STUDY ON THE POTENTIAL OF CHIA GEL USAGE AS A NATURAL FAT SUBSTITUTE IN CAKE FORMULATION

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Abstract In the current study, cakes were prepared with the addition of different levels of chia gel obtained by soaking 1 part of chia seeds in 9 parts of water by weight. Mix was allowed to stand for 30 min for gel formation and seeds were left in the gel and later incorporated into the batter. The addition of chia gel to cake batter to partially substitute the fat from the basic recipe (control) resulted both in improved quality characteristics at all levels of substitution and reduction of caloric value, at the expense of energy from fat, especially at higher reduction levels (40 and 60%). The fat replacement at 40 and 60% had a caloric value decrease by 48 kcal per 100 g compared to the control and respectively the energy at the expense of the fat was 37.9 and 25.7% (reduction by 71.3% and 48.3%). Sensory evaluation demonstrated good acceptability for all the products with slight prevail for the samples with 40% followed closer by those with 20% fat replacement. Hence, chia gel proved to be a good alternative for fat substitution in baking goods recipes while preserving the quality and sensory parameters aiming to produce healthier foods.

***Key words*:** chia gel**,** fat substitute, thermal properties, cake batters, nutrition analysis

Introduction

In recent years, consumers have tended to adhere to dietary norms for fat consumption, leading to pressure on the industry to produce foods low in fat, sugar, cholesterol, salt and some supplements (LIU et al., 2007). In bakery products, the ingredients used as fat substitutes should play the same role as the real fat, i.e. to stimulate the aeration of the dough, homogenization during the mixing phase, to improve the final texture of the product and increase its volume (RIOS et al., 2014). Hydrocolloids or gums are widely used in various applications in the food industry due to their ability to absorb water. When chia seeds are soaked in water, they release a clear gel called chia mucilage. This gel consists mainly of soluble fibers, corresponding to about 6% of the seed composition (REYES-CAUDILLO et al., 2008) and can be found in the outer surface or its adjacent

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layer, which is not easy to be separated alone (SEGURA-CAMPOS et al., 2014). The formed gel has properties that allow its application in various products in the food industry such as a thickener, gelling agent and chelator (CAPITANI et al., 2012). In addition, it can serve as a fat substitute as it has the ability to hydrate, increase viscosity and maintain freshness, especially in bakery products (VÁZQUEZ-OVANDO et al., 2009). BORNEO and FELISBERTO, and co-authors (BORNEO et al., 2010; FELISBERTO et al., 2015) presented chia mucilage as a new ingredient substitute for fat in food as they found that the nutritional value, basic functional properties and sensory characteristics of cakes were preserved when the fat from the basic recipe was replaced up to 25%. Other authors extracted chia mucilage, dried it by two different methods and evaluated the effect of its incorporation on the technological quality of bread and cake when replacing fat with 25, 50, 75 and 100% (FERNANDES et al., 2017).

The aim of the present study was to determine how replacing partially the sunflower oil as a source of fat with chia gel would affect the nutritional value, basic functional properties and sensory characteristics of cakes, compared to the recipe with whole fat.

Materials and Methods

Materials. The ingredients used for the cake batter preparation included white wheat flour (10% moisture, 11.8% protein content (N × 5.95), 1.5% fiber; Sofia Mel, Ltd.), sucrose "Sladeya", (Sugar factories, Ltd.), refined sunflower oil (9% saturated fatty acids; Pearl Olive, Ltd.), eggs, 3.0% fat cow's milk "My day" (UHT sterilized; Cremio, Ltd.), baking powder, dried chia seeds (Dragon superfoods, Mexico) and vanilla, all purchased from a local supermarket.

Cake formulations and preparations

All variants of the cake batters preparation are shown in Table 1. The oil fat according to the basic recipe was replaced with a gel of chia at levels of 20, 40 and 60%, and the sample without the addition of gel represented the control. Prior to the batter preparation, chia seeds were soaked in tap water in a ratio of 1: 9 for about 30 minutes to form a gel as described by BORNEO at al. (2010) and the exact amount to add in each formulation was calculated. The batter samples of 450 g were baked at 180°C for 40 min in a commercial oven. After baking the cakes cooled down for 2 h, placed in plastic bags and stored at room temperature at different storage times (0, 24, 48, 72, 96, 120 and 150 h). Differential Scanning Calorimetry (DSC) Analysis (DSC 204 F1 Phoenix NETZSCH-Gerätebau GmbH, Germany) was used to study either the process of starch gelatinization and determination of the state of water in the cake batter system - bound or free (HATAKEYAMA et al, 1988) and to determine the peak of fat melting.

Table 1. Cake formulations recipe – control and samples with oil fat substituted by chia gel

Ingredients, g/100g	Control	Fat substitute, %		
		20	40	60
White flour	25.5	25.5	25.5	25.5
Sucrose	33.0	33.0	33.0	33.0
Cow's milk 3,0%	18.0	18.0	18.0	18.0
Eggs	15.0	15.0	15.0	15.0
Sunflower oil	7.5	6.0	4.5	3.0
Chia gel	-	1.5	3.0	4.5
Baking powder	1.0	1.0	1.0	1.0
Aroma	0.1	0.1	0.1	0.1

Texture profile parameter of "firmness" was measured by using texture analyzer (StableMicroSystems TA-XT2Plus). Crumb firmness (N) of cake samples was found during storage at times given. The biochemical composition of fresh cakes was determined: moisture, protein, lipid and fiber content were measured according to Bulgarian State Standards (BDS 12145, BDS 14431, BDS 6997 and BDS 11374, respectively). The energy value of the cakes was calculated empirically. Consumer acceptance test was performed using 9-point hedonic scale. The analysis of the results was performed with the statistical program Statistica 7.

Results and discussion

Effect of chia gel usage, in various concentrations, on the thermal properties of cake batter.

As with all gels/gums, the chia gel follows the same pattern and shows both endothermic and exothermic transitions. Endothermic and exothermic peaks correspond to water release and are due to polymer degradation (DAOUB et al, 2016). In the current study, for the endothermic peaks observed, the transition temperatures (Figures 1) in the batters with chia gel were 68.9°C, 73.3°C and 83.4°C, respectively. This narrow range of endothermic peak corresponds to the hydrophilic behavior of the functional groups of the polymer and can be attributed to the less tight structure. Some authors report a wide range of endothermic peaks in the study of the thermal properties of the chia gel, based on the uneven packaging structure of the gums in general, meaning more energy required for water release, related to the bound hydrogen and the loss of crystal structure (PUNIA et al., 2019). Although, the degradation reactions and the resulting fragments vary depending on the available structural and functional groups (ZOHURIAAN et al., 2004).

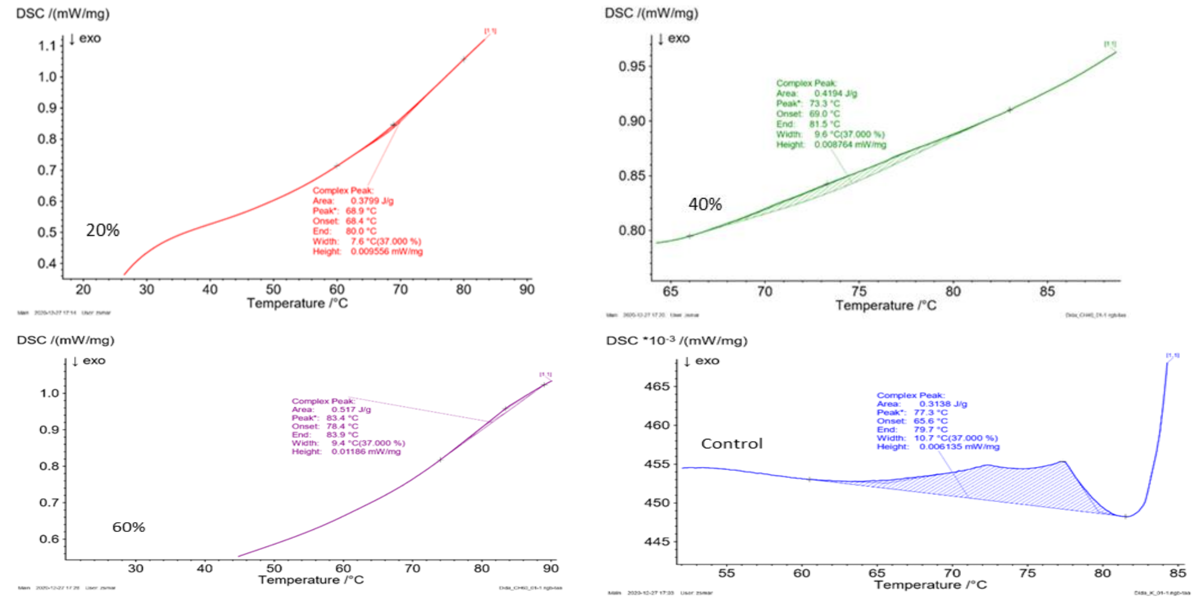


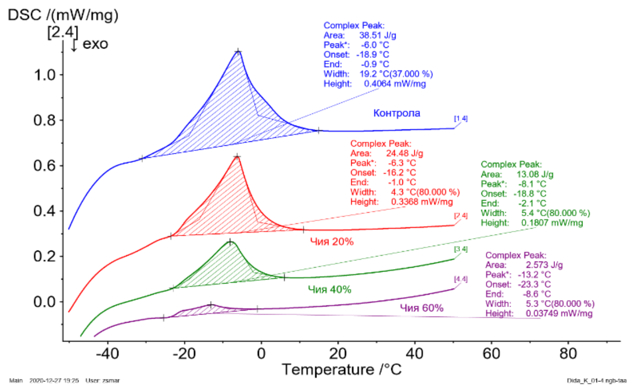
Figure 1. Endothermic transition during starch gelatinization in chia gel batters and the control

Therefore, in the current study the change in enthalpy (ΔH) in chia gel samples showed a higher value compared to the control (Table 2) because of more energy needs in the discharge of water associated with the loss of crystallization as well as the presence of bound hydrogen.

Table 2. Starch gelatinization in fat substituted cake batters by chia gel and the control

Batters	Temperature range ΔT, °C	Endothermic pick temperature, T_p, °C	Enthalpy (ΔH), J/g
Control	65.6 – 79.7	77.3	0.3138
20% fat reduction	68.4 – 80.0	68.9	0.3799
40% fat reduction	69.0 – 81.5	73.3	0.4194
60% fat reduction	78.4 – 83.9	83.4	0.517

The lowest value of the initial gelatinization temperature was at 65.6°C in the control, e.g. the swelling process began at the earliest, and the enthalpy of the endothermic transition was the smallest. At the same time, the highest enthalpy value of 0.517 J/g (Table 2) was referred to the sample with 60% substituted fat, with the endothermic peak occurring just before the end of the gelatinization process. This was most likely due to the ability of the chia gel to absorb the free water and subsequently more energy required to release it during the starch gelatinization if compared to the other batters with a lower concentration of chia. In the 20 and 40% substituted fat samples, probably again due to the lower content of free water, gelatinization was difficult and at the same time the enthalpies of the endothermic transition decreased in value.



From the DSC thermogram for fat melting (Figure 2) can be concluded that the energy consumption was at the the highest in the control 38.51 J/g, decreasing gradually with the increase of the concentration of substituted fat. Much less energy was needed for the sample with 60% fat reduction.

Figure 2. Endothermic transitions of fat melting

Quality of cakes

Effect of chia gel usage, in various concentrations, on the textural properties of cakes

The baked cake samples were evaluated in terms of loss of weight and firmness during storage as shown in Figure 3 and Figure 4, respectively.

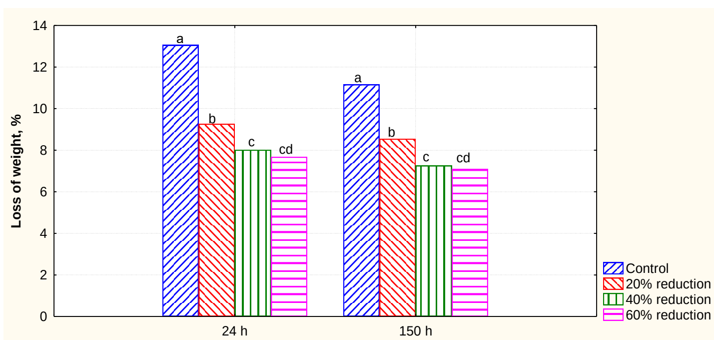


Figure 3. Effect of chia gel added at different levels of substitution on the loss of weight of cake samples during storage (* means with different letters are significantly different, $p \leq 0.05$)

In general, with the increase of the substitution levels, weight loss (%) decreases, and this trend is more pronounced during storage. This effect can be explained by the ability of hydrocolloids to bind water. (AHMED et al., 2020). During storage, the firmness of the crumb of all cake samples apparently has increased as a result of the staling. This initial trend was most clearly observed on the 4th and 5th day of storage (statistically insignificant differences, $p \leq 0.05$, data not shown), noting that samples with 20 and 40% fat reduction had softer crumb, in contrast to the control and the sample with 60% reduction ($p \leq 0.05$). It is also interesting to note that for the 60% fat reduction, the increase in the sample firmness was particularly dramatic between day 1 and day 5, but since then the crumb firmness increased negligible. On day 7 the control (26.5 N) had the highest values followed closely by the sample with a 20% fat reduction (25.4 N) ($p \leq 0.05$). Thus, samples with higher levels of fat substitution (40 and 60%) showed the lowest final firmness values of the crumb (25.2 and 26 N) compared to the reference sample. (Figure 4)

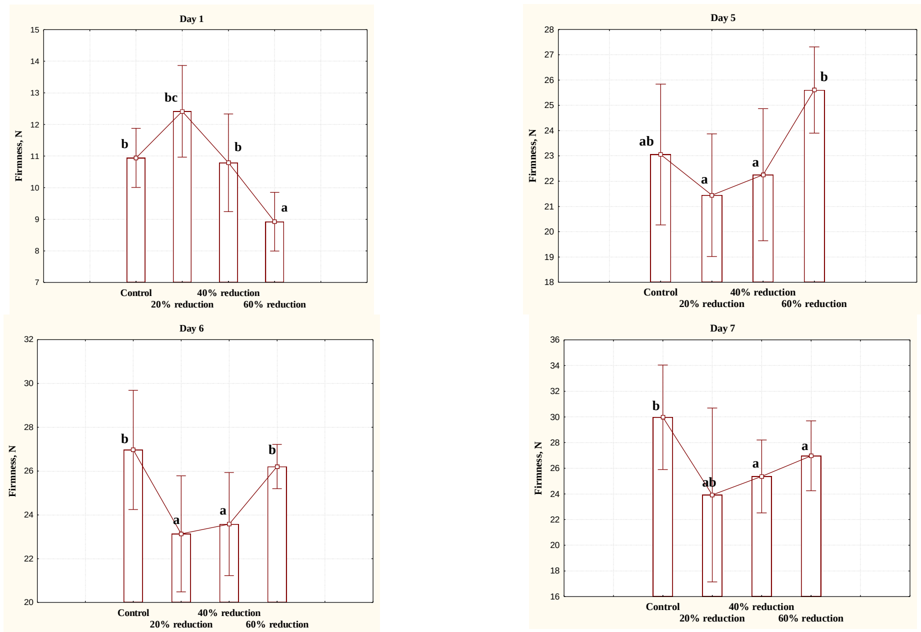


Figure 4. Effect of chia gel added in different levels of fat substitution on the crumb firmness of cake samples during storage (* means with different letters are significantly different, p≤ 0.05)

Biochemical and sensory parameters of cakes

Control cake contained 227 kcal, 10.6 g total fat (Table 3) and 41.9% energy from fat per 100 g cake (based on empirical calculations). The 40% and 60% oil substituted cake had 48 fewer kcal per 100 g portion than the control and 37.9% and 25.7%, respectively of energy from fat (a reduction of around 71.3% and 48.3% in actual energy derived from fat).

Table 3. Biochemical properties of cakes made with chia gel as oil replacer

Parameters	Control	Fat substitute, %		
		20	40	60
Moisture, % d.w.	20.6	21.9	25.5	25.6
Proteins, % d.w.	4.4	4.0	4.5	4.8
Fibers, % d.w.	8.4	10.8	12.2	14.4
Lipids, % d.w.	10.6	8.8	7.5	5.1
Carb., % d.w.	32.3	32.5	32.7	32.5
Energy, kcal/100g	227	213	179	179

A total of four samples (20, 40 and 60% fat reduction, and the control) were subjected to sensory analysis over a period of 7 days. The samples with 40% and 20% substituted fat, received a score above 6 ("like it a little") regarding “overall acceptance”, “texture” and “flavor” even at the end of the storage period on a 9-point hedonic scale. The control sample after 120 hours of storage rated "neither like nor dislike" ($x \leq 5$) on the sensory attributes evaluated. (data not shown).

Conclusion

Obviously, the chia gel because of high water retention capacity affected its loss during storage and thus slowed down the staling. Evaporation of water from the surface of the end product, during and after baking does not occur to such an extent, because the gel rich in fibers, binds free water. This is also explained by the fact that thanks to the added chia, the hydration in the conditions of the batter increases. This is most likely due to the ability of the gel to absorb the free water and then more energy to release it is needed during the starch gelatinization in the batters. In the products with 20 and 40% substituted fat, probably again due to the lower content of free water, gelatinization during baking was incomplete what explains the fact the samples tested were less firm and with moist mouthfeel if compare to the control for the entire storage period of 7 days.

It has been found that the addition of a chia gel, in order to replace the fat in a cake recipe, significantly improves the firmness of the crumb, slows down staling process and reduces the caloric value, at the expense of the energy from fat in the cake product and can therefore be recommended for incorporation.

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