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Evaluating the Physicochemical Properties of Milk Enriched with Sesame Seeds

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ABSTRACT:
Full-fat dairy products contain large amounts of saturated fatty acids and cholesterol, which can have a harmful impact on human health, especially in patients with cardiovascular diseases. Therefore, considerable efforts have been devoted to reducing the contents of these compounds in nutrients. In the ground sesame seeds, they were added to milk in 10%, 20%, 30%, and 40% proportions. The samples were stored in a refrigerator at 5°C. They were subjected to chemical tests (acid value (AV), peroxide value (PV), fatty acid analysis, and antioxidant compounds) and physical tests (color, syneresis, and apparent viscosity). The results indicated a significant increase in AV and PV ($p<0.01$) with an increased percentage of ground sesame seeds, which, in turn, led to increased amounts of unsaturated fatty acids and reduced amounts of saturated fatty acids according to the results of fatty acid profile analysis. Examining the total phenolic content of the treatments showed a significant increase ($p<0.01$) in phenolic compounds in milk on day 7 of storage, with an increase in the percentage of ground sesame seeds. According to the evaluation results of colorimetry components, the milk treatment containing 40% ground sesame seeds ($p\geq0.01$) had the lowest value of lightness index (L^*), the highest value of yellowness index (b^*), and the lowest value of redness index (a^*). Analyzing apparent viscosity on the first day after product manufacture indicated no significant difference ($p>0.01$) in the viscosity of milk samples with different percentages of ground sesame seeds, while it decreased on days 3 and 7 with an increase in sesame percentage. The results of this research generally indicated the feasibility of producing milk containing ground sesame seeds as a functional food with increased amounts of unsaturated fatty acids and antioxidant compounds as well as suitable physical properties.

Keywords: Functional, Unsaturated Fatty Acids, Phenolic Compounds, Black Sesame, Milk

1.INTRODUCTION:

Consuming full-fat dairy products such as full-fat milk is associated with serious nutritional problems, including high cholesterol levels and saturated fats as the most important ones. The presence of saturated fats in full-fat milk products causes an increase in the concentration of total cholesterol and serum low-density lipoprotein cholesterol (LDLC), which plays a leading role in causing cardiovascular diseases in humans [1]. While the demand for a healthy and balanced diet has led to the production of some low-fat and fat-free dairy products, whose taste, texture and sensory properties are not very popular with consumers. Since fat plays a crucial role in dairy products' texture, sensory, and flavor properties, a great deal of research is being done to improve them [2]. Using vegetable oils, especially unsaturated sesame oil, enriched with essential fatty acids and several unsaturated omega-3 and omega-6 fatty-acid-rich oils, instead of milk fat, can help balance the ratio of unsaturated to saturated fatty acids (UFA:SFA) [3].

Phytosterols are compounds found in plants and present a chemical structure similar to that of cholesterol. With a moderate phytosterol intake, total cholesterol levels and the risk of developing specific cancers are reduced, and the immune response is enhanced. The reports on phytosterol content in plants have introduced sesame as one of the richest nutrients in terms of phytosterol content (400-413 mg per 100 gr) [4]. In addition to unsaturated fatty acids, sesame seeds are rich in natural antioxidants, such as sesamol, sesamin, and sesamolin, which increase oil oxidative stability. They also contain various proteins and lignans. Lignans create specific biochemical and physiological properties for sesame oil, such as anti-cancer and anti-inflammatory activities, and reduce blood lipids and lipid peroxidation in people with hypercholesterolemia [5]. Milk and dairy products are the leading sources of dietary calcium, which are needed for growth, bone repair, ensuring enzymatic function, etc. [6]. Due to the detrimental effects of full-fat milk and dairy products, this research mainly aims to replace milk fat with ground sesame seeds at different levels and manufacture a functional dairy product that can benefit people on weight-loss diets, people with cardiovascular diseases, and general consumers.

2. MATERIALS AND METHODS

2.1. Materials

All solvents and chemicals used in this research were of analytical grade and purchased from Merck. Also, raw milk was obtained from the Department of Animal Husbandry, University of Tabriz, and sesame seeds and sugar were purchased from the Bazaar of Tabriz.

2.2. Product preparation and manufacturing steps

Sesame seeds were initially washed and then roasted for 20 min with indirect heat. Next, they were ground using a grinder and mixed with sugar. Then, the milk was pasteurized for 30 min at 65°C. Ground sesame seeds were then added to them in proportions of 10%, 20%, 30%, and 40%. After they were cooled, the samples were stored in a refrigerator at a temperature of 5°C until they were tested.

2.3. Oil extraction

Oil was prepared from enriched milk samples using Damirchi et al.'s (2005) method. Then, 10gr enriched (fortified) milk was mixed with 100mL chloroform/methanol mixture (1:2, v/v). After homogenization, the resulting mixture was placed in a homogenizer (at 750 rpm) for 3-4 minutes and then stirred with a laboratory shaker for 30 minutes. It was then poured into a decanter funnel using a normal filter paper, to which 25 mL of saturated NaCl solution was added. The chloroform phase was dehydrated using anhydrous sodium sulfate and dried by a rotary vacuum flatbed evaporator at 60°C. The extracted oil was then used for AV and PV tests as well as fatty acid analysis [7].

2.3.1. Fatty Acid Analysis

Fatty acid methyl ester (FAME) derivatization and analysis were performed using a gas chromatography system (Young Lee, South Korea). The starting oven temperature was 50ºC, which was held for 2 min and then raised at a rate of 10ºC/min to 180ºC and then raised at a rate of 10ºC/min to 230ºC, which was held for 10 min. The injection port and detector temperatures were 210°C and 240°C, respectively. Also, gas chromatograph (GC) injection was done in split mode [7].

2.3.2. Acid value

Acid value (AV) was determined using the Association of Official Analytical Chemists (AOAC) method [8].

2.3.3. Peroxide value

Peroxide value (PV) was determined using the AOAC method [8].

2.4. Determination of phenolic compound contents

Total phenolic compound contents were determined using UNICO 2150-UV Spectrophotometer (USA) and McDonald et al.'s method [9].

2.5. Measurement of apparent viscosity

The temperature of the samples was set at 13-15°C, and their viscosity was measured using a Brookfield Viscometer Spindle LV-4 (64) at 25 rpm [10].

2.6. Colorimetry of samples

The color of the samples was determined using a HunterLab colorimeter based on L*, b* and a* values. The *L** index represents the lightness of the sample ranging from 0 (black) to 100 (white). The a* index represents the degree to which the color of the sample is close to green and red colors ranging from -120 (pure green) to +120 (pure red). The b* index represents the degree to which the color of the sample is close to blue and yellow colors ranging from -120 (pure blue) to +120 (pure yellow) [11].

2.7. Statistical analysis

In the present study, enriched milk containing 10%, 20%, 30%, and 40% sesame seed flour was investigated, and the data obtained from physicochemical tests performed in three replicates were analyzed in SAS based on a completely randomized design.

3. DISCUSSION AND RESULTS

In this research, different milk samples containing ground sesame seeds were produced, and the effects of enrichment (fortification) on physicochemical properties were studied. Table 1 summarizes a general composition of milk samples containing ground sesame seeds. As can be seen, protein content, fat content, dry matter, and carbohydrates increased with an increase in the percentage of ground sesame seeds.

Table 1. A comparison of a general composition of milk samples without ground sesame seeds and enriched milk containing ground sesame seeds

Percentage of sesame XXX added to the milk	Fat Ash Carbohydrates	Protein

Without	3.9		3.2	
ground		0.7		
sesame seeds	4.8			
10%	5.8		4.8	
20%		1.7		8
30%	7.6		5.7	
40%		2.5		12.5
	9.5		7.5	
		4		16
	11		8.8	
		5.5		19.8

Figure 1 shows the results of AV measurement. As can be seen, AV increased significantly ($p>0.01$) with an increase in the percentage of ground sesame seeds. The sample with the highest percentage of ground sesame seeds had the highest AV. The increased AV in milk samples containing ground sesame seeds could be attributed to lipase activity. In addition to milk, lipase enzymes are active in oil seeds (sesame and soybean), cereals (wheat and barley), fruits, and vegetables [12].

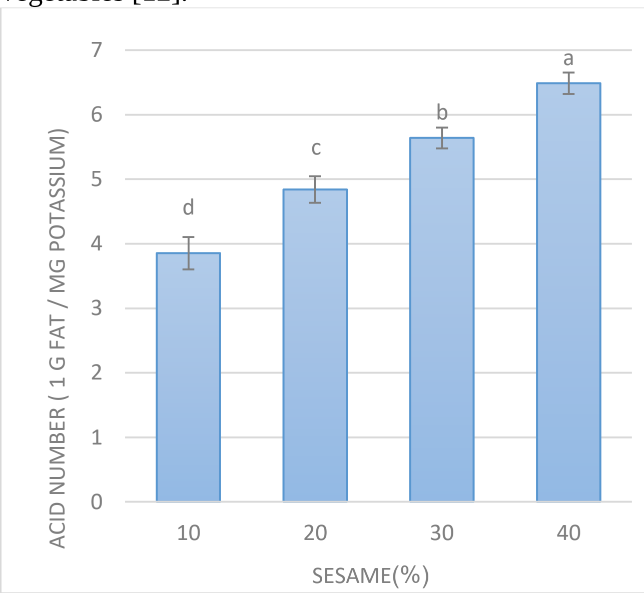

Figure 1. Results of AV measurement on day 1 (acid value [1g fat/1µg k]).

Figure 2 shows the results of the PV measurement. As it is clear, the sample with the highest percentage of ground sesame seeds had the highest PV. The PV of the samples increased significantly ($p>0.01$) with an increase in the percentage of ground sesame seeds. The sensitivity to oxidation increased with an increase in the percentage of ground sesame seeds and unsaturated fatty acids in the samples. Also, the presence of peroxidation agents, such as peroxidase and lipoxygenase activity in sesame seeds, as well as high copper and water activity in milk, caused an increase in PV in samples with a higher percentage of sesame seed flour [13].

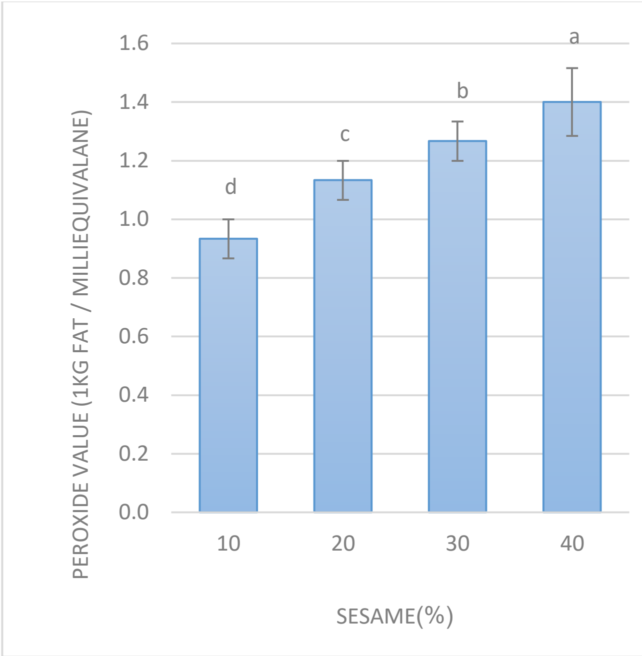

Figure 2. The results of PV measurement on day 1 (peroxide value [1kg fat/1 mEq gram of peroxide]).

Table 2 lists the profile analysis results of fatty acids of the oil extracted from milk samples containing ground sesame seeds. As can be seen, the amounts of saturated fatty acids decreased, and monounsaturated and polyunsaturated fatty acids increased with an increase in the percentage of ground sesame seeds. The sample containing 40% ground sesame seeds had the highest amount of polyunsaturated fatty acids. The most prominent unsaturated fatty acids were oleic and linoleic acids [14].

Table 2. Fatty acid analysis of sesame seed flour enriched milk samples using GC device.

Type of fatty acid	10% treatment	20% treatment	30% treatment	40% treatment
	0.46	0.50	0.31	0.2
C4	0.41	0.43	0.27	0.17
:0	0.29	0.29	0.17	0.12
C6:0	0.79	0.76	0.32	0.33
C8:0	1.42	1.41	0.95	0.62
C10:0	4.52	3.96	2.52	1.67
C12:0	19.15	17.49	14.31	12.72
C14:0	0.73	0.70	0.45	0.31
C16:0	8.39	7.80	6.94	6.65
C16:1	25.81	27.03	33.92	39.73
C18:0	28.03	29.62	34.65	37.47
C18:1n 9 c				
C18:2 n 6 c				

Figure 3 displays the results of the measurement of apparent viscosity. As shown, viscosity decreased with an increasing percentage of ground sesame seeds in milk. The sample containing 40% ground sesame seeds had the lowest viscosity. This could be justified due to the fact that the viscosity decreased with an increased percentage of ground sesame seeds due to the increase in the oil percentage of the samples. Also, viscosity decreased sharply at starting points due to broken intermolecular bonds in samples containing a higher percentage of ground sesame seeds and then decreased slowly [15].

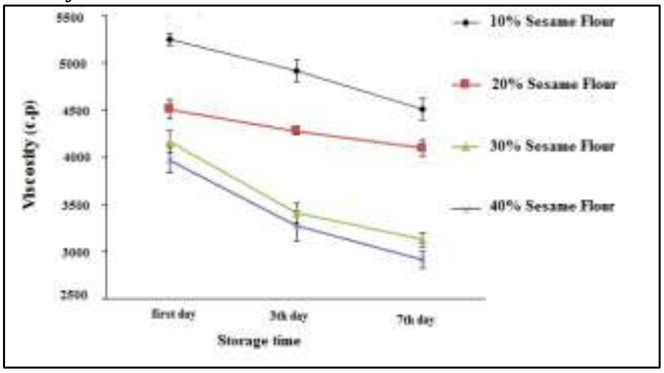

Figure 3. Viscosity measurement results (viscosity decreased with an increasing percentage of sesame seed flour) [viscosity (centipoise)/the trend of changes in viscosity during storage].

According to Figure 4, adding different proportions of ground sesame seeds significantly affected the total phenolic content in milk samples. The sample containing 40% ground sesame seed had the highest total phenolic content. The presence of phenolic compounds in the control sample can be attributed to the presence of polyphenols in milk, which is mainly derived from animal feed (nutrition). The presence of phenolic compounds (flavonoid and flavanol) in high concentrations in sesame as well as in the product increased the total phenolic content [5].

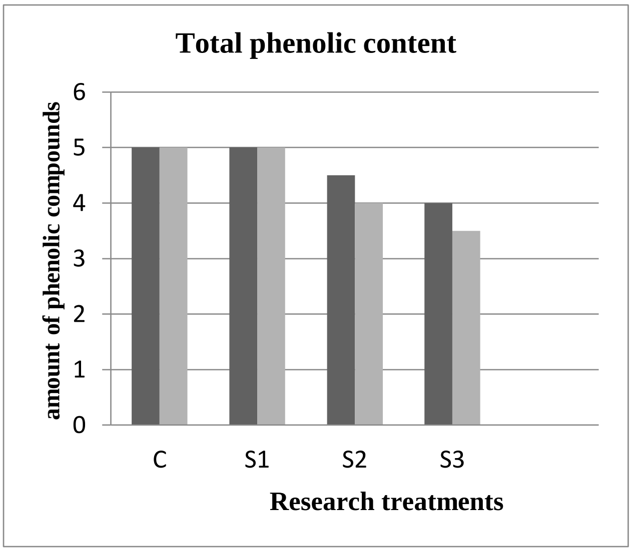

Figure 4. Total phenolic content in milk samples with ground sesame seeds (on the day of manufacture/on day 7).

Based on Figure 5, no significant difference can be observed between the value of lightness index (*L**), yellowness index (*b**) and redness index (*a**) of milk treatments in terms of ground sesame seed values higher than 20% compared to control treatment ($p<0.01$). According to Fig. 4, milk treatment containing 40% ground sesame seeds had the lowest value of lightness index (*L**) ($p\leq0.05$). Furthermore, the evaluation results of the lightness index (*L**) indicated a significant decrease in its value with increased amounts of ground sesame seeds in the pasta treatment formulation, which can be attributed to the increase in the accumulation of fiber particles. Therefore, the increased amount of fiber led to a more effective decrease in the lightness index (*L**) value in treatments containing 10% ground sesame seeds compared to other treatments [16]. Figure 4 also indicates a significant increase in amounts of yellowness index (*b**) in milk ($p\leq0.01$) as a result of using ground sesame seeds in the formulation of milk treatments. Milk treatment containing 40% ground sesame seeds had the highest value of the yellowness index (*b**) ($p\leq0.01$). The evaluation results of the yellowness index (*b**) revealed that the value of the yellowness index (*b**) of pasta treatments increased with an increased percentage of ground sesame seeds, which seems to be attributed to the color of ground sesame seeds and xanthophyll pigments present therein. The yellowness index (b*) value increased significantly compared to the control treatment with an increase in the percentage of ground sesame seeds [16]. As shown in Fig. X, the value of the redness index (*a**) decreased significantly ($p\geq0.01$) as a result of using ground sesame seeds in milk. The milk treatment containing 40% ground sesame seeds had the lowest value of the redness index (*a**) ($p\leq0.05$). The decreased redness index value can be attributed to the increased yellowness index value due to the presence of oil in sesame [16].

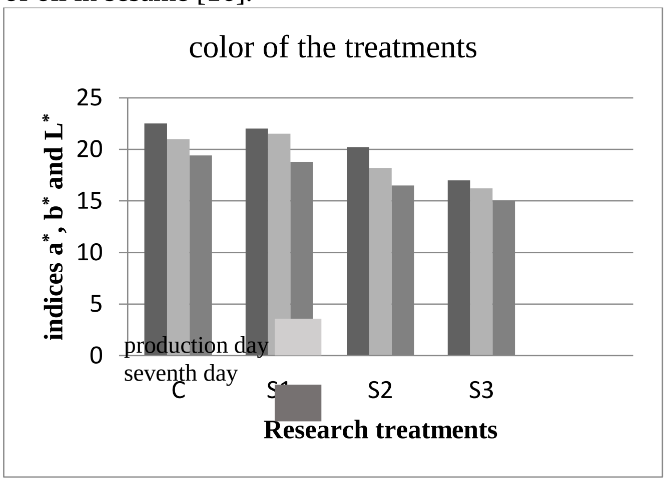

Figure 5. A comparison of average redness index (*L**), (*b**) and (*a**) of milk treatments (on the day of product manufacture/on the first month/on the third month).

CONCLUSIONS

The research results indicated an increase in AV and PV during storage. Moreover, the profile analysis of fatty acids showed that an increase in the percentage of ground sesame seeds in milk led to an increase in amounts of unsaturated fatty acids and a decrease in amounts of saturated fatty acids, with oleic acid and linoleic acid being the most significant. The total phenolic content in milk samples containing ground sesame seeds was significantly higher than in the control sample. It was also found that the quantities of these compounds increased with increasing storage duration. As seen, the sample with the highest percentage of ground sesame seeds on day 7 had the highest level of phenolic compounds. According to the evaluation results of colorimetry components, while the milk treatment containing 40% black sesame had the lowest value of the lightness index (*L**) and the redness index (*a**) ($p \leq 0.01$), the milk treatment containing 40% ground sesame seeds had the highest value of the yellowness index (*b**) ($p \leq 0.01$). In total, the research results proved the feasibility of enriching milk with sesame seed flour as a healthy, functional dairy product in terms of nutritional value due to high amounts of unsaturated fatty acids and high sensory properties.

Declarations

Availability of data and materials: All data related to the results of this manuscript are available upon requested from corresponding author.

Competing interests: The authors declare that they have no conflict of interest.

Funding: Not applicable

Authors' contributions: The practical part of the project was done by engineer Amani, the statistical part of the project by engineer Mohebbi, and the writing and submission of the paper by engineers Khazaei, Karbasi and Harati.

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