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Physicochemical and Sensory Characteristics of Whey-based White Cheese Supplemented with Whole Milk Powder

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Authors' contributions

This work was carried out in collaboration with both authors. Author MOMA designed the study, performed the statistical analysis, and wrote the protocol. Author ZBEY managed the analyses of the study, wrote the first draft of the manuscript and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of the study is to manufacture and determine the physicochemical and sensory characteristics of white cheese from whey supplemented with milk powder.
Methodology: Cheese was manufactured from whey left after mozzarella cheese manufacture Cheese was manufactured from whey only (T1), and whey + milk powder (T2 and T3). Salt (2% w/w) was added to all treatments, while white vinegar (5% w/w) was added to T2 and T3. Cheese was stored without whey at 5℃ for 30 days, and physi cochemical and sensory characteristics were determined at 1, 7, 14 and 30-day intervals.
Results: Fat and protein contents were significantly affected by the concentration of milk powder being high in T3, while the pH was lower in T3, and total solids and ash contents were not significantly affected. The fat and total solids contents steadily increased towards the end of the storage period, while the protein and pH declined to the minimum at day 7, and the ash content reached the maximum at day 14. The concentration of milk powder and storage period significantly affected the sensory characteristic except colour and saltiness, respectively.

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Conclusion: The concentration of whole milk powder affected all physicochemical characteristics of cheese except total solids and ash contents, while the storage period affected all physicochemical characteristics except fat content and pH of cheese.

Keywords: Cheese; milk powder; physicochemical; sensory; whey.

1. INTRODUCTION

Utilization of whey proteins to food and dairy products is considered as one of the most important functions due to their effects either on the product characteristics or the health promotion [1]. The utilization of whey in whey-based cheeses in small cheese factories has been considered to be one of the economical methods, so the manufacture of cheese could easily be undertaken as an additional source of income [2]. A wide range of ingredients containing protein have been prepared including whole-milk ricotta, whey-based ricotta, ricotta from blends of milk and whey with the potential to produce casein, Paneer and Queso Blanco [3]. Whey cheese is a dairy product manufactured mainly from ovine whey, and its production is important because the heating process allows the recuperation of whey protein from whey. These cheeses have different names depending on the country, for example, in Italy, Spain and Portugal, the whey cheeses obtained from ovine cheese whey are called Ricotta, Requeson and Requeijao, respectively [4]. Cheese is obtained by heating the whey at a temperature ranging from 90℃ to 100℃ for 10-15 min with the addition of skim milk. The residual whey resulting from the manufacture of cheese contains approximately 60% of the original dry matter of the whey. Lactose and minerals largely contribute to its dry mass, but residual fat and non-thermally precipitated nitrogen components are still present. Hence, attempts to recover some of the solid components present before the final disposal may be of interest [5].

The consumption and manufacture of cheese is increasing worldwide at a rate of about 2% per year, and as a result, the amount of cheese whey is also increasing [6]. Whey is a by-product of the dairy industry in which the principal components are lactose, protein and mineral salts [7]. Approximately 47% of whey produced world-wide every year is disposed in the environment [8-10]. This represents a significant loss of resources and causes serious pollution problems since whey is a high strength organic pollutant with high biological oxygen demand (BOD) and chemical oxygen demand (COD) with values of 40,000-60,000 mg/L and 50,000-80,000 mg/L, respectively [11,12], and more than 90% of whey BOD_5 is due to lactose [13]. Utilization of skim milk in cheese manufacture was found to increase the fresh and pickled cheese yield throughout the storage time, which may be attributed to increased moisture retention. Contamination of fresh whey cheese occurs mainly during curd formation; Hence, packaging seems necessary and useful to retard microbial contamination. However, little attention has been paid to this straight forward fact, so studies encompassing packaging of whey cheese and consumer safety are scarce [4]. Utilization of whey left after cheese making is important to reduce the pollution of the environment and the manufacture of cheese is one of these methods to utilize the whey. Therefore, this study is conducted to manufacture white cheese from whey left after mozzarella cheese manufacture and evaluate the resultant cheese physicochemically and organoleptically.

2. MATERIALS AND METHODS

2.1 Manufacture of Cheese

Cheese was manufactured from whey left after manufacture of mozzarella cheese. Three treatments were prepared: The first treatment (control, T1) was made from whey (4000 ml) without addition of vinegar or milk powder, while the second treatment (T2) was made from whey (4000 ml) to which white vinegar (5% w/w) and whole milk powder (5% w/w) were added, and the third treatment (T3) was made from whey (4000 ml) to which white vinegar (5% w/w) and milk powder (7% w/w) were added. Whey was heated to 100℃ followed by addition of whole milk powder, salt (2% w/w) and white vinegar (5% w/w) for T2 and T3, while for T1 only salt was added to heated whey. The whey was drained and the curd was pressed in cheese moulds lined with cloth overnight. Next morning the curd was cut into small cubes (2.5x2.5x2.5 cm) and preserved in sterile cups without whey at 5℃ for 30 days. Physicochemical and sensory characteristics were determined at 1, 7, 14, and 30 day-intervals.

2.2 Physicochemical Analysis of Cheese

The fat, protein, total solids and ash contents were determined by Gerber method according to AOAC [14]. The pH was determined using pH meter (Hanna-instrument model 98107, Mauritium). Before determination, pH meter was calibrated using buffer solutions No. 4 and 7.

2.3 Sensory Evaluation

A Panel of 10 untrained panelists were chosen and asked to judge on the quality of cheese (color, flavor, body, taste, saltiness, and overall acceptability), using an evaluation sheet where color ranged from 1 = not acceptable to 4 = acceptable; flavor from 1 = bland to 4 = extremely intense; taste from 1 = absent to 4 = excessive acid; body from 1 = smooth to 4 = pasty; saltiness from 1= moderate to 4= too salty; Overall acceptability from 1 = unacceptable 4 = acceptable.

2.4 Statistical Analysis

Data were analyzed using Statistical Analysis Systems (SAS, ver. 9). General linear models (GLM) procedure was used to determine the effect of treatment and storage period on the physicochemical and sensory characteristics of white cheese. Mean separation was carried out by Duncan multiple range test ($P \leq 0.05$).

3. RESULTS AND DISCUSSION

3.1 Physicochemical Characteristics of Whey-based Cheese Supplemented with Whole Milk Powder

The physicochemical characteristics of whey-based white cheese supplemented with whole milk powder is presented in Table 1. The fat content was significantly ($p<0.01$) higher in T3 (21.69%), while the lowest content was found in T2 (19.21%). As the percentage of whole milk powder increased, the fat content in cheese increased. These results are in line with those reported by ElOwni and Hamed [15] who reported a fat content of 19.27-23.83% for white cheese (*Gibna* ba*yda*) produced in Darfur region, west Sudan. Salih et al. [16] and Mustafa et al. [17] reported similar results for white cheese (*Gibna bayda*). This result is higher than that reported by Pintado et al. [4] who reported 11.6% fat for whey cheese made with 80% whey and 20% cow milk. The composition of whey cheese depends on the source of whey, composition, ratio of whey to milk (if added) and technological practices [4]. Elhaseen et al. [18] reported that the fat content of white cheese made with lime juice was significantly higher than that made with grapefruit juice. Abdel Razig and AlGamry [19] reported that fat content of whey cheese made with white vinegar recorded the highest fat compared to fat content of cheese made with grapefruit juice and lemon juice. During the storage period, the fat content steadily but insignificantly increased from 19.71% at day 1 to 21.42% at day 30 in all treatments (Table 2). The fat content of T1, T2 and T3 separately increased gradually to a maximum level at the end of storage period with a slight decrease in T3 at day 14 (Table 1; Fig. 1). These results are in agreement with those reported by Abdel Razig and Al Gamry [19] for white cheese made by natural acidifying agents, and in disagreement with El Owni and Hamid [20], Abdel Razig and Babiker [21], Dhuol and Hamid [22] and Mancuso et al. [23].

The protein content was significantly ($p<0.001$) higher (16.85%) in cheese made with 7% whole milk powder (T3) compared to other treatments (Table 1). It was noticed that as the level of whole milk powder increased from 0 (T1) to 7% (T3), the protein content increased. This result is in accordance with that reported by El-Sheikh et al. [24] who reported that the protein content of ricotta cheese from whey protein concentrate increased from 17.75% in whey protein concentrate only to 21.30% in whey protein concentrate+6% skim milk powder. Similar results were reported by Pintado et al. [4] for whey cheese made by 80% whey to 20% milk, and that as whey percentage increased, the protein content decreased. During the storage period, the protein content decreased to a minimum (12.87%) at day 7 before increasing again towards the end of the storage period (Table 2). The protein of cheese in T1and T2 showed a slight decrease at day 7 then steadily increased towards the end of storage period, while for T3 the protein increased till day 14, then slightly decreased at the end (Fig. 2). The results are in agreement with those ElOwni and Hamid [20] who reported that the protein content of white cheese (*Gibna bayda*) increased to a maximum at day 120 then decreased thereafter. The cheese in this study was stored only for 30 days since it is unripened cheese, and it is possible that the protein content could have decreased if the storage period was extended. Abdel Razig and Al Gamry [19] reported that the protein content of unripened whey cheese

steadily increased during the storage period of 60 days. The total solids content was higher (43.71%) in cheese made with whey only (T1) and lower (40.23%) in T2 although the difference was not significant (Table 1). The results in this study are lower than those reported by ElOwni and Hamed [15] for white cheese, and Salih et al. [16]. El-Sheikh et al. [24] reported that total solids content of ricotta cheese increased with increasing skim milk powder concentration when cheese was made with 1.5% glucono-delta-lactone (GDL) and 0.14% citric acid. During the storage period, the total solids content significantly ($p<0.05$) increased with the storage period from 37.50% at day 1 to 45.85% at day 30 (Table 2). The same trend was followed for the three treatments separately (Fig. 3). These results are in line with those reported by Abdel Razig and AlGamry [19], Abdel Razig and Babiker [21] and Dhuol and Hamid [22] for unripened whey cheese. However, Mancuso et al. [23] reported that the total solids content of ovine ricotta cheese in modified atmosphere packaging increased from 24.76% at 24 hr to 26.40% at day17 but not detected at days 21 and 24. However, our results are in disagreement with Ismail et al. [25] who reported that TS content gradually decreased during the storage of traditional white soft cheese made from milk fortified with skim milk powder.

Table 1. Physicochemical characteristics of whey-based cheese supplemented with whole milk powder

Physicochemical characteristics	Treatment[1]			SE	*p*
	T1	T2	T3		
Fat (%)	20.18^{ab}	19.21^{b}	21.69^{a}	0.529	0.0079
Protein (%)	14.66^{b}	12.36c	16.85a	0.687	0.0002
Total solids (%)	43.71^{a}	40.23^{a}	43.38^{a}	1.674	0.2803
Ash (%)	2.47^{a}	3.78^{a}	2.32^{a}	0.660	0.2430
pH	4.43^{ab}	4.77^{a}	4.14^{b}	0.175	0.0510

Means in each row bearing similar superscripts are not significantly different (P>0.05)
SE = Standard error of means = T1= Whey only (control); T2 = Whey (4000 ml) +whole milk powder (5% w/w); T3 = Whey (4000 ml) + whole milk powder (7% w/w)

Table 2. Effect of storage period on the physicochemical characteristics of whey-based cheese supplemented with whole milk powder

Physicochemical characteristics	Storage period (days)				SE	*p*
	1	7	14	30		
Fat (%)	19.71^{a}	20.07^{a}	20.25^{a}	21.42^{a}	0.631	0.2405
Protein (%)	13.16^{b}	12.87^{b}	15.89^{a}	16.58^{a}	0.793	0.0028
Total solids (%)	37.50^{b}	41.21^{ab}	45.18^{a}	45.85^{a}	1.933	0.0144
Ash (%)	1.84^{b}	1.96^{ab}	4.21^{a}	3.40^{ab}	0.762	0.0955
pH	4.71^{a}	4.10^{a}	4.36^{a}	4.63^{a}	0.202	0.1490

Means in each row bearing similar superscripts are not significantly different (P>0.05)
SE = Standard error of means

Table 3. Sensory characteristics of whey-based cheese supplemented with whole milk powder

Sensory characteristics	Treatment			SE	*p*
	T1	T2	T3		
Colour	3.69^{a}	3.90^{a}	3.94^{a}	0.105	0.2158
Taste	2.10^{b}	2.18^{b}	2.51^{a}	0.102	0.0154
Consistency	1.65^{c}	3.94^{a}	2.79^{b}	0.037	<0.0001
Saltiness	2.66^{ab}	2.76^{a}	2.39^{b}	0.111	0.0501
Overall acceptability	1.84^{b}	2.04^{b}	2.44^{a}	0.078	<0.0001

Means in each row bearing similar superscripts are not significantly different (P>0.05)
SE = Standard error of means

Table 4. Effect of during storage period on the sensory characteristics of whey-based cheese supplemented with whole milk powder

Sensory characteristics	Storage period (days)				SE	*p*
	1	7	14	30		
Colour	4.07[a]	4.38[a]	3.52[b]	3.40[b]	0.122	<0.0001
Taste	3.77[a]	1.93[b]	1.68[b]	1.67[b]	0.117	<0.0001
Consistency	3.13[a]	2.80[b]	2.82[b]	2.42[c]	0.043	<0.0001
Saltiness	2.45[a]	2.78[a]	2.58[a]	2.60[a]	0.128	0.3366
Overall acceptability	3.82[a]	1.62[b]	1.72[b]	1.27[c]	0.091	<0.0001

Means in each row bearing similar superscripts are not significantly different (P>0.05)
SE = Standard error of means

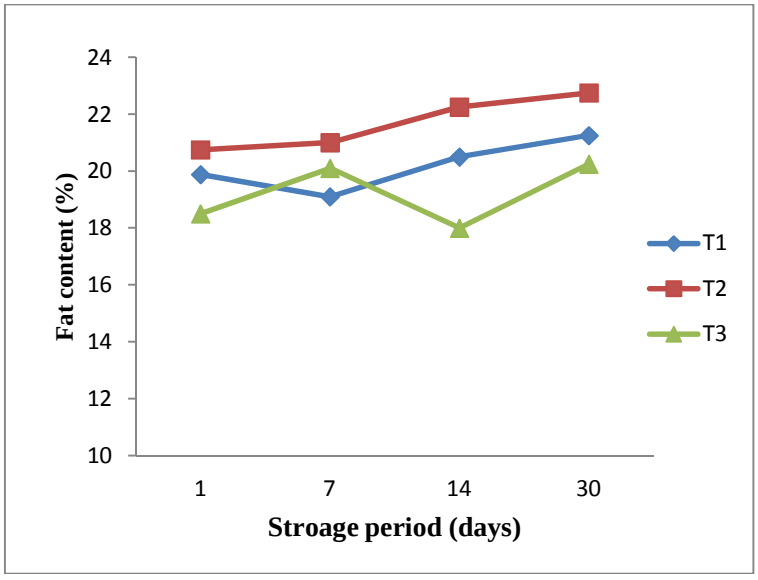

Fig. 1. Effect of storage period on fat content of whey-based cheese supplemented with whole milk powder

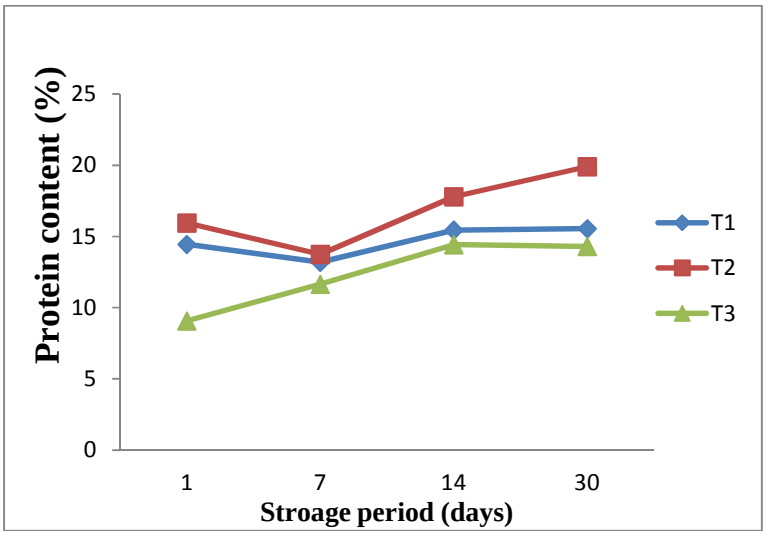

Fig. 2. Effect of storage period on protein content of whey-based cheese supplemented with whole milk powder

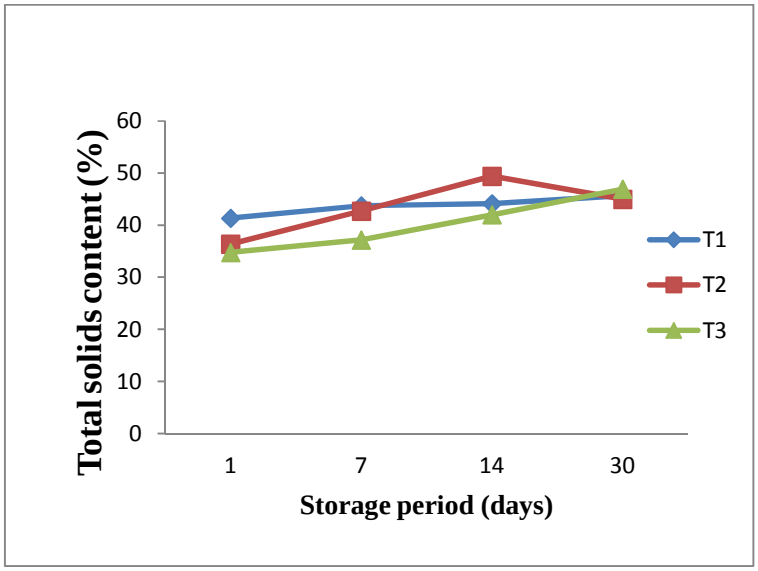

Fig. 3. Effect of storage period on total solids content of whey-based cheese supplemented with whole milk powder

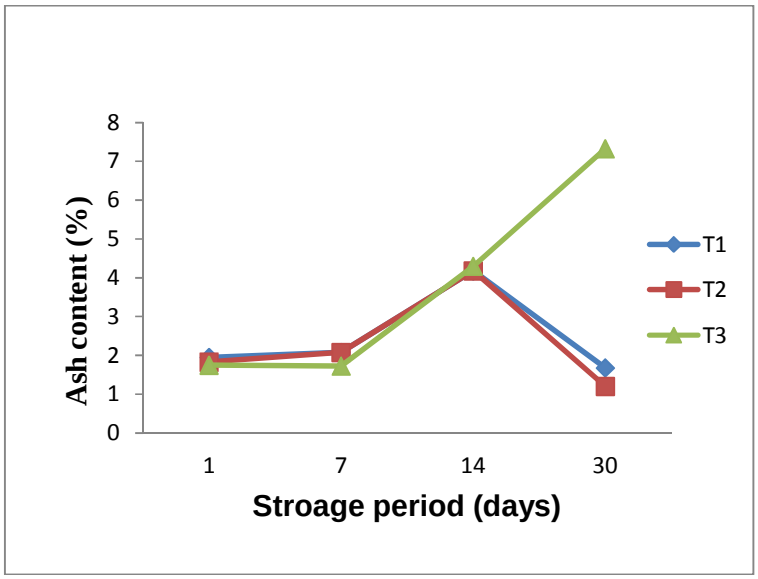

Fig. 4. Effect of storage period on ash content of whey-based cheese supplemented with whole milk powder

The ash content was significantly ($p<0.05$) higher (3.78%) in cheese made with 5% whole milk powder (T2), and lowest (2.32%) in T3 (cheese made with 7% whole milk powder) (Table 1). These results are in disagreement with those of El-Sheikh et al. [24] who reported that ash content increased as the concentration of skim milk powder is increased to 6% in ricotta cheese made with whey protein concentrate and two organic acids GDL (Glucono-Delta-Lactone) and citric acid. These results are lower than those reported by Salih et al. [16] and Mustafa et al. [17] for white cheese. During the storage period, the ash content increased to a maximum at day 14 before decreasing at the end of storage period (Table 2). For separate treatments, the ash content increased regularly till day 14, then the ash content of cheese in T1 and T2 decreased, while that of T3 increased at the end of storage period (Fig. 4). Similar results were

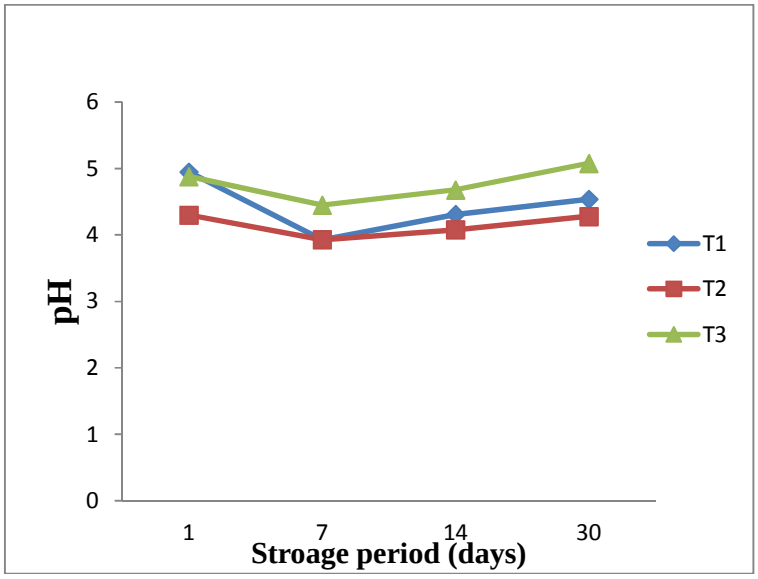

Fig. 5. Effect of storage period on pH of whey-based cheese supplemented with whole milk powder

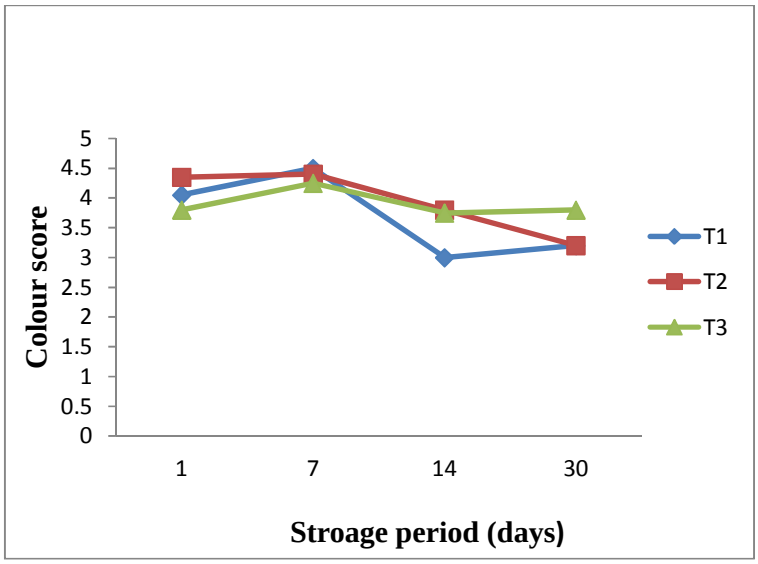

Fig. 6. Effect of storage period on colour score of whey-based cheese supplemented with whole milk powder

reported by El Owni and Hamid [20]. However, results in this study are in disagreement with Abdel Razig and Al Gamry [19] and Abdel Razig and Babiker [21]. The pH of cheese was significantly ($p<0.05$) higher (4.77) in T2 compared to other treatments (Table 1). The addition of vinegar did not affect the pH of cheese, and the pH is in the normal range of acid coagulation since the casein precipitation takes place by acid at the isoelectric point of casein (pH 4.6-4.7), and even pH of cheese in T1 (control) is lower than the isoelectric point. This may be attributed to pH of whey from cheese making meaning that whey from cheese making was slightly acidic due to pH reduction by starter cultures. Lower pH values (3.28-3.74) were reported for white cheese made by direct acidification with lemon juice, orange juice and grapefruit juice [21]. Elhaseen et al. [18] reported titratable acidity of 0.25% and 0.89% for white

cheese made with lemon juice and grapefruit juice respectively. El-Sheikh et al. [24] reported that pH value increased from 5.35 in whey protein concentrate cheese to 5.9 in cheese made with whey protein concentrate+6% skim milk powder when acidification was carried out by 1.5% GDL, and from pH 5.91 to pH 6.21% in cheese acidified with 0.14% citric acid. During the storage period, the pH decreased (4.10) at day 7 before increasing to 4.63 at the end of storage (Table 2). The pH of cheese in all treatments decreased at day 7 before increasing thereafter (Fig. 5). These results are in disagreement with those of Mancuso et al. [23] who reported that the pH of ovine ricotta cheese in modified atmosphere packaging decreased from 6.54 at 24 hr to 5.96 at day 24 of storage, and Abdel Razig and Babiker [21] who reported that the pH of white soft cheese made by direct acidification decreased from 5.20 at day 0 to 2.73 at day 60.

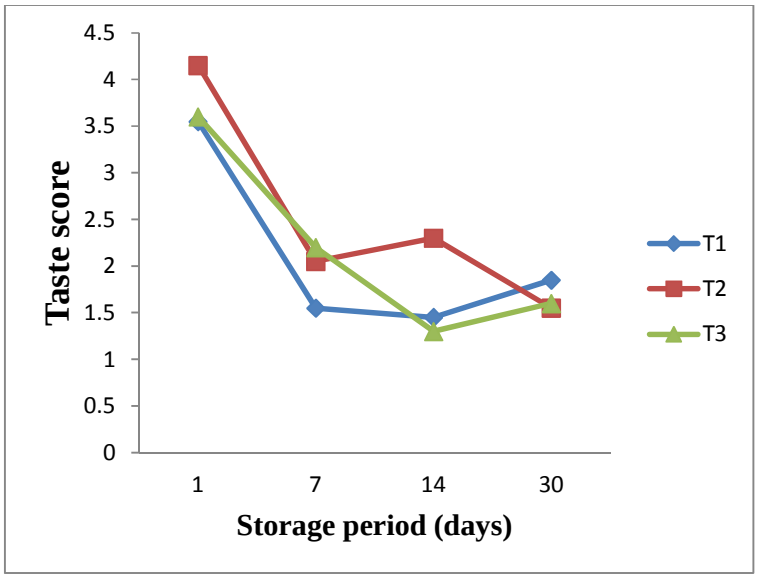

Fig. 7. Effect of storage period on taste score of whey-based cheese supplemented with whole milk powder

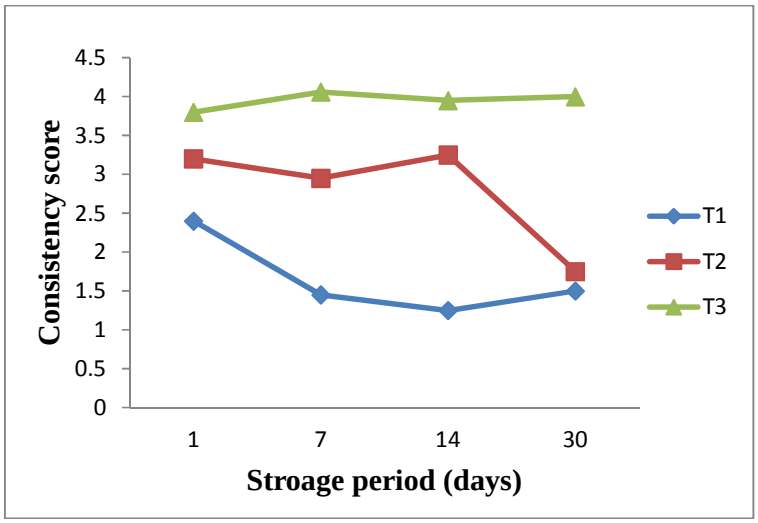

Fig. 8. Effect of storage period on consistency score of whey-based cheese supplemented with whole milk powder

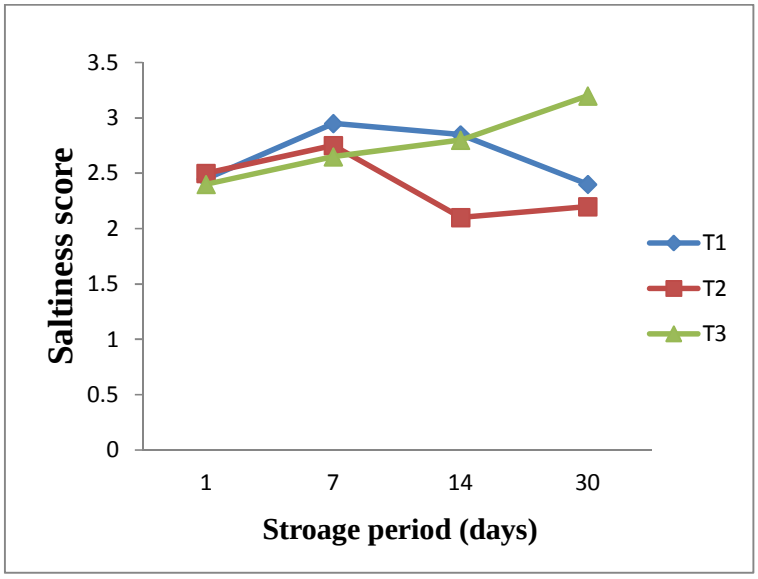

Fig. 9. Effect of storage period on saltiness score of whey-based cheese supplemented with whole milk powder

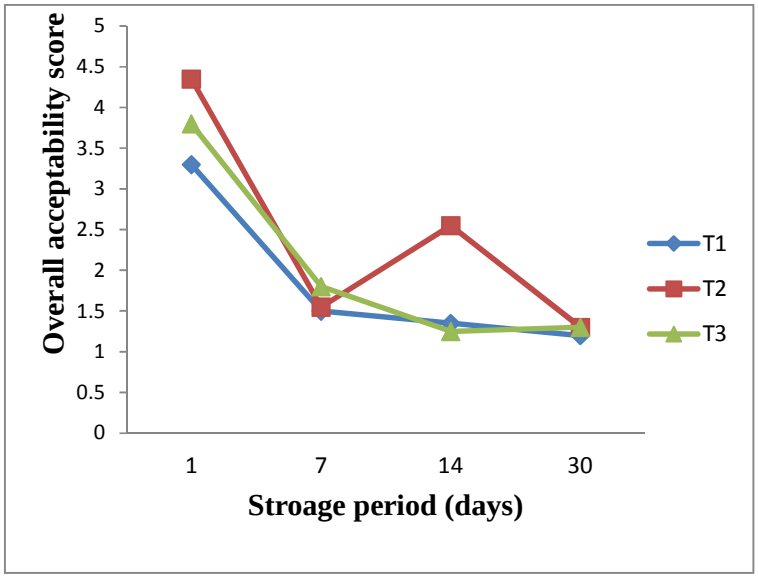

Fig. 10. Effect of storage period on overall acceptability score of whey-based cheese supplemented with whole milk powder

3.2 Sensory Characteristics of Whey-based Cheese Supplemented with Whole Milk Powder

The colour of white cheese was not significantly affected by the addition of whole milk powder, although slightly higher score (3.94) was obtained from cheese in T3 (Above Table 3). The colour improved till day 7 (4.38) before gradually decreasing towards the end (Table 4). The colour of cheese in all treatments separately showed a gradual decrease during the storage period (Fig. 6). These results are in agreement with Dhuol and Hamid [22] who found the best color of white cheese at day 0 of storage period. Similar results were reported by Mohammed and Abdalla [26] for cooked and uncooked white cheese, and ElOwni and Hamid [20]. These results are in agreement with Abdalla and Mohammed [27] who reported that the colour of

cooked white soft cheese scored the highest at day 20 of storage period before decreasing thereafter. The addition of whole milk powder to whey for the manufacture of cheese slightly improved the taste, with the best (2.51) being in T3 (Table 3). The taste of cheese deteriorated during the storage from 3.77 at day 1 to 1.67 at day 30 (Table 4). Taste of cheese in all treatments separately showed a gradual decrease towards the end of storage (Fig. 7). These results are in agreement with those of Dhuol and Hamid [22] for white cheese made from different levels of cassava powder. However, Abdalla and Mohammed [27] and Mohammed and Abdalla [26] reported that taste of cooked and uncooked white soft cheese improved at the end of storage period. The consistency of cheese was best ($p<0.001$) in cheese made with 5% whole milk powder (T2), while the worst consistency score was in control cheese (T1) made only from whey (Table 3). Cheese consistency deteriorated as the storage period progressed (Table 4). Consistency of cheese in T1 (control) gradually decreased till day 14 before increasing again towards the end, while cheese in T2 showed best consistency at day 14 then deteriorated, and cheese in T3 showed a slight increase in consistency as the storage period progressed (Fig. 8). El-Sheikh et al. [24] reported that body and texture of ricotta cheese from whey protein concentrate supplemented with skim milk powder deteriorated as the concentration of skim milk powder increased in cheese made with both GDL and citric acid acidifying agents. The results in this study are in disagreement with those of ELOwni and Hamid [20], Abdalla and Mohammed [27] and Mohammed and Abdalla [26]. Cheese in T2 was too salty (2.76) as judged by the panelists (Table 3), and saltiness increased as the storage period progressed (Table 4). The saltiness of cheese from T1 increased at day 7 before decreasing at the end, while in cheese from T2 decreased to a minimum at day 14 then slightly increased thereafter and in cheese from T3 a steady increase with the storage period was observed (Fig. 9). These results are in disagreement with the findings of ElOwni and Hamid [20], Abdalla and Mohammed [27] and Mohammed and Abdalla [26] who reported a decreasing trend of saltiness during the storage period. Overall, cheese in T3 was most acceptable (2.44), while cheese in T1 (control) was least acceptable (1.84) (Table 3). During the storage period cheese deteriorated till day 30 when cheese was least acceptable (Table 4). For individual treatments, cheese in T1 and T3 deteriorated and became less acceptable as the storage period progressed, while for T2 a slight improvement in acceptability was noticed at day 14 before deteriorating towards the end (Fig. 10). The results are in agreement with Abdalla and Mohammed [27], Mohammed and Abdalla [26] and Dhuol and Hamid [22]. Mancuuso et al. [23] reported that judgment of ovine ricotta cheese in modified atmosphere packaging was good for most of panelists till day 3 and always was acceptable overall up to day 14; at day 17, 7 out of 12 panelists evaluated cheese as acceptable, while at day 24 all panelists agreed that the cheese was unacceptable.

4. CONCLUSION

Increasing the concentration of whole milk powder increased the contents of fat and protein and improved the taste and overall acceptability of cheese. The storage period significantly affected protein, total solids, ash contents and all sensory characteristics except saltiness. The significance of this research is that it focuses on the utilization of whey from cheese industry in the manufacture of cheese in order to reduce the cost of cheese manufacture when manufacture depends on the milk alone, in addition to reducing the pollution of the environment whey rich in BOD and COD values.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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