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ORIGINAL PAPER

A comparison of the quality of plain yogurt and icelandic yogurt (skyr)*

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Abstract

The consumption of high-protein products has increased in recent years owing to their high nutritional value and attractive flavor and texture. Icelandic yogurt (skyr) is an example of such products. The available scientific literature lacks the results of a direct comparison of the quality parameters of skyr and traditional yogurt. Therefore, the aim of this study was to compare the quality of plain yogurt and skyr produced from cow's milk. Regular and drinkable yogurt and skyr produced with the use of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* bacteria were analyzed. The physicochemical properties (color, pH, titratable and volatile acidity, water-holding capacity) of both products, and the fatty acid profile and nutritional value of yogurt fat (drinkable yogurts) were compared. The color analysis revealed that skyr was darker ($P \le 0.05$) than plain yogurt, and that the value of a* (redness) was higher ($P \le 0.05$) in drinkable skyr, whereas the value of b* (yellowness) was lower ($P \le 0.05$) in regular skyr. Skyr was also characterized by higher ($P \le 0.05$) titratable acidity and water-holding capacity, and pH was lower ($P \le 0.05$) in regular skyr. No significant differences ($P > 0.05$) in volatile acidity or the nutritional value of fat were observed between the compared products, excluding the n-6/n-3 PUFA ratio which was higher ($P \le 0.05$) in plain yogurt. Further research is needed to identify the factors that are responsible for the observed differences in the quality of plain yogurt and skyr. They can be resulted from natural differences in the milk matrix, but also from production technology, including the quantity and quality of added protein.

Keywords: plain yogurt, Icelandic yogurt (skyr), quality

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INTRODUCTION

Lactic acid fermentation is one of the oldest biological food preservation methods (Zapaśnik et al. 2022). The chemical compounds produced during fermentation (lactic acid) not only preserve foods, but also enhance their sensory properties (Kumar Verma et al. 2022). Lactic fermentation plays a special role in the dairy processing sector, and fermented milk drinks are among the oldest and most widely consumed dairy products (Kardas et al. 2022). This group of products includes yogurt, which is derived from the fermentation of milk by *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* bacteria (Rul 2017). Yogurt has high nutritional value because it contains concentrated milk ingredients (Mckinley 2005). Furthermore, during fermentation, lactic acid bacteria produce enzymes that break down milk ingredients increasing the bioavailability of the resulting lactic fermentation products (Wang et al. 2021).

Yogurt is widely consumed, and it has attracted interest from researchers due to its health-promoting properties. There is a growing body of evidence to indicate that yogurt consumption plays a role in the prevention of osteoporosis, diabetes, and cardiovascular disease, promotes intestinal function, boosts immunity, and reduces the risk of cancer (Hadjimbei et al. 2022). Bacteria used in yogurt production secrete enzymes that convert lactose to lactic acid, which is why yogurt can be safely consumed by people with lactose intolerance (Capcanari et al. 2021). The nutritional value and probiotic properties of yogurt can be enhanced through the addition of non-dairy ingredients, such as fruit which is a source of antioxidants, prebiotic fiber, and polyphenols, and which improve the sensory attributes of yogurt (Fernandez, Marette 2017). These factors are responsible for the steady increase in yogurt consumption in recent years. The yogurt market is projected to grow by USD 42.2 billion in 2022-2027 at a compound annual growth rate (CAGR) of 6.23% (Technavio 2023).

Yogurt manufacturers are introducing new product varieties and flavors to increase yogurt consumption. New yogurt varieties and products with novel ingredients are being placed on the market to drive consumer interest. Skyr or Icelandic yogurt is an example of such products. Skyr has been a staple of the Icelandic diet ever since Iceland was colonized by the Vikings in the 9^{th} century (Gudmundsson, Kristbergsson 2016). Skyr is classified as yogurt or fresh sour milk cheese that is produced from skim milk without or with the addition of rennet, respectively. Both plain skyr and fruit-flavored and sweetened varieties of skyr are available (Yazdi et al. 2022). Skyr has the consistency of thick yogurt because it is high-protein product (Pereira et al. 2021). The consumption of high-protein yogurt has increased in recent years due to its high nutritional value and attractive flavor and texture (Jørgensen et al. 2019). According to estimates (FMI, 2023), the global high protein yogurt market value progressed at a CAGR of roughly 2.6%

from 2018 to 2022. According to Arla Foods Ingredients (2020), skyr has the potential to reach up to 25% of yogurt volume sales on large dairy markets, which implies that this product is gradually heading out of its niche into the mainstream. The growing popularity of skyr requires new research to compare the properties of skyr and traditional yogurt. General information about the properties of both products is widely available, but the qualitative parameters of skyr and traditional yogurt have not been directly compared in the scientific literature. Therefore, the aim of the present study was to compare selected physicochemical properties and the fatty acid profile of plain yogurt and Icelandic yogurt (skyr).

MATERIALS AND METHODS

Plain yogurt and Icelandic yogurt (skyr) produced with the use of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* bacteria were analyzed in the study. Both "regular" and drinkable versions of the examined products were compared. Regular plain yogurt (n=10) and skyr (n=10) were supplied by the same manufacturer, whereas drinkable yogurt (n=10) and skyr (n=10) were obtained from two different producers (Table 1).

Table 1

Experimental design and nutritional value of the compared products

Items	Regular		Drinkable	
	plain yogurt – brand A (n=10)	Skyr – brand A (n=10)	plain yogurt – brand A (n=10)	Skyr – brand B (n=10)
Fat (g 100 g^{-1})	2.4	0.0	2.0	1.8
Carbohydrates (g 100 g^{-1})	4.0	4.1	4.6	4.3
Protein (g 100 g^{-1})	5.0	12.0	3.4	7.6
Salt (g 100 g^{-1})	0.1	0.1	0.1	0.1
Energy value (kJ/kcal)	242/58	274/64	210/50	269/64

The choice of products for the analysis was determined by their availability in retail during the study period (products with similar fat content were not available from a single manufacturer at the time). All products had different batch numbers and were purchased in a supermarket in Olsztyn, Poland, in November and December 2022. Regular plain yogurt and skyr were packaged in polypropylene (PP) tubs with aluminum foil lids, whereas drinkable yogurts were packaged in polyethylene terephthalate (PET) bottles. They were bought two weeks before end of shelf life declared by the manufacturers, and their quality was evaluated after one day of storage at a temp. of 4°C. All samples were measured in duplicate (color in triplicate), and the average value of the replicates was used for analyses.

In the color analysis, the values of L* (lightness), a* (redness), and b* (yellowness) were determined in the CIELAB color space (CIE 1978). The values obtained were then used to calculate chroma (C*) with the following formula: $C^* = (a^{*2} + b^{*2})^{1/2}$. During laboratory measurements, product samples with a temp. of approximately 20°C were kept in a standard glass cuvette. The color analysis was performed with the use of the MiniScan XE Plus spectrophotometer (Hunter Associates Laboratory Inc., Reston, Virginia, USA).

The pH of yogurt samples (25 g) diluted with demineralized water (25 ml) was determined with the use of a Polilyte Lab electrode and inoLab Level 2 pH meter with the TFK 325 temperature sensor (WTW Wissenschaftlich-Technische Werkstätten, Weilheim, Germany).

Titratable acidity was determined according to ISO/TS 11869 (2012) with the use of the TitroLine easy automatic titrator (SCHOTT Instruments GmbH, Mainz, Germany) and the SenTix 81 pH electrode (WTW Wissenschaftlich-Technische Werkstätten, Weilheim, Germany). The results for titratable acidity have been presented as the amount of lactic acid, taking into account that 1 ml of 0.1 N NaOH used in titration corresponds to 0.009008 g this acid.

The volatile acidity of product samples was determined in the distillate obtained by distillation in the Kjeltec™ 2200 Auto Distillation Unit (FOSS Analytical, Hillerod, Denmark. A mixture of 25 g sample and 50 ml deionized water was placed in a flask and connected to a Kjeltec apparatus. The extraction time was 6 min. After extraction the collected distillate was heated to boiling and titrated with 0.1 M NaOH standard solution using 0.3 ml of phenolphthalein solution (1% solution in ethanol) as an indicator. The results were expressed as the concentration of acetic acid, taking into account that 1 ml of 0.1 N NaOH is equivalent to 0.0060052 g this acid.

The water-holding capacity of plain yogurt and skyr was determined with the use of the method described by Li et al. (2014).

Fat for the analysis of the fatty acid profile was extracted by the Röse-Gottlieb method (ISO 1211 | IDF 1:2010). Fatty acid methyl esters were obtained by the IDF method with the use of KOH solution in methanol (IDF standard 182:1999). Fatty acid methyl esters were separated by gas chromatography (VARIAN CP-3800 gas chromatograph with a flame ionization detector; capillary column with a length of 50 m and an internal diameter of 0.25 mm; film thickness – 0.25 μm). The column oven was programmed with an initial column oven temp. of 50°C for 3 min, and increased to 200°C at a rate of 2°C min^{-1}. The total run time was 40 minutes. The injector and detector temp. were kept at 225°C and 250°C, respectively. Helium was used as a carrier gas with a flow rate of 1.2 cm^3 min^{-1}. Fatty acids were identified by comparing the retention times of fatty acid methyl esters in the analyzed sample with the reference (methyl esters of fatty acids ranging from C4 to C22, including key monounsaturated and polyunsaturated fatty acids; Sigma-Aldrich, St. Louis, MO, USA).

The results were processed statistically in the Statistica 13.3 program (TIBCO Software Inc., Palo Alto, CA, USA). The significance of differences (P≤0.05) between the mean values of the examined parameters in plain yogurt and skyr (separately for regular and drinkable yogurt) was determined by Student's t-test.

RESULTS AND DISCUSSION

The mean values of color parameters (L*, a*, b*, C*) in the analyzed products are presented in Table 2. Both regular and drinkable plain yogurt have higher L* values (P≤0.05, differences 0.11 and 0.32, respectively) than skyr. Rój and Przybyłowski (2012) observed that the value of L* was correlated with the fat content of plain yogurt. In the cited study, L* values ranged from 87.00 to 92.58 and were higher in high-fat products (7.5-10%) than in skim yogurt. The same relationship was observed in the present study (skyr had lower fat content and lower values of L* than plain yogurt). In products that are more abundant in fat (plain yogurt), higher L* values can probably be attributed to higher light reflectance from the surface of more numerous fat globules, which increases perceptions of the product's lightness (Chudy et al. 2020).

The pigments present in milk influence the color of both milk and dairy products (Nozière et al. 2006). Milk contains water-soluble pigments (such as riboflavin with imparts a yellow color) as well as fat-soluble pigments (such as carotenoids which impart a yellow and orange-red color) – Chudy et al. (2020). These pigments are responsible for the creamy white color of milk. High-fat dairy products are more abundant in carotenoids, which

Table 2

Color parameters of plain yogurt and skyr

Parameter	Regular		SEM	P-value	Drinkable		SEM	P-value
	plain yogurt (n=10)	Skyr (n=10)			plain yogurt (n=10)	Skyr (n=10)		
L* (lightness)	94.51^a	94.40^b	0.023	0.012	94.42^a	94.10^b	0.044	<0.001
a* (redness)	-1.70	-1.70	0.015	0.901	-1.83^b	-1.46^a	0.044	<0.001
b* (yellowness)	10.45^a	9.45^b	0.122	<0.001	10.66	10.59	0.049	0.515
C* (chroma)	10.59^a	9.60^b	0.120	<0.001	10.81	10.69	0.050	0.238

^{ab} P≤0.05

impart a yellowish hue (Nozière et al. 2006), as demonstrated by Rój and Przybyłowski (2012) in a study of plain yogurts. In the current study, the value of b* was also higher in regular plain yogurt, whose fat content was higher than that of regular skyr. No significant differences (*P*>0.05) in b* values were noted between drinkable plain yogurt and skyr, which could be attributed to a smaller difference in their fat content (0.2 percentage points).

Negative values of a* were noted in all studied products, which indicates a shift towards green color. Regular products did not differ significantly (*P*>0.05) in a* values. However, in drinkable products, the value of a* was significantly (*P*>0.05) higher in skyr. In the work of Rój and Przybyłowski (2012), low-fat yogurts (0.02%) were characterized by lower values of a* (-4.13 to -4.82) than products with 1-10% fat content (-3.49 to -3.82). These results suggest that parameter a* is correlated with the fat content of yogurt. However, the above observation was not confirmed in the present study.

The observed differences in the average values of a* and b* of compared yogurts contributed to differences in the mean values of chroma (C*), but only between regular products. Color analysis of these products demonstrated that C* value was higher in plain yogurt.

The color of plain yogurt can be influenced by the interactions between several factors, and a single dominant factor may be difficult to identify. These factors include the content of natural pigments and fat content as well as the fortification of the milk matrix with whey proteins (Delikanli, Ozcan 2014) and minerals which are added to promote gel formation (Szajnar et al. 2017).

Lactic acid fermentation is one of the most important stages in yogurt production. The pH of milk is decreased to ≤4.6 to promote coagulation and curd formation, and to extend the shelf life of the end product (Lee, Lucey 2010). For this reason, pH and titratable acidity are the main quality indicators in fermented dairy products. The analyzed products were characterized by the pH at around 4.4 (Table 3). The pH value was significantly higher (*P*≤0.05) in regular plain yogurt than in regular skyr. In turn, titratable acidy was significantly higher (*P*≤0.05) in both regular and drinkable skyr. The acidity of yogurt in the present study could have been affected by a few factors, like milk base used in production (composition and buffering capacity), ratio of yogurt starter cultures (speed of the acidification rate, tolerance to acid), incubation temperature and time (Deshwal et al. 2021). The buffering capacity of dairy products is correlated with the content of salt, organic acids, and proteins, and it is directly influenced by the buffering properties of ionized acid-base constituents in these compounds (Salaün et al. 2005). Products that are more abundant in protein have a higher buffering capacity, and their pH decreases less rapidly during lactic acid fermentation. Therefore, the protein content also affects enzyme activity and microbial growth in fermented dairy products (Kim et al. 2018). The above significantly influences the quality of the end product because milk ingredients are more

Table 3

Acidity and water-holding capacity of plain yogurt and skyr

Parameter	Regular		SEM	*P*-value	Drinkable		SEM	*P*-value
	plain yogurt (*n*=10)	Skyr (*n*=10)			plain yogurt (*n*=10)	Skyr (*n*=10)		
pH	4.41[a]	4.35[b]	0.011	0.005	4.40	4.40	0.023	0.958
Titratable acidity concentration of lactic acid (%)	0.101[b]	0.129[a]	0.004	<0.001	0.079[b]	0.111[a]	0.004	<0.001
Volatile acidity concentration of acetic acid (%)	0.008	0.007	0.001	0.499	0.006	0.007	<0.001	0.129
WHC (%)	40.98[b]	54.20[a]	1.555	<0.001	34.60[b]	40.84[a]	0.877	<0.001

WHC – water holding capacity, [ab] $P \leq 0.05$

effectively decomposed by enzymes and bacteria, which affects the product's texture, aroma, and flavor (Chen et al. 2017).

Usually, yogurt starter cultures are comprised of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* in a 1:1 or 1:2 ratio, but it can be changed as required by the industry (Dan et al. 2023). *Streptococcus thermophilus* starts acidification and reduces milk pH to 5.2. At pH 4.4, the bacterial growth is dominated by *Lactobacillus delbrueckii* subsp. *bulgaricus*, which is acid tolerant. This starter culture continues producing lactic acid also during storage and leads to post-fermentation acidification in yogurt (Deshwal et al. 2021). Therefore, rapid cooling of yogurt after fermentation and keeping low temperature during storage (restrict the activity of starter cultures) is a very important factor in controlling the product's final pH (Khan et al. 2020).

In addition to lactic acid, other organic acids are also produced during fermentation (Zaręba et al. 2008). These acids influence the flavor and shelf life of the end product (Adhikari et al. 2002). The quantity of organic acids, including volatile acids, is determined by the species and strain of fermenting bacteria, as well as fermentation (incubation) and storage conditions (Chen et al. 2017). In the present study, the volatile acidity of the examined products was expressed by the concentration of acetic acid to evaluate the production process and product storage. Typical starter cultures in yogurt are homofermentative, and they produce small amounts of acetic acid during incubation and storage (Chen et al. 2017). Therefore, high volatile acidity could suggest that the fermentation process was conducted under suboptimal conditions. The compared products did not differ significantly ($P>0.05$) in volatile acidity (Table 3). In a study by Vénica et al. (2014), the fatty acid profile, including acetic acid concentration, of yogurt produced with the use of *S. thermophilus* and *L. bulgaricus* starter cultures was affected by the composition of the milk matrix. In yogurt produced with the addition of skim milk powder and whey protein concentrate, the concentration of acetic acid was determined at 8.33-9.93 mg 100 g^{-1} and 8.95-10.21 mg 100 g^{-1} after 14 and 28 days of storage, respectively. In yogurt produced without the above additives, acetic acid concentration was determined at only 7.82 and 8.28 mg 100 g^{-1} after 14 and 28 days of storage, respectively.

In this study, regular and drinkable skyr was characterized by higher (P≤0.05) water-holding capacity than yogurt (Table 3). Water-holding capacity is directly associated with the quantity and quality of protein in dairy products. Higher protein content generally improves water binding in yogurt (Jørgensen et al. 2019). It was confirmed in the present study in skyr, which contained more protein. Whey proteins are particularly effective in enhancing the water-holding capacity of yogurt (Lange et al. 2020). Whey proteins are denatured under the influence of high temperature, and they interact with κ-casein to form a uniform, porous structure which encapsulates and immobilizes free water (Hashim et al. 2021).

The profiles of saturated and unsaturated fatty acids in the examined products are presented in Tables 4 and 5, respectively. The results of the fatty acid analysis were used to determine the nutritional value of fat in drinkable plain yogurt and skyr (Table 6). Both products were most abun-

Table 4

Proportion of saturated fatty acids (%) in the total content of fatty acids in plain yogurt and skyr

SFAs	Drinkable		SEM	*P*-value
	plain yogurt (*n*=5)	Skyr (*n*=5)		
C4:0	2.63	2.64	0.044	0.938
C6:0	1.98	1.99	0.023	0.839
C8:0	1.29	1.30	0.013	0.613
C10:0	3.10	3.11	0.018	0.874
C12:0	3.75	3.78	0.017	0.390
C14 *iso*	0.11	0.12	0.002	0.852
C14:0	12.49	12.53	0.052	0.740
C15:0	1.30[b]	1.35[a]	0.010	0.007
C16 *iso*	0.30	0.30	0.007	0.880
C16:0	35.95	35.41	0.184	0.145
C17:0	0.61	0.63	0.005	0.065
C18:0	9.96[b]	10.27[a]	0.071	0.017
C20:0	0.45	0.47	0.008	0.312
C22:0	0.03	0.03	0.003	0.987
Total SFAs (%)	73.96	73.90	0.161	0.879

SFAs – saturated fatty acids, [ab] $P \leq 0.05$

Table 5

Proportion of unsaturated fatty acids (%) in the total content of fatty acids in plain yogurt and skyr

UFAs	Drinkable		SEM	*P*-value
	plain yogurt (*n*=5)	Skyr (*n*=5)		
C10:1	0.35	0.36	0.003	0.059
C12:1	0.12	0.13	0.001	0.169
C14:1	0.55[b]	0.58[a]	0.007	0.001
C16:1	2.15	2.11	0.011	0.052
C17:1	0.35	0.33	0.048	0.830
C18:1 *c*9	20.11	20.37	0.107	0.247
C18:2	1.48[a]	1.22[b]	0.059	0.014
CLA	0.14	0.14	0.007	0.842
C18:3	0.55[b]	0.62[a]	0.015	0.022
C20:1	0.03	0.04	0.004	0.052
C20:2	0.05	0.04	0.003	0.280
C20:4	0.10	0.10	0.005	0.609
C20:5	0.01	0.02	0.005	0.513
C22:5	0.03	0.02	0.005	0.555
Total MUFAs (%)	23.67	23.93	0.130	0.338
Total PUFAs (%)	2.37	2.16	0.066	0.114

UFAs – unsaturated fatty acids, MUFAs – monounsaturated fatty acids, PUFAs – polyunsaturated fatty acids, [ab] $P \leq 0.05$

Table 6

Nutritional value of fat in drinkable plain yogurt and skyr

Fatty acid ratio	Drinkable		SEM	*P*-value
	plain yogurt (*n*=5)	Skyr (*n*=5)		
UFA/SFA	0.35	0.35	0.003	0.877
MUFA/SFA	0.32	0.32	0.002	0.463
PUFA/SFA	0.03	0.03	0.001	0.138
DFA/OFA	0.56	0.57	0.005	0.405
n-6/*n*-3	2.74[a]	2.05[b]	0.130	<0.001

SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, UFA – unsaturated fatty acids (MUFA + PUFA), DFA – desirable fatty acids (UFA + C18:0), OFA – hypercholesterolemic fatty acids (SFA – C18:0), [ab] $P \leq 0.05$.

dant in saturated fatty acids (SFAs) and least abundant in polyunsaturated fatty acids (PUFAs). Skyr contained significantly ($P \leq 0.05$) more pentadecanoic acid (C15:0), stearic acid (C18:0), myristoleic acid (C14:1), and linolenic acid (C18:3), whereas plain yogurt was significantly more abundant ($P \leq 0.05$) in linoleic acid (C18:2). The compared products did not differ significantly in nutritional value, excluding the *n*-6/*n*-3 PUFA ratio, which was more desirable (lower by approx. 25%) in skyr ($P \leq 0.05$).

The fatty acid profile of the dairy products is related to the concentrations of fatty acids in cow's milk used in their production. Saturated fatty acids are predominant (approx. 70%) in cow's milk (Markiewicz-Keszycka et al. 2013). However, numerous factors, including cattle nutrition, health status, season, stage of lactation, breed, and genotype (Lindmark Månsson 2008), can induce significant differences in the composition of milk fat (Pietrzak-Fiećko, Kacprzak 2012, Młynek et al. 2021). Fatty acid ratios in dairy products are also affected by technological processes, such as thermal processing, homogenization, choice of the type and level of starter culture, fermentation, and storage (Paszczyk, Czarnowska-Kujawska 2022). Nikolova et al. (2022) reported that lactic acid bacteria demonstrate different degrees of lipolysis, which is important for the selection of strains that can be used for starter cultures. According to Chen et al. (2017), the lipolytic activity of lactic acid bacteria in yogurt is limited because most their esterases are unable to hydrolyse lipids until these enzymes have been released from lysed cells. Khan et al. (2022) demonstrated that post fermentation cooling patterns had a pronounced.

Effect on antioxidant characteristics, fatty acid profile and lipid oxidation of yogurt (higher temperature may induce lipid oxidation). A study carried out by Paszczyk et al. (2020) shows that refrigerated storage time also affects the fatty acid profile of yogurt. They observed a decrease in MUFA and PUFA of products on the 21^{s}t day of storage at 8±1°C. Moreover, storage resulted in a significant decrease of CLA and *trans* C18:1 isomers in cow milk yogurts. Serafeimidou et al. (2012) found that the fatty acid profile of yogurt can also be influenced by fat content. The cited authors analyzed yogurts made from cow's milk and sheep's milk, and found that low-fat yogurts were characterized by a significantly higher content of SFAs and a lower content of monounsaturated fatty acids (MUFAs).

CONCLUSION

The study demonstrated differences in the physicochemical properties of plain yogurt and skyr. The interpretation of these results is difficult due to various associated factors. Higher titratable acidity and water-holding capacity of skyr could be attributed to higher protein content (a larger amount of this ingredient increases the buffering capacity and limits syneresis). However, further research is needed to elucidate the observed differences in the color parameters of plain yogurt and skyr. These differences could have resulted from numerous factors, including the content of natural pigments in the milk matrix, the content and quality of added protein, as well as the fat content. Additional work is also required to identify the reasons behind the observed differences in the *n*-6/*n*-3 PUFA ratio between the analyzed products.

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