5. The use of chia seeds in the production of muffins made from sponge-fat dough

G. Adamczyk[1], I. Bobel[1,2]
[1] *University of Rzeszow (Poland)*
[2] *National University of Food Technologies (Ukraine)*

Introduction. Fat-sponge cakes are appreciated all over the world due to their simplicity, taste and wide range of products. They are also often referred to as "sand cakes" due to their texture [2, 3, 6].

There are two methods of preparing sponge-fat cakes - the "cold" and "warm" methods. "Cold method": this method includes the following steps: joint aeration of fat with sugar, breaking eggs with separation of yolks from whites, combining the yolks with the aerated sugar-fat mass, and then introducing whipped whites and mixing the whole with sifted flour and chemical leavening agents, putting in the mass to the mold and baking. "Warm method": aerating the eggs with a sweetener at room temperature, and then heating them to 37-42 °C and further whisking the mass until it cools down again to 20-25 °C, separate fat grating with gradual merging with the cooled egg mass, mixing it with the sifted flour and chemicals raising agents, mass formation and baking.

The main ingredients used in their preparation are flour, fat, eggs, sugar and chemical leavening agents. Moreover, all kinds of flavor and aroma additives are often used [10]. Fat-sponge cakes belong to the group of "heavy cakes" and, compared to sponge cakes, they show higher moisture and firmness, with a tendency to crumble at the same time. The addition of fat at the level of 25-40% in the total mass of raw materials determines their brittleness, but also their loading, therefore it is necessary to use chemical leavening agents in order to obtain a leavened dough. The type of fat selected largely affects the quality of the product - saturated fatty acids, in contrast to mono- and polyunsaturated fatty acids, show a better effect on its texture and sensory quality [10, 11].

Materials and methods. The following raw materials were used to obtain the muffins: wheat flour type 450 (manufacturer LUBELLA FOOD Sp.z o.o., Lublin); refined rapeseed oil (PPHU "OLMAJ" Sławomir Majewski, Pruszków); 2% fat milk (Spółdzielnia Mleczarska "MLEKPOL", Grajew), eggs (Nowy Sącz and Chełmiec), white sugar (Polski Cukier S.A., Toruń), baking powder (Nestle Polska S.A., Warsaw), salt (CENOS Sp. z o.o. , Września), chia seeds (Intenson Europe Sp.z o.o., Karczew, country of origin: Bolivia); distilled water to soak chia seeds.

The dry matter content was determined by thermal drying using a Binder dryer (Germany). Drying was carried out at the temperature of 105 ° C for 3 hours [16]. The ash content was determined in a Nebertherm (Germany) muffle furnace at a temperature of 900ºC [16]. To determine the fat content, the extraction-weight method and the SoxtecTM device by FOSS (Denmark) were used, using 80% petroleum ether as a solvent [16]. The color of the crumb of the samples was determined in the CIE Lab system (L * a * b) using a HunterLab brand spectrophotometer (USA), using a 10 ° observer and D65 illuminant. The L *

parameter is responsible for the brightness of the image, and a * and b * determine its chromaticity - the colour change in the range from green to red and from blue to yellow, respectively. The device was previously calibrated on a white standard and the muffins were cut in half [14]. The texture determination of the finished products was performed using the Brookfield CT3 analyser (USA) equipped with the Texture Pro CT V1.2 Build 9 software. The muffin samples were cut in the shape of a cylinder (h = 27 mm, d = 27 mm, v = 22 cm^3) and tested compression with deformation of samples equal to 50% of their height. For this purpose, an aluminum cell probe with a diameter of 25 mm was used. The following parameters were directly read and calculated from the TPA (Texture Profile Analysis) test – hardness [N], elasticity [-], cohesiveness [-], gumminess [N] and chewiness [N].

Results. Recipes for baking sponge-fat dough in order to obtain a finished product – muffins were included in Table 1.

Table 1. **Recipes for baking sponge-fat dough in order to obtain a finished product – muffins [9]**

Sample	Wheat flour [g]	Oil [cm^3]	Milk [cm^3]	Eggs [g]	Sugar [g]	Baking powder [g]	Salt [g]	Chia seeds [g]	Water [cm^3]
K	320	100	200	60	40	20	5	-	-
A	320	80	200	60	40	20	5	20	-
B	320	80	200	60	40	20	5	20	-
C	320	80	200	60	40	20	5	20	60
D	320	80	200	60	40	20	5	20	60
E	320	90	200	60	40	20	5	10	-
F	320	90	200	60	40	20	5	10	-
G	320	90	200	60	40	20	5	10	60
H	320	90	200	60	40	20	5	10	60

Coding of samples: K – control sample without chia seeds, 100% oil; A – sample with whole chia seeds in 20% instead of the oil; B – sample with ground chia seeds in 20% instead of the oil; C – sample with whole, soaked chia seeds in 20% instead of the oil; D – sample with ground, soaked chia seeds in 20% instead of the oil; E – sample with whole chia seeds in 10% instead of the oil; F – sample with ground chia seeds in 10% instead of the oil; G - sample with whole, soaked chia seeds in 10% instead of the oil; H – sample with ground, soaked chia seeds in 10% instead of the oil.

The dry matter content (Table 2) of samples was varied and ranged from 56.46% to 67.66%. The control sample (K) had the largest amount (67.66%), while the samples enriched with chia seeds contained less (56.46-63.84%). It was found that muffins with grains soaked in water were characterized by the lowest percentage of dry matter. Due to the fact that chia seeds absorb water, swell and form a characteristic mucus, the moisture of the finished products is higher compared to the control sample. This effect occurs due to the fiber content of chia seeds, which means that some of the water is retained during the baking process [7].Visible changes were observed in the ash content (Table 2) – sponge-fat products with the addition of chia seeds contained more ash (1.88-2.52%) than the control sample (1.83%), which is a

result of an increased share of minerals in chia seeds [1]. Pizzaro et al. [13] also noticed an increase in ash content in sand cakes made from chia seed flour compared to the control sample made only from wheat flour. The highest amounts of fat (Table 2) were contained in sample B – 15.08% and sample K – 15%, and the lowest in sample H – 11.53%, which gives as much as 3.5 percentage points of difference. It follows that muffins, in which part of the rapeseed oil was replaced with chia seeds, were characterized by a lower fat content. Fernandes et al. [5] examined bread and cakes in which they replaced part of the vegetable oil with freeze-dried mucus from chia seeds. In both of these cases, they also received products with a reduced fat content.

Table 2. **Contents of dry matter, ash and fat in the muffin samples**

Sample	Dry matter [%]	Ash [%]	Fat [%]
K	67.66 ± 0.41^{g}	1.83 ± 1.06^{b}	15.00 ± 0.37^{abc}
A	63.84 ± 0.15^{c}	2.35 ± 0.07^{d}	13.02 ± 0.97^{ab}
B	61.80 ± 0.01^{f}	2.52 ± 0.07^{a}	15.08 ± 0.04^{cd}
C	59.64 ± 0.03^{e}	2.35 ± 0.04^{ae}	11.79 ± 1.62^{a}
D	57.61 ± 0.20^{d}	2.34 ± 0.03^{a}	12.61 ± 0.35^{abc}
E	62.85 ± 0.05^{b}	1.88 ± 0.05^{c}	13.43 ± 0.64^{ab}
F	63.19 ± 0.43^{bc}	2.14 ± 0.08^{f}	14.47 ± 0.12^{bc}
G	56.46 ± 0.90^{a}	2.10 ± 0.09^{de}	14.71 ± 0.56^{d}
H	56.76 ± 0.01^{a}	1.89 ± 0.07^{bc}	11.53 ± 0.73^{ab}

Parameters marked with the same letter in the column do not differ significantly at a confidence level of $\alpha = 0.05$.

It was found that muffins with the addition of chia seeds had a darker crumb than the control sample (K), for which the L * parameter was the highest (75.73) (Table 3). Such a change in colour brightness was also observed by Pizzaro et al. [13] when they examined sand cakes made with different concentrations of chia seed flour. With the increase in the content of oilseed flour, the colour was getting darker, which may be related to the higher share of dietary fiber and fat in the composition of cakes [8].

Table 3. **Colour parameters of muffin samples**

Sample	Colour parameters		
	L*	a*	b*
K	75.73 ± 0.33^{b}	1.21 ± 0.40^{a}	27.63 ± 0.23^{d}
A	72.79 ± 0.20^{ab}	1.53 ± 0.63^{a}	25.86 ± 1.21^{ad}
B	57.75 ± 0.16^{c}	4.41 ± 0.45^{b}	24.1 ± 0.13^{ab}
C	72.99 ± 0.57^{ab}	0.52 ± 0.12^{a}	25.45 ± 1.06^{a}
D	55.42 ± 4.26^{c}	4.39 ± 0.42^{b}	21.57 ± 0.03^{c}
E	74.78 ± 0.33^{ab}	1.30 ± 0.40^{a}	25.95 ± 0.23^{ad}
F	65.00 ± 0.48^{d}	2.66 ± 0.44^{c}	23.29 ± 1.43^{bc}
G	71.36 ± 1.90^{a}	1.09 ± 0.40^{a}	24.39 ± 1.05^{ab}
H	61.42 ± 0.63^{d}	3.76 ± 0.59^{b}	22.74 ± 0.96^{bc}

Parameters marked with the same letter in the column do not differ significantly at a confidence level of $\alpha = 0.05$.

The a * parameter (chromaticity in the range from green to red) of the tested samples was characterized by values ranging from 0.52 to 4.41. These results indicate that all samples contained the red colour. The b * parameter (colour chromaticity ranging from blue to yellow) ranged from 21.57 to 27.63 in all tested muffins. This means that all samples had a greater proportion of yellow, but in comparison to the control sample, the addition of chia seeds decreased the value of this parameter. The same result was obtained by Mesias et al. [12], where the examining muffins had the addition of chia flour.

The texture of the tested muffins was analyzed using the TPA test. The following parameters were determined – hardness, elasticity, cohesiveness, gumminess and chewiness (Table 4).

Table 4. Texture of muffin samples

Sample	Hardness [N]	Elasticity [-]	Cohesiveness [-]	Gumminess [N]	Chewiness [N]
K	4.76 ± 0.59^{ab}	0.31 ± 0.12^{abc}	0.41 ± 0.06^{a}	1.94 ± 0.25^{ab}	0.60 ± 0.29^{a}
A	4.76 ± 0.68^{ab}	0.29 ± 0.05^{ab}	0.37 ± 0.03^{a}	1.77 ± 0.34^{ab}	0.50 ± 0.12^{a}
B	6.06 ± 0.62^{c}	0.39 ± 0.05^{cde}	0.51 ± 0.04^{bc}	3.05 ± 0.29^{c}	1.19 ± 0.27^{b}
C	9.79 ± 1.06^{e}	0.38 ± 0.01^{bcd}	0.47 ± 0.02^{cd}	4.62 ± 0.50^{e}	1.77 ± 0.18^{c}
D	6.46 ± 0.34^{cd}	0.44 ± 0.09^{de}	0.53 ± 0.03^{b}	3.43 ± 0.32^{c}	1.52 ± 0.42^{bc}
E	3.86 ± 0.41^{a}	0.31 ± 0.06^{abc}	0.42 ± 0.05^{ad}	1.63 ± 0.22^{a}	0.51 ± 0.14^{a}
F	5.43 ± 0.29^{bc}	0.28 ± 0.03^{a}	0.40 ± 0.03^{a}	2.15 ± 0.29^{b}	0.60 ± 0.13^{a}
G	10.05 ± 1.23^{e}	0.48 ± 0.05^{ef}	0.53 ± 0.02^{bc}	5.26 ± 0.44^{f}	2.52 ± 0.31^{d}
H	7.25 ± 0.39^{d}	0.56 ± 0.03^{f}	0.55 ± 0.02^{b}	4.01 ± 0.22^{d}	2.24 ± 0.16^{d}

Parameters marked with the same letter in the column do not differ significantly at a confidence level of $\alpha = 0.05$.

Muffins, as sponge-fat products, are characterized by a delicate and soft crumb, hence they show lower hardness and chewiness, but high elasticity [15]. It was noted that the addition of chia seeds in most cases increased the hardness of the muffin crumb. The same conclusion was made by Kaszuba et al. [8] in a study of bread with oilseeds and Felisberto et al. [4], when they replaced part of the vegetable oil with the mucilage of chia seeds. The highest hardness was characteristic for muffins with 20% and 10% addition of whole seeds soaked (C and G samples). The addition of chia seeds in most cases increased the elasticity and cohesiveness of the products. The values of these parameters ranged between 0.28-0.56 and 0.37-0.55. In gumminess and chewiness, it can be seen that the samples with soaked seeds showed much higher values compared to the other muffins.

Conclusion. Sponge-fat products contain chia seeds in their compositions were characterized by higher moisture than the control sample, which may indicate their water retention capacity during the baking process. Part of the vegetable oil (10-20%) in muffins can be successfully replaced by the addition of oilseeds, reducing the fat content and not deteriorating their texture.

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