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Possibilities of using different combinations of lactic acid bacteria in the production of Sudanese white cheese (*Gibna Bayda*)

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Abstract

Sudanese White cheese (*Gibna Bayda*) was produced by using different starter culture combinations to find the most suitable starter culture. Four cheeses were prepared with pasteurized milk inoculated with different starter culture combinations at the rate of 1% (v/v), while control cheese (T5) was made without the addition of starter culture. Cheeses were stored in vacuum bags at 4 °C and 15 °C for 90 days, and the properties of cheeses were determined at intervals of 1, 15, 30, 45, 60, and 90 days. The yield of control (T5) cheese was higher than T4 and T1 cheeses and lower than T2 and T3 cheeses. Total solids, protein, fat, and acidity values and lipolysis degree of control (T5) cheese were lower than T4 and T1 cheeses, and higher than T2 and T3 cheeses. The proteolysis degree of control (T5) cheese was the lowest when the cheeses were stored at 15 °C, and the highest among all cheeses except T1 and T4 cheeses when stored at 4 °C. The acidity value, protein, salt, and the degree of lipolysis and proteolysis were higher in cheese samples stored at 15 °C. All sensory properties scored best in T1, T4, and T3 cheeses compared to control (T5) cheese. Cheeses stored at 4 °C scored better for odor and overall acceptability. The use of starter culture in the production of white cheese positively affected the properties of the cheeses, especially T4 cheeses containing *Lactobacillus helveticus,* and T1 cheeses made with mesophilic culture were better than other cheeses in terms of physicochemical and sensory properties.

Keywords: Sudanese White cheese; Starter culture; Physicochemical; Yield; Storage temperature

1. Introduction

Milk is known to have an important place in human nutrition because it is rich in nutrients such as protein, fat, vitamins, and mineral substances. Since it also supports microbiological development [1], milk is processed into various products to extend the shelf life and obtain products with different tastes and aromas [2]. Among these products, the most produced dairy product is cheese. Cheese making is the main method of preserving milk in Sudan, especially during the rainy season when it is abundant [3]. Sudanese white cheese is considered the most popular variety of brine-aged cheese in Sudan [1]. Most of the cheese production in Sudan is done on small farms without adequate equipment and without a starter culture addition. Sudanese white cheese is a semi-soft cheese made in small quantities using the traditional method [4]. It is generally produced from sheep or cow's milk or a mixture of these. The traditional production process begins by straining raw cow's milk through a cheesecloth and adding calf rennet. After leaving it to coagulate for 45-60 minutes at 26-30 °C, the clot is cut and the whey is drained, the surfaces of the clot are covered with cheesecloth and pressed overnight. Salting of cheese is done by adding salt to either milk or whey. On the next day of production, cheeses are put into whey and stored for 120 days at room temperature, which may exceed 30 °C in summer [5].

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The use of raw milk in cheese production poses a risk to public health and it is not always possible to find products of standard composition and quality. In scientific studies focusing on the relationship between pasteurization and the milk to be processed into cheese, it is argued that pasteurization of the milk is mandatory, regardless of the type of cheese. In pasteurized milk, in addition to pathogenic microorganisms, microorganisms that play an important role in the maturation of dairy products and the formation of their unique characteristic taste and aroma become inactive. Therefore, the addition of pure cultures of these microorganisms to milk during processing is of great importance for the quality of the final product [1]. Their presence contributes to flavor development during cheese ripening based on their multiple enzymatic activities [6]. In most cheeses, lactobacilli generally dominate the population of non-starter lactic acid bacteria (NSLAB). Other LAB species, *Lactococcus lactis*, *Leuconostoc mesenteroides* subsp. *mesenteroides* and *Leuconostoc*. *mesenteroides* subsp. *dextranicum* has also been found in the microbiota of traditional raw milk cheeses [7]. Selected mesophilic lactobacillus strains from non-starter lactic acid bacteria (NSLAB) have been used as co-cultures in cheese-making to control potentially harmful microbiota, improve cheese flavor, diversify, and possibly accelerate ripening [6]. As a result, many studies have examined the effect of different starter cultures on the properties of soft and semi-hard cheeses [8-13]. Relatively few studies have investigated the effects of starter culture on the properties of Sudanese white cheese during ripening [1, 3,14−16]. In this study, Sudan White Cheese was produced by using different starter culture combinations to find the most suitable starter culture. During 90 days of storage, the physicochemical and sensory properties of cheese were analyzed and the best combination was determined.

2. Material and methods

2.1. Material

Raw cow's milk was obtained from Menemen Research and Production Farm, Faculty of Agriculture, Ege University (Izmir, Turkey). Rennet powder (1.3 gm/50 L milk) was obtained from Chr. Hansen's (Denmark). DVS Cultures PTB1(*Lactococcus lactis*, *Lactobacillus cremoris*, *Streptococcus thermophilus*), DOM1 (*Lactococcus lactis*, *Lactococcus cremoris*), DHL IDC13 (*Lb. helveticus*) and CASEI 39 (*Lb. casei*) provided by NFC GIDA & KIMYA company (Izmir, Turkey). $CaCl_2$ (Horasan Kimya, Ankara) was obtained commercially from the market. Normal salt is bought from Billur Salt Industry (Izmir, Turkey). Vacuum bags, provided from Istanbul Ticaret-Hamza Güllüce A.Ş (Istanbul, Turkey).

2.2. Method

2.2.1. Activation of starter cultures

12% UHT skimmed milk was used to prepare the bulk culture prepared from freeze-dried DVS culture. Starter cultures were inoculated in one liter of UHT milk under aseptic conditions. *Lc*. *lactis* ssp. *cremoris* and *Lc. lactis* ssp. *lactis* culture at 30 °C, *Lc*. *lactis* ssp. *cremoris* + *Lc*. *lactis* ssp. *lactis* + *Streptococcus thermophilus* culture at 37 °C, *Lb. helveticus* culture at 42 °C and *Lb. casei* culture was kept at 37 °C until its pH decreased to approximately 4.50-4.60. Later, the bulk starter cultures were kept at 4-6 °C in the refrigerator overnight and used in production the next day.

2.2.2. Cheese production

Cheese production was carried out at Ege University, Faculty of Agriculture, Dairy Technology Department, Pilot Plant. The cheese production scheme is given in Figure 1. Cheesemaking was made with 175 L of cow's milk, and five groups of white cheese were produced. Four cheeses were produced using different starter cultures and control cheese was made without the addition of starter culture. The milk was pasteurized at 70 °C for 15 seconds, cooled to 37 °C, and then divided into five equal parts. 20 g of 100 L^{-1} $CaCl_2$ solution was added to each part. Next, one of the four starter culture mixes (1 ml 100 ml^{-1} milk) was added and left for fermentation (Figure 1). The fermentation was continued until the pH reached 6.1-6.2. Chymosin (Chris Hansen, Denmark) was added to coagulate the milk in 90 minutes. After coagulation, the curd was cut into small cubes (2 cm^3) and left in whey for 10-15 minutes, then mixed for about 15 minutes. The curd was poured into small clean wooden molds lined with clean cheesecloth and pressed overnight (1 kg weight). When the curd reached the proper strength, the cheese cloths were opened and the cheeses were cut into 5×5×5 cm cubes. The brine solution was prepared by adding salt to the collected whey (6% w/v), pasteurized at 72 °C/1 min, and cooled to 40 °C, and the curd was preserved in the brine solution at 4° C for 24 hr. Then the cheeses were stored in vacuum bags at 15 °C and 4 °C for 90 days. Analyzes were carried out in two replications at 1, 15, 30, 60, and 90 days of the ripening period. The manufacture of cheese was performed in triplicate.

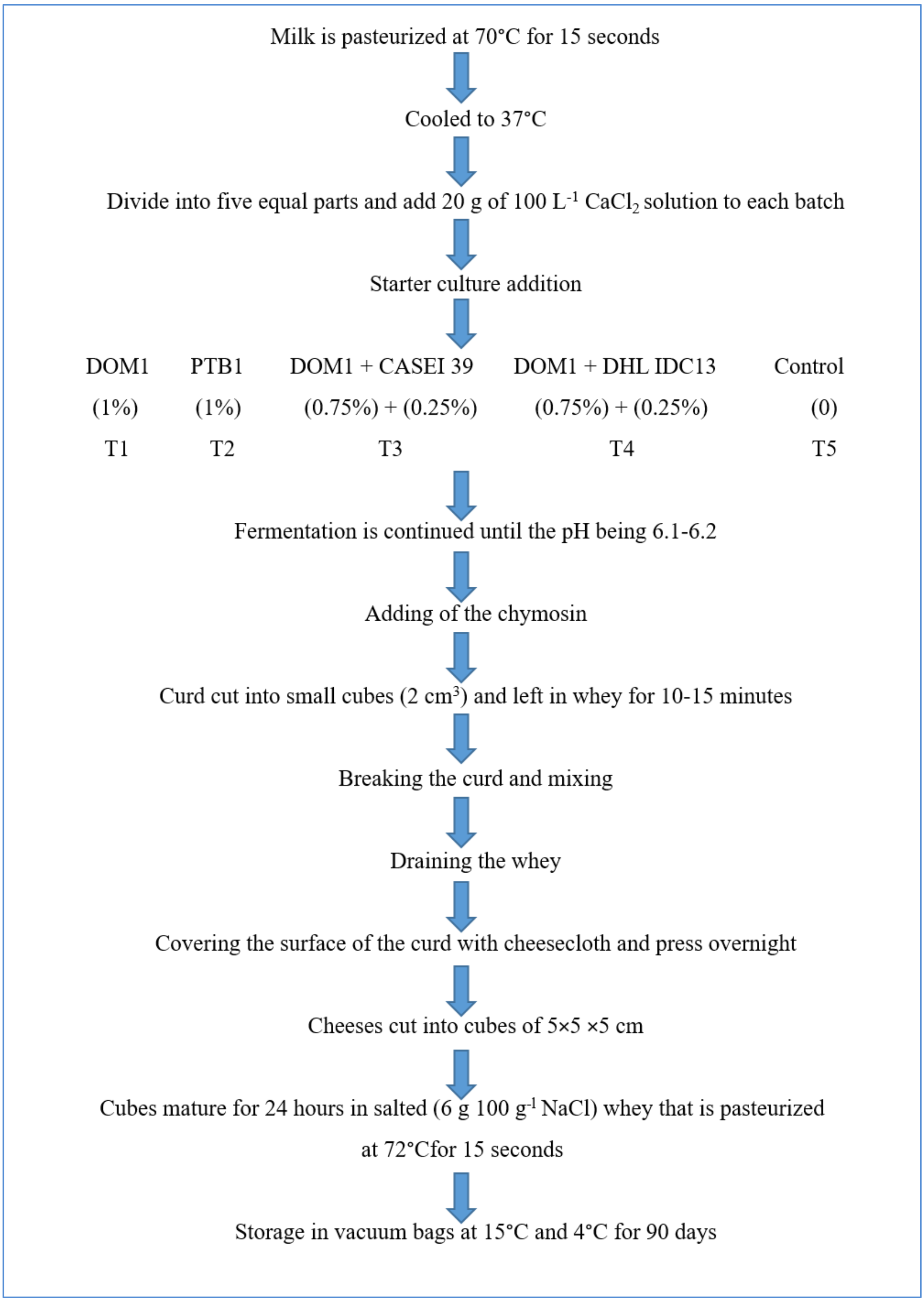

Figure 1 Cheese production scheme

2.2.3. Physicochemical analysis of milk processed into cheese

Total solids, fat, protein, and ash contents, titration acidity, and the pH values of the milk samples processed into cheese were determined by the method reported by AOAC [17]. Specific gravity was read using (MilkoScan FT 120; Foss Electric A/S, Hillerød, Denmark).

2.2.4. Cheeses yield

The yield was calculated according to the method reported by Fox et al. [18] and expressed as kg cheese obtained from 100 kg milk.

2.2.5. Physicochemical analysis methods for cheese samples

The pH value of the cheese samples was determined using a digital pH meter (HANNA Instruments pH 211, Portugal) [19]. Titratable acidity was determined as % lactic acid according to AOAC [20]. The total solids of the cheese samples were determined by the gravimetric method and the method specified in the TS 591 White cheese standard [21]. Protein determination in cheese was carried out using the kjeltec nitrogen determination mechanism, which was developed based on the Kjeldahl method [22]. The fat content in the cheese samples and the % fat content in the dry matter were determined using the method specified by Kurt et al. [23]. Ash was determined using the method specified by AOAC [24]. The salt content in the cheese samples and the % salt content in the dry matter were determined using the method specified by Kurt et al. [23]. Total free fatty acids values were determined by the fat extraction and titration method according to the method specified by Renner [25], and the results were expressed as g oleic acid (%) in 100 g cheese fat. Proteolytic activity in Sudanese white cheese samples was determined using the OPA method (o-Phthalaldehyde agent) [26]. For this purpose; 50 µl of WSN prepared according to Kuchroo and Fox [27] was taken, mixed with 1 ml of OPA solution, left for 2 minutes at room temperature, and then measured at 340 nm wavelength in aUV-an AUVS spectrophotometer.

2.2.6. Sensory analysis

The scoring test was used in the sensory evaluation of the cheese samples [28]. The scoring test was conducted by a panelist group of 10 people (5 graduate students from Ege University Faculty of Agriculture, Dairy Technology Department, and 5 Sudanese graduate students). The samples were evaluated for color, odor, texture, taste-aroma, and general acceptability. Cheese samples were presented to the panelists on plastic plates coded with different letters. The panelists were asked to write additional comments on sensory properties and order of preference on the evaluation papers, and it was tried to determine the quality factors that are important in the taste of cheeses.

2.2.7. Statistical analysis methods

One-way analysis of variance (One-way ANOVA) was applied to determine the difference between the properties of cheese samples, the effects of storage period, and the effect of storage temperature. For this purpose, SPSS version 15.0 (SPSS inc. Chicago, Illinois) statistical analysis package program was used. The data that were important as a result of the analysis of variance were tested at the $P<0.05$ level according to the Duncan multiple comparison test.

3. Results and discussion

3.1. Physicochemical properties of raw cow's milk used in the production of Sudanese White cheese

The properties of raw cow's milk used in cheese production are given in Table 1.

Table 1 Properties of raw milk used in the production of Sudanese white cheese

Characteristics	Mean± Standard Deviation (n=3)
Fat (%)	3.72±0.02
Total solids (%)	11.46±0.01
Non-fat total solids (%)	7.57±0.02
Protein (%)	3.22±0.02
Ash (%)	0.62±0.04
Titratable acidity (%)	0.20±0.01
pH	6.76±0.01
Density (g ml^{-1})	1.028±0.00

3.2. Yield of produced Sudanese White cheese

The yield of T1, T2, T3, T4, and T5 cheeses was 11.15%, 11.50%, 12.32%, 10.91%, and 11.21%, respectively. The yield of T5 cheeses made without a starter was higher than T4 and T1 cheeses and lower than T2 and T3 cheeses ($P<0.05$). This is because the moisture content (%) of T5 cheese is higher than T1 and T4 cheeses and lower than T3 and T2 cheeses. The yield values of cheeses might be low because the proteolytic activity causes the proteins to break down more and pass into the whey while the milk coagulates [29]. Raveschot et al. [30] reported that the Lactobacillus species hydrolyze proteins to meet their nitrogen requirements and develop a proteolytic system that provides amino acids, and *Lb. helveticus* is the most proteolytic species in Lactobacillus.

3.3. Physicochemical properties of Sudanese White cheeses

The pH values of cheeses were significantly affected by the starter culture and storage period ($P<0.001$). The average pH values of the samples varied between 4.08±0.20 and 4.52±0.17 during storage (Table 2). On the first day of ripening, the pH value of T5 cheese was significantly ($P<0.001$) higher than T3 and T4 cheeses, but not significantly different from T1 and T2 cheeses. This is thought to be the result of the *Lb. helveticus* and *Lb. casei* bacteria continuously metabolize residual lactose and galactose in the clot during the initial phases of the repining period [31]. T5 cheese stored at 4 °C had significantly lower pH values as the storage period progressed compared to other cheeses ($P<0.001$). This is due to the growth of non-starter bacteria from milk, which lowers the pH of the cheese during ripening [32]. The pH values of T5 cheese stored at 15 °C were found to be significantly higher than those of other cheeses, indicating that 15 °C is the ideal ripening temperature for cultures. During the storage period, the pH values of the cheeses decreased significantly ($P<0.001$). The decrease in pH values during ripening was consistent with the results of similar studies [33–35]. This decrease in pH values can be attributed to the formation of different acids, phosphorylation of caseins, protein-protein reactions resulting in proton release, the breakdown of lactose, and changes in the calcium-phosphorus balance [36]. The pH values of T4 cheese stored at 4 °C decreased significantly until the 60th day of maturation and then increased significantly on the 90th day. The change in pH values of T4 cheese made with starter culture containing *Lb. helveticus* during ripening is consistent with similar study results [31]. It is thought that this situation is caused by ammonia formed as a result of the deamination of free amino acids with the progression of maturation [37,38,31].

A significant change was observed in the titratable acidity values of the cheeses in terms of storage period and the starter culture used ($P<0.001$). The average titratable acidity values of the samples varied between %0.45±0.01 and %1.44±0.00 during storage (Table 2). The titration acidity values of all cheese samples, except T4 cheese, which was stored at 4°C, increased significantly during ripening. The increase in titration acidity values detected in white cheeses is compatible with other studies on white cheese [38,39].

Total solids are the basis of cheese, and as its amount increases, the nutritional value of cheese also increases. A significant difference was observed in the total solids contents of the cheeses in terms of storage period and the starter culture used ($P<0.001$). The total solids content of cheeses varies between 38.93-53.69% (Table 2). While the total solids content of cheese without starter culture added (T5) is lower than that of T1 and T4 cheeses, it is higher than that of T3 and T2 cheeses. The low values of T3 and T2 cheeses may be due to the reduction of acidity during cheese production [31]. The low total solids content of cheeses made with cultures containing *Lactobacillus casei* are compatible with other studies [40,16]. The total solids content of T4 cheese was significantly higher than the other cheeses in the early stages of the storage period ($P<0.001$). A similar study showed that cheeses made with cultures containing *Lactobacillus helveticus* had a significantly higher total solids content than other cheeses [41]. Excluding T5 cheese stored at 4 °C, T2 and T3 cheeses stored at 15 °C, and T1 cheeses, the total solids content of all cheeses increased in the early stages of the storage period and subsequently declined in the later stages. In the last stages of the storage period, it was noticed that the total solids content did not significantly change and or tended to decrease. The trend of increase in total solids content in early storage periods in cheese varieties is consistent with other studies on white cheese [42,43]. This increase may be due to the decrease in moisture content due to lactic acid developments [44]. It is thought that the decrease in the last stages of the storage period is due to the formation of new peptides with high water absorption capacity as a result of advanced proteolysis [45].

A significant difference was observed in the protein contents of the cheeses in terms of storage period and the starter culture used ($P<0.001$). The protein content of cheeses varies between 16.13-21.66% (Table 2). T5 cheeses made without starter culture addition at all storage periods showed significantly lower protein contents than the other cheeses when the protein contents of the cheeses stored at 4 °C were examined ($P<0.001$). This result is in line with the finding of Dafalla et al. [16], and this is assumed to be caused by the starter culture addition, which lowers the pH at the rennet time, increasing rennet activity and increasing protein recovery in the curd while reducing the net load of casein micelles during cheese fermentation [1]. The protein content of T5 cheeses without starter added was found to be lower than that of T1 and T4 cheeses, but higher than that of T3 and T2 cheeses when the protein contents of the cheeses stored at 15 °C were examined (*P*<0.001). In addition, the protein content of T1 cheese was found to be significantly higher than other cheeses in all stages of ripening (*P*<0.001). de Azambuja et al. [12] reported that the cheeses made with mesophilic or mesophilic + *Lactobacillus helveticus* contain high amounts of protein. As seen in Table 2, there was an increase and decrease in the protein percentage during the storage period. The increase in the protein rate detected in cheese samples in the early stages of the storage period is compatible with other studies on white cheese [1,44] and is thought to be due to the decrease in moisture content [44]. The decrease in the protein content of cheeses in the last stages of the storage period can be attributed to the proteolytic activity that leads to the formation of water-soluble nitrogen [46,44].

A significant difference was observed in the fat contents of the cheese samples in terms of storage period and the starter culture used (*P*<0.001). The fat content of cheese samples varies between 19.00-31.50% (Table 2). It is thought that the different total solids contents cause a significant difference in the fat contents of the cheeses. Hayaloğlu [47] reported that the difference in starter culture affects the pH of cheese, and when the pH value is high, fat loss is higher with whey. In our study, cheeses with high pH values showed more fat loss with whey (T3 and T2 cheeses). The fat content of all cheeses except T1 cheeses increased in the early stages of the storage period and then decreased significantly in the middle stages. The fat content did not show a significant change and/or tended to decrease in the last stages of the storage period. The increase in the fat content detected in white cheese in the early stages of the storage period is compatible with other studies on white cheese [44], and this is probably due to moisture loss during ripening [44,16]. The decrease in fat contents was consistent with the results of similar studies [39,37], and this may be due to the decrease in the total solids content of the produced cheese samples and the hydrolysis of fats during storage [10,37].

A significant difference was observed in the fat content on a dry matter basis (FDM) of the cheeses in terms of storage period and the starter culture used (*P*<0.001). The fat content on a dry matter basis (FDM) of cheeses varies between 49.27-58.20% (Table 2). While the fat content on a dry matter basis (FDM) of T5 cheese without starter added was lower than that of T4 and T1 cheeses, it was higher than that of T3 and T2 cheeses in all stages of the storage period. The decrease in the total solids contents of the cheeses also affected the fat content on a dry matter basis (FDM) proportionally. Except for T2 cheese stored at 4 °C and 15 °C and T3 cheese stored at 15 °C, the fat content on a dry matter basis in cheese follows the same trend of increasing and decreasing fat content in cheese over the storage period. It is thought that the decrease in fat content as maturation progresses is a result of lipolysis reactions [37].

A significant difference was observed in the salt contents of the cheeses in terms of storage period and the starter culture used (*P*<0.001). The salt content of cheeses varies between 49.27-58.20% (Table 2). The salt content of T5 cheeses made without starter addition is higher than T4 cheeses and lower than T3 and T1 cheeses in the early stages of the storage period. As the storage period progressed, T5 cheese had a significantly higher salt content than all other cheeses except T2 cheese stored at 15 °C. It is thought that the titration acidity values and total solids contents of the samples may be effective in the difference in the salt content of the cheese samples [48,45]. Suliman et al. [49] found that as the fat content increased, the salt content decreased significantly (*P*<0.05). Considering the salt content of cheeses stored at 4°C, the salt content of all cheeses except T1 and T5 cheese samples decreased in the early stages of the storage period and then increased significantly in the middle stages. In the last stages of the storage period, it was seen that the salt content did not significantly change and/or tended to decrease. When the salt content of cheeses stored at 15°C is examined, the salt content of all cheeses except the T1 cheese sample increased in the early stages of ripening and then decreased significantly in the middle stages. In the last stages of the storage period, it was seen that the salt content did not significantly change and/or tended to increase. It is believed that this decrease and increase in salt values is due to the balance between cheese and brine due to osmotic pressure [50]. The fact that there is no change in the salt content after the 60th day of ripening indicates that a salt balance has occurred between the brine and cheese. Salt penetration is almost complete in the first 30 days of ripening, and then the salt levels of cheeses change in a very narrow range [45].

A significant difference was observed in the salt content on a dry matter basis (SDM) of the cheeses in terms of storage period and the starter culture used (*P*<0.001). The salt content on a dry matter basis of cheeses varies between 4.41-9.28% (Table 2). Considering the cheeses stored at 4° C, it was observed that T5 cheese without starter added had significantly higher salt content on a dry matter basis (SDM) during the storage period than all other cheeses except T3 cheese. When we look at the cheeses stored at 15 °C, we found that the salt content on a dry matter basis (SDM) of T5 cheese, has higher values than T1 and T4 cheeses, while it has lower values than T2 and T3 cheeses in all stages of storage period. When cheeses stored at 4 °C and 15 °C were examined, the salt content on a dry matter basis (SDM) of T4 cheese in all stages of ripening was lower than other cheeses. This is due to the high proteolytic activity and the reduction in the soluble components of the cheese resulting from the partial degradation of the protein, followed by solubility in the whey solution [51]. The salt content on a dry matter basis (SDM) in cheese follows the same trend of increasing and decreasing salt content in cheese samples over the storage period.

A significant ($P<0.001$) difference was observed in the ash contents of the cheeses in terms of storage period and the starter culture used (Table 2). The T5 cheese without starter added had a significantly higher ash content than other cheeses. This result was similar to the results of Dafalla et al. [16]. The low amount of ash in the other cheese samples is due to the low amount of salt in the same cheese samples. Also, it is thought that the titration acidity and pH value of the cheese samples affect the salt rate taken into the cheese and this situation is directly reflected in the ash ratio [28]. The ash content of all cheeses except T4 cheese samples stored at 4 °C and T1 stored at 15 °C increased in the early stages of the storage period and then decreased significantly in the middle stages. The ash content did not show a significant change in the last stages of the storage period and/or tended to increase. The increase in ash content in the early stages of the storage period was consistent with the results of similar studies [10]. Tarakcı and Akyuz [52] found that the ash content increased due to the increase in the salt and total solids contents of the cheese samples during ripening. The decrease in ash content in the last stages of the storage period was consistent with the result of Gulzar et al. [53] who stated that as the pH decreases, the ash content of the cheese decreases.

Lipolysis is an important biochemical event in the development of the final flavor of cheese [38]. Since advanced lipolysis causes a rancid taste, it is not desired for some cheese varieties [54]. A significant ($P<0.001$) change was observed in the total free fatty acid values of the cheese samples in terms of storage period and the starter culture used (Table 2). The control cheese(T5) had a lower value than all cheeses on the 1st day of the storage period. McCarthy et al. [55] found that total and most individual free fatty acid (FFA) concentrations decreased as the fat content decreased. Considering the cheeses stored at 4 °C as the storage period progressed, the T5 cheese without starter added had higher values than all other cheeses except T1 cheese and had lower values than all other cheeses except T4 cheese after the 60th day. Considering the cheeses stored at 15 °C, the total free fatty acid values of T5 cheese were lower than T1 and T4 cheeses but higher values than T2 and T3 cheeses during the storage period. This may be because T1 and T4 cheeses have the highest fat content [55]. In similar studies, it has been reported that cheeses are made with *Lb. helveticus* have the highest free fatty acids during ripening [56,57]. The total free fatty acids values of all cheeses, except T4 stored at 4°C and T5 cheeses, increased during the storage period ($P<0.001$). This situation was consistent with the results of similar studies [58,35,16]. A significant increase in total free fatty acids values of T5 cheese in the early stage of the storage period and a decrease in the last stages was observed. The decrease in total free fatty acids values can be attributed to the use of some free fatty acids by microorganisms [42,59].

During cheese ripening, proteolysis plays an important role in the development of texture as well as flavor [60]. A significant change ($P<0.001$) was observed in the degree of proteolysis in cheeses in terms of storage period and the starter culture used (Table 2). Considering the proteolysis degree of cheeses stored at 4 °C and 15 °C, the proteolysis degree of T5 cheese without starter added on the 1st day of the storage period was lower than T1 cheese and higher than T2, T3, and T4 cheeses. When the degree of proteolysis of cheeses stored at 4 °C was examined as the storage period progressed, the proteolysis degree of T5 cheese was significantly higher than that of other cheeses ($P<0.001$). When cheeses stored at 15 °C were examined, the proteolysis degree of T5 cheese without a starter was significantly lower than that of other cheeses ($P<0.001$). This may be attributed to a lower bacterial proteolytic activity in the T5 cheese with no starter culture added. Except for the 90th day of the storage period, the proteolysis degree of T4 cheese containing *Lactobacillus helveticus* was found to be significantly higher than the other cheeses ($P<0.001$). McCarthy et al. [55] reported that the use of support cultures such as *Lactobacillus helveticus* led to significant increases in the concentration of free amino acids (FAA) in 180-day low-fat Cheddar cheese. The faster accumulation of free amino acids in T4 cheeses compared to other cheeses may be due to the autolysis of *Lb. helveticus* [12]. There was no significant difference between cheeses on the 90th day of the storage period ($P>0.05$). The degree of proteolysis increased during the storage period in all cheeses stored at 4 °C and 15 °C. This result is consistent with the results of similar studies [55,12]. The increase in proteolysis rate could be due to the proteolytic activity of starter bacteria, non-starter bacteria, and residual rennet [61].

The titratable acidity, protein content, salt content, and the degree of lipolysis and proteolysis were significantly ($P<0.01$) higher in cheese samples stored at 15 °C (Fig. 2). The higher acidity of cheese stored at 15 °C may be due to the increased lactic acid level due to the activation of lactic acid bacteria with temperature increases [62,39]. The result of protein was consistent with that of Elowni and Hamed [62] and this may be due to the low moisture content and high acidity in cheese which inhibit the growth of proteolytic bacteria [62]. The result of salt was comparable to that obtained by Baran [63]. The higher degree of lipolysis and proteolysis in cheese samples stored at 15 °C may be due to the high temperature increases microbial activity and other biochemical reactions [64].

Table 2 Physiochemical properties of Sudanese white cheese samples during the storage period

Properties	Days	Cheese Type					
		T1	T2	T3	T4	T5	Mean
pH	4 °C						
	1	8.90±1.20^{xA}	9.20±0.92^{xA}	9.20±0.63^{xA}	9.10±1.27^{xA}	8.90±1.29^{xA}	9.06±0.71^{A}
	15	8.40±0.52^{xAB}	9.20±0.92^{xA}	9.10±0.82^{xA}	9.00±0.72^{xA}	8.60±1.43^{xAB}	8.86±1.00^{A}
	30	8.50±0.53^{yzAB}	9.00±1.05^{xyA}	9.20±1.03^{xyA}	9.60±0.52^{xA}	8.00±0.82^{zB}	8.86±0.84^{A}
	45	7.90±0.32^{xB}	7.70±0.48^{xB}	8.00±0.67^{xC}	8.00±0.82^{xC}	7.10±0.47^{yC}	7.74±0.90^{B}
	60	7.90±0.32^{yB}	7.80±0.42^{yB}	8.00±0.00^{yC}	8.60±0.52^{xBC}	7.10±0.57^{zC}	7.88±1.18^{B}
	90	8.00±0.47^{yzB}	7.80±0.42^{zB}	8.40±0.52^{xyC}	8.60±0.52^{xBC}	7.10±0.57^{rC}	7.98±1.18^{B}
	Mean	8.27±0.71^{y}	8.45±1.00^{xy}	8.65±0.84^{x}	8.81±0.90^{x}	7.80±1.18^{z}	
	15 °C						
	1	9.00±1.05^{xA}	9.20±0.92^{xA}	9.20±0.63^{xA}	9.10±1.29^{xA}	8.90±1.29^{xA}	9.08±1.06^{A}
	15	8.90±0.79^{xA}	8.08±0.88^{yAB}	8.40±1.17^{xyB}	8.90±0.57^{xyA}	8.80±0.63^{xA}	8.61±0.88^{A}
	30	9.00±1.25^{xyzA}	8.10±1.85^{zAB}	8.30±0.48^{yzB}	9.50±0.71^{xA}	9.30±0.95^{xyA}	8.84±1.23^{A}
	45	8.70±0.68^{xA}	8.10±1.85^{xAB}	7.50±0.82^{yB}	8.60±0.97^{xAB}	7.90±0.57^{xyB}	8.16±1.20^{BC}
	60	8.70±0.68^{xA}	7.20±0.79^{zB}	8.00±0.67^{yB}	8.80±0.79^{xAB}	8.00±0.47^{yB}	8.14±0.88^{BC}
	90	8.70±0.68^{xA}	7.36±1.12^{zB}	6.90±0.32^{zC}	8.60±0.97^{xAB}	7.90±0.57^{yB}	7.89±1.03^{C}
	Mean	8.83±0.88^{x}	8.01±1.42^{y}	8.05±1.07^{y}	8.91±0.98^{x}	8.46±0.94^{x}	
TA (%)	4 °C						
	1	0.45±0.01^{zD}	0.45±0.00^{zB}	0.54±0.00^{yC}	0.63±0.00^{xB}	0.45±0.00^{zC}	0.50±0.07^{C}
	15	0.63±0.00^{yC}	0.45±0.01^{rB}	0.54±0.00^{zC}	0.63±0.00^{yB}	0.72±0.00^{xB}	0.60±0.09^{BC}
	30	0.72±0.01^{yB}	0.45±0.00^{nB}	0.57±0.05^{rC}	0.66±0.05^{zB}	0.81±0.00^{xA}	0.64±0.13^{B}
	45	0.72±0.00^{yB}	0.45±0.01^{rB}	0.63±0.00^{zB}	0.72±0.00^{yA}	0.81±0.00^{xA}	0.67±0.13^{B}
	60	0.72±0.01^{yB}	0.48±0.05^{zB}	0.72±0.00^{yA}	0.72±0.00^{yA}	0.81±0.00^{xA}	0.69±0.12^{B}
	90	0.78±0.05^{yzA}	1.19±0.02^{xA}	0.72±0.00^{zA}	0.45±0.00^{rC}	0.84±0.05^{yA}	0.80±0.24^{A}
	Mean	0.67±0.11^{xy}	0.58±0.28^{z}	0.62±0.08^{z}	0.64±0.10^{xy}	0.74±0.14^{x}	
	15 °C						
	1	0.45±0.00^{yD}	0.45±0.00^{yD}	0.54±0.00^{xF}	0.54±0.00^{xF}	0.45±0.00^{yD}	0.49±0.05^{E}
	15	1.17±0.00^{xC}	0.72±0.00^{rC}	0.81±0.00^{zE}	0.90±0.00^{yE}	0.90±0.00^{yC}	0.90±0.16^{D}
	30	1.20±0.00^{xC}	1.20±0.00^{xB}	0.96±0.05^{yD}	1.17±0.00^{xD}	0.93±0.05^{yC}	1.09±0.13^{C}
	45	1.32±0.05^{xB}	1.20±0.00^{yzB}	1.17±0.00^{yzC}	1.24±0.03^{yC}	1.15±0.06^{zB}	1.22±0.07^{B}
	60	1.29±0.05^{yB}	1.20±0.00^{zrB}	1.24±0.03^{yzB}	1.35±0.00^{xB}	1.17±0.00^{rB}	1.25±0.07^{B}
	90	1.44±0.00^{rA}	1.24±0.03^{rA}	1.41±0.05^{rA}	1.41±0.05^{rA}	1.35±0.00^{rA}	1.37±0.08^{A}
	Mean	1.15±0.33^{x}	1.00±0.31^{x}	1.02±0.30^{x}	1.10±0.29^{x}	0.99±0.18^{x}	
	4 °C						
	1	49.84±0.24^{yE}	40.95±0.00^{rC}	38.73±0.39^{nC}	53.96±0.08^{xBC}	46.63±0.05^{zA}	46.02±5.54^{A}

TS (%)	15	50.52±0.08^{yD}	41.54±0.00^{rB}	38.73±0.22^{nC}	52.92±0.15^{xC}	46.50±0.00^{zB}	46.04±5.65^{A}
	30	50.70±0.00^{yD}	42.51±0.02^{rA}	39.41±0.19^{nB}	52.96±0.05^{xC}	46.48±0.03^{zB}	46.41±5.19^{A}
	45	51.26±0.24^{yC}	40.54±0.00^{rD}	40.47±0.35^{rA}	53.19±0.00^{xB}	45.50±0.00^{zC}	46.19±5.48^{A}
	60	52.46±0.22^{yB}	38.70±0.45^{rE}	38.51±0.01^{rC}	53.70±0.00^{xA}	45.12±0.14^{zD}	45.70±6.72^{A}
	90	53.40±0.11^{xA}	38.94±0.00^{nE}	39.28±0.02^{rB}	52.50±0.00^{yD}	45.03±0.03^{zD}	45.83±6.43^{A}
	Mean	51.36±1.26^{y}	40.53±1.40^{r}	39.18±0.83^{n}	53.21±0.39^{x}	45.88±0.70^{z}	
	15 °C						
	1	49.84±0.24^{yC}	40.95±0.00^{rA}	38.99±0.27^{nA}	53.06±0.08^{xD}	46.63±0.00^{zD}	46.02±5.54^{A}
	15	53.26±0.00^{yB}	40.20±0.00^{rB}	38.57±0.18^{nB}	53.80±0.03^{xC}	51.51±0.11^{zC}	47.46±7.10^{A}
	30	53.26±0.00^{yB}	40.30±0.31^{rB}	39.03±0.05^{nA}	53.84±0.00^{xB}	52.36±0.01^{zB}	47.76±6.87^{A}
	45	53.26±0.00$^{z B}$	39.00±0.00^{rC}	39.00±0.00^{rA}	53.79±0.00^{yC}	54.56±0.02^{xA}	47.91±7.55^{A}
	60	53.25±0.56^{yB}	39.00±0.33^{zC}	39.00±0.00^{rA}	53.82±0.00^{xBC}	54.21±0.15^{xC}	47.85±7.25^{A}
	90	55.75±0.06^{xA}	38.54±0.02^{nD}	39.00±0.00^{rA}	53.80±0.07^{zBC}	54.27±0.03^{yC}	48.27±8.06^{A}
	Mean	53.10±1.78^{xy}	39.67±0.86^{z}	38.93±0.20^{z}	53.69±0.52^{x}	52.27±2.81^{y}	
Protein (%)	4 °C						
	1	19.18±0.00^{yE}	16.50±0.00^{rD}	16.51±0.00^{zB}	20.35±0.00^{xF}	16.50±0.00^{rA}	17.81±1.70^{A}
	15	19.62±0.01^{yD}	16.50±0.01^{zD}	15.62±0.14^{nD}	21.17±0.00^{xE}	16.10±0.00^{rC}	17.80±2.31^{A}
	30	20.24±0.01^{yC}	16.85±0.00^{zBC}	15.66±0.00^{nD}	21.31±0.00^{xD}	16.10±0.00^{rC}	18.03±2.37^{A}
	45	20.20±0.00^{yC}	16.80±0.00^{zC}	16.71±0.00^{rA}	22.02±0.00^{xC}	16.08±0.00^{nC}	18.36±2.35^{A}
	60	20.91±0.01^{yB}	17.01±0.00^{zB}	16.12±0.00^{rC}	22.89±0.00^{xA}	16.10±0.00^{rC}	18.61±2.88^{A}
	90	21.36±0.06^{yA}	17.50±0.01^{A}	16.17±0.00^{nC}	22.24±0.01^{xB}	16.30±0.00^{rB}	18.71±2.67^{A}
	Mean	20.25±0.78^{y}	16.86±0.35^{z}	16.13±0.46^{r}	21.66±0.85^{x}	16.20±0.17^{r}	
	15 °C						
	1	19.18±0.00^{yE}	16.50±0.00^{rA}	16.51±0.00^{rD}	20.35±0.00^{xD}	17.07±0.12^{zF}	17.92±1.62^{A}
	15	20.30±0.00^{yC}	16.50±0.00^{nA}	16.75±0.00^{rC}	21.08±0.00^{xC}	18.00±0.00^{zE}	18.54±1.93^{A}
	30	21.51±0.00^{xD}	16.50±0.00^{nA}	17.20±0.00^{rB}	21.00±0.00^{yC}	18.50±0.00^{zD}	18.94±2.07^{A}
	45	23.00±0.00^{xA}	16.50±0.14^{nA}	17.19±0.00^{rB}	21.00±0.00^{yC}	19.00±0.00^{zC}	19.34±2.88^{A}
	60	21.74±0.23^{xB}	16.80±0.45^{rA}	17.25±0.29^{zA}	21.70±0.00^{xA}	20.41±0.07^{yA}	19.58±2.23^{A}
	90	21.80±0.00^{xB}	16.67±0.29^{nA}	17.25±0.00^{rA}	21.31±0.00^{yB}	20.00±0.00^{zB}	19.41±2.17^{A}
	Mean	21.26±1.25^{x}	16.58±0.62^{r}	17.03±0.30^{z}	21.08±0.42^{x}	18.83±1.17^{y}	
	4 °C						
	1	27.17±0.29^{yD}	19.00±0.00^{rC}	19.00±0.00^{rB}	29.00±0.00^{xB}	23.50±0.00^{zB}	23.53±4.25^{A}
	15	28.00±0.01^{yC}	20.00±0.01^{rB}	19.00±0.01^{nB}	29.00±0.01^{xB}	25.20±0.29^{zA}	24.24±4.23^{A}
	30	29.00±0.01^{yB}	20.50±0.00^{rA}	19.20±0.29^{nB}	30.00±0.00^{xA}	25.00±0.00^{zA}	24.74±4.41^{A}
	45	29.00±0.00^{xB}	20.30±0.29^{zA}	20.00±0.00^{nA}	29.00±0.00^{xB}	25.00±0.00^{yA}	24.67±4.10^{A}
	60	29.00±0.01^{xB}	20.00±0.00^{rB}	20.00±0.01^{rA}	28.20±0.29^{yC}	25.00±0.00^{zA}	24.67±4.10^{A}
	90	30.00±0.00^{xA}	20.00±0.00^{rB}	20.00±0.00^{rA}	28.00±0.00^{yC}	22.83±0.29^{zC}	24.17±4.27^{A}
	Mean	28.70±0.92^{x}	19.97±0.61^{z}	19.53±0.50^{r}	28.86±0.68^{x}	24.42±0.94^{y}	

Fat (%)	15 °C						
	1	27.17±0.29^{yC}	19.00±0.00^{zC}	19.00±0.00^{zB}	29.00±0.00^{xC}	23.50±0.00^{rF}	23.53±4.19^{A}
	15	31.00±0.00^{xA}	20.20±0.29^{zA}	19.00±0.29^{rB}	31.00±0.00^{xA}	28.00±0.00^{yE}	25.84±5.51^{A}
	30	30.00±0.00^{xB}	20.00±0.00^{zAB}	19.00±0.00^{rB}	30.00±0.29^{xB}	28.50±0.00^{yD}	25.50±5.05^{A}
	45	30.00±0.00^{xB}	20.00±0.00^{zAB}	19.00±0.00^{rB}	30.00±0.00^{xB}	29.20±0.29^{yC}	25.64±5.20^{A}
	60	29.50±0.50^{yB}	20.00±0.00^{zAB}	20.00±0.00^{zA}	30.00±0.00^{xB}	30.30±0.29^{xA}	25.97±5.05^{A}
	90	31.50±0.50^{xA}	20.00±0.29^{zB}	20.00±0.00^{zA}	30.00±0.00^{yB}	30.00±0.29^{yB}	26.30±5.40^{A}
	Mean	21.26±1.25^{x}	16.58±0.62^{r}	17.03±0.30^{z}	21.08±0.42^{x}	18.83±1.17^{y}	
FDM (%)	4 °C						
	1	54.50±0.52^{xD}	46.39±0.00^{rE}	49.06±0.49^{zCD}	54.65±0.07^{xBC}	50.40±0.04^{yC}	51.00±4.25^{D}
	15	55.43±0.07^{xC}	48.14±0.00^{rD}	49.97±0.29^{zC}	55.01±0.15^{xB}	54.12±0.62^{yB}	52.53±4.23^{C}
	30	57.20±0.01^{xA}	49.40±0.01^{zC}	48.64±0.95^{zD}	56.64±0.00^{xA}	53.78±0.04^{yB}	53.13±4.41^{B}
	45	56.57±0.26^{xB}	50.15±0.71^{zB}	49.41±0.42^{rCD}	54.52±0.53^{yC}	54.94±0.00^{yA}	53.12±4.10^{B}
	60	56.28±0.24^{xB}	51.67±0.60^{rA}	51.94±0.02^{zrA}	52.45±0.00^{zE}	55.41±0.16^{yA}	53.55±4.10^{A}
	90	56.17±0.11^{xB}	51.36±0.00^{zA}	50.92±0.02^{zrB}	53.33±0.00^{yD}	50.70±0.60^{rC}	52.50±4.27^{E}
	Mean	55.86±0.94^{x}	49.52±1.91^{r}	49.99±1.23^{r}	54.44±1.37^{y}	53.22±2.05^{z}	
	15 °C						
	1	54.50±0.52^{xC}	46.39±0.00^{rC}	48.73±0.33^{zB}	54.65±0.07^{xC}	49.27±0.00^{yE}	50.70±4.19^{E}
	15	58.20±0.00^{xA}	50.16±0.71^{rB}	48.39±0.66^{nB}	56.56±0.02^{yA}	54.35±0.11^{zC}	53.53±5.51^{B}
	30	56.33±0.01^{xB}	49.63±0.37^{rB}	48.68±0.06^{nB}	55.65±0.53^{yB}	54.43±0.01^{zC}	52.94±5.05^{D}
	45	56.32±0.00^{xB}	51.28±0.00^{rA}	48.71±0.00^{nB}	55.81±0.00^{yB}	54.45±0.38^{zC}	53.31±5.20^{C}
	60	55.41±1.41^{xBC}	50.01±0.40^{zB}	51.28±0.00^{yA}	55.74±0.00^{xB}	55.95±0.52^{xA}	53.67±5.05^{B}
	90	56.50±0.93^{xB}	51.46±0.73^{zA}	51.28±0.00^{zA}	55.76±0.04^{xyB}	55.28±0.02^{yB}	54.05±5.40^{A}
	Mean	56.22±1.31^{x}	49.83±1.76^{z}	49.52±.1.32^{z}	55.61±0.64^{x}	53.79±2.24^{y}	
Salt (%)	4 °C						
	1	3.74±0.00^{xB}	3.04±0.00^{zA}	3.51±0.00^{yA}	2.58±0.02^{rB}	3.04±0.00^{zC}	3.18±0.42^{A}
	15	3.97±0.01^{xA}	3.04±0.01^{yA}	3.04±0.00^{yB}	2.58±0.02^{zB}	3.04±0.00^{yC}	3.13±0.47^{A}
	30	2.80±0.01^{zD}	2.34±0.01^{rC}	3.07±0.06^{yB}	2.34±0.00^{rC}	4.22±0.23^{xA}	2.96±0.72^{A}
	45	2.83±0.12^{zD}	2.10±0.00^{rD}	3.07±0.06^{yB}	3.04±0.00^{yA}	4.22±0.23^{xA}	3.05±0.71^{A}
	60	3.04±0.01^{zC}	2.57±0.01^{rB}	3.51±0.00^{yA}	3.04±0.00^{zA}	3.98±0.00^{xB}	3.23±0.50^{A}
	90	3.04±0.01^{yC}	3.04±0.01^{yA}	3.51±0.00^{xA}	3.04±0.00^{yA}	3.04±0.00^{yC}	3.13±0.19^{A}
	Mean	3.24±0.46^{y}	2.69±0.39^{z}	3.29±0.23^{y}	2.77±0.29^{z}	3.59±0.57^{x}	
	15 °C						
	1	3.74±0.00^{xA}	3.04±0.06^{zD}	3.51±0.00^{yB}	2.58±0.02^{rD}	3.04±0.00^{zD}	3.19±0.42^{BC}
	15	2.80±0.00^{zC}	3.04±0.06^{yD}	3.61±0.16^{xB}	2.58±0.02^{rD}	3.04±0.00^{yD}	3.02±0.36^{C}
	30	2.80±0.00^{nC}	3.28±0.00^{rC}	3.98±0.00^{xA}	3.51±0.00^{zB}	3.74±0.01^{yA}	3.46±0.42^{AB}
	45	3.04±0.00^{zB}	4.44±0.00^{xA}	3.04±0.00^{zC}	3.74±0.00^{yA}	3.74±0.01^{yA}	3.60±0.54^{A}

	60	3.04±0.00^{zB}	3.51±0.00^{xB}	3.04±0.00^{zC}	3.27±0.00^{yC}	3.51±0.00^{xB}	3.27±0.22^{BC}
	90	3.04±0.00^{zB}	3.51±0.00^{xB}	3.04±0.00^{zC}	2.57±0.00^{rD}	3.27±0.00^{yC}	3.09±0.32^{C}
	Mean	3.07±0.32^{y}	3.48±0.48^{x}	3.37±0.37^{x}	3.04±0.50^{y}	3.39±0.30^{x}	
SDM (%)	4 °C						
	1	7.50±0.03^{yB}	7.42±0.00^{yB}	9.06±0.09^{xA}	4.86±0.02^{rB}	6.51±0.01^{zE}	7.07±0.42^{A}
	15	7.86±0.02^{yA}	7.32±0.01^{zC}	8.00±0.05^{xC}	4.89±0.04^{nB}	6.53±0.00^{rE}	6.92±0.47^{A}
	30	5.52±0.01^{zD}	5.51±0.01^{zE}	7.73±0.04^{yD}	4.41±0.00^{rC}	9.08±0.05^{xB}	6.45±0.72^{A}
	45	5.47±0.03^{rE}	5.18±0.00^{nF}	7.51±0.06^{yE}	5.72±0.01^{zA}	9.28±0.05^{xA}	6.63±0.71^{A}
	60	5.80±0.03^{rC}	6.64±0.06^{zD}	9.12±0.01^{xA}	5.66±0.00^{nA}	8.82±0.03^{yC}	7.21±0.50^{A}
	90	5.75±0.01^{nC}	7.81±0.01^{yA}	8.95±0.03^{xB}	5.80±0.02^{rA}	6.76±0.02^{zD}	7.01±0.19^{A}
	Mean	6.31±1.00^{y}	6.65±1.02^{y}	8.40±0.69^{x}	5.23±0.54^{z}	7.84±1.27^{x}	
	15 °C						
	1	7.50±0.03^{yB}	7.44±0.03^{yF}	9.00±0.06^{xC}	4.86±0.03^{rD}	6.51±0.00^{zC}	7.07±0.42^{BC}
	15	5.26±0.01^{rC}	7.57±0.03^{yE}	9.34±0.41^{xB}	4.70±0.03^{nD}	5.90±0.00^{zF}	6.55±0.36^{C}
	30	5.26±0.02^{nC}	8.14±0.07^{yD}	10.20±0.00^{xA}	6.51±0.00^{rB}	7.14±0.01^{zA}	7.45±0.42^{AB}
	45	5.71±0.01^{nA}	11.38±0.00^{xA}	7.80±0.01^{yD}	6.95±0.00^{zA}	6.86±0.01^{rB}	7.74±0.54^{A}
	60	5.72±0.07^{nA}	8.78±0.08^{xC}	7.81±0.03^{yD}	6.07±0.00^{rC}	6.48±0.01^{zD}	6.97±0.22^{BC}
	90	5.45±0.01^{rB}	9.12±0.03^{xB}	7.79±0.00^{yD}	4.77±0.00^{nD}	6.02±0.00^{zE}	6.63±0.32^{C}
	Mean	5.82±0.80^{z}	8.74±1.36^{x}	8.661±0.97^{x}	5.65±0.93^{z}	6.49±0.44^{y}	
Ash (%)	4 °C						
	1	3.74±0.00^{xB}	3.04±0.00^{zA}	3.51±0.00^{yA}	2.58±0.02^{rB}	3.04±0.00^{zC}	2.76±0.47^{A}
	15	3.97±0.01^{xA}	3.04±0.01^{yA}	3.04±0.00^{yB}	2.58±0.02^{zB}	3.04±0.00^{yC}	2.91±0.86^{A}
	30	2.80±0.01^{zD}	2.34±0.01^{rC}	3.07±0.06^{yB}	2.34±0.00^{rC}	4.22±0.23^{xA}	2.72±0.74^{A}
	45	2.83±0.12^{zD}	2.10±0.00^{rD}	3.07±0.06^{yB}	3.04±0.00^{yA}	4.22±0.23^{xA}	3.05±0.62^{A}
	60	3.04±0.01^{zC}	2.57±0.01^{rB}	3.51±0.00^{yA}	3.04±0.00^{zA}	3.98±0.00^{xB}	2.62±0.63^{A}
	90	3.04±0.01^{yC}	3.04±0.01^{yA}	3.51±0.00^{xA}	3.04±0.00^{yA}	3.04±0.00^{yC}	2.52±0.55^{A}
	Mean	2.51±0.24^{yz}	2.41±0.25^{zr}	2.64±0.31^{y}	2.26±0.20^{r}	3.91±0.29^{x}	
	15 °C						
	1	3.74±0.00^{xA}	3.07±0.06^{zD}	3.51±0.00^{yB}	2.58±0.02^{rD}	3.04±0.00^{zD}	2.76±0.47^{BC}
	15	2.80±0.00^{zC}	3.07±0.06^{yD}	3.61±0.16^{xB}	2.58±0.02^{rD}	3.04±0.00^{yD}	2.77±0.50^{BC}
	30	2.80±0.00^{nC}	3.28±0.00^{rC}	3.98±0.00^{xA}	3.51±0.00^{zB}	3.74±0.01^{yA}	2.88±0.55^{AB}
	45	3.04±0.00^{zB}	4.44±0.00^{xA}	3.04±0.00^{zC}	3.74±0.00^{y}	3.74±0.01^{yA}	3.16±0.75^{A}
	60	3.04±0.00^{zB}	3.51±0.00^{xB}	3.04±0.00^{zC}	3.27±0.00^{yC}	3.51±0.00^{xB}	2.43±0.36^{C}
	90	3.04±0.00^{zB}	3.51±0.00^{xB}	3.04±0.00^{zC}	2.57±0.00^{rD}	3.27±0.00^{yC}	2.49±0.30^{BC}
	Mean	2.29±0.18^{z}	2.60±0.33^{y}	2.69±0.32^{y}	2.56±0.19^{y}	3.61±0.46^{x}	
	4 °C						
	1	3.86±0.05^{zF}	3.81±0.01^{zrB}	4.18±0.00^{yE}	5.26±0.00^{xBC}	3.65±0.21^{rC}	4.15±0.61^{C}
	15	5.06±0.05^{yE}	3.77±0.14^{rB}	4.17±0.00^{zE}	5.18±0.00^{yC}	6.55±0.05^{xA}	4.95±0.99^{B}

	30	6.22 ± 0.06^{xB}	3.77 ± 0.14^{rB}	4.43 ± 0.06^{zD}	4.81 ± 0.08^{zD}	5.39 ± 0.44^{yB}	4.92 ± 0.88^{B}
	45	5.59 ± 0.08^{xD}	3.77 ± 0.14^{rB}	4.78 ± 0.12^{zC}	5.39 ± 0.01^{xyB}	5.47 ± 0.06^{yB}	5.00 ± 0.70^{B}
	60	6.03 ± 0.00^{xC}	3.77 ± 0.14^{rB}	5.45 ± 0.01^{zB}	5.85 ± 0.00^{yA}	5.47 ± 0.06^{zB}	5.31 ± 0.83^{AB}
	90	7.00 ± 0.01^{xA}	6.92 ± 0.02^{xA}	6.02 ± 0.27^{yA}	3.56 ± 0.17^{rE}	5.60 ± 0.00^{zB}	5.82 ± 1.30^{A}
	Mean	5.63 ± 1.01^{x}	4.30 ± 1.21^{z}	4.84 ± 0.71^{yz}	5.00 ± 0.74^{xy}	5.35 ± 0.94^{xy}	
TFA (%)	15 °C						
	1	3.86 ± 0.14^{zF}	3.81 ± 0.01^{zF}	4.18 ± 0.00^{yF}	5.26 ± 0.00^{xE}	3.65 ± 0.21^{zF}	4.15 ± 0.62^{E}
	15	8.30 ± 0.00^{xE}	5.58 ± 0.10^{zE}	5.55 ± 0.08^{zE}	8.27 ± 0.00^{xD}	5.70 ± 0.00^{yE}	6.68 ± 1.36^{D}
	30	9.40 ± 0.00^{xD}	7.13 ± 0.12^{zD}	6.97 ± 0.00^{zD}	8.31 ± 0.00^{yD}	6.85 ± 0.02^{rD}	7.73 ± 1.02^{C}
	45	10.64 ± 0.00^{xC}	7.44 ± 0.00^{nC}	7.94 ± 0.10^{rC}	9.18 ± 0.00^{yC}	9.08 ± 0.00^{zB}	8.85 ± 1.15^{B}
	60	10.40 ± 0.26^{yB}	8.86 ± 0.17^{rB}	9.42 ± 0.12^{zB}	10.88 ± 0.06^{xB}	7.87 ± 0.00^{nC}	9.48 ± 1.13^{B}
	90	11.95 ± 0.0^{xA}	9.43 ± 0.33^{zA}	10.90 ± 0.0^{yA}	12.14 ± 0.39^{Xa}	11.16 ± 0.08^{yA}	11.11 ± 1.01^{A}
	Mean	9.08 ± 2.70^{x}	7.04 ± 1.97^{y}	7.49 ± 2.32^{xy}	9.00 ± 2.25^{x}	7.38 ± 2.47^{xy}	
	4 °C						
	1	0.60 ± 0.01^{xC}	0.29 ± 0.03^{zC}	0.33 ± 0.01^{zC}	0.31 ± 0.02^{zC}	0.47 ± 0.01^{yD}	0.40 ± 0.12^{C}
	30	0.65 ± 0.09^{yC}	0.43 ± 0.02^{zB}	0.33 ± 0.01^{rC}	0.88 ± 0.03^{xB}	0.96 ± 0.04^{xC}	0.65 ± 0.26^{B}
	60	0.86 ± 0.08^{yB}	0.47 ± 0.03^{zB}	0.42 ± 0.06^{zB}	0.90 ± 0.00^{yB}	1.10 ± 0.00^{xB}	0.75 ± 0.28^{B}
	90	1.02 ± 0.01^{yA}	0.83 ± 0.13^{zA}	0.84 ± 0.05^{zA}	1.02 ± 0.01^{yA}	1.16 ± 0.04^{xA}	0.98 ± 0.14^{A}
DP (%)	Mean	0.78 ± 0.19^{Ax}	0.51 ± 0.22^{y}	0.48 ± 0.22^{y}	0.78 ± 0.29^{x}	0.93 ± 0.29^{x}	
	15 °C						
	1	0.60 ± 0.01^{xC}	0.29 ± 0.03^{zD}	0.33 ± 0.01^{zD}	0.31 ± 0.02^{zD}	0.47 ± 0.01^{yD}	0.40 ± 0.12^{D}
	30	1.03 ± 0.02^{xB}	0.73 ± 0.06^{rC}	0.98 ± 0.02^{yC}	1.06 ± 0.02^{xC}	0.90 ± 0.02^{zC}	0.94 ± 0.13^{C}
	60	1.03 ± 0.01^{xyB}	1.05 ± 0.02^{yB}	1.04 ± 0.01^{xyB}	1.10 ± 0.01^{xB}	1.02 ± 0.00^{zB}	1.04 ± 0.03^{B}
	90	1.12 ± 0.03^{yA}	1.15 ± 0.01^{xyA}	1.20 ± 0.03^{xyA}	1.22 ± 0.01^{xA}	1.14 ± 0.08^{xyA}	1.16 ± 0.05^{A}
	Mean	0.95 ± 0.21^{x}	0.81 ± 0.35^{x}	0.89 ± 0.34^{x}	0.92 ± 0.37^{x}	0.88 ± 0.26^{x}	

$^{A, B, C, D, E}$= Means with different exponential letters in the same column ± standard deviations differ from each other by $P<0.05$ significant level. ^{x,y,z,r,n}= Means with different exponential letters in the same row ± standard deviations differ significantly ($P<0.05$); T1= cheese made with DOM1 (*Lc. lactis* ssp. *cremoris* + *Lc. lactis* ssp. *Lactis*) starter culture; T2= Cheese made with PTB1 (*Lc. lactis* ssp. *cremoris* + *Lc. lactis* ssp. *Lactis* + *Streptococcus thermophilus*) starter culture; T3= cheese made with DOM1+ CASEI 39 (*Lb. casei*) starter culture; T4= cheese made with DOM1+ DHL IDC13 (*Lb. helveticus*) starter culture; T5= cheese made without starter culture addition (Control); TA= Titratable acidity, TS= Total solids, FDM=Fat on a dry matter basis, SDM= Salt on a dry matter basis, TFA= Total free fatty acids, DP= degree of proteolysis.

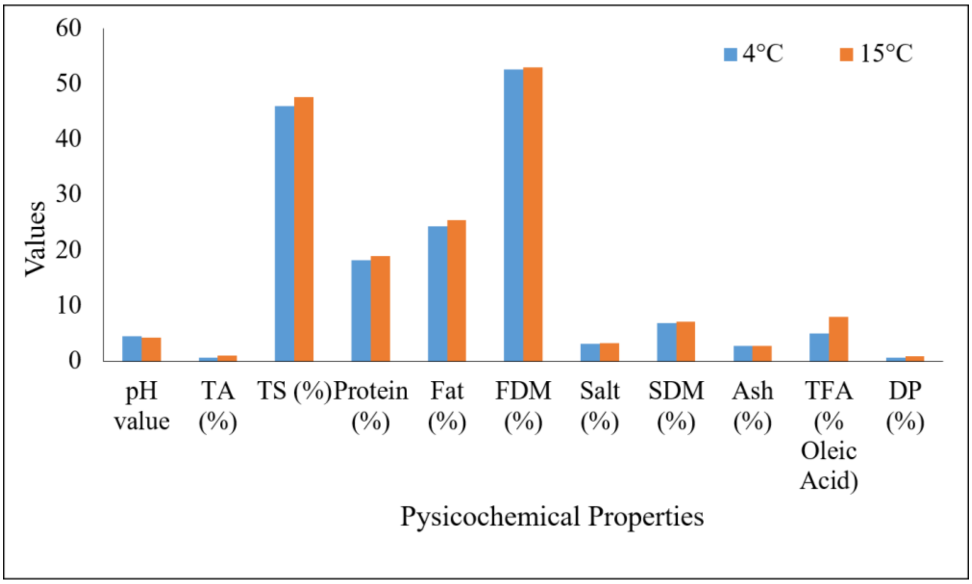

Figure 2 Physiochemical properties of Sudanese white cheese samples stored at different temperatures; TA= Titratable acidity, TS= Total solids, FDM=Fat on a dry matter basis, SDM= Salt on a dry matter basis, TFA= Total free fatty acids, DP= degree of proteolysis

3.4. Sensory properties of Sudanese White cheeses

The main purpose of the producers in the food sector; is to produce new products that are liked and demanded by the consumer with their sensory properties such as color, taste, aroma, and texture. A significant change was observed in the color score values of the cheese samples in terms of storage period and the starter culture used (P<0.001). The average color scores of the samples varied between 9.20 and 7.10 during the storage period (Table 3). T1, T2, T3, T4, and T5 cheeses stored at 4 °C and 15 °C were found to have values close to each other on the 1st and 15th days of the storage period and were not significantly different (P>0.05). When cheese samples stored at 4 °C were examined, the lowest color score was found in the T5 sample (7.10±0.57) without starter culture added after the 15th day of ripening. This result is compatible with the findings of Gheisari et al. [10]. When the cheese samples stored at 15 °C are examined, the T5 cheese has lower values than T1 and T4 cheeses, but higher values than T3 and T2 cheeses as the storage period progresses. The lowest color score value in all cheeses was determined on the 90th day of storage, and the highest on the 1st day. This result is compatible with the finding of Salih and Abdalla [1]. Gülzar et al. [53] noted that when the pH of the cheese is high, the protein network becomes less dense and allows more light to scatter, giving the cheese a whiter color.

A significant (P<0.001) change was observed in the odor score values of the cheese samples in terms of storage period and the starter culture used (Table 3). T1, T2, T3, T4, and T5 cheeses stored at 4 °C and 15 °C were found to have values close to each other on the 1st and 15th days of the storage period and were not significantly different (P>0.05). When cheese samples stored at 4 °C were examined, it was found that the odor score value of T5 cheese was not different from T2 and T3 cheeses and was significantly lower than T1 and T4 cheeses (P<0.001). When the cheese samples stored at 15 °C were examined, the odor score value of T5 cheese as the storage period progressed, was lower than T1 and T4 cheeses and higher than T3 and T2 cheeses. The odor score values of all cheeses, except T1 and T4 cheeses, decreased significantly (P<0.001) during the storage period. Dhuol and Hamid [32] reported that the odor score values of Sudanese white cheese made from cassava powder decreased during the 90-day storage period. There was no significant change in the odor score values of T1 and T4 cheeses in terms of storage period (P>0.05), and these cheeses had the highest values during storage.

A significant (P<0.001) change was observed in the texture score values of the cheese samples in terms of storage period and the starter culture used (Table 3). Considering cheese samples stored at 4 °C, it was found that the texture score value of T5 cheese was not different from T1 and T4 cheeses and was significantly higher than T2 and T3 cheeses (P<0.001) until the 15th day of maturation. As the storage period progressed, the texture score value of T5 cheese was lower than all cheeses except T2 cheese (Table 3). There was no significant change in the texture score values of T2 cheese stored at 4 °C in terms of storage period (P>0.05) and had the lowest value during storage. Katsiari et al. [8] investigated the quality of Galotyri-type cheeses made with different starter cultures and reported that the cheese containing *Streptococcus thermophilus* had a less hard structure than other cheeses. During the storage period, there was a significant decrease in the texture score values of T1 cheese and a significant increase in the texture score values of T3 cheese. The increase in the texture score values of T3 cheese is consistent with the result of Salih and Abdalla [1]. The texture score values of T4 cheese increased significantly until the 30th day of the storage period, decreased on the 60th day, and then remain constant until the last of the storage period. The initial increase in cheese hardness can be induced by protein crosslinking due to the hydrolysis of emulsifying salts the and subsequent gradual release of calcium ions [36]. The texture score values of T5 cheese decreased significantly until the 45th day of the storage period, increased on the 60th day, and no change was observed in the last month the of storage period. The texture score values of all cheeses, except T1 and T4 cheeses, decreased significantly during the storage period. The reduction in the texture of cheeses is thought to be due to the breakdown of casein into small peptides during storage, which causes the cheese texture to be softer [65,39]. It is also thought that it softens as the pH decreases, and this may be due to the separation of the casein network into smaller clusters [53]. Topçu and Saldamli [66] have linked the deterioration of Turkish white cheese to greater hydrolysis of proteins in the late stages of ripening, which contributes to the abnormal flavor and texture of the cheese. There was no significant change in the texture score values of T1 and T4 cheeses in terms of storage period (P>0.05), and these cheeses had the highest value during the storage period. de Azambuja et al. [12] reported that the cheeses containing mesophilic and mesophilic + *Lactobacillus helveticus* have high texture score values.

A significant (P<0.001) change was observed in the taste and aroma score values of the cheeses in terms of storage period and the starter culture used (Table 3). T1, T2, T3, T4, and T5 cheeses stored at 4 °C and 15 °C were found to have values close to each other on the 1st and 15th days of ripening (P>0.05). Considering the cheese samples stored at 4 °C, the taste and aroma score value of T5 cheese as the maturation progressed, had lower values than all samples except T2 cheese. Katsiari et al. [8] investigated the quality of Galotyri-type cheeses made with different starter cultures and reported that cheese containing *Streptococcus thermophilus* was more acidic than other cheeses. Taste and aroma scores of all cheeses decreased significantly during the storage period, except for T3 and T4 cheeses. Taste and aroma scores of T3 and T4 cheeses significantly increased until the 30th day of the storage period, and then significantly decreased on the 45th day. After the 45th day of the storage period, no significant change was observed in the taste and aroma score values. The increase in the taste and aroma scores of these cheeses may be due to the formation of lactic acid from the natural flora in raw milk or the suppression of unwanted microorganisms by the starter culture added to the milk before cheese making [44]. When cheese samples stored at 15 °C were examined, it was found that the taste and aroma scores of T5 cheese as the storage period progressed, were not different from T1 and T4 cheeses, and were significantly higher than T2 and T3 cheeses (P<0.001). The taste and aroma scores of all cheeses, except T4 cheese, decreased significantly during the storage period. This result is consistent with that of Elkhider and Hamid [42] and Abdalla and Yahya [67], and this may be due to the lipolytic and proteolytic effects of the microorganisms. There was no significant change in the taste and aroma score values of T4 cheese in terms of storage period (P>0.05).

A significant (P<0.001) change was observed in the general acceptability score values of the cheeses in terms of storage period and the starter culture used (Table 3). It was observed that T5 cheeses stored at 4 °C and 15 °C had the highest values on the 1st day of the storage period (P<0.05). When looking at the cheese samples stored at 4 °C, the general acceptability score value of T5 cheese as maturation progressed, was lower than all cheeses except T2 cheese. The general acceptability scores of all cheeses decreased significantly during the storage period, except for T3 and T4 cheeses. This decrease may be due to the proliferation of undesirable non-starter bacteria that cause bitter tastes due to excessive proteolysis [49]. A significant increase was observed in the general acceptability score values of T4 cheese until the 30th day of the storage period and decreased significantly on the 45th day. After the 45th day, there was no significant change in the general acceptability score values. This result is compatible with the finding of Suliman et al [49]. Salih and Abdalla [1] and Al-Ghamdi et al. [44] reported that the acceptability score values increased until the 15th day of ripening, then decreased, and it was suggested that the decrease was due to the lipolytic and proteolytic effects of microorganisms. There was no significant change in the general acceptability score values of T3 cheese in terms of storage period (P>0.05). When cheese samples stored at 15°C were examined, the general acceptability score value of T5 cheese as the storage period progressed, was lower than T1 and T4 cheeses and higher than T3 and T2 cheeses. Studies have found that using moderately autolyzed strains of *Lb. helveticus* [57] and mesophilic lactic culture containing, *Lactococcus lactis* subsp. *lactis* and *Lactococcus. lactis* subsp *cremoris* [12] in cheese production results in the best-flavored cheese. The general acceptability score values of all cheeses, except T1 and T4 cheeses, decreased significantly during ripening. There was no significant change in the general acceptability score values of T1 and T4 cheeses in terms of storage period (P>0.05).

Table 3 Sensory properties of Sudanese white cheese samples during the storage period

Properties	Days	Cheese Type					
		T1	**T2**	**T3**	**T4**	**T5**	**Mean**
Color score	4 °C						
	1	8.90±1.20^{xA}	9.20±0.92^{xA}	9.20±0.63^{xA}	9.10±1.27^{xA}	8.90±1.29^{xA}	9.06±0.71^{A}
	15	8.40±0.52^{xAB}	9.20±0.92^{xA}	9.10±0.82^{xA}	9.00±0.72^{xA}	8.60±1.43^{xAB}	8.86±1.00^{A}
	30	8.50±0.53^{yzAB}	9.00±1.05^{xyA}	9.20±1.03^{xyA}	9.60±0.52^{xA}	8.00±0.82^{zB}	8.86±0.84^{A}
	45	7.90±0.32^{xB}	7.70±0.48^{xB}	8.00±0.67^{xC}	8.00±0.82^{xC}	7.10±0.47^{yC}	7.74±0.90^{B}
	60	7.90±0.32^{yB}	7.80±0.42^{yB}	8.00±0.00^{yC}	8.60±0.52^{xBC}	7.10±0.57^{zC}	7.88±1.18^{B}
	90	8.00±0.47^{yzB}	7.80±0.42^{zB}	8.40±0.52^{xyC}	8.60±0.52^{xBC}	7.10±0.57^{rC}	7.98±1.18^{B}
	Mean	8.27±0.71^{y}	8.45±1.00^{xy}	8.65±0.84^{x}	8.81±0.90^{x}	7.80±1.18^{z}	
	15 °C						
	1	9.00±1.05^{xA}	9.20±0.92^{xA}	9.20±0.63^{xA}	9.10±1.29^{xA}	8.90±1.29^{xA}	9.08±1.06^{A}
	15	8.90±0.79^{xA}	8.08±0.88^{yAB}	8.40±1.17^{xyB}	8.90±0.57^{xyA}	8.80±0.63^{xA}	8.61±0.88^{A}
	30	9.00±1.25^{xyzA}	8.10±1.85^{zAB}	8.30±0.48^{yzB}	9.50±0.71^{xA}	9.30±0.95^{xyA}	8.84±1.23^{A}
	45	8.70±0.68^{xA}	8.10±1.85^{xAB}	7.50±0.82^{yB}	8.60±0.97^{xAB}	7.90±0.57^{xyB}	8.16±1.20^{BC}
	60	8.70±0.68^{xA}	7.20±0.79^{zB}	8.00±0.67^{yB}	8.80±0.79^{xAB}	8.00±0.47^{yB}	8.14±0.88^{BC}
	90	8.70±0.68^{xA}	7.36±1.12^{zB}	6.90±0.32^{zC}	8.60±0.97^{xAB}	7.90±0.57^{yB}	7.89±1.03^{C}
	Mean	8.83±0.88^{x}	8.01±1.42^{y}	8.05±1.07^{y}	8.91±0.98^{x}	8.46±0.94^{x}	
Odor score	4 °C						
	1	8.70±1.06^{xAB}	7.70±1.25^{xA}	8.60±0.67^{xA}	8.20±1.69^{xB}	8.60±1.17^{xA}	8.36±1.22^{A}
	15	8.78±1.06^{xAB}	8.00±0.97^{xA}	8.10±0.95^{xAB}	8.80±0.84^{xAB}	8.40±1.16^{xA}	8.42±1.01^{A}
	30	9.20±1.03^{xA}	7.90±0.32^{yA}	8.30±0.48^{yAB}	9.30±0.48^{xA}	8.00±0.82^{yAB}	8.54±0.89^{A}
	45	8.00±0.48^{xC}	6.70±0.52^{yB}	7.70±0.52^{xBC}	8.010±0.48^{xB}	7.60±0.48^{xB}	7.60±0.65^{C}
	60	7.60±0.52^{xC}	6.50±0.52^{yB}	7.90±0.32^{xBC}	8.00±0.00^{xB}	7.60±0.52^{xB}	7.52±0.68^{C}
	90	8.10±0.31^{xyBC}	6.80±0.42^{rB}	7.90±0.32^{yzBC}	8.30±0.48^{xB}	7.60±0.52^{zB}	7.98±1.18^{B}
	Mean	8.27±0.71^{y}	8.45±1.00^{xy}	8.65±0.84^{x}	8.81±0.90^{x}	7.80±1.18^{z}	
	15 °C						
	1	8.70±1.06^{xA}	7.70±1.25^{xA}	8.60±0.70^{xA}	8.20±0.92^{xA}	8.60±1.17^{xA}	8.36±1.06^{A}
	15	8.40±0.70^{xA}	7.10±1.29^{yA}	7.90±1.29^{xyAB}	8.20±0.79^{xA}	8.40±0.74^{xA}	8.00±1.06^{AB}
	30	9.00±0.94^{xA}	6.60±0.97^{zB}	7.50±0.71^{yB}	8.50±1.08^{xA}	8.60±1.33^{xA}	8.04±1.63^{AB}
	45	8.40±0.52^{xA}	6.60±0.97^{zB}	6.70±0.82^{zC}	8.00±0.47^{xyA}	7.70±0.48^{yB}	7.48±1.21^{C}
	60	8.80±0.42^{xA}	6.30±0.68^{rB}	7.00±0.42^{zC}	8.50±0.53^{xA}	7.70±0.48^{yB}	7.66±1.34^{BC}
	90	8.80±042^{xA}	6.64±1.29^{rB}	6.60±0.52^{rC}	8.00±0.47^{yA}	7.20±0.42^{zB}	7.45±1.30^{C}
	Mean	8.68±0.73^{x}	6.82±1.35^{r}	7.38±1.03^{z}	8.23±0.75^{y}	8.03±1.02^{y}	
	4 °C						
	1	8.80±1.03^{xA}	7.20±1.40^{yA}	7.30±0.67^{yB}	8.30±0.95^{xB}	8.50±0.71^{xA}	8.02±1.15^{A}

Texture score	15	8.60±0.97^{xAB}	7.60±0.70^{xyA}	7.30±1.32^{yB}	8.30±0.63^{xyB}	7.70±1.42^{xyB}	7.90±1.12^{AB}
	30	8.60±0.52^{xAB}	6.90±0.87^{yzA}	7.40±1.17^{yB}	9.20±0.63^{xA}	6.50±0.53^{zC}	7.72±1.28^{AB}
	45	8.10±0.32^{xC}	7.10±0.00^{yA}	7.80±0.48^{yzAB}	8.00±0.42^{xB}	6.70±0.52^{zC}	7.54±0.67^{BC}
	60	7.90±0.32^{xyC}	6.90±0.32^{zA}	7.70±0.48^{yAB}	8.00±0.00^{xB}	7.00±0.00^{zBC}	7.50±0.54^{BC}
	90	8.00±0.00^{yC}	7.00±0.00^{zA}	8.00±0.00^{yA}	8.30±0.48^{xB}	7.00±0.00^{zBC}	7.66±1.18^{BC}
	Mean	8.33±0.72^{x}	7.12±0.75^{y}	7.58±0.88^{y}	8.35±0.72^{x}	7.23±0.97^{y}	
	15 °C						
	1	8.80±1.03^{xA}	7.20±1.40^{yA}	7.40±0.68^{yA}	8.30±0.95^{xA}	8.50±0.71^{xA}	8.04±1.15^{A}
	15	8.80±1.25^{xA}	7.10±1.33^{zA}	7.60±0.52^{yzA}	8.20±0.74^{xyA}	8.50±0.97^{xyA}	8.04±1.15^{A}
	30	9.00±0.82^{xA}	6.50±1.93^{yAB}	7.00±0.47^{yB}	8.60±0.97^{xA}	8.50±1.35^{xA}	7.92±1.59^{AB}
	45	8.20±0.42^{xA}	6.50±1.93^{zAB}	7.10±0.42^{yB}	8.20±0.79^{xA}	7.40±0.52^{xyB}	7.48±1.22^{BC}
	60	8.20±0.42^{xA}	6.00±0.85^{rB}	7.00±0.00^{zB}	8.60±0.52^{xA}	7.50±0.53^{yB}	7.46±1.21^{BC}
	90	8.20±0.42^{xA}	6.00±1.33^{zB}	7.00±0.32^{yB}	8.20±0.79^{xA}	7.40±0.52^{yB}	7.36±1.17^{C}
	Mean	8.53±0.83^{x}	6.55±1.54^{r}	7.18±0.49^{z}	8.35±0.80^{x}	7.97±0.96^{y}	
Taste and Aroma score	4 °C						
	1	8.30±1.34^{xyA}	7.50±0.85^{yA}	8.10±1.29^{xyAB}	8.10±1.29^{xyB}	8.70±1.05^{xA}	8.14±1.24^{A}
	15	8.50±1.29^{xyA}	7.40±0.74^{yA}	8.10±1.33^{xyAB}	8.70±1.14^{xB}	8.40±1.52^{xyAB}	8.22±1.31^{A}
	30	8.30±0.95^{xA}	7.10±1.20^{yAB}	8.30±1.25^{xA}	9.20±0.63^{xA}	8.30±1.25^{xAB}	8.24±1.24^{A}
	45	7.40±0.68^{yzB}	6.50±0.52^{rB}	7.60±0.53^{xyB}	8.10±0.82^{xB}	7.10±0.57^{zrB}	7.34±0.82^{B}
	60	7.30±0.67^{yB}	6.50±0.53^{zB}	7.70±0.48^{yB}	8.40±0.52^{xAB}	7.20±0.42^{yB}	7.42±0.81^{B}
	90	7.40±0.52^{zB}	6.70±0.48^{rB}	7.90±0.32^{yB}	8.70±0.48^{xAB}	7.20±0.42^{zB}	7.58±0.81^{B}
	Mean	7.87±1.20^{y}	6.95±0.82^{z}	7.95±1.01^{y}	8.53±0.94^{x}	7.81±1.19^{y}	
	15 °C						
	1	8.30±1.20^{xA}	7.50±0.85^{yA}	8.10±1.29^{xyA}	8.10±1.29^{xyA}	8.70±1.05^{xA}	8.14±1.26^{A}
	15	8.80±0.84^{xAB}	7.40±1.87^{yA}	8.10±1.29^{xyA}	8.10±1.10^{xyA}	8.50±0.67^{xyAB}	8.18±1.38^{A}
	30	8.80±1.03^{xAB}	5.60±0.97^{zB}	7.80±1.03^{yAB}	8.00±0.82^{xyA}	8.60±0.86^{xyAB}	7.76±1.48^{AB}
	45	8.10±0.32^{xB}	5.60±0.97^{zB}	7.00±0.67^{yB}	8.00±0.67^{xA}	7.70±0.77^{xC}	7.28±1.13^{B}
	60	8.10±0.32^{xB}	5.70±0.95^{zB}	7.10±0.74^{yB}	8.20±0.42^{xA}	7.80±0.87^{xC}	7.38±1.11^{B}
	90	8.10±0.32^{xB}	5.82±1.17^{yB}	5.80±0.42^{yC}	8.00±0.67^{xA}	6.00±0.60^{yD}	6.74±1.25^{C}
	Mean	8.36±0.81^{x}	6.27±1.38^{r}	7.31±1.21^{z}	8.06±0.84^{xy}	7.88±1.27^{y}	
	4 °C						
	1	8.80±0.63^{xyA}	7.90±1.10^{zA}	8.20±1.14^{yzA}	8.40±0.52^{xyzB}	9.10±0.88^{xA}	8.48±0.95^{A}
	15	8.60±0.97^{xA}	7.60±0.67^{yAB}	8.10±0.74^{xyA}	8.70±1.18^{xAB}	8.80±0.79^{xAB}	8.46±1.11^{A}
	30	8.60±0.52^{yA}	7.60±1.08^{zAB}	8.30±1.25^{yzA}	9.60±0.52^{xA}	8.20±1.03^{yzB}	8.24±1.24^{A}
	45	7.90±0.32^{xyB}	7.00±0.00^{zB}	8.10±0.52^{yA}	8.10±0.57^{xB}	7.30±0.42^{zC}	7.68±0.58^{C}
	60	7.90±0.32^{yzB}	7.10±0.32^{rB}	8.10±0.57^{xyA}	8.40±0.52^{xB}	7.50±0.53^{zrC}	7.80±0.64^{BC}
	90	8.00±0.00^{rB}	7.00±0.00^{rB}	8.10±0.57^{xA}	8.70±0.48^{xB}	7.50±0.53^{xC}	7.86±0.70^{BC}
	Mean	8.30±0.63^{y}	7.36±0.75^{z}	8.15±0.84^{y}	8.65±0.80^{x}	8.07±1.00^{y}	

General acceptability score	15 °C						
	1	8.80±0.63^{xyA}	7.90±1.10^{zA}	8.20±1.14^{yzA}	8.40±0.52^{xyzA}	9.10±0.88^{xA}	8.48±0.95^{A}
	15	8.70±0.82^{xA}	6.90±1.79^{yA}	8.50±1.43^{xA}	8.20±0.79^{xA}	8.70±0.95^{xA}	8.20±1.36^{B}
	30	8.90±0.88^{xA}	5.60±0.97^{zB}	7.20±0.79^{yB}	8.60±0.97^{xA}	8.70±1.16^{xA}	7.80±1.57^{BC}
	45	8.40±0.52^{xA}	5.60±0.97^{rB}	7.10±0.32^{zB}	8.00±0.47^{xyA}	7.60±0.52^{yB}	7.34±1.15^{CD}
	60	8.40±0.52^{xA}	5.50±0.85^{zB}	7.10±0.57^{yB}	8.20±0.42^{xA}	7.60±0.52^{yB}	7.36±1.19^{C}
	90	8.40±0.52^{xA}	5.73±1.10^{zB}	6.00±0.00^{yzC}	8.00±0.47^{xA}	6.20±0.63^{yC}	6.86±1.29^{D}
	Mean	8.60±0.67^{x}	6.20±1.42^{r}	7.35±1.17^{z}	8.23±0.65^{xy}	7.98±1.26^{y}	

$^{A, B, C, D, E}$= Means with different exponential letters in the same column ± standard deviations differ from each other by P<0.05 significant level. ^{x,y,z,r,n}= Means with different exponential letters in the same row ± standard deviations differ significantly (P<0.05); T1= cheese made with DOM1 (*Lc. lactis* ssp. *cremoris* + *Lc. lactis* ssp. *Lactis*) starter culture; T2= Cheese made with PTB1 (*Lc. lactis* ssp. *cremoris* + *Lc. lactis* ssp. *Lactis* + *Streptococcus thermophilus*) starter culture; T3= cheese made with DOM1+ CASEI 39 (*Lb. casei*) starter culture; T4= cheese made with DOM1+ DHL IDC13 (*Lb. helveticus*) starter culture; T5= cheese made without starter culture addition (Control).

While the color, Texture, and taste and aroma score values were not significantly (P>0.05) affected by the storage temperature, the odor and general acceptability scores values of the cheese samples stored at 15 °C were lower than those of the cheese samples stored at 4 °C (Fig. 3). The result of the color is consistent with the findings of Cuffia et al. [6]. The result of texture is consistent with the findings of Bubelova et al. [36] in their study on the properties of sterilized processed cheese. The result taste and aroma is consistent with the findings of ElOwni and Hamed [62] in their study on the properties of Sudanese white cheese. The results of the odor and general acceptability are consistent with the findings of Cuffia et al. [6] who reported that storing cheeses at high temperatures can cause various changes in their quality due to volatile compounds.

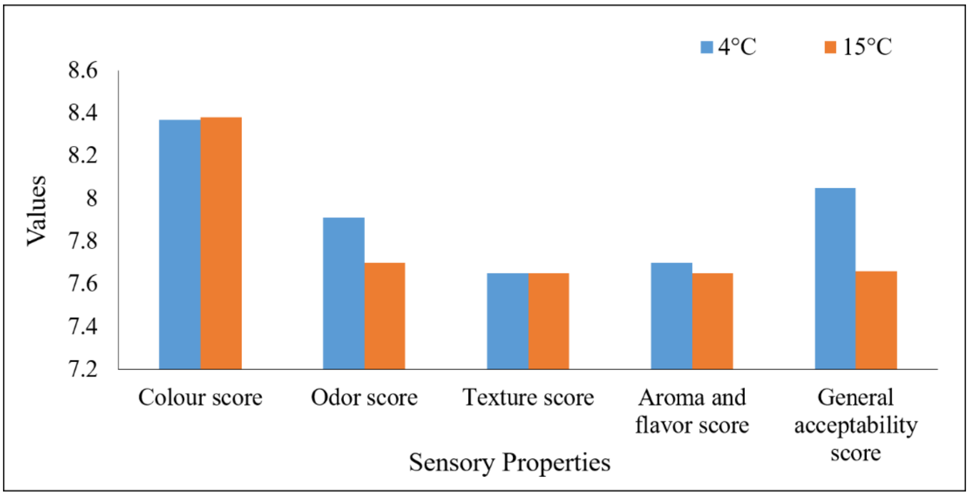

Figure 3 Sensory properties of Sudanese white cheese samples stored at different temperatures

4. Conclusion

As a result, the use of starter culture in the production of white cheese did not adversely affect the properties of the cheeses, especially T4 cheeses containing *Lactobacillus helveticus,* and T1 cheeses made with mesophilic culture received better physicochemical values than other cheeses during control storage and were highly appreciated. However, storing the cheeses at 15 °C provided high-quality cheese in terms of nutrients. On the other hand, our findings revealed that the use of commercially available starter cultures significantly affected proteolysis and lipolysis during the cheese ripening period, resulting in differences in the flavor components of cheese and thus in sensory properties. In future research, we suggest using lactic acid bacteria isolated from Sudanese white cheese to produce a cheese with the unique flavor of Sudanese white cheese.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no competing interest.

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