans. Eggs improve the flavor and texture of food products [3].

Flaxseed is an ancient plant which is currently employed in both manufacturing and food production [4]. According to Hussain et al. [5], flaxseed has a crude protein content of roughly 8%, making it a useful food ingredient. Because of its high protein (albumin and globulin) content, flaxseed has been used as an egg substitute in numerous plant-based dishes, demonstrating its suitability for baking [6]. Flaxseed is a good source of polyunsaturated fatty acids and may meet dietary needs, with a high ratio of omega-3 to omega-6 [7]. Flaxseed protein reduces plasma triacyl-glycerides and cholesterol [8]. The sensory properties of flax hermit cookies and flax muffins remained unaffected by the addition of 9 - 11% flaxseed. Whereas, when it was substituted with 40% level flour, no significant difference was observed in the muffin [9].

Bakery businesses are currently working on egg replacers that will reduce the number of eggs in the finished baked good in accordance with all the concerns mentioned above. Eggs are a cheaper and more readily available source of protein for non-vegans, whereas flaxseed powder is a more affordable source of protein for vegans. Therefore, the objective of this study was to develop FSG as an egg substitute for cakes of various compositions and utilize it as an egg replacer in cakes by evaluating its functional and structural properties in different proportions in cake samples with respect to the control sample.

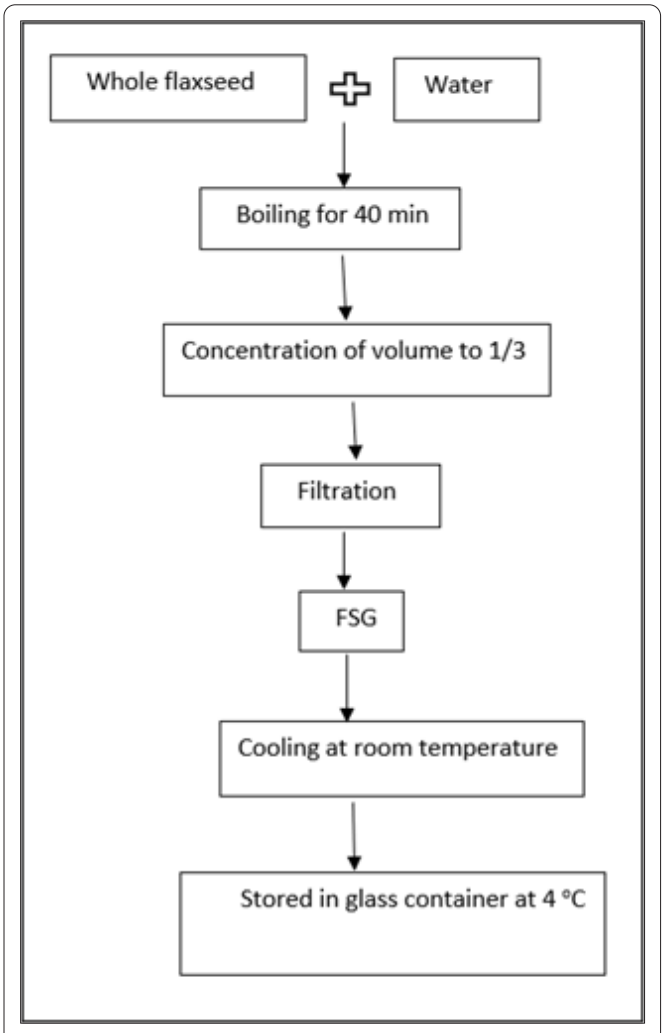


Figure 1: Preparation of FSG.

Materials and Methods

Sample collection

Dry cake mix was bought from the market (Pristine Brand, IFFCO Group, UAE). A control sample was made by mixing cake mix with fresh eggs (Al Khaleej Eggs, UAE) and sunflower oil (ERCO, IFFCO, UAE). Flaxseed was purchased from a local supermarket (Earth Goods Golden Flaxseed, UAE).

FSG preparation

FSG was produced in the lab by boiling whole flaxseed with water as depicted in figure 1. The whole flaxseed was mixed with water and boiled for 40 min. The concentration was reduced by 1/3, and the mix was filtered and cooled to room temperature. After cooling, the FSG was stored under refrigeration conditions (4 ± 1 ˚C) in a glass container.

Cake preparation

All formulations for cake preparations are mentioned in table 1. A control sample was prepared with 100% fresh eggs, and in another sample, eggs were substituted by FSG at levels of 20%, 40%, 50%, 60%, 80%, and 100% (w/w). The standard industrial cream cake method was used to prepare the batter by using a planetary mixer as depicted in figure 2. Dry mix and eggs/FSG were pre-weighed accurately, mixed for 1 min on

Table 1: Formulation of cake.

S. No.	Ingredient (g/100 g)	Cake formulations						
		Control	FSG20	FSG40	FSG50	FSG60	FSG80	FSG100
1	Cake mix	53.3	53.3	53.3	53.3	53.3	53.3	53.3
2	Fresh egg	**18.7**	**14.93**	**11.20**	**9.33**	**7.47**	**3.73**	**0.00**
3	FSG	**0.0**	**3.73**	**7.47**	**9.33**	**11.20**	**14.93**	**18.67**
4	Oil	16.0	16.0	16.0	16.0	16.0	16.0	16.0
5	Filtered water	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Note: Bold values indicate replacement level of fresh egg with FSG. [a]Control, FSG20, FSG40, FSG50, FSG60, FSG80 and FSG100; cake prepared with replacement level of 0, 20, 40, 50, 60, 80 and 100% of fresh egg, respectively.

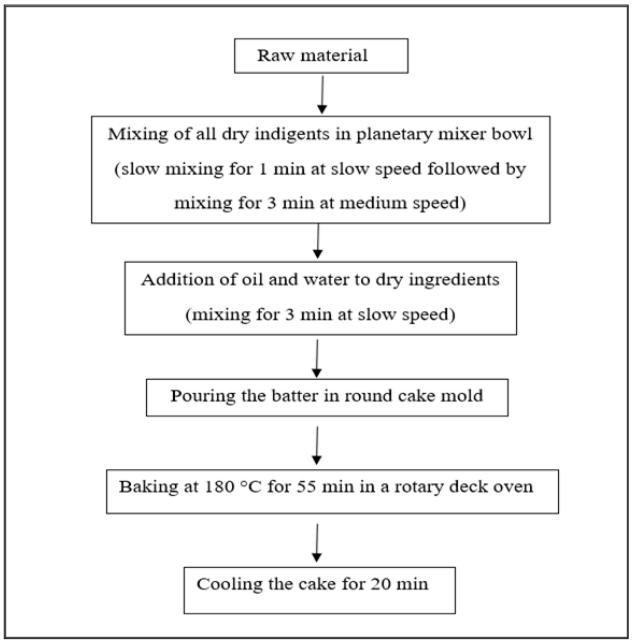


Figure 2: Preparation of cake.

slow speed, and then mixed on medium speed for 3 min. After this, the bowl was scraped down and again mixed with oil and water on slow speed for 3 min. 250 g batter from each sample in 2 sets was poured into a 6-in round cake pan and baked at a temperature of 180 ˚C for 55 min in a rotary deck oven. After the baking process, cakes were cooled for 20 min, removed from baking pans, and cooled further for an hour. One set of each sample was coded and stored in plastic bags. Sensory analysis took place after 4 to 6 h of cooling.

Physical characteristics of batter

The physical characteristics of control and FSG batters, such as batter density, pH, and viscosity, were calculated. After mixing by the creaming method, the sponge batter (η) viscosity was determined at 25 ± 0.1 ˚C using the Brookfield viscometer (LV spindle, RVDV-E 230, Brookfield Engineering Laboratories, Inc., USA) at a rotational speed of 30 rpm.

The density of batter is indicative of the level of aeration, or air circulation, enabling bakers to assess whether it is excessively compact or not. The batter density of each batter sample was measured by dividing the weight of the cake batter by the volume of the cake [10]. The pH of each sample was determined by using a calibrated pH meter at 25 ˚C.

Nutritional characteristics of cake

A complete proximate analysis was performed for all samples except FSG80 and FSG100, along with sodium, phosphorous, and aluminum, according to the methods cited in table 2. Total cholesterol and omega-3 fatty acids were also analyzed to confirm the impact of FSG on baked cakes.

Functional characteristics of cake

Cake yield rates were calculated based on the weight difference between pre- and post-baking cakes. After baking, the physical measurements were analyzed for each sample except

Table 2: Nutritional parameters analyzed and its units.

Parameter analyzed	Reference method	Unit
Moisture	AOAC 925.10	%
Ash	AOAC 923.03	%
Fat	AOAC 922.06	%
Protein	AOAC 950.36	%
Carbohydrate	-	%
Energy	-	kcal/100 g
Sodium	AOAC 985.01	mg/100 g
Aluminum	AOAC 985.01	mg/100 g
Total sugar	AOAC 980.13	g/100 g
Cholesterol	AOAC 994.10	mg/100 g
Dietary fiber	AOAC 985.29	g/100 g
Phosphate	HACH	mg/100 g
Omega-3 fatty acids	AOAC 996.06	g/100 g

FSG80 and FSG100. Specific volume was determined by the rapeseed displacement method [11] and results were expressed as mean values. Textural properties like hardness and firmness of the sample cakes were analyzed by a textural profile analyzer (TA-XTplus, Stable Micro Systems, Surrey, UK). Moisture for all samples was analyzed by the standard oven method. There was a visible variation observed for FSG80 and FSG100, hence they were excluded from the analysis.

Sensory evaluation

Twenty-five semi trained working adults consumed cake as part of the sensory evaluation for the baked cake samples. For testing, each round cake was sliced by hand using an appropriate knife. For testing purposes, the crust was not removed. Each semi-trained panelist assessed four samples simultaneously (one control and one at each of the three replacement levels). The taste (mouth), color (visual), texture (mouth), and overall acceptability of the samples were assessed. Participants used a seven-point hedonic scale to rate their feelings: like extremely, neither dislike nor like, and dislike highly. Based on the score given, overall acceptability was measured.

Statistical evaluation

Each parameter was tested in triplicate and the results were expressed as means with a standard deviation. The statistical analysis of the results was conducted using ANOVA with the assistance of Statistica 8.0 software (Statsoft Inc., Tulsa, USA, 2007). A statistically significant difference was identified by using the method of Duncan's multiple range test at a significant level of $p \leq 0.05$.

Results and Discussion

Physical attributes of batter

Changes in the physical attributes of cake batter with respect to changes in fresh eggs with FSG are shown in table 3. The result shows that there are no significant changes observed in batter properties like pH and density up to the egg replacement level of 50% with FSG. Also, there is a slight increase in viscosity after 50% FSG addition as an egg replacement. The findings are in line with Lorenc et al. [12] conclusion that FSG can increase the viscosity of bakery products. The prima-

Table 3: Physical and rheological characteristics of batter.

Batter characters	Control	FSG20	FSG40	FSG50	FSG60
Batter density (g/ml)	1.02 ± 0.02[a]	1.04 ± 0.01[a]	1.04 ± 0.01[a]	1.06 ± 0.03[a]	1.06 ± 0.05[a]
Batter pH	7.21 ± 0.78[a]	7.19 ± 0.92[a]	7.27 ± 0.47[a]	7.25 ± 1.2[a]	7.24 ± 0.85[a]
Viscosity (Cp)	48400 ± 250[a]	48190 ± 130[b]	48250 ± 149[b]	48300 ± 214[b]	48900 ± 178[c]

Note: Different letters in the same row indicate significant differences, $p < 0.05$.

ry cause of this may be FSG, which is typically characterized by high viscosity (rheological characteristics or factors including viscosity, shear-thinning, and Newtonian flow) [13].

Nutrition parameters of cake

The effect of replacement of fresh eggs with FSG on nutritional parameters of baked cake was shown in table 4. FSG has more water binding capacity than egg, as there was a slight increment in final moisture content of the cake with respect to FSG addition. There was significant change in total ash content as ash content is slightly decreasing with incremental level of FSG. Total fat content was increasing with increased level of FSG, which also impart to maintain the total energy level of the baked cake. There was a significant decrease in protein and carbohydrates as increasing the level of FSG and decrease in egg level. Flaxseed has a relatively low carbohydrate content (1 g/100 g), making a very small contribution to daily carbohydrate consumption [14].

There was a noticeable drop with an increased level of FSG as an egg replacer, even though fresh eggs are a strong source of minerals including sodium, magnesium, and phosphorus at 124 mg, 10 mg, and 172 mg per 100 g, respectively. FSG is a rich source of minerals, particularly phosphorous (650 mg/100 g), calcium (236 - 250 mg/100 g), and a very low amount of sodium (27 mg/100 g) [14]. The cholesterol level of the baked cake was reported to have significantly decreased with a reduction in eggs replaced by FSG. Also, omega-3 fatty acids have a significant increase in baked goods with increasing levels of FSG. Additionally, flaxseed is well-known for providing plant-based eaters with omega-3 fatty acids. According to Gutte et al. [15], oleic acid, 17% linoleic acid, and 53% linolenic acid make up most of the lipids in flaxseed.

Physical properties of cake

Table 5 reports that there were no significant changes in cake volumes with egg replacement by 20%, 40% and 50%. Although, there was a slight variation observed in overall cake volumes and cake heights from center and sides with FSG replacement with 60% level. There are no significant changes in cake texture with egg replacement by 20%, 40% and 50%. There was a variation observed in overall cake texture, as there are cracks in cake surface with FSG replacement with 60% level. Lorenc et al. [12] also found similar results and concluded that using FSG's high water and oil binding capacities to improve baked goods' texture is a good idea.

Table 4: Nutritional parameters of cake.

Nutrient content/100 g	Control	FSG20	FSG40	FSG50	FSG60
Moisture (%)	21.7 ± 0.15[a]	22.7± 0.17[a]	23.4 ± 0.18[b]	23.3 ± 0.15[b]	23.2 ± 0.16[b]
Ash (%)	2.32 ± 0.01[a]	1.65 ± 0.02[b]	1.38 ± 0.02[b]	1.33 ± 0.01[b]	1.28 ± 0.01[b]
Fat (%)	21.4 ± 0.11[a]	23.1 ± 0.09[b]	23.2 ± 0.14[b]	23.6 ± 0.12[b]	23.7 ± 0.10[b]
Protein (%)	3.87 ± 0.08[a]	3.15 ± 0.05[b]	3.17 ± 0.07[b]	3.18 ± 0.05[b]	3.10 ± 0.06[b]
Carbohydrate (%)	50.71 ± 0.6[a]	49.4 ± 0.8[b]	48.85 ± 0.6[b]	48.59 ± 0.9[b]	48.72 ± 0.7[b]
Energy (kcal)	410.92 ± 10.3[a]	418.1 ± 11.5[b]	416.88 ± 10.7[b]	414.61 ± 10.5[b]	412.33 ± 11.3[b]
Sodium (mg)	172.48 ± 2.7[a]	141.91 ± 4.7[b]	140.59 ± 6.3[b]	140.45 ± 7.1[b]	140.3 ± 9.2[b]
Total sugar (g)	24.47 ± 1.4[a]	24.47 ± 2.3[b]	24.51 ± 2.9[b]	25.36 ± 1.2[b]	26.21 ± 1.8[b]
Cholesterol (mg)	63.9 ± 2[a]	49.2 ± 3[b]	45.4 ± 2[c]	36.1 ± 4[d]	26.8 ± 3[e]
Dietary fiber (g)	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Phosphorous (mg)	120.5 ± 17.9[a]	111.4 ± 20.6[b]	108.6 ± 19.6[b]	101.75 ± 18.4[b]	94.9 ± 19.5[b]
Omega-3 fatty acids (g)	8.77 ± 0.89[a]	9.95 ± 0.73[b]	9.42 ± 0.31[c]	9.43 ± 0.39[c]	9.44 ± 0.52[c]

Note: Different letters in the same row represent significant differences, $p < 0.05$.

Table 5: Physical properties of cake.

Physical properties	Control	FSG20	FSG40	FSG50	FSG60
Sponge volume (ml)	540 ± 8.7[a]	538 ± 10.2[a]	530 ± 7.7[a]	530 ± 9.2[a]	471 ± 11.7[b]
Sponge height - center (mm)	47 ± 2[a]	47 ± 1[a]	46 ± 3[a]	46 ± 5[a]	39 ± 7[b]
Sponge height side 1 (mm)	45 ± 6[a]	45 ± 6[a]	44 ± 5[a]	43 ± 6[a]	38 ± 8[b]
Sponge height side 2 (mm)	45 ± 6[a]	45 ± 6[a]	44 ± 5[a]	43 ± 6[a]	38 ± 8[b]
Sponge pH	7.13 ± 0.5[a]	7.09 ± 0.3[a]	7.06 ± 0.8[a]	6.98 ± 0.6[a]	7.03 ± 0.4[a]
Hardness (N)	2.866 ± 2.4[a]	2.94 ± 1.8[a]	2.849 ± 2.7[a]	2.799 ± 4.3[a]	2.158 ± 3.2[b]

Note: Different letters in the same row represent significant differences, $p < 0.05$.

FSG can be used as an alternative to thickeners, emulsifiers, beverage stabilizers, and other additives. In a variety of applications, FSG can be utilized in place of thickeners, emulsifiers, beverage stabilizers, and other additives. It affects the stickiness, dough rheology, and baking process of bread, among other baking qualities. Due to the presence of the arabinoxylan component, it also softens the texture, keeps the bread soft for longer, and inhibits hardening during storage. The behavior of the gluten in the dough is strongly influenced by FSG since, during leavening and baking, a volume increase was seen. FSG can also take the place of egg whites in baked goods [16].

Sensory evaluation of the cake

Sensory properties of the cakes play an important role in product acceptance. With the increasing level of FSG, there was a moist feeling in the center part of the cake observed which might be a result of binding capacity of FSG (Figure 3). In addition, there was a slight negative impact on taste and chewing profile of the cake. Some panelists observed slightly less sweet taste with increasing level of FSG. The color and internal textural feel were found satisfactory with FSG cakes as control sample. Eggs replaced with FSG 40% and FSG 50% were observed to be closer to the control sample in terms of overall acceptability (Figure 4). FSG lacks taste qualities, which is a necessary quality for its application in food companies [17]. Similar findings were also noted by Korus et al. [18] in the freshly baked gluten-free bread, showing that by replacing starch with flaxseed gum, the sensory characteristics (appearance, structure, crumb color, and taste) may be enhanced.

Conclusion

FSG was used in different proportions as a fresh egg replacer, considering the health benefits of FSG. Replacing fresh eggs with FSG positively affects the physical, functional, and sensory characteristics of the cake. Increased levels of FSG increased the fat content while reducing cholesterol and sodium content. Eggs replaced with FSG 40% and FSG 50% were observed to be closer to the control sample in terms of overall acceptability. FSG has a good binding capacity, but 100% replacement of fresh eggs is still a challenge. However, FSG can be used as an egg replacement up to a 50% level. The addition of FSG did not yield a substantial effect on the cake's firmness, but it slightly affects the sensory properties. It is advised that further research be carried out regarding the influence of FSG on the rheological properties of batter as well as the microstructure of cakes. The findings of this research show that FSG can be used as an egg replacer and a valuable functional ingredient.

Acknowledgements

None.

Conflict of Interest

None.

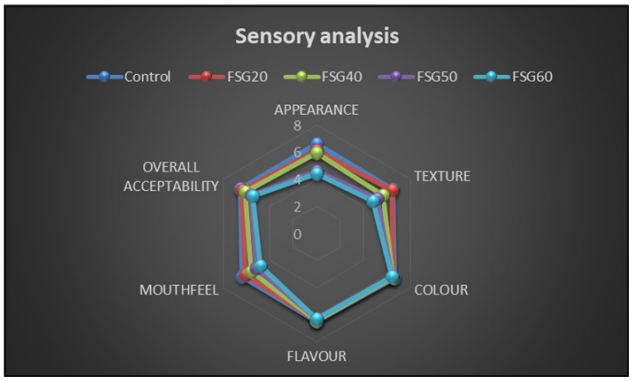


Figure 3: Sensory evaluation of cake.

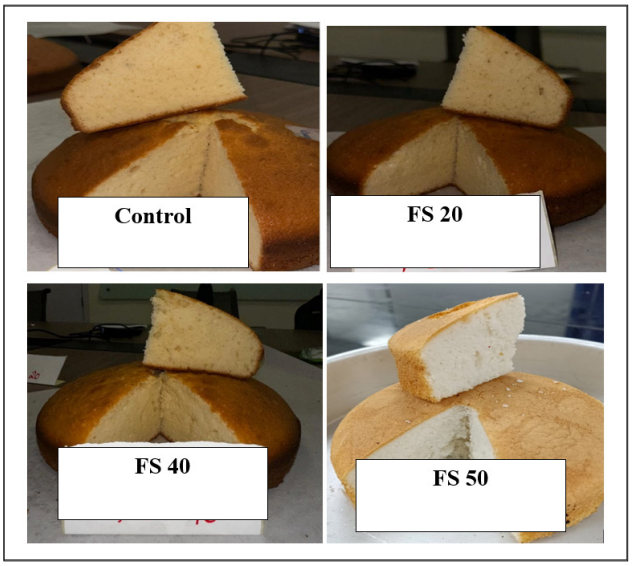


Figure 4: Cake containing different levels of FSG.

References

1. Wilderjans E, Luyts A, Brijs K, Delcour JA. 2013. Ingredient functionality in batter type cake making. *Trends Food Sci Technol* 30(1): 6-15. https://doi.org/10.1016/j.tifs.2013.01.001
2. Lin M, Tay SH, Yang H, Yang B, Li H. 2017. Replacement of eggs with soybean protein isolates and polysaccharides to prepare yellow cakes suitable for vegetarians. *Food Chem* 229: 663-673. https://doi.org/10.1016/j.foodchem.2017.02.132
3. Vaclavik VA, Christian EW. 2008. Evaluation of Food Quality. In Vaclavik VA, Christian EW (eds) Essentials of Food Science. Food Science Texts Series. Springer, New York, pp 3-19.
4. Hrušková M, Švec I. 2017. Rheological characteristics of composite flour with linseed fibre - relationship to bread quality. *Czech J Food Sci* 35(5): 424-431. https://doi.org/10.17221/450/2016-CJFS
5. Hussain S, Anjum FM, Butt MS, Sheikh MA. 2008. Chemical composition and functional properties of flaxseed (*Linum usitatissimum*) flour. *Sarhad J Agric* 24(4): 649-653.
6. Bernacchia R, Preti R, Vinci G. 2014. Chemical composition and health benefits of flaxseed. *Austin J Nutr Food Sci* 2(8): 1-9.
7. Hussain S, Anjum FM, Alamri MS, Mohamed AA, Nadeem M. 2013. Functional flaxseed in baking. *Qual Assur Saf Crop Foods* 5(4): 375-385. https://doi.org/10.3920/QAS2012.0207
8. Bhathena SJ, Ali AA, Haudenschild C, Latham P, Ranich T, et al. 2003. Dietary flaxseed meal is more protective than soy protein concentrate against hypertriglyceridemia and steatosis of the liver in an animal

model of obesity. *J Am Coll Nutr* 22: 157-164. https://doi.org/10.1080/07315724.2003.10719289

9. Gambuś H, Mikulec A, Gambuś F, Pisulewski P. 2004. Perspectives of linseed utilisation in baking. *Polish J Food Nutr Sci* 13(1): 21-27.
10. Premi M, Sharma HK. 2018. Effect of drumstick leaves powder on the rheological, micro-structural and physico-functional properties of sponge cake and batter. *J Food Measure Charact* 12(1): 11-21. https://doi.org/10.1007/s11694-017-9612-4
11. Seibel W. 1989. Approved Methods of the American Association of Cereal Chemists. Inc. St. Paul/Minnesota, USA.
12. Lorenc F, Jarošová M, Bedrníček J, Smetana P, Bárta J. 2022. Structural characterization and functional properties of flaxseed hydrocolloids and their application. *Foods* 11(15): 1-24. https://doi.org/10.3390/foods11152304
13. Chang Y, Li Y, Miao Q, Jiang H, Gao X. 2017. Rheological properties of six plant-based seed gums. *Am J Anal Chem* 8(11): 690-707. https://doi.org/10.4236/ajac.2017.811051
14. Morris DH. 2007. Flax: A Health and Nutrition Primer. Flax Council of Canada.
15. Gutte KB, Sahoo AK, Ranveer RC. 2015. Bioactive components of flaxseed and its health benefits. *Int J Pharm Sci Rev Res* 31(1): 42–51.
16. Giavasis I, Seviour RJ, Hudman P, McNeil B. 2019. Fungal Bioproducts for Use in Food: Polysaccharides, Organic Acids, and Mycoprotein. In Chavez-Gonzalez ML, Balagurusamy N, Aguilar C (eds) Advances in Food Bioproducts and Bioprocessing Technologies. CRC Press, Boca Raton, pp 511-548.
17. Kaewmanee T, Bagnasco L, Benjakul S, Lanteri S, Morelli CF, et al. 2014. Characterisation of mucilages extracted from seven Italian cultivars of flax. *Food Chem* 148: 60-69. https://doi.org/10.1016/j.foodchem.2013.10.022
18. Korus J, Witczak T, Ziobro R, Juszczak L. 2015. Linseed (*Linum usitatissimum* L.) mucilage as a novel structure forming agent in gluten-free bread. *LWT Food Sci Technol* 62(1): 257-264. https://doi.org/10.1016/j.lwt.2015.01.040