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Effect of Oat β- glucan as a Fat Replacer on Physicochemical, Rheological and Sensory Properties of low-fat Sheep Milk Yoghurt

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ABSTRACT

The notion of yoghurt's positive impact on human health and nutrition has been widely held throughout several civilizations for a considerable duration. The aim of this study is to examine the benefits of adding oat beta glucan to skim milk in order to enhance the production of yogurt. An investigation was conducted on yogurt samples to analyze their physicochemical properties (pH, titratable acidity, syneresis, water-holding capacity (WHC), and hardness) as well as their sensory qualities. The samples were stored at a temperature of 4±1 °C for 1, 7, 14, and 21 days. The analysis revealed that the average pH value of both types of sheep milk samples was within the range of 6.6 to 6.5, indicating that the acidity level was within the usual range for all milk compositions. The yoghurt samples had the maximum acidity at beta glucan concentrations of 0.75% and 1%. The study is shown that the addition of oat β-glucan, particularly at a concentration of 0.25%, enhances the qualitative characteristics of low-fat yogurt and increases sensory evaluation ratings when compared to control treatments.

1.Introduction

Yoghurt is conventionally produced by the process of fermenting liquid milk. The belief in the positive impact of yoghurt on human health and nutrition has been present in several civilizations for an extended duration (Singh *et al.*, 2012). Yoghurt is more nutritious than milk because it contains higher levels of milk solids, protein, calcium, phosphorus, and several vitamins, as well as additional minerals produced during fermentation (Ibrahim and Al Saaid, 2018). Yoghurt texture as food is influenced by total solids. Milk with higher total solids content enhances smoothness, reduces susceptibility to syneresis, Singh *et al.* (2012) and results in shorter casein particle chains (Jasim and Al-Saadi, 2020). Sheep milk can be an ideal for producing yoghurt since it has a high protein and total solids content. In addition, sheep milk yoghurt had the highest viscosity compared to yoghurt made from goat, cow, and camel milk (Jumah *et al.*, 2001). People in industrialized nations started looking for varieties of yogurt that included less fat in the market. Yoghurt with a lower fat content that is of the same quality as full-fat yoghurt is becoming increasingly popular among consumers. In order to enhance the quality of low-fat yogurts, the manufacturers begun an evaluation of different components. These components include gelatin, κ-carrageenan, inulin, pectin, dietary fibers, and other hydrocolloids (Ibrahim *et al.*, 2020). In addition, decreasing the amount of fat that is contained in yoghurt may have a negative impact on the thickness of the yoghurt as well as the separation of the whey, which may lead to a decrease in the levels of consumer approval and the quality of low-fat yoghurt (Tamime and Robinson, 2007). Oat β-glucan has recently gained recognition as a hydrocolloid dietary component that offers numerous benefits. Beta-glucan possesses a number of properties, including the ability to replace fat, stabilize, and thicken substances among other things (Ibrahim and Selezneva, 2017). Furthermore, these qualities have the potential to promote the enhancement of the thickness, consistency, and water retention attributes of low-fat yoghurt. Vasiljevic *et al.* (2007) performed a research investigation to examine the impact of oat β-glucan on the development and metabolic function of probiotic bacteria in yogurt and β-Glucan has the potential to function as a prebiotic, meaning that it provide as a source of nutrition for probiotic bacteria. It has shown that the addition of β-glucan improves the ability of probiotics to survive and maintain their stability (Ibrahim *et al.*, 2020).

B-glucan exerts a lowering effect on the reaction of postprandial blood glucose and insulin, therefore mitigating the elevation of blood cholesterol levels. Beta-glucan has positive impacts on the body such as enhanced intestinal function (by dietary fiber), decreased levels of uric acid and glucose in the bloodstream, immune system stimulation, reduced blood pressure, cholesterol (HDL), and coronary heart disease (Xu *et al.*, 2013). Furthermore, beta glucan enhances the capacity to produce suitable texture (Sahan *et al.*, 2008). In low-fat dairy and other products including pasta, oat flakes, cereals, bakery items, and beverages, beta-glucan can be utilized to improve prebiotic characteristics, serve as structural additions, and act as a fat substitute (Lyly, 2006) . It also contributes to achieving desired texture in food products. Adding β-glucan to food products has numerous benefits. Low-fat dairy products like yogurt use β-glucan to simulate the creamy texture of fat, making them more appealing without the added calories and saturated fats. Adding β-glucan to pasta improves texture, mouth feel, and fiber intake (Ladjevardi *et al.*, 2018). The objective of the current study is to find out the impact of Beta glucan addition on the physiochemical and sensory traits of sheep milk yoghurt.

Materials and Methods

Materials

Oat β-glucan (100%) was obtained from Henry Bloom Bio-Technology Co., Ltd, located at 16/20 Baker St, Banksmeadow NSW 2019 in Australia.

Sources of milk

The process of collecting of sheep milk in Shamzinawa village, located in Erbil city, involved the use of thirteen animals. Milk was skimmed by a separator-Elecrem model-France.

Milk chemical analysis

The milk fat content in the samples was determined using the Gerber method, as described by the British Standards Institution B. SS (1989) .The moisture content in milk and yoghurt samples was evaluated using drying procedures as described by Siamand and Al-Saadi (2017).The ash content in milk was determined using the methodology outlined in the Association of Official Analytical Chemistry (AOAC, 2000)criteria .The nitrogen concentration in the milk sample was analyzed using Kjeldahl's method, which had been recommended by the Association of Official Analytical Chemistry AOAC (2000). The protein concentration in milk was calculated by multiplying the nitrogen percentage by a factor of 6.38.Carbohydrate content was determined by difference using the following equation

Carbohydrate(%) = 100 – (moisture % + protein %+ fat % + ash).

Yoghurt manufacturing

There were six different treatments developed, including of four variations of skim milk with the addition of oat β-glucan at concentrations of 0.25, 0.5, 0.75, and 1%, as well as samples of skim milk and fresh whole milk. The addition of β-glucan to skim milk was performed in steps, followed by heating the mixture to 60 °C while constantly stirring for approximately 20 minutes on a magnetic stirrer. This process was carried out to facilitate the dissolution of β-glucan (Ibrahim and Al Saaid, 2018). The milk samples were subjected to a heating process at a 90 ±2 °C for duration of 10 minutes. Following that, the samples were cooled down to a temperature of 42°C. Following this, 3% of pre-activated starter was added within the skim milk. The milk sample that was treated with a inoculated was separated into plastic cups with a volume of 100 ml. It was then placed in an environment with a temperature of 42 ±2 °C and kept there for incubation for a period of 3 – 4 hours, until the pH level dropped to 4.6. After that, it was stored at 4 -5°C (Tamime and Robinson, 2007).

Physiochemical analysis

Determination of pH and Titratable acidity

The pH of the Yoghurt samples was measured using a sensor pH meter (Model ECscan 10L) of type HQ 411 d, which originated from the USA (Al-Saadi, 2014). The measurements were taken directly in the Yoghurt samples after 1, 7, 14, and 21 days of processing. The Association of Official Analytical Chemistry AOAC (2008) methodology was applied to determine the titratable acidity of the yoghurt samples.

Assessment of whey separation occurring naturally

In order to assess spontaneous whey separation (SWS) as outlined by Amatayakul et al. (2006), a refrigerated yogurt sample was extracted from the refrigerator and kept at a temperature of 5 degrees Celsius. The liquid whey was carefully removed from the yogurt using a syringe equipped with a needle, and the total volume of separated whey was measured.

Water-holding capacity determination

The water-holding capacity (WHC) of yoghurt was assessed using the procedure described by Harte et al. (2003). Briefly, 10 g of milk gel was centrifuged at 5000xg for 10 min at 5 °C. The resulting supernatant was carefully weighed to determine the amount of excluded water,

WHC% = [1-(w2 / w1)] ×100

[w1: the weight of milk gel used, and w2: the weight of whey after centrifugation].

Determination of hardness

This was conducted to determine the hardness level of the samples, as documented by Ali and Al-Saadi (2019).

Sensory assessment

The sensory qualities of low-fat sheep milk yoghurt were evaluated to determine product acceptance as described by Othman et al. (2019).

Statistical analysis

The study compared the average values of each measured parameter in yoghurt prepared with or without β-glucans on the same storage day using a one-way analysis of variance. SPSS software 2.5 was used for statistical analysis. Results were statistically significant with a p-value of 0.01.

Results and discussion

Sheep milk composition

Table (1) showed the chemical composition of sheep whole and skim milk. The percentage of moisture, Ash, Protein, Fat, Carbohydrate, solid non fat and total solid in whole milk were 83.1 %, 0.89%, 5%, 6.1%, 4.91%, 10.8% and 16.9% respectively, while their values in skim milk were 86.53%, 0.89%, 6.38%, 0.29%, 5.91%, 13.18% and 13.74 % respectively. It is revealed that all compositions of milk samples were in a normal range and similar to that obtained by (Ibrahim and Al Saaid, 2018). The findings correspond with (Al-Saadi and Mohmmed, 2002) research, which demonstrated that both sheep and camel milk have higher fat content compared to goat and cow milk.

Table 1: **Chemical composition of sheep whole and skim milk.**

Component (%)	whole milk	Skim milk
Moisture	83.1	86.53
Ash	0.89	0.89
Protein	5	6.38
Fat	6.1	0.29
Carbohydrate	4.91	5.91
Solid non Fat	10.8	13.18
Total solids	16.9	13.47
pH	6.6	6.5

Effect of beta glucan on the physicochemical and rheological properties of low-fat sheep milk yoghurt

Acidity and pH

Adding sheep milk with oat β-glucan had a notable impact on the pH and titratable acidity of yogurt after being stored for 21 days at 4 °C. It is evident that the acidity of the yoghurt samples escalated as the storage duration rose, which can be attributed to the starter's role in converting lactose into lactic acid. As the content of beta glucan grew from 0.25% to 1%, the pH of the yoghurt declined (Figure 1) and the acidity of the samples increased progressively (Figure 2). At beta glucan concentrations of 0.75% and 1%, the yoghurt samples had the highest acidity. A reverse trend was observed for pH values with increasing of concentration of beta glucan and storage time the pH was decrease. The addition of beta glucan to set-type yogurt resulted in a slight rise in acidity and a corresponding decrease in pH. This is due to the fact that beta glucan, acting as a prebiotic, facilitates the production of acid by Lactobacillus during the process of fermentation (Ibrahim et al. (2020); Rosburg et al. (2010)).

Spontaneous whey separation

The occurrence of spontaneous whey separation (SWS) was assessed by quantifying the amount of whey that separated and accumulated on the surface of the yogurt sample. SWS can be considered a primary defect in yoghurt (Lucey, 2002). The results in figure 3 showed that spontaneous whey separation decreased gradually in yoghurts treated with β- glucan levels up to 1% in comparison to control. The yoghurt sample made with the addition of 0.75% and 1% β-glucan showed the least amount of spontaneous whey separation, with a maximum reduction of 0.00 ± 0.00%. The addition of β-glucan resulted in a notable reduction in the natural separation of whey in skim milk yogurt after being stored for 21 days at 5 ± 1°C.This refers to the capacity of oat beta-glucan to effectively retain water inside the structure of yoghurt.

Water holding capacity

Water holding capacity (WHC) refers to the ability of a gel to retain water. As the WHC increases, the amount of water held by the gel also increases. The concentration of β-glucan added to sheep milk for making sheep milk protein yoghurt may be directly influenced the rise in WHC. This may be attributed to the ability of oat beta-glucan to bind water and inhibit its movement out of the gel network. Beside that WHC increased with the increment of storage time and this increment may be related to the effect of beta-glucan in increasing the number of interactions between milk proteins (Aljewicz et al., 2021). From these results, we can notice a significant difference between WHC of yoghurt gels produced using different concentrations of beta-glucan.

Hardness

Hardness can be defined by mean the amount of force that must be applied in order to for the gel to experience deformation. Indicators of the gel network's strength are frequently taken into consideration while applying it (Gunasekaran and Ak, 2002). The significant effect of β-glucan is evidenced by its capacity to form a physical bond with the water present in yogurt, so keeping the water from separating on the surface (Kaur and Riar, 2020). Addition β-glucan to sheep milk resulted in increased hardness of resulting yoghurt. It was found that the hardness of treatment 6 and 5 was higher in comparison to T1 or the control, and the mean value for hardness of both treatments significantly increased, with a significant raise occurring after 21 days of storage time (Figure, 5). The results demonstrate that the gel strength of the gels increased as the concentration of β-glucan used for their preparation increased. There is a possibility that this increase can be attributed to the capacity of β-glucan to preserve water and to strengthen the amount of bonds that are present between milk proteins (Aljewicz et al., 2021).

Sensory evaluation

A sensory evaluation was performed on yogurt samples for evaluating the level of acceptance. The panelists assessed the taste, consistency, level of acidity, and visual presentation of the yogurt within 21 days of production. Table (2) showed that all sensory evaluation were significantly affected by adding β-glucan, T1 and T2 total scores were 89.9 and 87.2 respectively, while the total scores for T3 , T4 , T5 and T6 were 87.60 ,85.80, 78.80 and 64.80 respectively . Low concentrations of β-glucan (0.25 and 0.5 %) had sensory evaluation score close to T1 and T2, but the increment of β-glucan ratio in sheep milk (0.75 and 1%), had negative effect on the sensory evaluation score of yoghurt. Despite the yoghurt being produced from skim sheep milk, several panelists characterized T3 and T4 yogurt as creamy. This observation could be attributed to the ability of β-glucan to bind water, resulting in a smoother and creamier product. Therefore, it is feasible to utilize this technique to produce low-fat dairy products that possess comparable textures to their counterparts with higher fat content.

Table 2: Sensory evaluation of different yoghurt treatments after 21 days of storage. T1= yoghurt prepared from whole sheep milk , T2= yoghurt prepared from skim sheep milk ,T3= yoghurt contain 0.25% β-glucan T4= yoghurt contain 0.5% β-glucan ,T5= yoghurt contain 0.75% β-glucan and T6= yoghurt contain 1% β-glucan.

		Flavor (40)	Texture (30)	Acidity (20)	Appearance (10)	Total (100)
T1	**S1**	35.60 ± 0.60a	29.00 ±0.63a	18.60± 0.98a	9.20 ±0.20a	89.90 ±2.63a
	S2	31.20±2.33abcd	27.60 ±1.94abc	16.20 ±0.73abcde	9.40 ±0.24a	84.40 ±4.17abc
	S3	33.40 ±0.93abc	26.20 ±1.53abc	15.80 ±0.49abcde	9.00 ±0.45a	84.40 ±1.33abc
	S4	25.83 ±2.01cde	26.67 ±1.65abc	14.00 ±0.82bcdefg	9.33 ±0.42a	75.83 ±4.62bcdef
T2	**S1**	34.40 ±0.81ab	26.80 ±1.39abc	16.80 ±0.97abc	9.20 ±0.37a	87.20 ±2.15a
	S2	30.40 ±1.12abcde	25.40 ±1.44abc	16.60 ± 0.68abc	9.40 ±0.24a	81.80 ±1.83abc
	S3	33.00 ±1.26abc	28.60 ±0.93ab	14.40 ± 0.24bcdefg	9.40 ±0.24a	85.40 ±1.69a
	S4	29.20 ±1.36abcde	24.80 ±2.40abcd	14.20 ±1.02bcdefg	9.20 ±0.49a	77.40 ±2.79abcdef
T3	**S1**	32.80 ±1.24abc	28.00 ±0.55abc	18.40 ±0.93a	8.40 ±0.51abc	87.60 ±2.52a
	S2	31.20 ±0.49abcd	26.40 ±0.87abc	14.80 ±1.53abcdef	8.60 ±0.40ab	81.00 ±2.05abcd
	S3	33.33 ±1.23abc	25.33 ±2.03abc	11.50±1.50efg	8.00 ±0.58abc	78.17 ±4.29abcde
	S4	30.00 ±2.24abcde	25.00 ±2.14abcd	12.40 ±1.12efg	7.00 ±0.95bcde	74.40 ±5.96bcdefg
T4	**S1**	32.80 ±1.24abc	27.40 ±0.24abc	17.20±1.02ab	8.40 ±0.51abc	85.80 ±1.83a
	S2	28.00 ±2.19abcde	25.00 ±0.55abcd	15.40 ±0.51abcdef	7.20 ±0.20bcde	75.60 ±2.11bcdef
	S3	32.20 ±2.42abc	25.00 ±0.00abcd	12.80 ±0.20defg	8.00 ±0.32abc	78.00 ±2.66abcde
	S4	24.00 ±1.79de	22.00 ±1.55cdef	13.20 ±0.73cdefg	5.20 ±0.20fg	64.40 ±3.03fgh
T5	**S1**	32.40 ±1.60abc	22.60 ±1.03bcde	16.20 ±1.20abcde	7.60 ±0.60abcd	78.80 ±3.97abcd

	S2	29.20 ±3.56abcde	18.60 ±0.68efg	16.40±0.40abc	7.20 ±0.37bcde	71.40 ±4.08cdefgh
	S3	30.20 ±1.24abcde	16.00 ±1.00g	10.80±0.49g	5.00 ±0.00g	62.00 ±1.10gh
	S4	23.60 ±1.57de	18.00 ±2.00efg	12.40±0.68efg	5.60 ±0.24efg	59.60 ±3.23h
T6	**S1**	24.40 ±0.60de	19.20 ±0.49defg	14.40±1.29bcdefg	6.80 ±0.37cdef	64.80 ±1.56efgh
	S2	27.60 ±3.26bcde	18.20 ±1.20efg	15.80±0.97abcde	6.00 ±0.00defg	67.60 ±4.45defgh
	S3	27.40 ±1.25bcde	16.20 ±0.73fg	11.60 ±0.24fg	5.00 ±0.00g	60.20 ±1.39h
	S4	23.00 ±1.22e	18.80 ±2.33efg	11.60 ±0.75fg	5.00 ±0.45g	58.40 ±2.54h

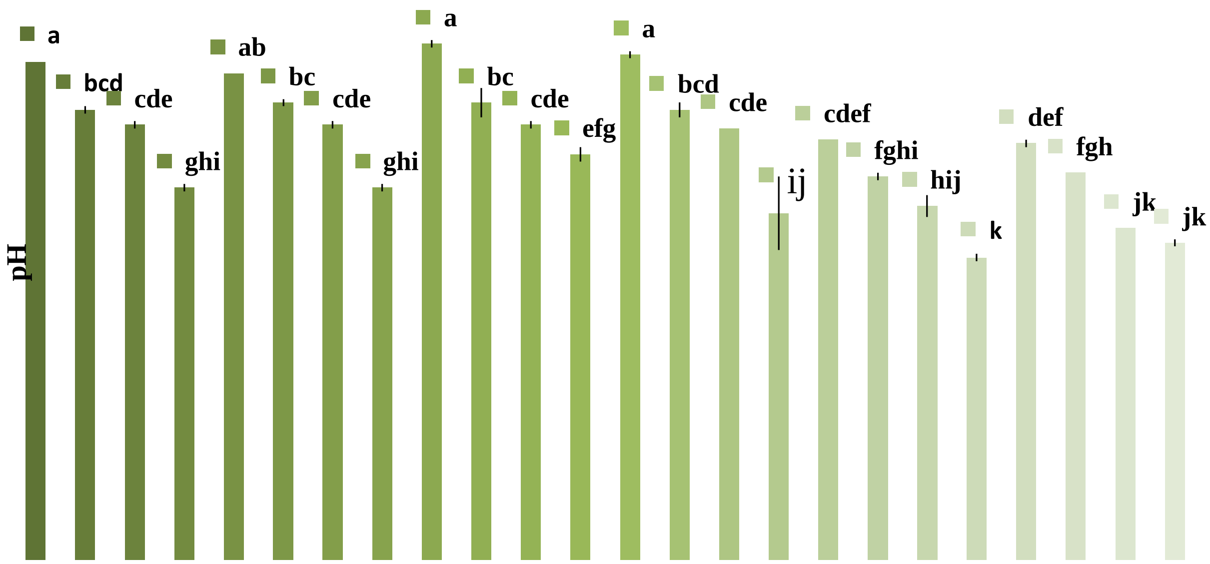

Figure 1. Influence of storage time on the pH of different sheep milk yoghurt , Where:T1= yoghurt prepared from whole sheep milk , T2= yoghurt prepared from skim sheep milk ,T3= yoghurt contain 0.25% β-glucan T4= yoghurt contain 0.5% β-glucan ,T5= yoghurt contain 0.75% β-glucan and T6= yoghurt contain 1% β-glucan.S1=day 1 ,S2=day 7,S3=day 14 and S4 =day 21.

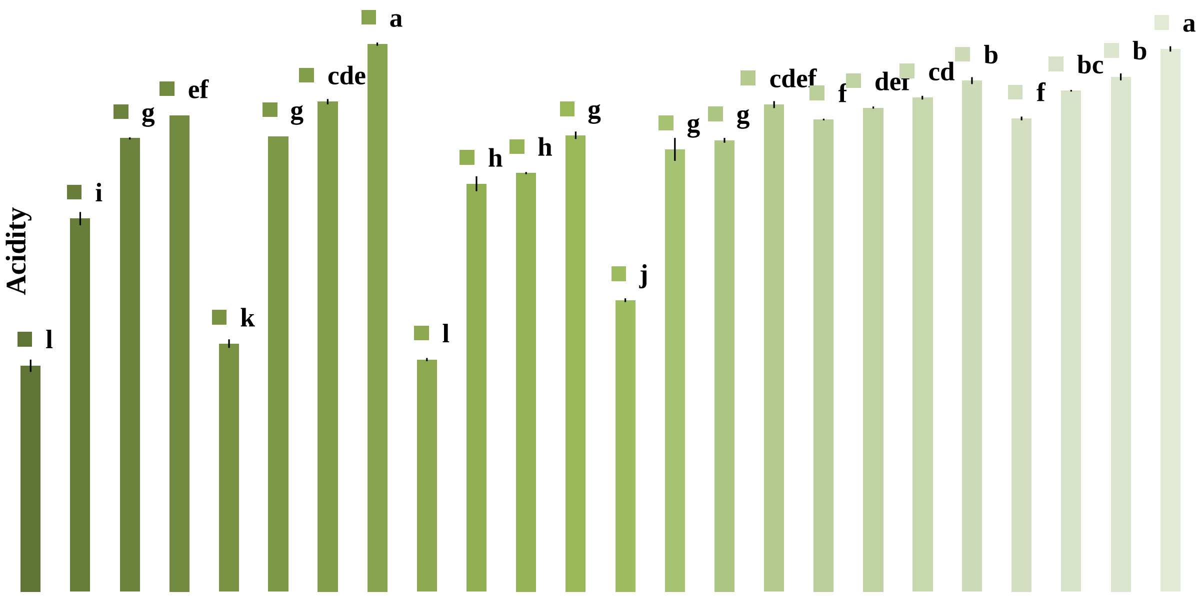

Figure 2: Influence of storage time on the acidity(%) of different sheep milk yoghurt , Where:T1= yoghurt prepared from whole sheep milk , T2= yoghurt prepared from skim sheep milk ,T3= yoghurt contain 0.25% β-glucan T4= yoghurt contain 0.5% β-glucan ,T5= yoghurt contain 0.75% β-glucan and T6= yoghurt contain 1% β-glucan.S1=day 1 ,S2=day 7,S3=day 14 and S4 =day 21.

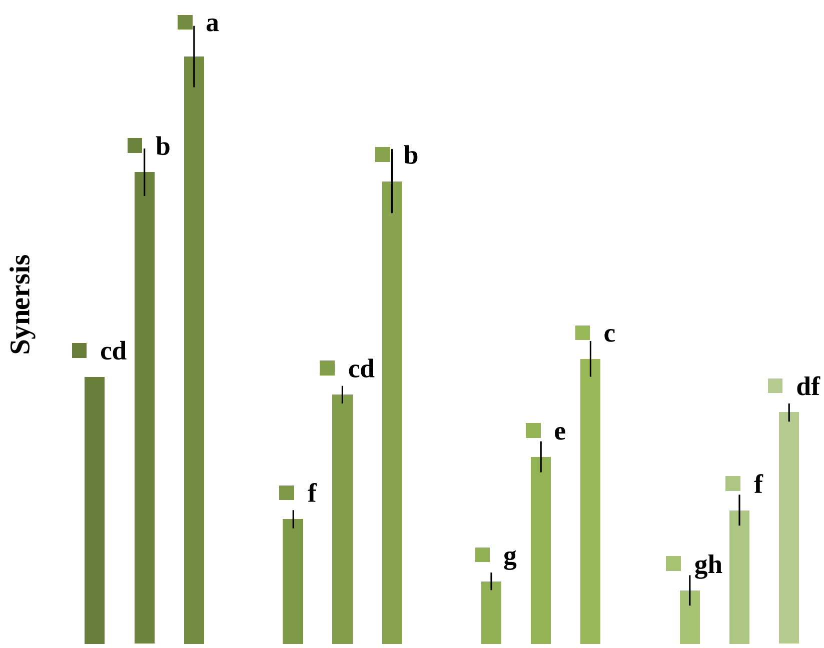

Figure 3: Influence of storage time on the synersis of different sheep milk yoghurt , Where:T1= yoghurt prepared from whole sheep milk , T2= yoghurt prepared from skim sheep milk ,T3= yoghurt contain 0.25% β-glucan T4= yoghurt contain 0.5% β-glucan ,T5= yoghurt contain 0.75% β-glucan and T6= yoghurt contain 1% β-glucan.S1=day 1 ,S2=day 7,S3=day 14 and S4 =day 21.

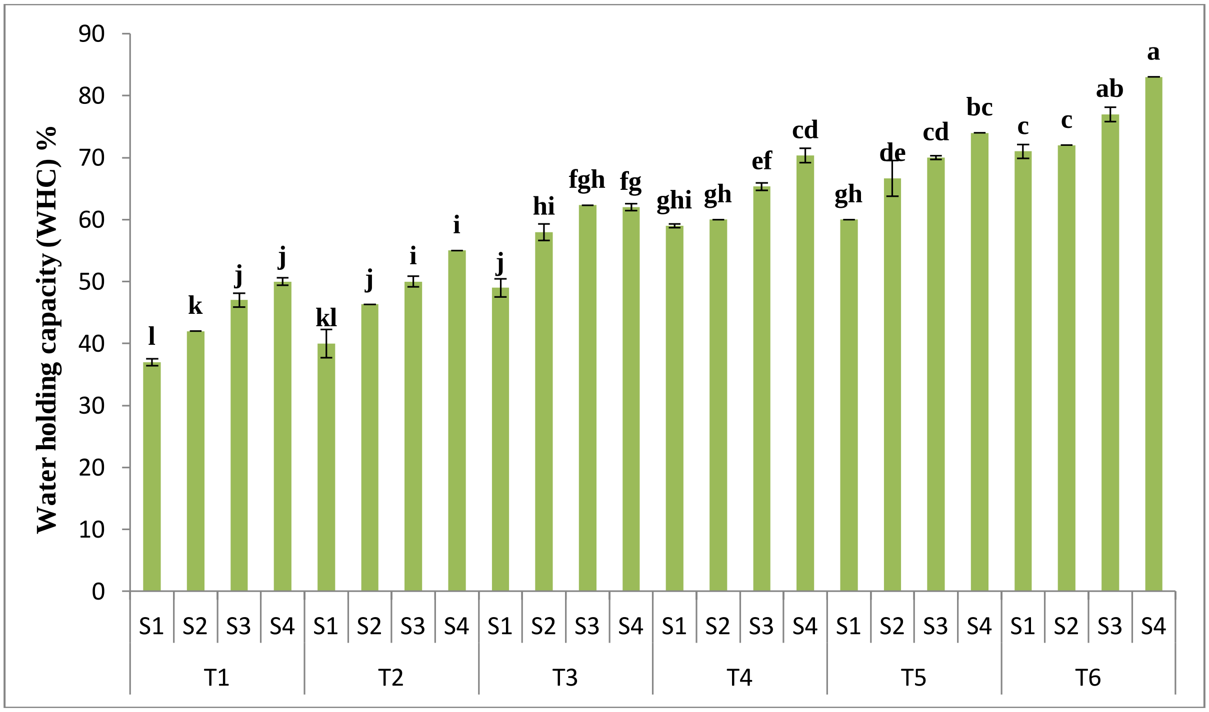

Figure 4: Influence of storage time on the WHC of different sheep milk yoghurt , Where:T1= yoghurt prepared from whole sheep milk , T2= yoghurt prepared from skim sheep milk ,T3= yoghurt contain 0.25% β-glucan T4= yoghurt contain 0.5% β-glucan ,T5= yoghurt contain 0.75% β-glucan and T6= yoghurt contain 1% β-glucan.S1=day 1 ,S2=day 7,S3=day 14 and S4 =day 21.

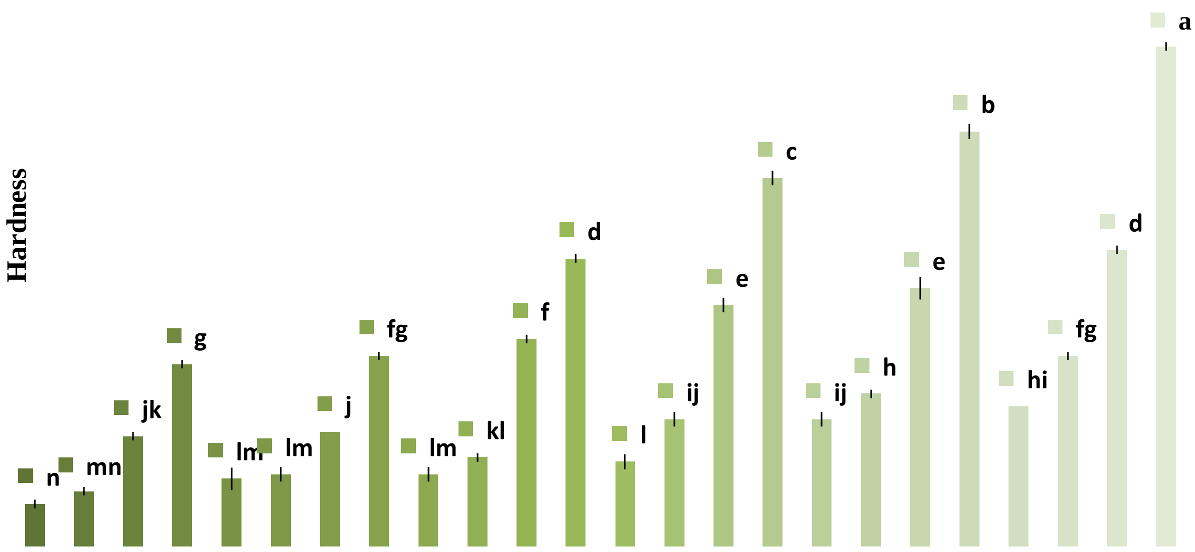

Figure 5: Influence of storage time on the hardness of different sheep milk yoghurt, Where:T1= yoghurt prepared from whole sheep milk , T2= yoghurt prepared from skim sheep milk ,T3= yoghurt contain 0.25% β-glucan T4= yoghurt contain 0.5% β-glucan ,T5= yoghurt contain 0.75% β-glucan and T6= yoghurt contain 1% β-glucan.S1=day 1 ,S2=day 7,S3=day 14 and S4 =day 21.

Conclusion

The study revealed that the addition of β-glucan to sheep milk had a substantial impact on the characteristics of texture and sensory perception in low-fat yogurt. Although the addition of β-glucan did not significantly change the taste characteristics of the yogurt, it greatly enhanced its rheological properties, hence improving its texture and consistency. The most favorable outcomes in the production of low-fat sheep yogurt were attained by including oat β-glucan at a concentration of 0.25%. This strategic choice effectively combined the enhancement of texture with the preservation of the overall quality of the product.

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