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Research Article

Impact of Chia Seeds Powder on the Chemical, Microbiological, and Sensorial Characteristics of Low Fat UF-soft Cheese

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Abstract:

The present study was carried out as an attempt to improve the properties of low-fat UF-soft cheese using chia seeds powder. Chemical composition, microbiological as well as sensory characteristics were investigated for resultant fresh and stored cheese. The results showed that the dry matter content, protein, water-soluble nitrogen, ash, fat, minerals content, and titratable acidity were significantly ($p \leq 0.05$) higher than those of control cheese either in fresh or after the storage period of chia-enriched cheese. Chia seeds powder resulted in an innovative light brown color that increased as the storage period progressed. The addition of chia seeds powder improves the overall acceptability of low-fat UF-soft cheese as their level increases except for the highest level of chia (3%). On the other hand, the highest level of chia powder decreased the appearance score. Total bacterial counts and psychotropic counts after 28 days of storage of chia-enriched cheese are slightly higher than control. No significant ($p \leq 0.05$) differences in mold and yeast count of fresh cheese containing chia powder compared to the control. Notably, coliform and *E. coli* counts were not detected in all UF-soft cheese samples during the cold storage for 28 days. Hence, chia seeds powder (2%) could be used as a functional ingredient and fat replacer in such low-fat cheese which led to improvements in its characteristics close to control full-fat cheese.

1. Introduction

Chia (*Salvia hispanica* L.) is an annual herbaceous plant belonging to the family Lamiaceae, which has incredible nutritional and functional properties and health benefits (Muñoz et al., 2013). Chia seeds possess excellent nutritional value and are considered a good source of carbohydrates, fats, proteins, ash, and dietary fibers. Chia seed is known as power house of omega fatty acids which contains high ratio of omega-3, omega-6, and omega-9 fatty acids of its fat content (Di Marco et al., 2020). Thus, the wide range of chia seed incorporation into food products is attributed to its approval by the European Parliament as a novel food (Ullah et al., 2016).

Chia has been cultivated recently in many regions of the world such as Australia, Colombia, Argentina, South-East Asia, Africa, North America, and Europe (Grancieri et al., 2019). Chia is one of the most important autumn and winter medicinal plant crops in Egypt (Moghith, 2019). Chia has great economic value due to consumption increments for use as a raw material in producing supplements, beverages, medicine, and processed foods (Peperkamp, 2015).

There has been substantial interest in developing some dairy products with reduced fat contents to avoid the health problems associated with high fat intake (Wakai et al., 2014). However, low-fat ratios are highly recommended in food production since this may aid in reduced risk of many syndromes such as cardiovascular disease (CVD), hepatic steatosis, and obesity (Felisberto et al., 2015). Also, bioactive components found in chia seeds may be used to fortify food products, besides being used as a vehicle for increasing the number or amount of vital nutrient intake (Coelho and Salas-Mellado 2014). Chia seeds can play a vital role in eradication and minimization of health disorders such as cardiovascular diseases and diabetes (Oliva et al., 2021)

Chia seeds have been widely applied in food applications such as yogurt, juices, bakery products, and sweets or cakes in different countries all over the world including New Zealand, Canada, Chile, Mexico, Australia, and USA (Ali et al., 2012). The chia seeds act as a thickener because they absorb liquid from the fruits and offer a great jam-like texture (Grancieri et al., 2019).

Therefore, the present study aimed to investigate the impact of chia seed powder as a functional ingredient for low-fat UF-white soft cheese production. In addition, chemical, sensorial, and microbiological characteristics of the resulting low-fat UF-white soft cheese with chia seeds powder were investigated.

2. Materials and Methods

2.1. Raw materials and chemicals

Chia seeds were obtained from the Medicinal and Aromatic Plants Research Department, Horticulture Research Institute, Agriculture Research Center, Ministry of Agriculture, Egypt. The dried samples were ground into a fine powder by a laboratory mill and then sieved through 60 mesh sieves (250µm). Chia seeds powder was stored in closed containers at 5±1 °C until further analysis.

Fresh milk retentate was obtained from the Animal Production Research Institute, Ministry of Agriculture, Giza, Egypt. Microbial rennet powder (RENIPLUS) from *Mucor miehei*, obtained from Gaglio Star, Spain. The starter culture used in the cheese manufacture consisted of a mixture of *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris* were obtained from Egyptian Microbial Culture Collection, (MIRCEN), Ain Shams University.

All other reagents and chemicals were used in analytical grade.

2.2. Methods

2.2.1. Cheese production with chia seeds powder

Ultrafiltration white soft cheese manufacture was carried out as given by (Hofstede et al., 2001)**.**

Fresh skim milk was heated to 72 °C for ~15 seconds and then ultrafiltrated (concentration factor ~ 4.5) using tubular concentration module DC2, supplied by Amicon Corporation, USA. The inlet and outlet pressure were ~5 bar and ~3 bar, respectively. Milk fat was added to the concentrated milk then it was homogenized at 50 °C.

The homogenized low fat retentate was heated at 72 °C for ~15 seconds then cooled to 37 °C and inoculated with 2% active cheese starter culture. Calcium chloride was added at 0.02% and 2% salt was added to pre-cheese milk and mixed well. The low-fat retentate was divided into four containers, the first served as a control (LC0), while the other treatments which were supplemented with chia seeds powder at the level of 1, 2, and 3% served as LC1, LC2, and LC3, respectively. The full fat retentate was served as control full UF-white soft cheese (F). The microbial rennet was added to all containers, and then the pre-cheese was immediately distributed into suitable plastic containers. The containers were incubated at the same temperature (37 °C); the curd was formed within 40 min. The resulting cheese samples were tightly closed with their lids and stored at 5 °C for four weeks. The whole experiment was repeated in duplicate and each analysis in duplicate and average results were tabulated.

2.2.2. Chemical characterization of cheese

The chemical analyses were carried out on the resulting cheese samples according to (AOAC 2000) including moisture, ash, fat, and total protein, and the acidity was determined as lactic acid by titration with 1/9 N NaOH. Water soluble nitrogen (WSN) was estimated according to (Ling 1963). The mineral content of selected UF-white soft cheese samples was determined as described by (Hankinson 1975) using atomic absorption spectrophotometer No. 3300 (Perkin Elmer, Waltham, Massachusetts, USA).

2.2.3. Color development of cheese

Color parameters of UF-white soft cheese samples were performed using a Hunter colorimeter (model D2s A-2, Hunter Assoc. Lab., Virginia, USA) tri-stimulus values of the color namely l*, a* and b* as described by (Hunter and Harold 1987).

2.2.4. Microbiological analysis of cheese

UF-soft cheese samples were evaluated on the presence count of the key pathogenic and spoilage microbial populations after 0, and 28 days of storage. Total viable counting was performed using the plate count agar medium and aerobically incubated at 35 °C for 48 h, the plates were analyzed for the total growing population (cfu/g) as recommended by FDA (2002). Mold and yeast counts were examined using malt extract agar and aerobically incubated at 30 °C for 3 days the plates were analyzed (cfu/g) for yeast and fungal populations (Tassew and Seifu 2011). The psychrotrophic bacteria count was performed by adding samples (0.1 ml) in duplicate on the surface of the plate count agar. The plates were inverted and incubated at 7 °C for 10 days (Rosso and Azam 1987). Total coliform counting and *E. coli* detection were performed as described by (El-Hadedy and Abu El-Nour 2012)**.**

2.2.5. Organoleptic evaluation of cheese

The organoleptic properties of cheese samples were evaluated by a regular score panel using a five-point hedonic scale test (including 1 = dislike very much; 2 = “dislike”, 3 = “neither like nor dislike”, 4 = like and 5 = like very much) for body and texture, flavor, appearance, and overall acceptability.

2.2.6. Statistical analysis

The result's average values were analyzed by SAS software (SAS Institute, Cary, North Carolina, USA) (SAS Institute Inc 1999) using the ANOVA procedure for analysis of variance. The results were expressed as mean ± standard error and the differences between means were tested for significance using Duncan’s multiple range at $p \leq 0.05$.

3. Results

Chia seeds were used during the processing of UF-white soft cheese in fine powder form (Figure 1) which is composed of protein (15-25%), fat (30-33%), carbohydrates (26-41%), fiber (18-30%), and 4-5% ash (Mohd Ali et al., 2012).

Fig. (1): Chia (*Salvia hispanica* L.) seeds (A), and seeds powder (B).

3.1. Effect of chia powder on chemical characteristics of cheese

Results of UF-soft cheese chemical characterization containing chia seeds powder are presented in Table 1. It could be noted that the dry matter content including protein, ash, and fat of chia-enriched cheese was significantly ($p \leq 0.05$) higher than that of control cheese (LC0). Also, dry matter content increases were observed in all cheese samples throughout the storage period.

Table (1): Effect of using chia powder on the chemical characteristics of UF-soft cheese.

Parameter	Storage period (day)	UF-soft cheese treatments				
		F	LC0	LC1	LC2	LC3
Dry matter (%)	0	32.75 ± 0.29^{BCb}	24.12 ± 0.23^{Cg}	25.93 ± 0.29^{BCf}	25.50 ± 0.29^{Ce}	28.41 ± 0.17^{BCe}
	14	33.22 ± 0.58^{Bb}	26.38 ± 0.58^{Bf}	26.28 ± 0.001^{Bf}	28.83 ± 0.001^{Be}	29.23 ± 0.58^{Bde}
	28	37.10 ± 0.23^{Aa}	30.02 ± 0.29^{Acd}	30.20 ± 0.001^{Acd}	30.83 ± 0.58^{Ac}	31.12 ± 0.29^{Ac}
Protein (%)	0	8.61 ± 0.23^{Ae}	8.74 ± 0.29^{Ade}	9.83 ± 0.12^{Aabc}	9.25 ± 0.14^{Acde}	9.57 ± 0.01^{Bbcd}
	14	8.93 ± 0.29^{Acde}	8.93 ± 0.58^{Acde}	9.25 ± 0.14^{Acde}	9.57 ± 0.001^{Abcd}	10.21 ± 0.001^{Aab}
	28	9.25 ± 0.001^{Acde}	8.93 ± 0.29^{Acde}	9.57 ± 0.23^{Abcd}	9.76 ± 0.001^{Aabc}	10.53 ± 0.58^{Aa}
Fat (%)	0	14.0 ± 0.001^{Aa}	2.0 ± 0.001^{Be}	3.5 ± 0.001^{Bc}	3.5 ± 0.001^{Bc}	3.5 ± 0.001^{Bc}
	14	14.0 ± 0.001^{Aa}	2.0 ± 0.001^{Ba}	3.5 ± 0.001^{Be}	4.0 ± 0.001^{Ab}	4.0 ± 0.001^{Ab}
	28	14.0 ± 0.001^{Aa}	2.5 ± 0.001^{Ad}	4.0 ± 0.001^{Ab}	4.0 ± 0.001^{Ab}	4.0 ± 0.001^{Ab}
Ash (%)	0	2.36 ± 0.001^{Cn}	4.24 ± 0.001^{Ck}	4.47 ± 0.001^{Cj}	4.65 ± 0.001^{Cg}	4.75 ± 0.001^{Cd}
	14	2.50 ± 0.001^{Bm}	4.50 ± 0.001^{Bi}	4.61 ± 0.001^{Bh}	4.70 ± 0.001^{Bf}	4.91 ± 0.001^{Bb}
	28	3.07 ± 0.001^{Al}	4.73 ± 0.001^{Ae}	4.73 ± 0.001^{Ae}	4.83 ± 0.001^{Ac}	5.36 ± 0.001^{Aa}

F: control full UF-soft cheese; **LC0**: control low-fat UF-soft cheese; **LC1, LC2, LC3**: low-fat UF-soft cheese containing chia powder in the level of 1, 2, and 3%, respectively. All parameters are represented as mean of replicates ± standard error. Means with different capital superscript letters in the same column (storage time) and different small superscript letters in the same row (treatment) are significantly different at $p \leq 0.05$.

A significant ($p \leq 0.05$) increase in WSN of cheese containing chia powder among both control cheese LC0 and F samples, as well as WSN, was increased with the storage period prolonged (Figure2).

It is clear from Table 2 that the incorporation of chia powder in low-fat UF-soft cheese improved its mineral content containing chia powder including Ca, Na, Zn, Fe, and P compared to control cheese. Also, the levels of Mg, Cu, and K for chia-enriched cheese are close to the control full-fat UF-soft cheese (F).

The titratable acidity of chia-enriched UF-soft cheese during the cold storage (5±1 ºC) for 28 days is presented in Figure 3. The titratable acidity of chia-containing cheese treatments is higher than control cheese (LC0) as well as close to controlling full-fat cheese (F) during their storage period. Also, titratable acidity gradually increased in all cheese samples as the storage period progressed.

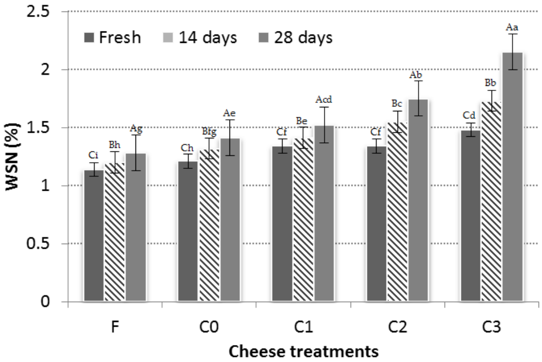

Fig. (2): Water soluble nitrogen (WSN) of UF-soft cheese containing chia powder.

F: control full UF-soft cheese; **LC0**: control low-fat UF-soft cheese; **LC1, LC2, LC3**: low-fat UF-soft cheese containing chia powder in the level of 1, 2, and 3%, respectively. Means with different capital superscript letters (storage time) and different small superscript letters (treatment) are significantly different at $p \leq 0.05$.

Table (2): Minerals content of UF-soft cheese containing chia powder.

Minerals (mg/Kg)	F	LC0	LC2
Ca	8750	10500	13750
Na	7100	10750	11750
K	2125	2500	3275
Zn	31.75	33.00	48.50
Fe	17.50	21.00	34.75
Cu	0.50	2.25	0.75
Mg	300	550	400
P	4825	6100	8075

F: control full UF-soft cheese; **LC0**: control low-fat UF-soft cheese; **LC2**: low-fat UF-soft cheese containing chia powder at the level of 2%.

3.2. Effect of chia powder on the color of the cheese

The supplementation of low-fat UF-soft cheese with chia seeds powder led to an innovative light brown color (Figure 4) which was mainly due to the presence of chia seeds color (Figure 1B).

Table 3 shows the addition of chia seeds powder during UF-soft cheese processing showed significant ($p<0.05$) darkening in L* color attributes of the chia-enriched cheese with increasing as the storage period progressed compared to control cheese. Also, a*, and b* color attributes were decreased in cheese containing chia powder compared to control samples.

However, the storage period of 28 days led to an increase in a* and reduced b* color attributes. It could be mainly due to the color of the chia seed powder being light brown while the control cheese is creamy/white in color.

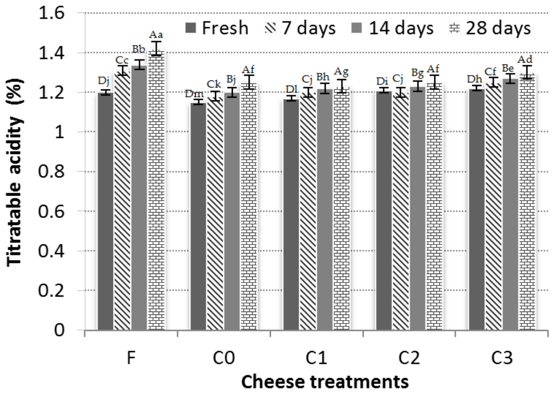

Fig. (3): Titratable acidity of UF-soft cheese containing chia powder.

F: control full UF-soft cheese; **LC0**: control low-fat UF-soft cheese; **LC1, LC2, LC3**: low-fat UF-soft cheese containing chia powder in the level of 1, 2, and 3%, respectively. Means with different capital superscript letters (storage time) and different small superscript letters (treatment) are significantly different at $p \leq 0.05$.

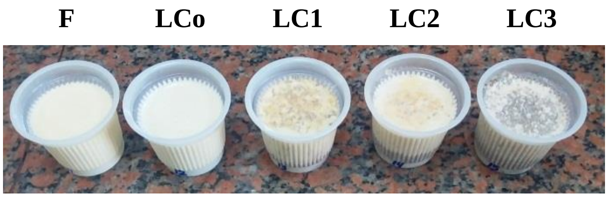

Fig. (4): Photos of UF-soft cheese containing chia powder.

F: control full UF-soft cheese; **C0**: control low-fat UF-soft cheese; **C1, C2, C3**: low-fat UF-soft cheese containing chia powder in the level of 1, 2, and 3%, respectively.

Table (3): Color properties of UF-soft cheese containing chia powder.

Parameter	Storage period (day)	UF-soft cheese treatments F	LC0	LC1	LC2	LC3
l*	0	42.32	39.16	35.86	34.82	29.52
	28	34.85	38.30	33.10	31.36	26.30
a*	0	0.67	1.35	0.29	0.20	0.18
	28	0.70	2.80	0.57	0.28	0.23
b*	0	11.45	12.46	8.94	7.22	5.42
	28	14.42	12.47	8.27	7.05	4.57

L*: value represents darkness from black (0) to white (100)**; a*:** value represents color ranging from red (0) to green (100)**; b*:** value represents color ranging from blue (0) to yellow (100).
F: control full UF-soft cheese; **LC0**: control low-fat UF-soft cheese; **LC1, LC2, LC3**: low-fat UF-soft cheese containing chia powder in the level of 1, 2, and 3%, respectively.

3.3. Effect of chia powder on the sensory evaluation of cheese

The incorporation of chia seeds powder improves the overall acceptability of low-fat UF-soft cheese as their level increases except for the highest level of chia (3%). However, the overall acceptability of chia-containing cheese (2%) is close to full-fat UF-soft cheese (F) and higher than control low-fat cheese (LC0) without chia powder (Figure 5A).

The flavor (Figure 5B) and body and texture (Figure 5C) of chia-enriched cheese are higher than control low-fat UF-soft cheese (LC0) and close to full-fat UF-soft cheese (F). No significant ($p \leq 0.05$) differences in the appearance of cheese containing chia powder among both control cheese LC0 and F samples, as well as the highest level of chia powder decreased the appearance score (Figure 5D).

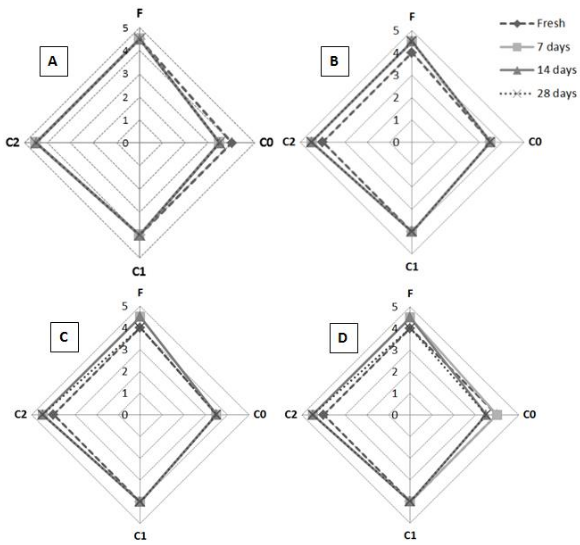

Fig. (5): Sensorial characteristics of UF-soft cheese containing chia powder.

F: control full UF-soft cheese; **LC0**: control low-fat UF-soft cheese; **LC1, LC2, LC3**: low-fat UF-soft cheese containing chia powder in the level of 1, 2, and 3%, respectively.

3.4. Effect of chia powder on microbiological characteristics of cheese

It is clear from Table (4) that all cheese treatments showed a decrease in the number of total bacterial counts (TBC), and psychotropic counts after 28 days of storage. Also, TBC and psychotropic counts of chia-enriched cheese are slightly higher than control cheese (LC0).

No significant ($p \leq 0.05$) differences in mold and yeast count of fresh cheese containing chia powder compared to control cheese (LC0); while after 28 days of storage slight decrease in their count in the level of 1(LC1), and 2% (LC2) except the highest level (LC3) (Table 4).

Notably, coliform and *E. coli* counts were not detected in all UF-soft cheese samples during the cold storage for 28 days (Table 4).

4. Discussion

The addition of chia seed powder in the complete seed form during the processing of low-fat UF-soft cheese increased the dry matter content of such cheese including protein, ash, and fat in comparison to control cheese (LC0), which is mainly due to chia powder ingredients content (Mohd Ali et al., 2012).

Table (4): Microbiological characterization of UF-soft cheese containing chia powder.

Parameter	Storage period (day)	UF-soft cheese treatments				
		F	C0	C1	C2	C3
Total bacterial count	0	8.43 ± 0.00^{cA}	8.43 ± 0.00^{cA}	8.43 ± 0.00^{cA}	8.56 ± 0.00^{aA}	8.78 ± 0.00^{aA}
	28	7.44 ± 0.01^{dA}	7.56 ± 0.00^{dA}	7.97 ± 0.00^{bA}	8.00 ± 0.00^{bA}	8.18 ± 0.01^{aA}
Mold and yeast count	0	2.11 ± 0.00^{dB}	1.0 ± 0.00^{aB}	1.0 ± 0.00^{aB}	1.0 ± 0.00^{aB}	1.0 ± 0.00^{aB}
	28	7.08 ± 0.00^{cA}	7.30 ± 0.00^{cA}	7.00 ± 0.00^{cA}	9.26 ± 0.00^{aA}	8.00 ± 0.00^{bA}
Psychotropic counts	0	6.48 ± 0.00^{aA}	6.78 ± 0.00^{dB}	7.32 ± 0.00^{cA}	9.60 ± 0.00^{aA}	8.87 ± 0.00^{bA}
	28	6.04 ± 0.00^{aB}	6.86 ± 0.00^{dA}	6.76 ± 0.01^{dB}	9.38 ± 0.00^{aA}	8.30 ± 0.00^{bB}
Coliform	0	ND	ND	ND	ND	ND
	28	ND	ND	ND	ND	ND
E. coli	0	ND	ND	ND	ND	ND
	28	ND	ND	ND	ND	ND

F: control full UF-soft cheese; **LC0**: control low-fat UF-soft cheese; **LC1, LC2, LC3**: low-fat UF-soft cheese containing chia powder in the level of 1, 2, and 3%, respectively. All parameters are represented as mean of replicates ± standard error. Means with different capital superscript letters in the same column (storage time) and different small superscript letters in the same row (treatment) are significantly different at $p \leq 0.05$.

The apparent gradual increase in different components (protein, fat, ash, and WSN) of cheese samples during the cold storage (5±1 ºC) is mainly due to the moisture loss of all samples as the storage period progressed.

The incorporation of chia powder in low-fat UF-soft cheese improved their mineral content containing chia powder compared to control cheese which might be due to the mineral content of chia powder. Chia seeds contain various minerals such as calcium (456–631 mg/100 g), phosphorus (860–919 mg/100 g), potassium (407–726 mg/100g), magnesium (335–449 mg/100 g). The calcium content of chia is greater than in rice, barley, corn, and oats. Also, other minerals content including magnesium, potassium, and phosphorus are higher than other cereals (Jin et al., 2012; Ullah et al., 2016). However, chia seeds have six times more calcium, eleven times more phosphorus, and four times potassium more than milk content (Suri et al., 2016).

The supplementation of low-fat UF-soft cheese with chia seeds powder led to an innovative light brown color which was mainly due to the presence of chia seeds brown color while the control cheese is creamy/white color. However, the chia seed surface is smooth, and shiny, ranging in color from white through grey to brown, with irregularly arranged black spots (Ali et al., 2012).

The incorporation of chia seeds powder improves the sensorial acceptability, flavor, body, and texture of low-fat UF-soft cheese as their level increases except for the highest level of chia (3%). It might be due to the highest level of chia powder affecting the appearance of the resulting cheese which reduces the score of overall acceptability. However, the overall acceptability of chia-containing cheese (2%) is close to full-fat UF-soft cheese (F) and higher than control low-fat cheese (LC0) without chia powder.

Further research will be done to investigate the total phenolic compounds; total flavonoid contents, and antioxidant activity, as well as identify and quantify phenolic compounds using HPLC of chia seed powder. Moreover, the textural and nutritional characteristics of low-fat cheese with chia seeds powder compared to full-fat cheese will be studied.

Conclusions

It could be concluded that the incorporation of whole chia seeds in powder form during low-fat UF-soft cheese production improves both chemical characteristics and sensorial acceptability. Hence, chia seeds powder (2%) could be used as a functional ingredient and fat replacer in such low-fat cheese which led to improvements in its characteristics close to control full-fat cheese.

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