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Probiotic Shelf-life, Mineral Contents and Others Properties of Probiotic Yogurts Supplemented with Corn Flour

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ABSTRACT

It was aimed in the present study to determine the mineral content, probiotic, sensory, physical and chemical characteristics of probiotic yogurt-PC (only probiotic *Lactobacillus acidophilus* DSMZ 20079 strains with direct vat set starter culture) obtained with the addition of corn flour (CF) at different concentrations during a 21-day storage period. It was found in the study that all probiotic yogurt formulations with CF gave high *L. acidophilus* viabilities between 6.89 and 7.87 log cfu g^{-1} during the storage and CF addition did not affect the viability of the probiotic bacteria. The viscosity and dry matter content increased in CF added samples with increasing CF concentrations. Syneresis in PC yogurt sample was found to be significantly higher than that in other samples. The greater the CF supplementation (5%) has the lower the syneresis on the 21^{st} day of storage. The CF+PC (5%) sample was determined to be a better source of Ca, Mg, P and Fe than the Control and PC yogurts. The general acceptability of yogurt involving 5% PC decreased significantly than the others. Considering all the properties in general, 2.5% CF + PC sample it is recommended to be found as probiotic yohurt.

Keywords: Yogurt; Corn flour; Probiotic bacteria; Functional food; Yogurt analysis

Mısır Unu İlavesiyle Üretilen Probiyotik Yoğurtların Probiyotik Raf Ömrü, Mineral İçeriği ve Diğer Özellikleri

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ÖZET

Bu araştırmanın amacı, farklı konsantrasyonlarda mısır unu ilavesi (M) ile üretilen probiyotik yoğurdun (PY) (yoğurt starter kültürü ve *Lactobacillus acidophilus* DSMZ 20079 ile üretilen) mineral içeriği, probiyotik, duyusal, fiziksel ve kimyasal karakteristiklerini 21 günlük depolama süresince belirlemekti. Mısır unlu bütün probiyotik yoğurt formülasyonlarının hepsinde *L. acidophilus* sayıları depolama süresince 6.89 and 7.87 log kob g^{-1} arasında bulundu. Mısır unu ilavesi probiyotik bakterinin canlılığını etkilemedi. Mısır unu ilaveli örneklerde mısır unu konsantrasyonuna bağlı olarak viskozite ve kurumadde oranı arttı. Probiyotik kontrol örnekte sineresis diğer örneklerden önemli derecede daha yüksek bulundu. Sineresis düşüşü en fazla 21. günde % 5 mısır unu ilaveli örnekte bulundu. % 5 M+PY örneğinin, Kontrol ve PY yoğurtlarından daha fazla Ca, Mg, P ve Fe kaynağı olduğu tespit edildi. % 5 mısır unu ilaveli probiyotik yoğurdun genel kabul edilebilirliği diğerlerinden önemli ölçüde düşmüştür. Tüm özellikler dikkate alındığında, genellikle % 2.5 mısır unu katkılı probiyotik yoğurdun tavsiye edilen örnek olduğu belirlendi.

Anahtar Kelimeler: Yoğurt; Mısır unu; Probiyotik bakteri; Fonksiyonel gıda; Yoğurt analizleri

1. Introduction

Today, people are interested in both nutritional values and health benefits of food and thus focusing on functional dairy products such as yogurt and ice cream (Shiby & Mishra 2013). Probiotic bacteria are known to have certain benefits to human health when they are inhabited in efficient amount (FAO/WHO 2002; Settachaimongkon et al 2014). However, the number of such bacteria having benefits to human health is not so clear, but estimated to be between 10^6 and 10^9 cfu g^{-1} (Abadía-García et al 2013). Dairy products, fermented by bacteria such as yogurt, can provide convenient media for probiotic microorganisms and have turned out to be an important sector including functional food (Cruz et al 2013; Seleet et al 2016) with the raising awareness that consumption of such products may have benefits to human health (Seleet et al 2016).

Results of the microbiologic research on yogurt show that due to its low pH content yogurt permits poor microbial survival and thus directing new research to the definitions of new probiotic formulations on yogurt derivatives (Sanchez et al 2009; Çakmakçı et al 2012). For instance, bifidobacteria and *Lactobacillus* species are commonly studied probiotic bacteria on yogurt (Dave & Shah 1997; Patrignani et al 2007; Ersan et al 2016). Since probiotic cultures are not so tolerant to acidic pH and gastric fluids, they may sometimes be affected negatively in their performance. Recent studies have begun to emphasize on the development of new probiotic cultures without negative impacts on organoleptic qualities (Heller 2001; Ersan et al 2016).

Corn flour (CF) and its products having unique taste and nutritional benefits (Voca et al 2009; Naqvi et al 2011; Rahman & Rosli 2014) are obtained as the result of various agricultural, food production and health care processes. Benefits of maize grains to human health due to their phenolic compound content are also closely associated with their high antioxidant activities and mechanisms like anti-mutagenesis and anti-carcinogenesis (Adom & Liu 2002; Žilić et al 2013). Both children and adults have a dietary habit in Turkey to consume yogurt or milk by putting wheat or maize bread in it. Quantity and quality of the studies on the development of CF- based new products are quite limited.

Therefore, the aim of the present study is to evaluate the effects of CF on probiotics, sensory properties, physical, chemical, mineral contents and the quality of newly formulated yogurt samples produced using *Lactobacillus acidophilus* DSMZ 20079 as a probiotic culture.

2. Material and Methods

2.1. Materials

L. acidophilus DSMZ 20079 was purchased from the German Collection of Microorganisms and Cell Cultures (DSMZ, Braunschweig, Germany) and yogurt was obtained using a starter culture (direct-to-vat system; *S. thermophilus* and *L. bulgaricus*) YC350 (Peyma-Hansen, Istanbul, Turkey) and cow's milk taken from the Research and Application Farm of Atatürk University. Corn flour was fetched from Hayrat village, Trabzon, Turkey and CF was produced in a traditional milling machine. Table 1 represents the gross chemical and physical properties of milk and CF.

Table 1- The gross chemical and physical properties of raw milk and corn flour

Analysis	*Milk*	*Corn flour*
Dry matter (%)	12.37±0.02	87.14 ±0.26
Fat (%)	3.45±0.07	n.d
pH	6.71±0.02	n.d
Protein (%)	3.43±0.12	7.54±0.84
Ash (%)	0.64±0.02	1.88±0.08

n.d, not determined

2.2. Sub-cultivation of probiotic strain

L. acidophilus DSMZ 20079 strains in the form of direct-vat-inoculation pellets were frozen at -80 °C and defrosted at room temperature (20±2 °C) for 15 min before use. It was reported by Mortazavian et al (2007) that when yogurt bacteria (*S. thermophilus* and *L. bulgaricus*) were present, MRS-bile agar was used easily for selective enumeration of mixed probiotic bacteria (*L. acidophilus, Lactobacillus casei* and bifidobacteria). Probiotic bacteria were sub-cultured and prepared using sterile peptone water and nonselective media (MRS Bile Agar; MRS agar: Merck, Darmstadt, Germany, and Bile: Sigma, Reyde, USA) and adjusting pH to 6.2 for *L. acidophilus* cultures. The plates then were incubated at 37 °C anaerobically for 2 days. Inoculum, efficient for the production of 10^8 cfu g^{-1} yogurt or more was put in milk considering the freeze-dried weight of cultures, which often means that nearly 1 g of freeze-dried cultures is enough for 10 g yogurt (Phillips et al 2006).

2.3. Manufacture of yogurt samples

Yogurt samples were produced at Food Engineering Department of Atatürk University (Erzurum, Turkey) by heating and cooling cow's milk up to 85 °C for 20 min then to 43±1 °C, respectively, for the inoculation of yogurt starters added in the milk (in the rate of 1.5%). Milk was then mixed and then *L. acidophilus* (10^8-10^9 cfu g^{-1}) was added in it. Yogurt samples were categorized into four groups; C (Control), which was added direct vat set starter culture in the rate of 20 g per 100 L milk without CF and probiotic strain), PC (added only probiotic strain with direct vat set starter culture), 2.5% CF+PC (inoculated probiotic strain with direct vat set starter culture and 2.5% CF) and 5% CF+PC (inoculated probiotic strain with direct vat set starter culture and 5% CF). Prepared samples were taken to incubation cups at 43±1 °C and pH 4.6 and then to cold storage (4±1 °C) to remain for 21 days by conducting analyses at 7-day intervals.

2.4. Microbiological analysis

10 mL yogurt was taken from each sample and diluted in 90 - mL 0.85% (w v^{-1}) sterile saline solution to determine the number of coliform bacteria (Violet red bile agar; Oxoid), yeast and mould (Dichloran Rose-Bengal Chloramphenicol Agar [DRBC Agar]; Merck) according to Harrigan (1998). *L. bulgaricus*, *L. acidophilus* DSMZ 20079 and *S. thermophilus* counts were also determined using MRS, MRS bile and M17 Agars (Merck) respectively and adopting the method in Vinderola and Reinheimer (1999). Agar plates were incubated for 1 day at 35-37 °C, 5-7 days at room temperature, 3 days at 35-37 °C in an anaerobic jar and 2 days at 35-37 °C for coliform bacteria, yeast and mould, *L. bulgaricus* and *L. acidophilus* and *S. thermophilus*, respectively.

2.5. Physical and chemical analysis

Gravimetric method (AOAC 1990) was used in the study to analyse the rates of total solids, protein and ash in yogurt and milk samples and a pH meter (Mettler-Toledo AG 8603 Schwerzenbach, Switzerland) to pH in the samples. Titratable acidity (lactic acid, %) was measured according to Kurt et al (2007). Syneresis was measured in convenience with Atamer and Sezgin (1986). A digital Brookfield viscometer (Model DV-II, Brookfield Engineering Laboratories, Stoughton, MA, USA) with a spindle (No. 64) was used to measure apparent viscosity. Rotation speed was 20 rpm and temperature of the samples was 4±1 °C. Nearly 150 mL yogurt was used from each sample and for each analysis by stirring them for 10 s before measurements.

2.6. Mineral analysis

An inductively coupled plasma optical emission spectrophotometer (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT, USA) and the methods of

Güler (2007) were used to analyse the mineral contents (Ca, P, Mg, K, Na, and Fe) of the yogurt samples. All diluted digests were analysed using ICP-OES.

2.7. Sensory analysis

The methods in (Lawless & Heymann 2010) were used to evaluate sensory characteristics of yogurt samples and 50 consumer panellists (in two replicates) who were experienced and familiar with yogurt and corn. Categorized samples stored at 4±1 ºC were tested in the centre of Erzurum city of Turkey by the panellists chosen among the students, teaching staffs at Atatürk University Food Engineering Department and families in homes. Panellists tried to be provided as the same conditions as possible i.e. the samples were given to the panellists in a glass jar (150 mL) to score (1 the lowest to 9 the highest) their colour and appearance, texture, syneresis, flavour, acidity and general acceptability on the 1st, 7th, 14th and 21st days of storage. They were permitted to drink water to clean their palates when passing other sample.

2.8. Statistical analysis

Completely randomized design in factorial arrangement was used to conduct the experiments in the study, which are four yogurt sample types (C, PC, 2.5% CF+PC and 5% CF+PC), four storage periods (1, 7, 14 and 21 days) and two replicates. A variance analysis (ANOVA) was applied to data obtained and Duncan's multiple interval test (at P<0.05 and P<0.01) was used to determine the scale of deviation from average (through the Statistica 6.0 software package (Statsoft Inc., Tulsa, OK, USA) and SPSS 13.0.

3. Results and Discussion

3.1. Microbiological evaluation

Table 2 gives the findings of the microbiological analysis conducted over the yogurt samples. The counts of lactobacilli in the samples were determined to range from 6.15 to 7.42 log cfu g^{-1}. Present study showed that the addition of CF did not have any effects

Table 2- Microbiological properties of yogurt samples (log cfu g^{-1})

Yogurt samples	*Storage time (days)*	*Lactobacilli MRS*	*Streptococci M17*	*L. acidophilus*	*Coliform bacteria*	*Yeast and mould*
C	1	6.51±0.02^{g}	5.72±0.01^{d}	<1	<1	<10
	7	7.42±0.02^{a}	6.10±0.07^{c}	<1	<1	<10
	14	6.71±0.01^{ef}	6.36±0.05^{c}	<1	<1	<10
	21	7.21±0.01^{b}	5.81±0.02^{d}	<1	<1	<10
Average		6.96±0.18^{b}	6.00±0.70^{b}	<1	<1	<10
PC	1	6.75±0.02^{e}	6.40±0.02^{bc}	7.51±0.03^{bc}	<1	<10
	7	7.16±0.02^{bc}	6.10±0.02^{c}	7.53±0.02^{bc}	<1	<10
	14	7.22±0.01^{b}	6.92±0.01^{a}	7.57±0.01^{b}	<1	<10
	21	7.12±0.04^{bc}	6.78±0.01^{a}	7.17±0.08^{de}	<1	<10
Average		7.06±0.29^{a}	6.30±0.29^{a}	7.44±0.02^{a}	<1	<10
2.5% CF+PC	1	6.53±0.01^{fg}	6.19±0.01^{c}	7.23±0.03^{de}	<1	<10
	7	7.02±0.01^{cd}	6.65±0.02^{ab}	7.08±0.04^{ef}	<1	<10
	14	7.21±0.02^{b}	6.15±0.04^{c}	7.21±0.03^{de}	<1	<10
	21	6.63±0.00^{eg}	6.35±0.04^{c}	7.87±0.01^{a}	<1	<10
Average		6.85±0.47^{c}	6.33±0.34^{a}	7.34±2.97^{a}	<1	<10
5% CF+PC	1	6.93±0.02^{d}	6.39±0.03^{bc}	7.32±0.05^{cd}	<1	<10
	7	6.65±0.02^{eg}	6.77±0.01^{a}	7.35±0.12^{cd}	<1	<10
	14	6.15±0.21^{h}	6.37±0.33^{c}	7.19±0.21^{de}	<1	<10
	21	6.63±0.01^{eg}	6.22±0.04^{c}	6.89±0.01^{f}	<1	<10
Average		6.59±0.28^{d}	6.43±0.37^{a}	7.19±2.99^{b}	<1	<10

Averages of the same column values (each section separately) followed by same letter did not differ significantly from Duncan's multiple range tests (P<0.01); C, control (without corn flour and probiotic strain); PC, probiotic yogurt; 2.5% CF+PC, probiotic yogurt made 2.5% (w w^{-1}) corn flour; 5% CF+PC, probiotic yogurt made 5% (w w^{-1}) corn flour on the number of living lactobacilli. The samples with lentil flour content reflected the significant stability of the lactobacilli and this content did not have any effects on the number of living lactobacilli (Zare et al 2011). Carbohydrates (da Silva & Arrabaca 2004) were determined to contribute to the stability of yogurt cultures during storage. These findings are convenient with those in the present study.

In yogurt samples, the smallest number of (5.72 log cfu g^{-1}) streptococci was counted in the C sample on the 1st day of storage while the largest was detected in PC (6.92 log cfu g^{-1}) on the 14th day. It was found in Seleet et al (2016) that the number of streptococci subjected to different treatments decreased in wheat germ added probiotic yogurt in increasing storage time. Such a condition may result from inadequate lactobacilli counts in the products because streptococci grow depending on the presence of lactobacilli metabolites (Tamime & Robinson 1999). It was found by Zare et al (2011) that the number of living *S. thermophilus* in yogurt samples fortified with lentil flour and skim milk powder changed from 8.3 to 8.6 log cfu g^{-1} after the manufacture and some significant decreases were seen certain samples on 28th day of storage. These findings are convenient with the findings in the present study.

It was found in the present study that fortification and storage conditions did not significantly affect the population sizes of the yeast, mould and coliform bacteria ($P<0.01$) in the yogurt samples. Yeasts and moulds were undetected in yogurt samples (<10 log cfu g^{-1}) and the counts of <1 log cfu g^{-1} coliform bacteria were observed in them. Bedani et al (2013) reported similar coliform results and did not detect yeast or mould in any of the probiotic soy yogurt samples.

3.2. Survival of L. acidophilus

Microorganisms sustain their growth in storage period and the benefits of probiotics in yogurt to human health are closely related to the size of living microorganisms. In the present study, PC sample represented the largest number of *L. acidophilus* (7.57 log cfu g^{-1}) on 14th day of storage, 2.5% CF+PC sample had the largest (7.87 log cfu g^{-1}) total viable count of probiotic bacteria on 21st day. Yogurt manufactured using 5% CF+PC showed the smallest number (6.89 log cfu g^{-1}) of probiotic bacteria on also 21st day. However, during also the storage period, other yogurt samples containing probiotics had a probiotic population size of 10^7 cfu g^{-1} (Table 2). It was stated by Wang and Daun (2004) and Zare et al (2011) that complex carbohydrates turned this ingredient to be a good source of potential prebiotic components. It is required by FAO that a standard probiotic product must contain at least 10^6-10^7 cfu g^{-1} live and active probiotic microorganisms when it is consumed (FAO/WHO 2002).

It is shown that amino acids, vitamins and minerals may contribute to the growth of starter cultures in milk (Zare et al 2011). Present study revealed that when the population of probiotic bacteria was lower than 3×10^7 cfu mL^{-1} and that of total yogurt starter was 5×10^8 cfu mL^{-1}, they had minimal effect on the final carbohydrate concentrations (Farnworth et al 2007).

3.3. Chemical characteristics of yogurts

Table 3 gives the results of chemical analysis of yogurt samples on the 1st storage day. It is seen that ash, fat and protein contents change between 0.65 and 1.06%, 3.40 and 3.60% and 3.76 and 3.95%,

Table 3- Physical and chemical properties of yogurt samples (n= 8)

Yogurt samples	*Ash (%)*	*Fat (%)*	*Protein (%)*
C	0.65 ± 0.01^c	3.40 ± 0.28^a	3.80 ± 0.03^b
PC	0.68 ± 0.02^c	3.50 ± 0.00^a	3.76 ± 0.03^b
2.5% CF+PC	0.80 ± 0.00^b	3.50 ± 0.14^a	3.84 ± 0.03^b
5% CF+PC	1.06 ± 0.13^a	3.60 ± 0.28^a	3.95 ± 0.00^a

C, control (without corn flour and probiotic strain); PC, probiotic yogurt; 2.5% CF+PC, probiotic yogurt made 2.5% (w w^{-1}) corn flour; 5% CF+PC, probiotic yogurt made 5% (w w^{-1}) corn flour. Mean values followed by different letters in the same column are significantly different ($P<0.05$) values are means ± SD respectively. 5% CF+PC sample gave the highest fat, protein and ash rates and they increased with increasing flour concentration in the samples.

In this study, dry matter content of C sample was found to be significantly lower than that of CF-containing samples (P<0.01) by increasing with the CF concentration. Acidity is an important factor to affect shelf life and acceptability of yogurt (Otaibi & Demerdash 2008). Acidity was the highest in PC sample and pH values in all yogurt samples decreased during the storage period in the study (Table 4). The pH value of the PC sample was found lower than the other samples (C, 2.5% CF+PC and 5% CF+PC samples) during the storage. Generally, in the yogurt samples which produced with CF found higher pH values than other samples, except for the first week of control. Decrease in pH is accepted to be a function of acidity increasing during the storage period where lactose is converted into lactic acid. It was found in the study that pH of PC yogurt sample involving probiotic bacteria was lower than that in CF+PC yogurt sample. Farnworth et al (2007) stated that pH of yogurt made of cow's milk and probiotic bacteria was lower than that involving fermented soy beverage and probiotic bacteria. Kailasapathy et al (2008) stated that as the buffering capacity of yogurt increases then pH changes decrease depending on the changes in acid content of the food system. These findings are convenient with the findings in the present study.

Syneresis or whey separation is among the quality parameters of yogurt, high rate of which implies low quality (Mahmood et al 2008). In this study, syneresis rates were seen to decrease in all samples during the storage period. C samples reflected higher syneresis rate (10 mL 25 g^{-1}) on the 1st storage day than the others. Storage period affected significantly the syneresis rate in yogurt samples (P<0.01) due to the contracting effect of low pH on casein particles and so increased resistance of yogurt to syneresis (Lucey & Singh 1997). Syneresis may result from high incubation temperatures, low dry matter content or

Table 4- Gross chemical composition of yogurt samples

Yogurt samples	*Storage time (days)*	*Dry matter (%)*	*Titratable acidity (%)*	*pH*	*Syneresis (mL 25 g^{-1} yogurt)*
C	1	13.92±0.09^{d}	0.96±0.01^{h}	4.41±0.00^{a}	10.0±0.00^{a}
	7	13.94±0.18^{d}	1.15±0.02^{cd}	4.21±0.02^{cd}	9.45±0.07^{df}
	14	13.61±0.12^{de}	1.19±0.00^{b}	4.04±0.01^{ij}	9.60±0.14^{ce}
	21	13.88±0.33^{d}	1.18±0.00^{b}	4.03±0.01^{j}	8.30±0.14^{j}
Average		13.84±1.24^{c}	1.11±0.03^{c}	4.17±0.03^{b}	9.34±0.56^{c}
PC	1	13.54±0.01^{de}	1.04±0.00^{f}	4.33±0.04^{b}	9.90±0.14^{ac}
	7	13.73±0.07^{de}	1.18±0.00^{b}	4.11±0.00^{eg}	9.90±0.14^{ac}
	14	13.42±0.16^{e}	1.18±0.00^{b}	4.09±0.01^{hi}	9.75±0.07^{ad}
	21	13.82±0.14^{de}	1.22±0.01^{a}	4.02±0.00^{j}	9.90±0.07^{ac}
Average		13.63±1.14^{d}	1.15±0.02^{a}	4.14±0.04^{c}	9.86±0.44^{a}
2.5 % CF+PC	1	15.52±0.12^{b}	1.02±0.00^{g}	4.38±0.02^{a}	9.30±0.14^{eg}
	7	15.28±0.01^{bc}	1.14±0.01^{d}	4.16±0.00^{f}	9.65±0.07^{bd}
	14	14.96±0.04^{c}	1.21±0.00^{a}	4.12±0.00^{eg}	9.25±0.07^{fg}
	21	15.13±0.10^{bc}	1.17±0.01^{bc}	4.15±0.01^{eg}	9.10±0.14^{gh}
Average		15.22±0.01^{b}	1.13±0.18^{b}	4.20±0.05^{a}	9.32±0.41^{ab}
5 % CF+PC	1	16.41±0.12^{a}	1.04±0.01^{f}	4.36±0.00^{ab}	8.70±0.14^{i}
	7	16.38±0.01^{a}	1.11±0.00^{e}	4.23±0.01^{c}	8.80±0.00^{hi}
	14	16.70±0.10^{a}	1.17±0.01^{bc}	4.18±0.00^{ce}	8.75±0.07^{i}
	21	16.44±0.11^{a}	1.15±0.00^{cd}	4.10±0.03^{gh}	7.80±0.00^{k}
Average		16.48±1.15^{a}	1.12±0.26^{c}	4.22±0.05^{a}	8.51±0.87^{c}

Averages of the same column values (each section separately) followed by same letter did not differ significantly from Duncan's multiple range tests (P<0.01); C, control (without corn flour and probiotic strain); PC, probiotic yogurt; 2.5% CF+PC, probiotic yogurt made 2.5% (w w^{-1}) corn flour; 5% CF+PC, probiotic yogurt made 5% (w w^{-1}) corn flour inadequate storage temperatures (Lucey 2004) and in this study, decreased significantly (P<0.01) throughout the storage period in all samples in the order from the lowest to the highest as follows; 5% CF+PC, 2.5% CF+PC, C and PC samples (Table 4). There is a negative relationship between syneresis and the rate of stabilizers (Pavón et al 2014). Staffolo et al (2004) observed in their study no syneresis in yogurt samples fortified with 1.3% wheat, bamboo, inulin and apple fibre on 21st day of storage. Zare et al (2011) tried to detect the syneresis in yogurt supplemented with lentil flour and skim milk and control samples on the baseline and 14th and 28th days of storage.

Figure 1 shows that viscosity rate of yogurt samples increased significantly (P<0.01) when CF was added and the largest rates were found in the samples with 5% CF+PC (3509 cP) and on the 21st day of storage while smallest one was observed in the PC sample (1957 cP) on the 1st day of storage. Zare et al (2011) stated that the lentil flour added yogurt samples reflected significantly higher viscosity and elasticity rates than the control samples being consistent with the results found in the present study. Similarly, Şahan et al (2008) reported that the viscosity values increased throughout the storage. In the study, viscosity rate increased through the storage time, the highest being in the samples with 5% CF+PC and on the 21st day. Viscosity increase during storage period may show protein rearrangement and protein-protein contact (Özer et al 1998; Abu-Jdayil & Mohameed 2002; İşleten & Karagül 2006). Results of the study revealed that

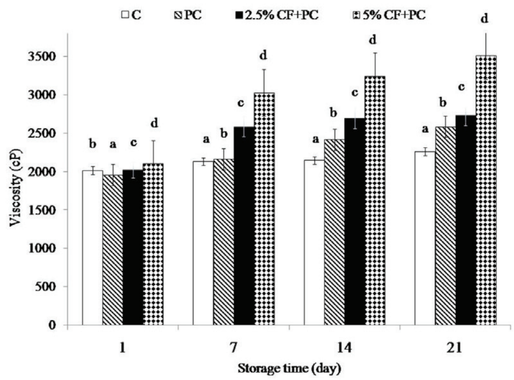

Figure 1- Viscosity values (20 rpm) of probiotic yogurt samples produced using corn flour during storage

moderate amount of probiotic inoculums caused higher hardness degree in the yogurts in convenience with Wu et al (2000) where maximum viscosity was observed at moderate inoculation rate. Such findings are similar to those found in the present study showing that the supply of CF increased the strength of the gel system.

3.4. Mineral contents of yogurt samples

Table 5 presents the changes in the mineral contents of the yogurt samples. K and Na contents decreased significantly with the addition of CF in the sample compared to control (P<0.05). Fe content of the yogurt samples increased significantly and 5% CF+PC sample showed the highest rates of Ca,

Table 5- Elemental composition of yogurt samples (mg kg^{-1})

	Yogurt samples and minerals concentrations (n= 2)			
Minerals	*C*	*PC*	*2.5% CF+PC*	*5% CF+PC*
Ca	2136±38.60^{c}	2159±6.54^{c}	2215±6.36^{ab}	2294±49.62^{a}
P	2015±139.01^{c}	2229±78.06^{bc}	2370±2.121^{ab}	2544±88.10^{a}
Mg	295±14.74^{c}	328±11.45^{bc}	351±15.45^{b}	505±7.91^{a}
K	4971±219.34^{a}	5235±349.8^{a}	4265±62.57^{b}	4099±288.99^{b}
Na	236±15.08^{a}	216±20.23^{ab}	198±4.09^{ab}	177±29.59^{b}
Fe	1.90±0.57^{b}	2.16±0.32^{b}	2.70±0.25^{ab}	3.46±0.03^{a}

Values followed by different letters in a column were significantly different (P<0.05) using Duncan's multiple range test; C, control (without corn flour and probiotic strain); PC, probiotic yogurt; 2.5% CF+PC, probiotic yogurt made 2.5% (w w^{-1}) corn flour; 5% CF+PC, probiotic yogurt made 5% (w w^{-1}) corn flour

Fe, Mg and P values as 2294, 3.46, 505 and 2544 mg kg^{-1}, respectively. It was reported in previous studies (Renner 1994; Sunny-Roberts 2004) that calcium can be absorbed more effectively with yogurt than its other forms. Pandey and Mishra (2015) reported high mineral content and good nutritional properties of synbiotic soy yogurt by determining its calcium content to be 61.85 mg kg^{-1}. Corn bears higher mineral contents such as copper, iron, manganese and zinc compared to control sample and therefore, the results in the present study show that the use of CF increases the mineral content of yogurt.

3.5. Sensory evaluations

Yogurt samples were scored in the sensory evaluation (1 for poor to 9 for excellent; Table 6). CF added in yogurts affected significantly (P<0.01) the sensory scores including colour and appearance, texture, syneresis, flavour and general acceptability. CF added probiotic yogurt samples exhibited better texture conditions, colour and appearance compared to control sample while there was no significant difference in acidity between the samples. Panellists were thought to give low scores to overall flavour for the samples containing 2.5 and 5% CF by indicating a mealy taste. Compared to other samples, PC and 2.5% CF+PC yogurt samples were preferred. Limited effects of probiotic bacteria were reported by Farnworth et al (2007) on sensory properties of soy beverage and cows' milk yogurts.

4. Conclusions

The study shows that CF (2.5 and 5%) is a good, nutritive and natural source to be added in yogurt, viscosity and mineral compositions of which can be improved through the addition of CF. Syneresis did not happen in CF enriched yogurt in 21-day storage at 4 °C. It was shown in the study that CF added probiotic yogurt formulations represented high *L. acidophilus* DSMZ 20079 viabilities from 6.89 to 7.87 log cfu g^{-1} in 21-day storage period and the viability of the probiotic microorganisms was not affected by the addition of CF. All the probiotic yogurt samples had the recommended probiotic bacteria rates (10^6-10^7 cfu g^{-1}) at the end of 21-day shelf life. Addition of probiotic bacteria and CF to such type of yogurt (2.5% CF+PC) owns functionality and satisfies consumers when bread is eaten with it. It is a good way to elaborate food types by adding CF in them to improve nutritional and physiological properties and functionality by regulating the rheological properties of the final product.

Table 6- Sensory properties of yogurt samples (n= 200)

Yogurt samples	*Colour and appearance*	*Texture*	*Syneresis*	*Flavour*	*Acidity*	*General acceptability*
C	7.85±0.48^{b}	7.90±0.58^{b}	8.14±0.43^{b}	8.02±0.55^{a}	7.20±0.85^{a}	7.65±0.70^{a}
PC	7.84±0.51^{b}	7.87±0.41^{b}	8.23±0.42^{b}	8.18±0.48^{a}	7.50±0.78^{a}	7.80±0.40^{a}
2.5% CF+PC	8.24±0.24^{a}	8.62±0.26^{a}	8.69±0.33^{a}	7.60±0.32^{b}	7.45±0.60^{a}	7.65±0.50^{a}
5% CF+PC	8.09±0.28^{ab}	8.12±0.24^{b}	8.70±0.11^{a}	7.05±0.30^{c}	7.25±0.40^{a}	6.70±0.65^{b}
Storage time (days)						
1	8.00±0.02^{a}	8.55±0.01^{a}	8.97±0.01^{a}	8.20±0.02^{a}	8.00±0.07^{a}	8.25±0.05^{a}
7	7.55±0.04^{b}	7.89±0.02^{c}	8.14±0.02^{c}	7.55±0.02^{c}	7.27±0.05^{b}	7.38±0.06^{bc}
14	7.95±0.03^{a}	8.35±0.02^{ab}	8.73±0.03^{ab}	7.50±0.02^{c}	7.00±0.02^{b}	6.95±0.02^{c}
21	8.20±0.02^{a}	8.00±0.01^{bc}	8.42±0.02^{bc}	7.30±0.02^{c}	7.25±0.05^{b}	7.35±0.04^{bc}

Averages of the same column values (each section separately) followed by same letter did not differ significantly from Duncan's multiple range tests (P<0.01); C, control (without corn flour and probiotic strain); PC, probiotic yogurt; 2.5% CF+PC, probiotic yogurt made 2.5% (w w^{-1}) corn flour; 5% CF+PC, probiotic yogurt made 5% (w w^{-1}) corn flour

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