

EFFECTS OF MUNG BEAN FLOUR ON SPONGE CAKE QUALITY

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Abstract: The possibility of the use of mung bean (*Vigna radiata* L.) flour, which application is almost unknown in our confectionary, was presented in this article. This study aimed to evaluate the effects of mung bean flour on the quality of sucrose-sweetened sponge cake through its physical and sensory characteristics. Two types of sponge cakes made by a partial and full substitution of wheat flour with mung bean flour were proposed. The methods of descriptive sensory analysis were used for a comparative analysis of the new cakes and the control sucrose-sweetened sponge cake. The newly obtained baker's goods were characterized with good quality characteristics in comparison with those of the cake without mung bean flour (the control cake-sample). Wheat flour could be replaced up to 100 % with mung bean flour for the preparation of sponge cakes without resulting in an unacceptable product in terms of its physical and sensory characteristics. Increasing mung bean flour up to 50 % had most significant effect on textural sensory characteristics. On the grounds of the received results, it can be expected a potential consumer interest in bakery sweet products enriched with vegetable functional ingredients.

Keywords: *descriptive sensory analysis, mung bean (Vigna radiata L.) flour, physical characteristics, sucrose-sweetened sponge cake*

INTRODUCTION

Cakes have an important place in the sweet bakery products consumption all over the globe. The quality of cakes is highly influenced by the quality and balance of ingredients. The primary ingredients of sponge cakes are wheat flour, sugar and eggs. Sponge cakes are low fat, foamed type of cakes that rely on incorporated air for volume and texture [1]. However, cakes are poor in dietary fiber, protein and have low antioxidant activity [2]. Given the well-known benefits of a healthy diet, the food industry has responded by developing new quality foods with health properties. One of the ways for the making-up of healthy sponge cakes is the exclusion or the reducing of some calorie charged ingredients. Since gluten is not so important for making sponge cake, many recipes have been developed with flour from other grains [3] and even legumes [4]. The enrichment of sponge cakes with bioactive compounds possessing functional properties can be realized by substituting wheat flour with legume [5, 6] or fruits [7] ingredients as flours because of their relatively high content of protein, dietary fiber, minerals and vitamins. The making-up of sweet bakery products by including poly-functional ingredients in them requires these goods to have a quality commensurable with that of sucrose-sweetened products, and it is a question of present interest all over the world. A new natural vegetable functional ingredient is the mung bean (*Vigna radiata* L.). Mung bean belongs to *Fabaceae* family. This bean is cultivated in Asia, Australia, New Zealand, and Africa [8]. The mung bean is considered as a rich source of proteins with balanced amino acidic composition, dietary fiber, mineral elements, vitamins and polyphenolic compounds which manifest a high antioxidant activity [9, 10]. Considering the health benefits associated to the consumption of proteins and dietary fiber in the diet, the presence of both functional components in mung bean could highlight the interest of such a product as a potential ingredient for the functional food industry. It is proved that the protein content of mung bean ranges from 24 % to 29 % and is rich in essential amino acids, especially the aromatic amino acids leucine, isoleucine, and valine [8, 9, 11]. It also contains 1.50 - 1.55 % of fats, 2.20 - 7.10 % of fiber, 7.91 % of water, 2.87 % of ash, 25.73 % of starch [8, 12]. Mung bean contains bioactive compounds like tannin, phytic acid, flavonoid, phenolic acid, and other organic acids [8]. Mung bean flour has high nutritional content. Mung bean flour contains a greater amount of protein (18.42 - 23.25 %) [13, 14], ash (3.02 %) [13], calcium (21.50 mg·100g⁻¹) [14], iron (89.62 mg·100g⁻¹) [14], and vitamin A (265 µg RE·100g⁻¹) [17], a percentage of 9.01 % water, fats 2.61 < [13] and is gluten-free [15]. The fiber content in mung bean flour is 7.5 g·100g⁻¹ [16]. The dietary fibers have a good water-holding capacity. Soluble fibers can lower the human's blood cholesterol and can help control the blood glucose. This would be considered as an action that can increase the chances of fighting heart disease and diabetes. Insoluble fiber can relieve constipation, lower the risk of diverticulosis, hemorrhoids, and appendicitis, and reduce the risk of colon and rectal cancer [18, 19]. It is proved [20] that in the biscuit fiber content increased due to the percentage of mung bean flour use. In addition, mung bean flour has been shown to increase protein levels in cookies [21] and vitamin A in pastries [22]. The influence of mung bean flour on the quality, textural and sensory properties of cakes that were prepared by replacing of wheat flour with mung bean flour in amounts of 10, 20 and 30 % was studied [2]. The addition of mung bean flour was shown significantly increase

of the dietary fiber, protein content and antioxidant activity of the cakes ($p < 0.05$). It was found that texture hardness was increased and texture cohesiveness and springiness were decreased with the addition of mung bean flour to the cake formulation. The research stated that wheat flour could be replaced up to 30 % with mung bean flour for making cakes without resulting in an unacceptable product in terms of its sensory properties. In another study, the use of mung bean flour was shown in the production of sponge cake with different percentages of wheat flour replacement (25 %, 50 %, 75 %, 100 %) [8]. It is proved that hardness, punch, density, ash and protein increased as the level of mung bean flour increased, whereas springiness, moisture content, fat and gluten decreased. Color measurements showed that crumb a^* increased and b^* , L^* reverse trend was observed. The results showed that increasing the amount of mung bean flour up to 50 % does not have any significant effect on texture and organoleptic properties of sponge cake. Another study [23] showed that the chiffon cake with wheat flour and mung bean flour was the hardest, gummiest, and chewiest and resembled that with wheat flour alone in crumb color with the latter having the lowest specific volume. Three types of legumes (soybean, mung bean and red bean flour) were analyzed in another study [5]. It was found that mung bean flour can be the best choice for wheat flour substitution as ingredient in biscuit because it has high swelling power and peak viscosity, and low setback, breakdown viscosity and pasting temperature. The aim of this article is to evaluate the effects of mung bean flour on the quality, physical and sensory characteristics of sucrose-sweetened sponge cake.

MATERIALS AND METHODS

Standard raw materials approved by the Ministry of Health of the Republic of Bulgaria were used: wheat flour (type 500) with an ash content of 0.5 % (Good Mills Bulgaria Ltd), granulated sugar ("Zaharni zavodi" Jsc), chicken eggs (local store). Mung bean (*Vigna radiata* L.) is a bio product delivered from India and purchased from the "Baharika" store in Plovdiv. Mung beans were grounded to a fine flour ($< 200 \mu\text{m}$) with a moisture content of 9.37 ± 0.14 %.

Sponge cake batter with sugar (control sample) was included in the analysis. The mixture for the sucrose-sweetened sponge cake was prepared according to a traditional technology and formulation [24], using a double mixing procedure by separately beating egg whites and yolks. The sponge cake mixture was poured into silicone molds each containing 40 g of batter and baked in the electric oven (Gorenje, Model BO7367AX, Slovenia) for 25 minutes at 170°C . The baked sponge cakes were cooled for 30 min at a temperature of 20°C , after which they were stored under standard conditions (temperature $20 \pm 2^\circ\text{C}$ and relative air humidity < 75 %).

The specific gravity of the sponge cake batter was calculated by dividing the mass of the batter in a standard cup by the mass of an equal volume of distilled water according to a method described by Kissell and Bean [25]. The volumes of the sponge cakes were measured by the rapeseed displacement according to AACC method 10-05.01 [26], and their porosity by the Jacobi method with Zhuravlev's metal cylinder (BDS 3412-79) [27] two hours after their baking. The specific volume was expressed as the ratio of the volume of the sponge cake (cm^3) to its mass (g). The water-holding capacity of the sponge cake was measured by the method for determining the swelling of biscuits in

water according to BDS 15221-81 [28]. To determine the structure of the sponge cake, photographs of the top surface and of the cross section of the cake cut in half were taken. Photomicrographs of the crumb of the sponge cakes were taken using an LCD Deluxe Digital microscope with an endoscope camera at 1000 magnification (Celestron, model CE822507). The characteristics of the structural-mechanical properties of the crumb of the sponge cake: shrinkage, plasticity and springiness [PU], were determined with an automatic penetrometer (model DSD VEB Feinmess, Dresden, Germany), according to a methodology described by other authors [29]. The samples total moisture content was determined after drying at 105 °C to a constant mass according to standard method AACC 44-15.02 [30].

The sponge cakes sensory evaluation was carried out by applying a quantitative descriptive sensory profiling test according to ISO 8586:2023 [31] and ISO 13299:2016 [32] methods. The conditions for the sensory assessment and the selected sensory characteristics for the sponge cakes evaluation were described by Baeva *et al.* [33] and Goranova *et al.* [34]. A panel of 10 trained tasters was selected to ensure the accuracy of the evaluation.

Depending on the type of the investigated characteristic, 3 to 10 repetitions of the experiments were made. Data were analyzed using MS Excel software. Results were presented as mean $\pm$ SD (standard deviation). To assess the results accuracy, a statistical method with a significance level of $p \leq 0.05$ was used. Additional, statistical data analyzes were performed using one-way ANOVA test and Tukey-Kramer test, according to Assaad *et al.* [35].

RESULTS AND DISCUSSION

The developed formulation of sponge cakes with mung bean as functional ingredient was prepared by the replacement of wheat flour with mung bean flour in quantity 50 % and 100 %.

The formulations of the control sample and the investigated cakes containing mung bean flour are presented in Table 1.

Table 1. *Sucrose-sweetened sponge cake batter's formulations*

Ingredients	Amount [%] based on flour weight:		
	Control sample	With 50 % mung bean flour	With 100 % mung bean flour
Yolk of egg	43.23	43.23	43.23
White of egg	96.77	96.77	96.77
Refined granulated sugar	83.87	83.87	83.87
Wheat flour type 500	100.00	50.00	-
Mung bean flour	-	50.00	100.00

The stages of technology were kept because of their easy fulfillment and the considerably small duration of the technological cycle. The sponge cakes containing mung bean flour were processed at constant regime of baking concurrent with that of the control sample, which according to the technological instruction was baked for 25 min at 170 °C.

The most accurate evaluation of the merits of the suggested technology can be given by juxtaposing the qualitative characteristics of cakes batter for the control batter-sample and the two kinds of batter containing mung bean flour, as also juxtaposing the same characteristics of the baked sponge cakes.

Specific gravity in cake batter provides an indication of the total air holding capacity of the batter. Low specific gravity values indicate good incorporation of air, yielding a higher final volume after baking. In this studying the control batter-sample and the sponge cake batter with 50 % mung bean flour had a bigger specific gravity towards the same of the sponge cake batter with 100 % mung bean flour (0.76 ± 0.01) as it is shown in Table 2. Probably it was due to the presence of surface-active substances in the mung bean flour. It was established by other researchers [11, 36, 37] that mung bean protein isolates have good gelling and foaming properties.

Table 2. Physical characteristics of the sponge sucrose-sweetened batters and cakes

Physical characteristics ¹	Sponge sucrose-sweetened cake type		
	Control sample	With 50 % mung bean flour	With 100 % mung bean flour
Specific gravity (for batter) ²	0.80 ± 0.01^{ab}	0.81 ± 0.01^a	0.76 ± 0.01^b
Volume [cm ³]	89.67 ± 0.58^a	81.00 ± 1.73^b	88.33 ± 1.04^a
Specific volume [cm ³ ·g ⁻¹]	2.54 ± 0.05^a	2.24 ± 0.06^b	2.55 ± 0.04^a
Porosity [%]	72.84 ± 1.5^a	63.86 ± 1.05^b	67.9 ± 1.00^{ab}
Shrinkage [PU] ³	35.67 ± 3.95^a	25.67 ± 2.10^b	21.33 ± 1.60^b
Plasticity [PU]	10.33 ± 0.58^a	8.00 ± 0.60^{ab}	6.67 ± 0.38^b
Springiness [PU]	25.33 ± 3.51^a	17.67 ± 1.90^b	14.67 ± 1.01^b
Water-holding capacity [%]	333.54 ± 8.3^a	263.58 ± 2.83^b	306.35 ± 9.00^{ab}
Total moisture [%]	21.94 ± 0.22^b	22.82 ± 0.10^a	22.29 ± 0.11^{ab}

¹ The values mean $\pm$ SD ($p \leq 0.05$).

² The temperature of the batter is on the average 20.3 ± 0.5 °C.

³ PU - Penetrometer Units.

^{a-b} Different letters in the same row indicate statistically significant differences ($p \leq 0.05$), according to ANOVA (one-way) and the Tukey test.

A reverse relationship between the batter specific gravity and the sponge cakes physical characteristics such as volume and porosity (Table 2) was established. For the sponge cake with 100 % mung bean flour and for the sponge control cake-sample, whose batters had a smaller specific gravity, a larger volume and specific volume were determined and statistically they do not differ. The cake with 100 % mung bean flour and the control sample had the bigger porosity than the cake with 50 % mung bean flour. The data in Table 2 show that the sponge cake-control sample had a higher shrinkage (35.67 ± 3.95 PU), plasticity (10.33 ± 0.58 PU) and springiness (25.33 ± 3.51 PU) than the same for the cakes with mung bean flour.

A difference in the sensory characteristics concerning the texture (1-shape, 3-cells size and uniformity, 7-crumbs tenderness) can be seen in Figure 1.

Our investigations showed that both cakes, the control sample and the one with 50 % mung bean flour, had approximately similar shape /1/ and cells size and uniformity /3/ (Figure 1 and Figure 2). The sponge cake containing 100 % mung bean flour was determined the best shape (Figure 1 and Figure 2). On the surface of that cake no visible cracks were observed (Figure 2).

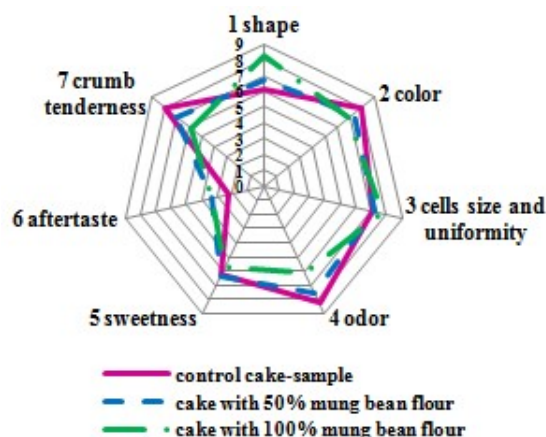


Figure 1. Sensory profiles of sucrose-sweetened sponge cakes (1-shape, 2-color, 3-cells size and uniformity, 4-odor, 5-sweetness, 6-aftertaste, 7-crumb tenderness)*

*A scale from 0 to 9 was used to evaluate sensory characteristics. Nine is ideal for the third sensory characteristic (3-cells size and uniformity) when the air cells are equally small

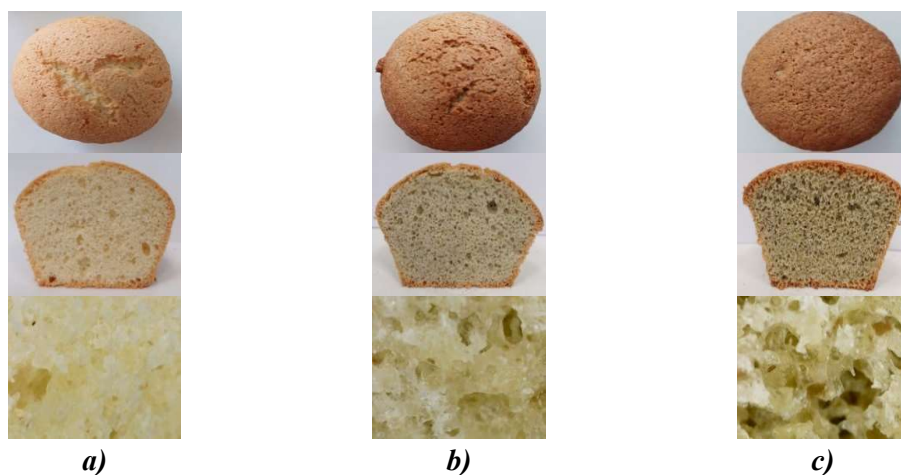


Figure 2. Photographs of top surface and of cross sections of sucrose-sweetened sponge cakes, and micrographs of cake crumbs:
a) without mung bean flour (control cake-sample);
b) with 50 % mung bean flour;
c) with 100 % mung bean flour.

The crumb air cells (pores) of the sponge cakes with mung bean flour had thicker walls, as at the same time they were smaller and equal in size, which can be seen in Figure 2. This fact corresponded with the same characteristic /3/ of its sensory profile represented in Figure 1. The air cells of the control sponge cake are larger and heterogeneous, uniformly distributed in the crumb and at the same time thinner-walled (Figure 1 and Figure 2). The cake springiness, shrinkage, plasticity, water-holding capacity and crumb tenderness are a surface response of its microstructure. As a result, the crumb of the cake-control sample had a higher springiness, plasticity, shrinkage and tenderness in comparison with that of the cakes containing mung bean flour (Table 2 and Figure 1). It

was observed that higher crumb tenderness scores were established for the control sample. The springiness of the cakes with mung bean flour was smaller, their crumb tenderness was also smaller, while their structure was stable at high loads, expressed by lower shrinkage in respect to sponge cake-control sample. The water-holding capacity of both cakes, the control sample and the one with 100 % mung bean flour, was bigger than the cake with 50 % mung bean flour, as shown in Table 2. The increase of mung bean flour amounts up to 50 % exercised the most significant effect on textural sensory characteristics of cake - cells size and uniformity /3/, and crumb tenderness /7/.

The control cake - sample had a more pronounced light-yellow color on the crust and crumb, due to the presence of the dye components from the yolks (mainly carotenoids). The crust color of the sponge cakes with mung bean flour was from light-brown to brown, and a yellow color of the crumb with greenery nuance depending on the percentage of the added mung bean flour (Figure 1 and Figure 2).

The odor of mung bean flour sponge cakes was stronger and more specific but was not perceived by the sensory assessors as unpleasant compared to the odor of the control sample. This was because cakes with mung bean flour had a strong nutty odor [6]. Other researchers had received similar results. Hartati and Royanda's [38] research concluded that the mung bean flour gave a distinctive odor to pie products. The distinctive odor of mung bean flour was because of lipoxygenase activity during flour preparation, which gives a characteristic unpleasant odor [39].

The intensity of the sweet taste (sweetness) in all sponge cakes analyzed was close and statistically indistinguishable.

The control sample had the smallest aftertaste.

CONCLUSIONS

The sponge cakes containing mung bean flour have good physical characteristics. The springiness of cakes with mung bean flour is smaller, the crumb tenderness is smaller, while the structure is stable at high loads expressed by a lower shrinkage in comparison with the control cake-sample. The difference in respect to porosity, volume and specific volume between the control cake-sample and the sponge cake with 100 % mung bean flour is minimal and statistically they do not differ.

The control cake-sample and the cake with 50 % mung bean flour have approximately similar shape and cells size and uniformity. The sponge cake containing 100 % mung bean flour has the best shape. The crumb air cells (pores) of the cakes containing mung bean flour are with thicker walls, smaller and equal in size. The increase of mung bean flour amounts up to 50 % exercised the most significant effect on textural sensory characteristics of cake - cells size and uniformity, and crumb tenderness. The crust color of the sponge cakes with mung bean flour is from light-brown to brown, and a yellow color of the crumb with greenery nuance. The odor of mung bean flour sponge cakes was more pronounced and more specific, but not perceived by sensory assessors as unpleasant. The intensity of the sweet taste (sweetness) in all sponge cakes analyzed was close and statistically indistinguishable. Wheat flour could be replaced up to 100 % with mung bean flour for the preparation of sponge cakes without resulting in an unacceptable product in terms of its physical and sensory characteristics. On the

grounds of the received results, it can be expected a potential consumer interest in sweet bakery products enriched with vegetable functional ingredients.

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