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RESEARCH PAPER

Effect of adding grain flour fibers on the physical, rheological, and sensorial properties of yogurt

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Abstract

Fiber can be employed as a bulking agent in low-sugar applications, to increase the texture, water, and oil holding capacity, emulsification, and/or gel formation in processed meals. This study aimed to determine the effect of the addition of grain flour fiber on the physical, rheological and sensorial properties of yogurt made from cow's milk. Milk was divided into five treatments which were as follows: (i) standard treatment C (control without additive), (ii) treatment S1 (milk with 1% wheat fiber powder), (iii) treatment S2 (milk with 2% wheat fiber powder), (iv) treatment S3 (milk with 3% wheat fiber powder) and (v) treatment S4 (milk with 4% wheat fiber powder). Rheological tests were conducted on the used milk, which included viscosity, spontaneous whey separation, water holding, hardness, stability, elasticity, and measurement of the pH value of the treatments. In addition, the sensory of the produced milk was evaluated. The results showed a large variation in the rheological and tissue properties according to the different percentages of wheat fibers added during manufacturing. Based on the results of this study, the addition of grain flour fiber improves the quality of yogurt such as texture, water holding capacity, spontaneous whey separation, viscosity, and the cohesion of the clot. Besides that, an increase in nutritional value is also observed.

1. Introduction

The importance of food safety and quality, and concern for consumer's health is increasing with the development of food health education (Grunert, 2005). With nutrient deficiencies in human societies, the production, importation and consumption of fortified foods are increasing (Preedy *et al*., 2013). Manufacturers use many additives in the dairy industry, including adding cardamom and cinnamon to make soft cheese (Salih *et al*., 2021), or the use of vegetable oils instead of milk fat in the manufacture of processed cheese (Saadi, 2018), or use of dried fruits or maple syrup in the ice cream industry (Hasan *et al*., 2021; Saadi, Jafar and Jassim, 2022). As well as the use of stabilizers in the yogurt industry (Saadi *et al*., 2022). Among the functional foods developed in the last few years, much attention has been focused on probiotic products and food containing dietary fiber (Blades, 2000). The fermentation process has been used for thousands of years in the food industry in order to increase its shelf life, reduce perishable, and gain its distinctive flavor and aroma (Buckenhüskes, 1993). Common fermented foods in the Middle East are wine, bread and cheese, as well as fermented dairy products like kefir and koumiss (Nair and Prajapati, 2003). Fermentation is a chemical method in which enzymes activate hydrolysis and organic matter is converted into minor compounds, as these foods are characterized by ease of digestion, and have a desired flavor and texture, in addition to increasing the nutritional value (Yousef and Carlstrom, 2003). Yogurt is one of the famous fermented dairies that is widely eaten all over the world. It is obtained by fermentation of lactic acid from milk by the act of a beginning culture of the *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. The function of these two bacteria in the yogurt industry can be reshaped by milk acid and the synthesis of fragrant compounds. It is well known that yogurt is a good source of protein, calcium, phosphorus, vitamin B2, thiamine, vitamin B12, folic acid, niacin, magnesium and zinc where in yogurt lactose is converted into lactic acid, and as a result, many people with lactose sensitivity can be consumed without health issues (Jasim and Al-Saadi, 2020; O'connell and Fox, 2001). Fermented dairy products have been utilized to provide a complete human diet by adding some important elements to improve its nutritional, organoleptic, and rheological properties since fermented dairy products are among the most eaten food products globally (Bonner *et al*., 1999).

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Where the structural properties of yogurt, such as viscosity (Marshall and Rawson, 1999), smoothness and thickness (Jaworska *et al*., 2005), and structural resistance to stress, are important traits for consumer identification, acceptance and these traits are nowadays accompanied by some health benefits (Behare *et al*., 2010). There have been many methods that are used to improve the quality of yogurt such as adding solids to milk (adding fats, proteins, or sugars such as sucrose and fructose), adding stabilizers (pectin, starch, alginate, and gelatin) (Duboc and Mollet, 2001; Lee and Lucey, 2010). Wheat fiber flour can be used to improve some functions and properties such as texture, water-holding capacity, and gel-forming (Garland *et al*., 1989; Mantell *et al*., 2000). Therefore, this study aimed to identify the effect of fortifying milk with grain flour fibers on yogurt's rheological quality and sensory qualities.

2. Materials and methods

2.1 Materials

Full-fat cow's milk was used to make yogurt obtained from local farmers in Al-Qasim, Babylon, Iraq. Grain flour fiber was purchased from Biotechnology Process Co. Karaj, Iran. Yogurt starter (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*) was purchased from a local market (DANISCO, Copenhagen, Denmark.

2.2 Treatments

Milk samples were divided into five treatments. The first treatment was control (C). The second treatment (S1) was to fortify milk with grain flour fiber of 1%, and the third treatment (S2) was milk fortified with grain flour fiber of 2%. The fourth treatment (S3) was 3% fortified milk and the fourth treatment (S4) was 4%.

2.3 Yogurt preparation

Yogurt is produced using techniques prescribed by Tamime and Robinson (1999) where milk is heated for all treatments at 90°C for 10 mins, then cooled to 42°C and inoculated by 2% of starter (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*), and wheat fiber was added to it after which the samples are filled in plastic containers with a capacity of 150 mL and incubated at 42±2°C until the clotting is completed, after which the samples are stored at a temperature of 5±1°C, until the necessary tests are performed.

2.4 Physiochemical analysis of yogurt

Physiochemical tests of yogurt samples are conducted during cold storage at (5°C) for 1, 7, 14, and 21 days.

2.5 Water holding capacity

The ability of yogurt to retain water (WHC) is calculated according to Harte *et al*. (2003). The 10 g yogurt was expelled by centrifuge at 5,000 rpm and for 10 mins at 5°C. The WHC is calculated according to the equation.

Water holding capacity (%) = (weight of precipitate/ weight of original sample) ×100

2.6 Spontaneous whey separation

The spontaneous whey exudation is estimated by placing 50 mL of yogurt in a 45°C for two hours at 5°C, then the exuding whey is pulled from the surface using the syringe, then the mug is weighed again and the operation is performed in a period of 10 s to avoid excessive exudation (Amatayakul *et al*., 2006).

2.7 pH values assessment

The pH of yogurt samples is estimated after 1, 3, 7, 14 and 21 days of cold storage using the Electronic Digital PH meter (Inolab WTW Series 720, Germany), buffer solutions of pH 4 and 7 are used to calibrate the pH meter.

2.8 Viscosity estimation

With some modifications, the Marshall and Rawson (1999) technique served as the basis for calculating the viscosity. Use a glass rod for stirring (10 times clockwise; 10 times counterclockwise). Spindle No.7 of Brookfield viscometer (DV-E; Brookfield Engineering Laboratory) to test rotational viscosity. Each measurement is made for 1 min at 100 rpm at room temperature.

2.9 Texture determination

The histological properties of the yogurt samples are evaluated after 1, 7, 14 and 21 days of manufacture using a tissue analyzer (Brookfield CT3 4500) in the College of Food Sciences/Al-Qasim graduate laboratory at Green University. The hardness, cohesiveness, and springiness of the samples were measured. An artificial plastic cylinder (15 mm diameter) was inserted into each product to a depth of 15 mm with a pressure of 5.0 g and a speed of 1 mm/s (Bonczar *et al*., 2002).

2.10 Sensory evaluation

Several staff from the Department of Dairy Science and Technology - Faculty of Food Sciences tested the sensory qualities of yogurt samples using the sensory assessment model for Nelson and Trout (1964), which includes flavor (40), texture (30), acidity (20) and appearance (10).

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3. Results and discussion

3.1 The effect of grain flour fiber on water holding capacity

One emphasized attribute to assess the quality of yogurt is its ability to hold water. Water holding capacity means the capacity of the gel to hold water, and with the increment of WHC, the quantity of water in the gel will be increased (Vanegas-Azuero and Gutiérrez, 2018; Al-Bedrani *et al*., 2019). Figure 1 shows the water holding capacity of the control treatment C made from whole cow's milk, and treatments S1, S2, S3, and S4 made from whole cow's milk containing 1, 2, 3, and 4% flour grain fiber respectively, during cold storage at 5±1°C for 21 days. On the first day of storage for treatment C, the water holding capacity value was 56%, while WHC for treatments S1, S2, S3, and S4 were 56.0, 57.0, 58.2, and 57.0 respectively. These values changed to 57.0 for C and to 57.0, 57.9, 59.0, 59.9 and 58.8% for treatments S1, S2, S3, and S4 respectively after 21 days of storage at 5°C. These results are close to the findings by Arslan and Bayrakci (2016), who found that the water holding capacity of yogurt treatment immediately after processing was 56.71%. It is noted that the water holding capacity increased with the increase of added grain flour fibers ratio, and a higher WHC was obtained in treatment S3. These results are inconsistent with the achievements of the previous study (Amal *et al.,* 2016), where the study showed that as the number of storage days increased, yogurt treatments' ability to hold more water also increased.

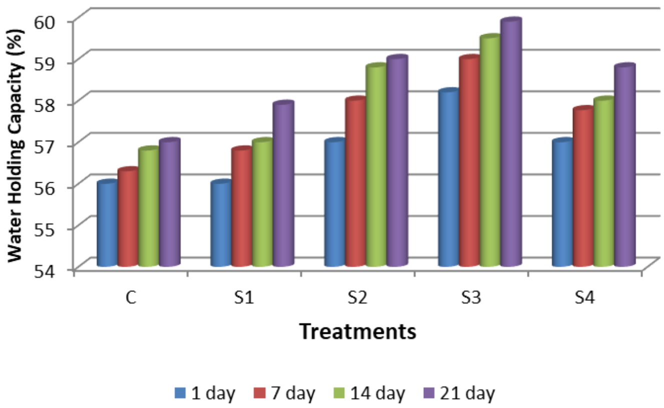

Figure 1. Effect of grain flour fiber on water holding capacity (WHC) of yogurt samples.

3.2 The effect of grain flour fiber on spontaneous whey separation

Spontaneous whey separation is defined as the exit of the whey from the protein network of yogurt to the outer surface, which occurs spontaneously without the influence of any external force on it (Lucey and Singh, 1997). Spontaneous whey separation occurs due to the lack of water holding by the protein network either due to lack of solids or insufficient heating or low pH. Besides that, SWS can result from to rearrangement of the gel matrix or damage to the network of gel proteins, for example, by vibration or cutting (Lee and Lucey, 2010). Figure 2 shows the values of spontaneous whey separation for control treatment C and the treatments S1, S2, S3, and S4, which were 2.0, 1.8, 1.5, 1.3 and 1.0 mL/50.0 mL, respectively. Immediately after processing, these values changed to 1.25, 1.1, 1, 0.9 and 0.5 mL/50.0 mL, respectively, after 21 days of storage at 5°C. SWS decreased in yogurt samples containing grain flour fibers in comparison with the control treatment because of the ability of grain flour fibers to bind water and to raise the milk's total solids content percentage. This is inconsistent with findings in the previous study (Andiç *et al*., 2013).

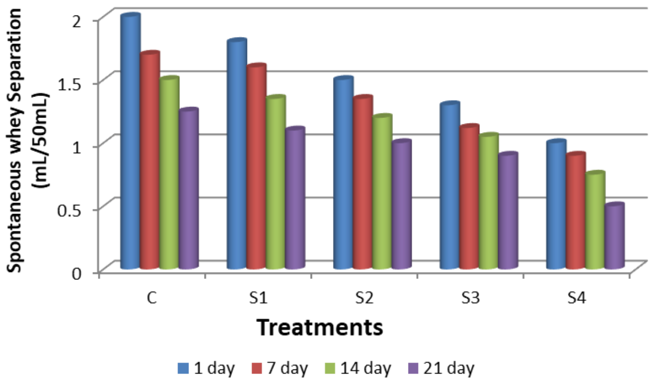

Figure 2. Effect of grain flour fiber on spontaneous whey separation of yogurt samples.

3.3 The effect of grain flour fiber on pH values

Both pH and total acidity express the acidity of milk and significantly influence the yogurt's flavor. Figure 3 shows the pH values of control treatment and treatments S1, S2, S3, and S4 made from whole cow's milk containing grain fiber flour with a percentage of 1, 2, 3, and 4%, respectively. PH values for control treatment C and the treatments S1, S2, S3, and S4 were 4.60, 4.30, 4.30, 4.30, and 4.35, respectively. Immediately after processing, these values changed to 4.1, 4.0, 3.9, 3.8, and 3.9, respectively, after 21 days of storage at 5°C. These results closely match the results of a previous study by

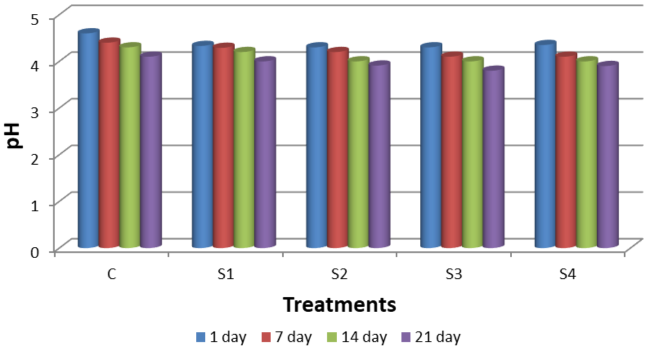

Figure 3. Effect of grain flour fiber on pH values of yogurt samples.

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Musaiger and Abuirmeileh (1998), who reported that after four weeks of storage, the pH of cow milk yogurt was 4.3. The decline in pH value during storehouse is attributed to the continuous fermentation of lactose into lactic acid (Pappa *et al*., 2018).

3.4 The effect of grain flour fiber on viscosity

One of the most crucial elements that determine the yogurt's quality is viscosity, which is related to both the stability of the product and the taste of fermented milk (Lewis, 1990). The results in Figure 4 indicated that on the first day of processing, the viscosities of treatments S1, S2, S3, and S4 were 2300, 2550, 2600, and 2750 cP, respectively, compared to 2100 centipoise for control treatment C. The results indicated an expansion in the percentage of "viscosity" of yogurt with the enlargement in the ratio of added grain flour fibers. Upon storage, it is observed that the viscosity values increased for all treatments and reached after 21 days for treatment C to 2660 centipoise, and for treatments S1, S2, S3 and S4 to 2800, 3000, 3010 and 3250 cP, respectively. The reason may be due to the low pH of the milk treatments, which guides to a boost in hydrophobic interactions between milk proteins which led to the formation of aggregated proteins and subsequently increased viscosity of yogurt and this has good agreement with the previous study (Walstra *et al*., 2005).

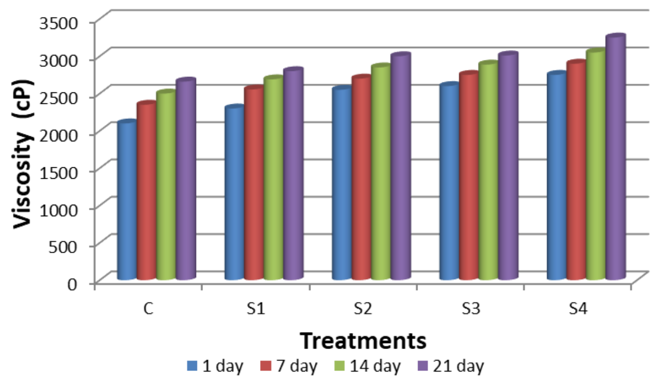

Figure 4. Effect of grain flour fiber on viscosity of yogurt samples.

3.5 The effect of grain flour fiber on hardness

The strength of the curd is related to the overall effect of chemical interactions. Heat treatments denaturing β-Lg protein and binding β-Lg to K-Cn on the surface of casein micelles via disulfide bridges, led to an increase in the gel strength of the resulting yogurt (Dannenberg and Kessler, 1988). Figure 5 shows the hardness test results of the hardness test of yogurt treatments immediately after manufacturing for the control sample of 115 g and for the "treatments" S1, S2, S3, and S4 are 125, 135, 133 and 130 g, one by one. It is clear from the results that adding grain flour fibers increased the hardness of yogurt in comparison with the control. This is inconsistent with what was mentioned by Akalin *et al*. (2012), who indicated that increasing the percentage of solids increases the hardness of yogurt. The data also show that all of the treatments' hardness increased during storage for 21 days, reaching 140 g for treatment C and 155, 166, 160, and 155.5 g for treatments S1, S2, S3, and S4, respectively. This agrees with the findings of Patrignani *et al*. (2006), who indicated that the hardness of yogurt is related to higher protein content and total milk solids.

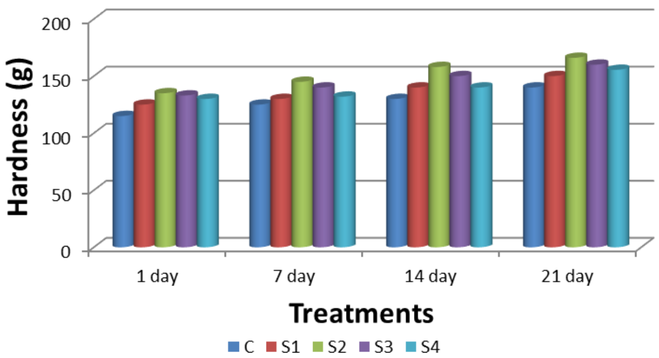

Figure 5. Effect of grain flour fiber on hardness of yogurt samples.

3.6 The effect of grain flour fiber on cohesiveness

Cohesiveness is one of the important characteristics of the texture of yogurt. Cohesion is described as the forces of interior bonds, which maintain the structure of the product for the consumer, and it is expressed as the extent to which the material is deformed when exposed to the cause of deformation before it ruptures, and this depends on the nature of the protein material (Mousavi *et al*., 2019). The results in Figure 6 show that cohesiveness values for control treatment C made, and treatments S1, S2, S3, and S4 were 0.45 and for the treatments 0.5, 0.55, 0.6 and 0.55, respectively, after 1 day of storage at 5°C. A decrease in the cohesiveness values is noted with the progression of the cold storage period, where the values after 21 days for the control treatment are 0.3 and for the other treatments 0.38, 0.40, 0.40 and 0.43,

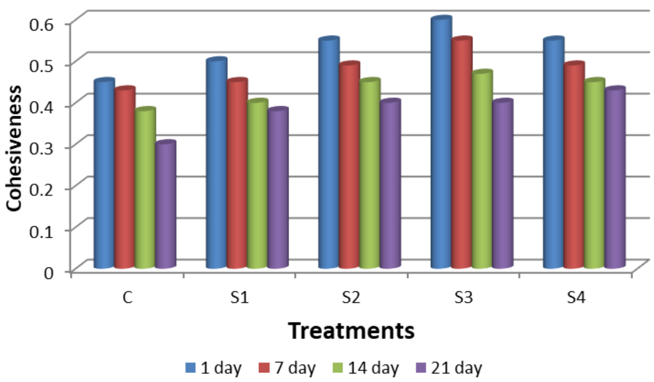

Figure 6. Effect of grain flour fiber on cohesiveness values of yogurt.

respectively. Yilmaz-Ersan and Kurdal (2014) indicated that the lower the cohesion in the yogurt, the smoother its texture (fineness to the touch). Yilmaz-Ersan and Kurdal (2014) indicated that the lower the cohesion in the yogurt, the smoother its texture (fineness to the touch).

3.7 The effect of grain flour fiber on springiness

Springiness is defined as the average or extent to which a deformed material returns to its initial state after eliminating or removing the effect of the force applied to it. Springiness depends on various factors such as heat treatment, protein interaction and binding, and the degree of protein dissociation and unfolding (Delikanli and Ozcan, 2014). The results in Figure 7 show the springiness values for treatment C and treatments S1, S2, S3, and S4 were 19.4 mm and 19.6, 19.3, 19.8 and 19.9 mm, respectively, after 1 day of storage at 5°C. It was also noted that the Springiness values of most of the yogurt treatments increased during storage, as it is after 7 days for treatment C 20.7 mm and for S1, S2, S3, and S4 were 20.5, 20.5, 21.0 and 20.6 mm, respectively. This may be due to the increased water holding capacity, which leads to higher springiness. This is inconsistent with the study of Ahmad *et al*. (2019), who assert the increase in the springiness of the yogurt to the rise in water in the milk gel. It is also noted that the springiness values decrease with the progress of storage for more than seven days, as after 21 days its value for treatment C is 17.4 mm and for treatments S1, S2, S3, and S4 were 19.0, 18.6, 19.0 and 18.7 mm, respectively. The result also agrees with what was found by Mustafa and Albadawi (2019), who indicated that the springiness values of yogurt changed from 17.6 mm directly after processing to 21.5 mm on the seventh day and then lowered at the end of the 21-day storage duration.

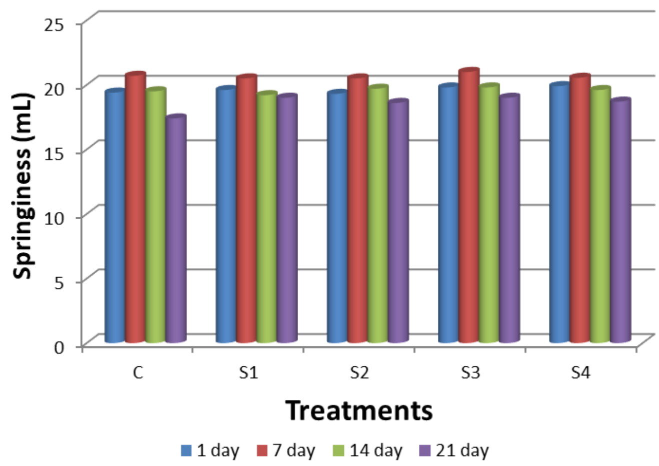

Figure 7. Effect of grain flour fiber on springiness values of yogurt.

3.8 The effect of grain flour fiber on sensory evaluation

Table 1 exhibits the consequences of sensory evaluation for different yogurt treatments manufactured in this study, and it is clear from these results that the degrees given to yogurt samples containing grain flour fibers are higher than the degrees given to control treatment directly after industrialization and it is also remarked that treatments S3 and S4 got the higher grades. During storage, the yogurt containing grain flour

Table 1. Effect of grain flour fiber on sensory evaluation of yogurt.

Day	Treatment	Flavor (40%)	Texture (30%)	Acidity (20%)	Appearance (10)	Total (100)
1	C	33.2	27	17.6	8.6	86.4
	S1	33.6	27.6	18	8.8	88
	S2	37.8	27.4	18.6	9.2	92.6
	S3	37.4	28.4	18.6	9.2	93.6
	S4	37	28.5	18.6	9.2	93.3
7	C	30.8	25.5	15.2	8.4	79.9
	S1	33.2	26.8	16	9	85
	S2	34.8	27.6	16.6	9	88
	S3	36.4	28.4	17	9.2	91
	S4	37.2	28.6	16.6	9.2	91.6
14	C	30.6	27.2	15.8	8.2	81.8
	S1	33	27.2	16.2	8.6	85
	S2	37.4	28.8	18.4	9.4	94
	S3	37.2	29.2	18.6	9.6	94.6
	S4	38.2	29.2	19.2	9.6	96.2
21	C	36.5	27	17.5	9.5	90.5
	S1	37	28	18	9.5	92.5
	S2	38.5	29	18.5	9.75	95.75
	S3	39	28.5	19	10	96.5
	S4	39.5	29	19.5	10	98

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fibers got higher sensory evaluation scores compared to the control. These results are inconsistent with the findings reported by Goyal and Hati (2019). The results in Table 1 show high acceptability among panelists to yogurt treatments containing grain flour fibers in comparison with control yogurt during storage at 5°C for 21 days.

4. Conclusion

The study shows that milk supported by grain flour fibers is instrumental in improving the quality of yogurt such as texture, water holding capacity, spontaneous whey separation, viscosity, the coherence of the clot and increase its nutritional value.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

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