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Full Length Research Paper

Physico-chemical and rheological properties of yoghurt manufactured with ewe's milk and skim milk

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Yoghurts were prepared with commercial strains "CHR HANSEN" Denmark using two types of milk, ewe's milk and skim milk, ''CELIA''. A dose of 2.5% of commercial starters was used for the preparation of the yoghurt. Physico-chemical, organoleptic and rheological properties of yoghurts prepared with both types of milk were studied in order to determine the best preparation depending on the type of milk. Sensory analysis revealed that the product made with ewe's milk was better compared to that made from skim milk. Furthermore, the effect of type of milk was clearly observed on the acidity, cohesiveness and number of lactic acid bacteria in this type of milk.

Key words: Yoghurt, fermentation, ewe's milk, lactic acid, viscosity, cohesiveness, adhesiveness.

INTRODUCTION

In recent years, there has been increasing demand for a new range of dairy products, including yoghurts, which are similar to traditional products but have a low fat content (Begona et al., 2000). Yoghurt is one of the most popular fermented dairy product widely consumed all over the world. It is obtained by lactic acid fermentation of milk by the action of a starter culture containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*. The role of these two genera in yoghurt manufacture can be summarized as milk acidification and synthesis of aromatic compounds (Sera et al., 2009), (Sahan et al., 2008).

Yoghurt is more nutritious than many other fermented milk products because it contains a high level of milk solids in addition to nutriments developed during the fermentation process. Different forms of yoghurt are now available in the market like stirred, set, frozen and liquid yoghurt.

To preserve its inherent quality during storage and, in particular, its physicochemical and sensory characteristics, packaging is essential (Saint Eve et al., 2008). Yoghurt can be stored for up to four weeks. During this period, the product undergoes physico-chemical and rheological changes that may affect its organoleptic quality. The aim of this work is to study these variations during the period of fermentation as well as storage period using two types of milk; ewe's milk and skim milk, ''CELIA''.

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MATERIALS AND METHODS

Analytical methods

All analytical determinations were performed at least in triplicate. Values of different parameters were expressed as the mean ± standard deviation (X ± SD).

Yoghurt manufacture

The yoghurt was manufactured according to international standards of yoghurt manufacture (IDF, 1987 standards). The milk is homogenized and heated to 90°C for 3 min for pasteurization, then cooled to 45°C. It is then inoculated with 2.5% of a mixed lactic starter (2:1 *Streptococcus salivarius* ssp. *thermophilus* and *L. delbrueckii* ssp. *bulgaricus*). Yoghurt samples were elaborated of quantities of 100 ml for each sample and the experiment was realized in triplicate.

The inoculated milk is incubated to 45°C until a pH of 4.4 was attained in approximately 4 h (the pH end point). When the pH end

Table 1. Physico-chemical analysis of yoghurt.

Analysis	Ewe's milk	Skim milk	Analysis of variance
Titratable acidity	85.667±27.21	101.533±15.268	NS
pH	5.569±0.318 (a)	4.34±0.338 (b)	**
Viscosity	0.304±0.135 (b)	24.39±6.68 (a)	**

NS: Not significant ; *Significant (≤ 0.05); **Highly significant (≤ 0.01).
a,b,c : The homogeneous groups after comparing means.

point was achieved, the yoghurts were cooled at 6°C and stored at the same temperature during all period of post-acidification (for 21 days).

Experimental analysis

Physico-chemical analyses were carried out according to AOAC (2005). During the fermentation period, the tests were conducted for 2 h and between 3 and 4 h for skim milk, while the period of post-acidification were made weekly for a period of 21 days.

Measurement of pH and acidity

The pH of yoghurt samples was measured at 1, 7, 14 and 21 days of storage at 6°C using a pH meter with a glass electrode over the range 6.8 to 4.0. Acidity was determined by titration with 0.1 N NaOH using phenolphthalein as an indicator color Results were expressed as degree Dornic (Afnor, 1980).

Measurement of viscosity

Viscosity was measured using a viscometer model model HAAKE Viscosimeter (Mess Technik GmbH) (Brookfield Engineering Laboratories Inc., Stoughton, MA) using a glass tube and a normalized ball equipped with a chronometer at 25°C and was expressed as mPas. Every experiment was repeated 3 to 5 times to have some meaningful results after statistical analyses. Viscosity was expressed as millipoises (m.p.s).

Organoleptic tests

Throughout the period of post-acidification (7th, 14th and 21st day of storage), the organoleptic quality of yoghurt products was evaluated by a jury of 10 panelists with a seven point scale (Meilgaard et al., 1999) and involved three parameters. Flavour, cohesiveness and adhesiveness of the samples were evaluated following the recommendations of International Dairy Federation standard 99A (1987).

Flavour was assessed by the estimation of acidity developed by specific lactic acid bacteria in the samples.

A strict protocol was imposed to panelists to minimize variability. At each session, subjects tasted samples of yoghurt (5 g) at 10°C. They were asked to keep the yoghurt in the mouth for 12 s and then swallow. This time was chosen after preliminary tests conducted with 10 subjects. The subjects tasted samples of yoghurt in the most natural possible way by keeping their mouth closed and swallowing the product.

The yoghurt samples were presented in random order. Water was used for rinsing between samples. A small period of several minutes was required between tasting samples.

Panel members were then asked for cohesiveness which reflects the maximum capacity of deformation of the sample before break. This technique was performed using a spoon. Judged samples were then evaluated for adhesiveness which reflects the power required to defeat the forces of links between the surface of the coagulum and the surface of materials (this technique is also performed with a spoon).

The texture can be defined as a property on the sensory touch. The analysis of the texture allows an objective measure by mechanical action. The importance of texture in the assessment of food varies depending on the expectations of consumers.

Microbiological analysis of yoghurt

Yoghurt is produced by fermentation of milk with two bacteria, *L. bulgaricus* and *S. thermophilus*, which act together. The enumeration of *S. thermophilus* and *L. delbrueckii* ssp. *bulgaricus* was performed as described by the International Dairy Federation (IDF Standard 306, 1995). The following media were selected as suitable for enumeration: M17 agar and aerobic incubation at 42°C for 24 h for the selective enumeration of *S. Thermophilus* while for the enumeration of *L. delbrueckii* ssp. *Bulgaricus*, MRS agar incubated at 42°C for 24 h was applied. Microbiological count data are expressed as colony forming units (cfu) per gram of yoghurt. Four dilutions were carried out to determine the number of bacteria during storage.

RESULTS AND DISCUSSION

Physico-chemical properties of yoghurt

The results obtained for chemical characterization of the yoghurt samples are presented in Table 1. During the period of fermentation, we noticed a remarkable decrease in pH for yoghurt samples manufactured with skim milk. This decrease is less important for yoghurt manufactured with ewe's milk with an average of 5.56 compared to 4.34 for the other samples. These results can be explained by the composition of each kind of milk. However, in a previous study, our results showed that the titratable acidity of ewe's milk is slightly low and does not exceed 21°D (Table 2). Our results are in keeping with those reported by Sokolinska et al. (2004), who indicated that the pH values of milk decreased during the manufacturing process, from the time it was inoculated with bacterial cultures to the time when it was manufactured ranging from 6.7 to 4.34. The same observations were reported by O'Neil et al. (1979).

Moreover, according to Luquet (1990), lactic strains have the ability to ferment lactose into lactic acid, with an increase in acidity and a decrease in pH of fermented

Table 2. Physico-chemical analysis of ewe's milk.

Analysis	pH	°D	Dry matter (%)	Fats (%)
Ewe's milk	6.7	21	11.5	6.5
Standards	6.5-6.85	22-25	18.3	7.1

Table 3. Sensorial analysis (∑ ranks n= 40).

Analysis	Ewe's milk	Skim milk	Analysis of variance
Flavour	70.50 (b)	49.50 (a)	**
Cohesiveness	75 (b)	45 (a)	**
Adhesiveness	77 (b)	44 (a)	**

*Significant (≤ 0.05); **Highly significant (≤ 0.01).
a,b,c : The homogeneous groups after comparing means.

milk, which reveals the influence on the composition of the inoculum on the rate of bacteria growth such as *Streptococcus*. Indeed, the development of these germs seem to be proportional to the rate of protein (and certainly the rate of amino acids) in the medium. In addition, during the total experimental period, the values of acidity are even higher.

The analysis of variance showed that the fermentation period and storage have a significant effect on reducing the pH. Similar changes were observed in the level of titratable acidity in the yoghurt during storage.

We noted that there is a proportional relationship between the rate of inoculation strains and acidity; the degree of acidity increases proportionally to inoculation rate (Chougrani et al., 2008).

In addition, we recorded low values of acidity for yoghurt prepared using skim milk with an mean of 101.53°D (Table 1). Gueimonde et al. (2003) and Salvador and Fiszman (2004) found similar results in pH and titratable acidity when they studied the quality of plain yoghurt.

Evolution of the viscosity during fermentation

The viscosity of yoghurt prepared with ewe's milk varies with time. The results indicate that the values differ from one type of milk to another. We noted that viscosity is much greater in the yoghurt made from skim milk compared to those made from ewe's milk, despite the richness of the fat. This may be due to some factors that affect the quality of ewe's milk such as the physiological status of the animal, its diet, race and the climate.

According to Rawson and Marshall (1997), *S. thermophilus* are the most germs incriminated in the production of exocellular texturising agents called exopolysaccharides that might interact with the protein content of milk and increase the viscosity and rheologial quality of products.

During the post-acidification period, the activity of *S. thermophilus* is not completely stopped, but it is less important compared to that of *L. bulcaricus* which not only produces lactic acid, but probably a small amount of texturising agents (Luquet, 1994).

Rheological properties of yoghurt

The panelists found the flavour of yoghurt inoculated at a rate of 2.5% prepared with commercial strains using ewe's milk as the best in relation to skim milk with an average sum of ranks of 70.50 against 49.50, respectively (Table 3). This difference in flavour was probably the result of important fermentation of lactose by lactic acid bacteria (Bourgeois and Larpent, 1989). However, the panelists described the flavour of yoghurt prepared with ewe's milk as more acceptable. In terms of statistical analysis, the factor type of milk has a highly significant effect on the evolution of this parameter.

Generally, cohesiveness is more satisfactory in the fermented milk made from ewe's milk ; it is an average of 75 against 45 of the sample produced from skim milk.

According Rawsan and Marshal (1997), the assessment of rheological properties of yoghurt (adhesiveness and cohesiveness) is probably linked to exopolysaccharides produced by specific strains of yoghurt *S. thermophilus* and *L. bulgaricus*. The analysis of variance showed significant effect of the factor, kind of milk on the development of cohesion in tested yoghurt.

Adhesiveness increased in the prepared yoghurt milk sheep between the 1st and 14th day using ewe's milk (Figure 1; Table 4). At the end of the experiment, during the 21st day, a slight decrease was observed (Figure 2). Furthermore, in the yoghurt made from milk powder, this is growing at the end of fermentation, it is about 77 against 44 on average compared to skim milk. Similar remarks were reported by Rawson and Marchal (1997) and Katsiari et al. (2002) who reported an increase in adhesiveness of ewe's yoghurt during storage.

The analysis of variance showed a significant effect

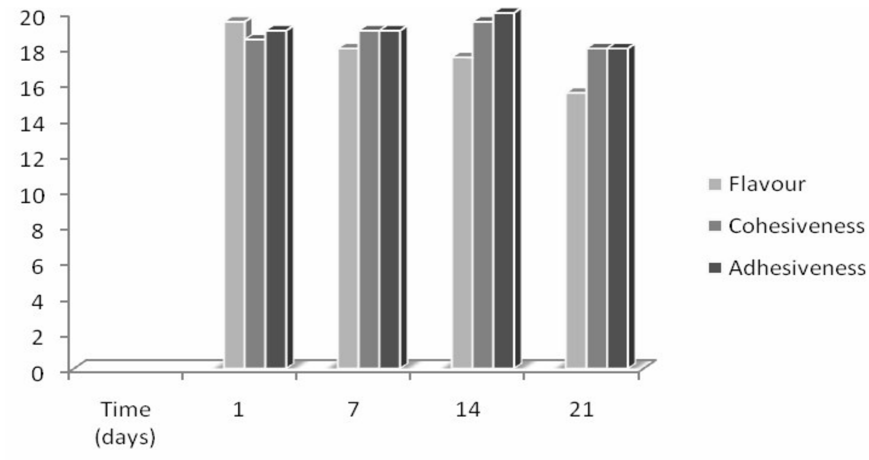

Figure 1. Evolution of rheological properties in ewe's milk yoghurt.

Table 4. Sensory evolution of flavour, cohesiveness and adhesiveness of experimental yoghurts prepared with ewe's milk and skim milk during fermentation and post-acidification period (∑ ranks n= 40).

Period of days	Ewe's milk			Skim milk		
	Flavour	Cohesiveness	Adhesiveness	Flavour	Cohesiveness	Adhesiveness
1	19.50	18.5	19	10.50	11.50	11
7	18	19	19	12	11	11
14	17.50	19.50	20	12.50	10.50	10
21	15.50	18	18	14.50	12	12

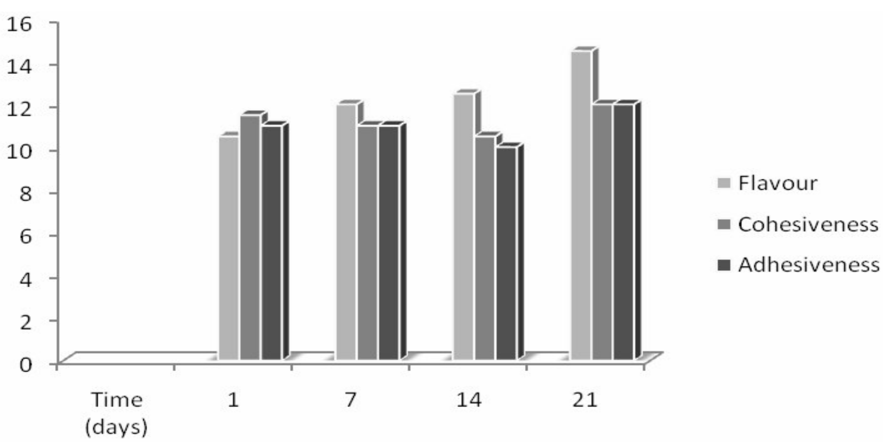

Figure 2. Evolution of rheological properties in skim milk yoghurt.

of the factor, kind of milk on the development of adhesiveness in tested yoghurt.

Microbiological analysis

Yoghurt consumption is beneficial to human health because of the bacteria the yoghurt contains. Although quantitative standards for yoghurt bacteria differ (Tamine and Death, 1980), it is generally accepted that yoghurt should contain 10^7 CFU of viable bacteria (*S. thermophilus* and *L. bulgaricus*) per ml of yoghurt.

During the fermentation process, the number of *S. thermophilus* is relatively higher compared to *L. bulgaricus*. In parallel, the presence of these germs is much greater in skim milk compared to ewe's milk; $21.6.10^6$ CFU/ml in skim milk against $1.8.10^6$ CFU/ml in ewe's milk.

In terms of analysis of variance, we reported a highly significant value for the factor, kind of milk in the evolution of this parameter.

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