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RESEARCH ARTICLE

Characterization of ultra-heat-treated whole milk in Tehran during their shelf life: Physicochemical changes, microbiological quality and sensory evaluation

Arameh Shahbaz[1], Mohammadreza Koushki✉[2], Elham Khanniri[2] and Nasim Khorshidian[2]

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Abstract: In the present study, the physicochemical changes (titratable acidity, fat, density and solids-not-fat), microbiological quality (total count) and sensory properties (odor, flavor, color and overall acceptance) of whole ultra-heat-treated (UHT) milk marketed in Tehran, Iran were assessed during the storage period (0, 90 and 180 days). Five brands of whole UHT milk were selected to determine the quality of samples. The results showed that acidity of UHT milk samples increased during storage, whereas the fat content decreased. However, titratable acidity and density of brands C and B respectively were not in accordance with standard. Total bacteria count tests indicated that there was less than 10 cfu D mL microorganism in UHT milk samples over storage time (0, 90 and 180 days). All brands were similar in respect of color and flavor. Although there was a decrease in sensory characteristics of UHT milk products during storage period (0, 90 and 180 days), they were organoleptically acceptable after six months storage.

Keywords: Quality, Storage, Sensory, Whole UHT milk

Introduction

The worldwide demand for production and consumption of milk and milk products is raising and its increasing trend is expected to continue due to urbanization expansion, population growth and increasing inclination to healthy diet and lifestyle (Krizsan et al. 2021, Zolin et al. 2021). For example, in 1998, the average production of milk in Iran was 4 million tons and it reached 8.8 million tons in 2014 (Abedi et al. 2020). In fact, one of the most nutritious products is milk that contains indispensable macro- and micro-nutrients (amino acids, fatty acids, minerals and vitamins) for human body (Bordoni and Gabbianelli 2021, Nayik et al. 2021, Verduci et al. 2021). Therefore, its daily consumption is necessary especially by infants and children (Ghaffarian Bahraman et al. 2020, Savarino et al. 2021). The per capita consumption of milk is 30 to 150 kg milk year^{-1} in Iran based on FAO report, whereas, WHO has recommended a per capita consumption of 200 kg year^{-1} for milk (Kurajdová et al. 2015, Abedi et al. 2020).

Milk is a suitable medium for growth of numerous pathogenic and spoilage microorganisms due to the presence of essential nutrients and desirable pH (nearly 6.6) (Coolbear et al. 2022). Heat treatment such as pasteurization is a common and old technique to produce a safe product with substantial shelf life (Lindsay et al. 2021). Ultra-high temperature process is applied to inactivate bacteria and enhance the shelf life of milk for up to 9 months in dairy industries. Milk is heated directly or indirectly at around 135-145 ! for around 2-3 s to make it sterile and then quickly cooled (below 32!) and packaged under aseptic conditions (Akkerman et al. 2021, Krishna et al. 2021). Suzuki et al. (2014) reported that UHT milk produced by direct heating had better quality during long storage time at cold condition compared to indirect heating. Although UHT milk is microbiologically safe for the consumer during storage period but posttreatment contamination and thermoresistant spore-forming bacteria such as Bacillus sporothermodurans spores are factors that may present in industrially contaminated UHT milk (Scheldeman et al. 2006). For these reasons, there are still reports of food poisoning owing to UHT milk consumption.

The quality of UHT processed milk is related to the amount of milk fat (fat free, full fat and semi-skim), storage temperature, raw milk properties, seasonal variations, stage of lactation and age of cow that affects the shelf life and acceptance of the product throughout long storage period. The UHT treatment applied to milk has demonstrated desirable results, including increasing the shelf life to several months, reducing consumption of energy and no need storage and distribution in cold conditions (Chavan et al. 2011). However, it has some adverse effects on the quality of milk. UHT processing can induce denaturation of protein, Maillard reactions and oxidation of fat along with the formation of off flavor compounds and the loss of some nutrients during

[1] North Tehran Branch, Islamic Azad University, Tehran, Iran

[2] Department of Food Technology Research, Faculty of Nutrition Sciences and Food Technology/National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran

(✉) e-mail: mr_koushki@sbmu.ac.ir; e.khanniri@sbmu.ac.ir

thermal processing and storage (Oz et al. 2021,Yun and Imm 2021). One of the causes of cooked off flavor as a common sensory defect in UHT milk is the release of sulfhydryl groups and hydrogen sulfide from lactoglobulin (Ansari et al. 2020, Deeth 2021, Mejares et al. 2022).

Many researches have been published about the quality of whole UHT milk during storage life in several countries (Mudalal et al. 2019, Silva et al. 2021) but there is scarce information about the physicochemical changes, microbial and sensorial characteristics of whole UHT milk in Iran. Furthermore, UHT milk is an important part of people's diet that its consumption has been enhanced in Iran. So, the objective of this work was to survey the physicochemical properties, microbiological quality and sensory evaluation of whole UHT milk from the most-consumed brands in Iran.

Materials and methods

Sampling

5 brands were selected from the most famous and most widely consumed brands of whole UHT milk. Samples were purchased from different supermarkets in Tehran province. All whole UHT milk samples had similar production dates and one -liter size.

Physicochemical analyses

Physicochemical characteristics were performed in this study were titratable acidity, fat content, solids not fat (SNF) and density. Titratable acidity was measured by titration of 10 ml of whole UHT milk with 0.1 N NaOH and phenolphthalein was used as indicator (Dornic method). Fat content was calculated according to the Gerber butyrometer method. SNF was determined gravimetrically according to Iranian National Standard (No. 5272). Also, the density (D) of milk was evaluated at 20! by a thermo-lactodensimeter and it was calculated at a temperature other than 20! as follows:

$$D = D_{read} + (\text{temperature of milk} - 20\ ^{\circ}C) \times 0.2$$

Microbial counts

To estimate the total bacteria count, 1 mL of whole UHT milk was inoculated on Petrifilm Aerobic Count Plates and counted using the pour-plate method in plate count agar and incubated at 30°C for 72 h. After this period, plates with 15-300 colonies were enumerated and the results declared as cfu D mL (colony-forming units per mL whole UHT milk) (Mudalal et al. 2019). The microbial analysis was done on days 0, 90 and 180.

Organoleptic analysis

The sensory properties of whole UHT milk including odor, flavor, color and overall acceptability were analyzed by 30 panelists familiar with evaluation of dairy products. The treatments were compared using a hedonic 5-point structured scale. Therefore, a 5-point rating scale was used for each of sensory characteristics (0 = not consumable; 1 = unacceptable; 2 = acceptable; 3 = satisfactory; and 4 = excellent). After production of whole UHT milk and on day 180, the sensory evaluation was carried out and mineral drinking water was given to assessors to rinse their mouth between tests.

Statistics

Analysis of variance (ANOVA) and Duncan's test ($P < 0.05$) were used to assess the physicochemical and sensorial properties of whole UHT milk during storage (SPSS software). The obtained data were expressed as mean and all measurements were done in triplicate.

Results and Discussion

Physicochemical analysis

According to Table 1, the mean values for titratable acidity of whole UHT milk samples were 0.14-0.17 during 180 days of storage. Table 2 demonstrates titratable acidity of five brands that were in accordance with Iranian National Standard (No. 1528) in the range of 0.14-0.16 (% lactic acid) except brand C at 30! and before incubation. It was observed that by increasing storage time from 90 days to 180 days, titratable acidity increased slightly. In line with the obtained results, acidity of UHT milk samples increased during storage for 4 months at 5 and 30°C and the rate of increase was higher at high temperature. Occurrence of Maillard reaction during processing and storage and conversion of lactose to acids leads to increase of titratable acidity during storage (Ranvir et al. 2021). Similar results have been reported by Ajmal

Table 1 Mean values of physicochemical attributes of the whole UHT milk samples during storage time*.

Days	Solids-not-fat (%)	Fat content (%)	Density (g⁄mL)	Titratable acidity (%)		
				Before incubation	Incubation at 30°C	Incubation at 55°C
0	8.83[a]	3.06[a]	0.98[b]	0.14[a]	0.14[b]	0.16[b]
90	8.83[a]	3.06[a]	0.98[b]	0.14[a]	0.14[b]	0.16[b]
180	8.81[b]	3[b]	1.03[a]	0.003[b]	0.17[a]	0.17[a]

*Means shown with different small letters represent significant differences ($P < 0.05$) in the same columns.

et al. (2018) by investigation of acidity change in UHT milk during 90 days storage that was associated with the presence of organic acids including lactic acid, acetic acid, citric acid, pyruvic acid, formic acid, succinic acid and oxalic acid. Free fatty acids and changes in calcium phosphate equilibrium have been also proposed to be responsible for increased acidity and reduced pH of stored UHT milk (Swartzel 1983, Schmidt and Renner 1978). Also, increase of acidity during storage of UHT milk and the relation between acidity and storage time has been reported by Kessler and Fink (1986) and Rerkrai et al. (1987), Taw et al. (2014).

Regarding fat content, there was a significant difference ($P < 0.05$) between the values on day 0 and 90 with day 180 and a decreasing trend was observed. According to Table 2, there was a significant difference between fat levels of different brands. However, the values were in accordance with Iranian National standard (No. 1528). Accordingly, Richards et al. (2016) reported an increase of lipolysis in low-fat UHT milk during storage. Similarly, De Longhi et al. (2012) reported reduction in fat level of UHT milk samples that was explained by using milk with a lower-than normal fat level or the fraudulent reduction in the original fat level of the packaged product. Taw et al. (2014) observed no significant changes for fat content in UHT milk samples at different temperatures (4, 22 or 37°C) and time of storage (0-180 days). According to Iranian national standard (No. 1528), the minimum Solid non-fat (SNF) content in UHT milk should be 8% and the results in Table 2 presents that SNF level in UHT milk samples were in the range of 8.51-9.11%. Moreover, Table 1 indicates that the mean values of SNF% were in accordance with the standard limit.

The mean density values in milk samples during 180 days storage were in the range of 0.98-1.03 g/mL. According to Iranian National standard (No. 1528), the minimum density of UHT milk should be 1.029 gr/mL at 15°C. As can be seen in Table 2, except brand B, the density of milk samples was in accordance with the standard. De Longhi et al. (2012) recorded an increase in density of UHT milk samples after 120 days storage reaching to normal values which was attributed to the gelation process that resulted in viscosity increase along with a decrease in the fat level.

Microbial analysis

The total bacterial count of whole UHT milk samples during their shelf life is presented in Table 3. The results indicated the microbial count of all brands analyzed in present study was less than 10 cfu D mL which was below the allowable limit in Iranian National Standard (maximum of 100 cfu D mL; No. 1528) and also storage time had no effect on the microbial population. This result is consistent with the study of Karmaker et al. (2020), Mudala et al. (2019) and Arafat et al. (2015) who reported the microbial counts in UHT milk below the acceptable level in Mymensingh, Gazipur and Toulkarem districts respectively. It seems that UHT treatment has been effective in reducing the microbial load of whole milk, which has led to an increase in storage time. Furthermore, the low microbial load in samples throughout the storage period of 180 days can be attributed to the high quality of raw milk applied for UHT process. In the study of Zhang et al. (2020), the correlation of bacterial count in raw milk and the quality of produced UHT milk was investigated. They mentioned that the shelf life of products made with raw milk containing 10^4 cfu/ mL of *Pseudomonas* reached less than 7 months and the increase of

Table 2 Mean values of physicochemical attributes of the whole UHT milk samples from different brands*.

Brands	Solids-not-fat (%)	Fat content (%)	Density (g/mL)	Titratable acidity (%)		
				Before incubation	Incubation at 30°C	Incubation at 55°C
A	9.11 ± 0.1^{a}	3.02±0.04^{c}	1.04±0.01^{a}	0.16±0.01^{a}	0.16±0.01^{b}	0.17±0.01^{a}
B	8.8 ± 0.23^{b}	3.09±0.2^{a}	0.87±0.41^{b}	0.16±0.01^{a}	0.16±0.01^{b}	0.17±0.02^{a}
C	9.10 ± 0.43^{a}	3.02± 0.4^{c}	1.04±0.01^{a}	0.13±0.07^{b}	0.17±0.01^{a}	0.17±0.01^{a}
D	8.63±0.19^{c}	3.04±0.08^{b}	1.04±0.01^{a}	0.16±0.01^{a}	0.14±0.07^{c}	0.17±0.1^{a}
E	8.51±0.004^{d}	3.05±0.12^{b}	1.04±0.01^{a}	0.16±0.01^{a}	0.14±0.07^{c}	0.17±0.01^{a}

*Means shown with different small letters represent significant differences ($P < 0.05$) in the same columns.

Table 3 Total bacterial count (cfu D mL) in whole UHT milk products from different brands during storage periods.

Brands	Incubation at 30°C			Incubation at 55°C		
	0 day	90 days	180 days	0 day	90 days	180 days
A	<10	<10	<10	<10	<10	<10
B	<10	<10	<10	<10	<10	<10
C	<10	<10	<10	<10	<10	<10
D	<10	<10	<10	<10	<10	<10
E	<10	<10	<10	<10	<10	<10

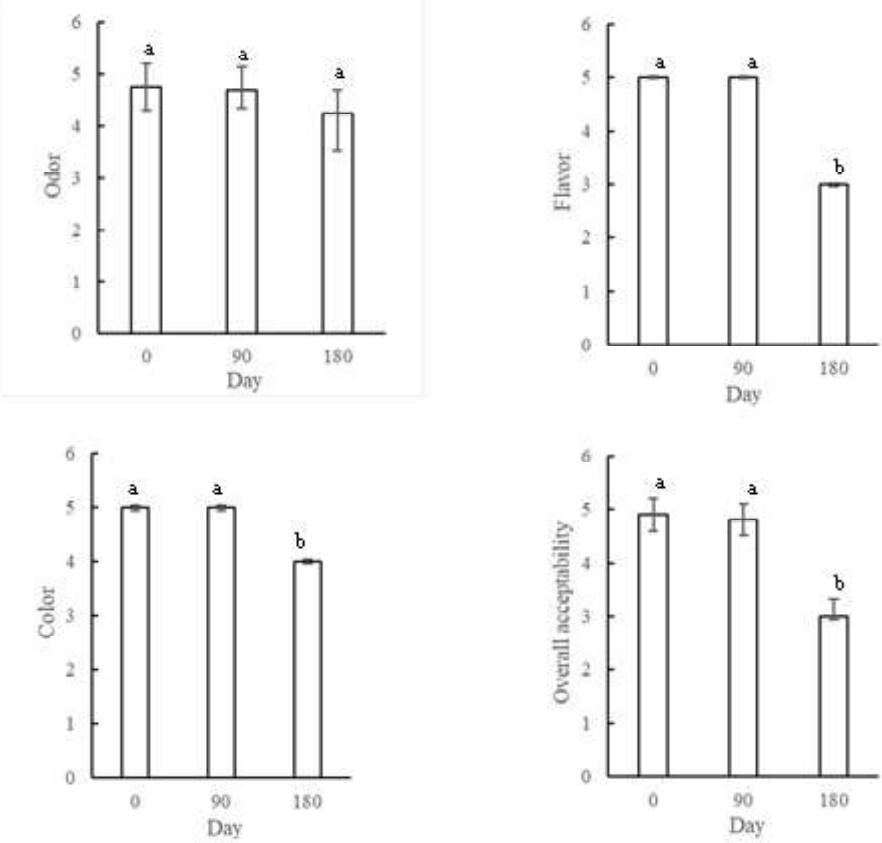

Fig. 1 Sensory evaluation of UHT milk products on days 0, 90 and 180

bacterial population of raw milk led to the production of UHT milk with a shorter shelf life.

Sensory evaluation

The results of the organoleptic test of whole UHT milk samples on days 0 and 180 are displayed in figure 1. It was indicated that there was a significant difference ($P < 0.05$) between the whole UHT milk samples on day 0 and day 180 regarding flavor, color and overall acceptability. Furthermore, the lowest scores were attributed to samples after 180 days of storage for flavor and overall acceptance. In this regard, other researchers also reported that sensorial properties of UHT milk change over the storage time (Hassan et al. 2009, Richards et al. 2016). Alterations in organoleptic attributes of UHT milk can be occurred due to proteolysis and lipolysis of milk- proteins and fat (Chen et al. 2003). Moreover, Maillard reaction may be responsible for color and flavor decrease during storage and also the formation of sulphur containing compounds causes cooked flavor during sterilization process and storage (Mudalal et al. 2019, Arafat et al. 2015). From the Table 4, it is seen that color and flavor scores of UHT milk samples were 4 and 4.5 respectively, which were similar in all brands. In addition, the highest odor scores belonged to brands A and D and brand E had the lowest overall acceptability compared to other brands. However, sensory quality of all brands was acceptable during storage period.

Conclusion

The present study revealed that all of whole UHT milk from the most-consumed brands in Tehran meet the standards in terms of solids-not-fat and fat level. Microbial quality of all brands was good over storage time. In addition, in respect of organoleptic analysis, the highest scores were related to the whole UHT milk samples at the beginning of the storage, because during storage time, decomposition of milk fat and Maillard reaction led to unpleasant changes in sensory parameters. In general, based on the parameters studied, UHT milk samples available in the Iranian market had acceptable quality during shelf life.

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Author contributions

Arameh Shahbaz: Investigation, Conceptualization, Validation, Writing - original draft, Writing – review and editing, Formal analysis, Visualization. **Mohammad Reza Koushki:** Conceptualization, Methodology, Investigation, Validation, Visualization, Writing – review & editing, Supervision, Funding

acquisition. **Elham Khanniri:** Methodology, Investigation, Conceptualization, Validation, Writing – review and editing. **Nasim khorshidian:** Conceptualization, Investigation, Writing – review & editing.

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