Journal of Food Science and Technology (Iran)

Homepage: www.fsct.modares.ir

Scientific Research

Textural and sensory characteristics of yogurt manufactured with liquid whey and strawberry supplementation

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ARTICLE INFO

Article History:

Received: 2023/12/29
Accepted: 2024/6/5

Keywords:

liquid whey,
fruit yogurt,
texture,
syneresis,
organoleptic characteristics

DOI: 10.22034/FSCT.21.150.139

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ABSTRACT

Cheese whey is the most polluting by-product of the dairy industry, and whey use has been the subject of much research; however, the conversion of liquid whey into value-added yogurt products is insufficient. The aim of the current research is to study the effect of fermentation of a milk-liquid whey mixture into yogurt and strawberry supplementation on the syneresis index and textural and organoleptic characteristics during cold storage. For yogurt preparation, 25% liquid whey was substituted with the milk used for yogurt production, and after the fermentation process was complete, strawberry supplementation (12%). Results show that by using liquid whey in yogurt formulation, the syneresis index increased, whereas for texture properties, higher mean values of cohesiveness and springiness and lower values for hardness, adhesiveness, and gumminess were found. The time of storage also had a significant impact on the yogurt properties, and as the time of storage increased, the syneresis index increased and sensory scores reduced noticeably. The level of whey separation was significantly increased in yogurt samples containing liquid whey on the last day of storage, according to an evaluation of yogurt qualities ($P<0.01$). The results showed that although adding liquid whey into the yogurt production decreased the sensory characteristics (consistency and taste scores), yogurt with liquid whey and strawberry supplementation had an acceptable sensory score. Therefore, the use of liquid whey in the production of functional yogurt enables its reintroduction in the food supply chain and enhances sustainability.

1- Introduction

Whey is a transparent yellowish to greenish solution derived from milk curd that has been coagulated with rennet or acid [1]. The expensive expense of disposal, along with the need to minimize pollution, has driven significant attempts to utilize cheese whey for sustainable use in an environmental approach [2, 3]. Whey disposal also represents a significant loss of potential nutrients and energy; therefore, to utilize the nutritional value of whey while also mitigating the negative environmental effects of disposal, it is critical to direct whey management toward a cost-effective and sustainable method of utilization and to direct it into the production of novel valuable products [3]. Whey discharge is an ongoing problem for the dairy industry in North Macedonia. The use of liquid cheese whey without pre-treatment in its original form for producing fermented dairy products would be a solution from an environmental and technological point of view. The form in which the whey is added is the main technological distinction between yogurts with added whey and fermented whey beverages. Whey protein concentrates (WPC) are recommended for yogurts; however, liquid or reconstituted whey is mostly used in fermented whey beverages [4]. Whey proteins are well known for their high nutritional value and versatile functional properties in food products [5]. All whey proteins have been linked to a variety of nutritional and physiological effects, including (i) physical performance, recovery after exercise, and muscle atrophy prevention; (ii) satiety and weight management; (iii) cardiovascular health; (iv) anticancer effects; (v) wound care and repair; (vi) infection management; (vii) infant nutrition; and (viii) healthy aging [6]. Products such as whole milk powder, caseinates, whey protein concentrate (WPC), liquid whey protein concentrates (LWPCs), and liquid milk whey (LW) are also employed in yogurt manufacturing [7, 8]. LWPCs production requires an ultrafiltration/diafiltration (UF/DF) section. The use of liquid whey protein concentrates, which have lower production costs than dehydrated products (WPC and WPI), enables the production of high nutritional value dairy products [9]. In addition, incorporation of LWPCs in dairy products showed good performance in yogurts functional properties [7]. Jaskiski et al. (2016) studied Brazilian consumers` liking of strawberry-flavored yogurts and whey beverages, in which low-fat yogurt with an unknown percentage of liquid whey was evaluated [4].

As mentioned, liquid whey comprises significant health benefits due to whey proteins, and by adding it to yogurt formulation, a functional product can be produced. However, to the best of our knowledge, this is the first study to examine the relationship between textural and sensory properties of yogurt made using both liquid whey and strawberry supplements. Therefore, in the current study, functional yogurt samples containing liquid whey and strawberry supplementation were produced, and their syneresis index and textural and sensory properties were investigated.

2- Materials and methods

2.1. Raw materials

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Yogurt was produced with milk, liquid whey, and a commercial yogurt starter culture consisting of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* YoFlex ® Premium 3.0, Chr. Hansen Co. Ltd. (Hørsholm, Denmark) in direct vat set (DVS) form (provided by Vemilk, a milk processing factory in Republic of North Macedonia). White sugar and frozen strawberries (stored at –18℃) were bought from a local market near our university in Bitola, Republic of North Macedonia.

2.2. Yogurt samples

The milk was pasteurized at a temperature of 90 ± 2℃ for 5 min and then cooled to 4℃. Whey (0.13% fat) was pasteurized at a temperature of 90 ± 1 ℃ for 25 min and then cooled to a temperature of 45 ± 2℃. Frozen strawberries were melted and pasteurized at a temperature of 65 to 70 ℃ for 15 min and then cooled to a temperature between 25 and 30 ℃. Furthermore, milk (3% fat) was heated to a temperature of 43.8 ℃ and 4% sugar was added. Milk and milk with 25% whey were inoculated with 0.04% and 0.05% active cultures, respectively. Before fermentation, the pH of the milk and milk with LW were 6.5 and 6.38, respectively. After 3 h of fermentation at 43 °C, the pH of the control yogurt and yogurt with LW were 4.64 and 4.55, respectively. The yogurt samples were cooled to an ambient temperature of 25 to 30 ℃, before being blended with strawberries (12%) for 5 min. Finally, the control yogurt with strawberries (CYS) and functional yogurt with strawberries (FYS) samples were stored at a temperature of 4 to 8 ℃ for 21 days.

2.3. Syneresis index

The yogurt syneresis index (SI) was determined using the drainage method [11]. The drainage method evaluates the separation of whey from gels that may have suffered a partial or total breakdown of the solid structure by the action of gravitational force [7]. SI was measured in one replicate.

2.4. Textural profile analysis

Textural parameters, such as hardness, adhesiveness, cohesiveness, gumminess, and springiness, were derived from texture profile analysis (TPA) (CT3-10kg, Amtek Brookfield, USA) using a cylindrical-shaped probe (38.1mm diameter). The tests were performed at temperatures ranging from 20 to 25°C, whereas yogurt samples were kept between 10 and 12°C. TPA was applied to yogurt samples in their original 110-mL container, which was placed underneath the probe with a 70% deformation test target at 1 mm/s [10]. The analyzer runs on a PC using TexturePro CT V1.8 software.

2.5. Sensory evaluation

The sensory evaluation of the yogurts was conducted using the five-point scoring system, where each aspect was scored on a scale of 1 to 5. When evaluating the sensory properties of yogurt, we assign coefficients of importance (Cv) to each property: taste (Cv = 8), smell (Cv = 6), consistency (Cv = 3), appearance (Cv = 2), and color (Cv = 1). Scores ranging from 1 to 5 assigned to each property are multiplied by the corresponding coefficient of importance (Cv). The sum of these values is expressed as a percentage of

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the maximum possible quality. To calculate the weighted general assessment of the yogurt's quality, we divide the maximum possible quality by the sum of the coefficient of importance (Σ = 20) [10, 12, 13]. Sensory parameters, including taste, smell, consistency, appearance, and color, were used to assess consumer acceptance of the products. Sensory descriptive evaluation of yogurts was conducted on 14 attributes: the distribution of the ingredients (strawberry), presence of mold, whey separation, milk aroma, fermentation aroma; the intensity of the flavor; and the taste of the yogurt—sweet, bitter, sour, strawberry, milky, whey, yogurt, and aftertaste [14,15,16]. Each quality was scored using an ascending scale of 1 (not present), 2 (very weak), 3 (moderate), 4 (intense), and 5 (extremely intense). The tests were performed by 12 trained panelists (including 7 males and 5 females with an average age of 35 years). Seventy milliliters of yogurt samples were placed in polystyrene cups and served between 8 °C and 12 °C. Tap water was served to clean the mouth between samples.

2.6. Statistical analysis

The samples included control yogurt and yogurt containing liquid whey. Statistical analysis of the data was performed using Minitab 18 (Minitab Inc, USA). To assess whether the data follows a normal distribution, we used Shapiro–Wilk`s test. The Shapiro–Wilk test confirmed that the data follow a normal distribution. We then used the parametric method for data analysis. Student`s t-test was used to compare means; differences between means were considered significant for p-values below 0.05. All figures were drawn using OriginPro 2021b (OriginLab Corporation, Northampton, MA). The tests were performed in 2 repetitions (unless mentioned otherwise), and the results are reported as the mean ± standard deviation (SD).

3- Results and discussion

3.1. Syneresis index

Figure 1 compares the syneresis of different types of yogurt during storage. It is obvious that there is a higher syneresis with the use of LW and a significant increase in syneresis during storage. SI in CYS and FYS was 35.56% and 44.64% on day 1, and 50.15% and 65.68% on day 21, respectively. This can be attributed to the low total solid content of the liquid whey. Syneresis increase could be attributed to LAB activity, which ultimately produces more acid and consequently weakens the gel network of the yogurts during storage [17]. However, the main factor in our study was the addition of LW, which had an additional negative impact on SI.

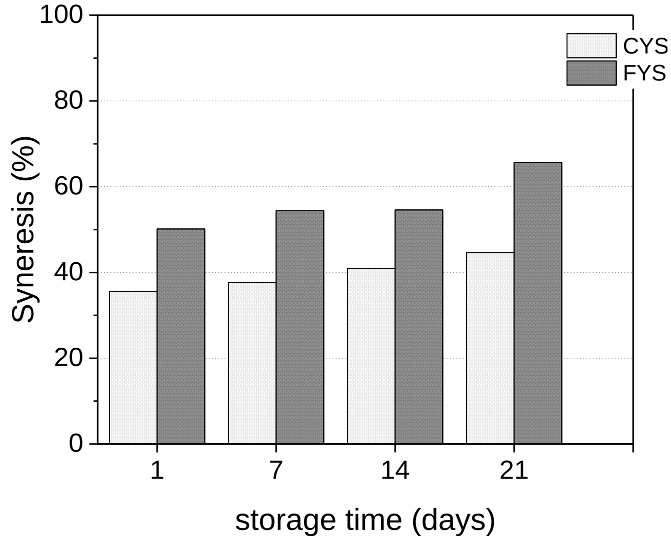

Figure 1. Comparison of syneresis index of yogurt samples. CYS = conventional yoghurt with strawberries (control); FYS = functional yoghurt with strawberries

The SI of FYS in our study is significantly higher than that reported by Gauche et al. (2009), in which SI (measured using centrifugation method) of yogurts C80 (80% milk + 20% milk whey) and C70 (70% milk + 30% milk whey) were 30.14% and 39.64%, respectively [8]. Henriques et al. (2013) reported a significant reduction in syneresis (measured using centrifugation method) with the use of liquid whey protein concentrate and its increase during storage of medium-fat yogurts (1.5-15LWPC with 15g/100g and 1.5-30LWPC with 30g/100g LWPC) [7]. The SI on day 20 for 1.5–15LWPC and 1.5–30LWPC were approximately 21% and 19%, respectively [7]. The SI results were significantly lower than those in our study. The evaluation method is one of the factors for the wide range of syneresis in literature, as the volumetric flask (siphon), Petri dish, low-speed centrifugation, and drainage method are used [7, 18, 19]. Li and Guo (2006) pointed out that whey proteins that have been denatured before being added to milk have good water retention capabilities [20]. They found that the denatured whey proteins and caseins in this case had stronger connections, which encouraged the development of a protein network with narrow pores, resulting in improved consistency and less syneresis.

3.2. Texture profile of yogurts during storage

Rheological evaluation can be divided into sensory and instrumental methods [21]. TPA was used to evaluate the textural properties of the samples. The TPA test yielded the following texture parameters: hardness, adhesiveness, cohesiveness, gumminess, and springiness (Figure 2). The hardness represents the maximum force of the first compression cycle [22]. According to Figure 2, adding whey to the yogurt formulation affected the hardness compared with the control sample. The highest level of hardness in samples with whey FYS was (59.00 g) and the lowest was (38.00g). The hardness of CYS was higher than that of FYS during storage ($P>0.05$). Higher results were reported by Gauche et al. (2009) for yogurts

[DOI: 10.22034/FSCT.21.150.139]

with milk whey C80 and C70. Adhesiveness is the force required to separate the probe from the sample by the first push [23]. It is influential in creating a favorable sensory feeling and improving the histological features of the product [21]. Adhesiveness is considered a measure of the stickiness of yogurt and is inversely related to the eating quality of yogurt [24].

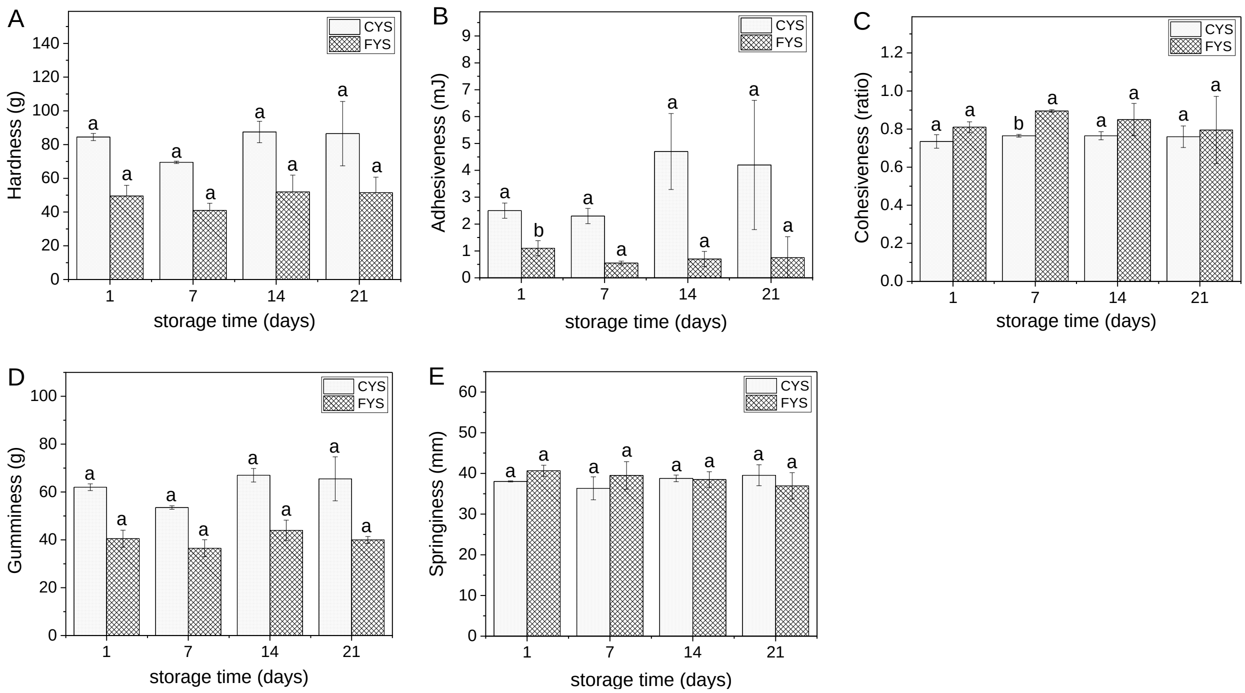

Figure 2. Comparison of yogurt samples for hardness (A), adhesiveness (B), cohesiveness (C), gumminess (D) and springiness (E). CYS = conventional yogurt with strawberries (control); FSY = functional yogurt with strawberries. The mean in the graph indicated by different letters (a–b) is significantly different (P<0.05) from the other product. Error bars represent the standard deviation (SD) of the mean of duplicate experiments

The highest level of adhesiveness was found in the control sample CYS (5.9 mJ) and the lowest level in samples with whey FYS (0.2 mJ). The addition of whey reduced the adhesiveness of FYS. Adhesiveness results were statistically significant only on day 1 (P<0.05). The adhesiveness results of CYS on days 14 and 21 showed high SD. In addition, adhesiveness increased proportionally with the increase in hardness. In this study, we confirmed a direct relationship between hardness and adhesiveness [21]. Greater magnitudes of adhesiveness reflect a greater association with the probe surface, indicating greater structural integrity, perhaps due to increased charged groups on the amino acid group, a function of whey protein denaturation [25]. Higher results were reported by Ziarno and Zareba (2019) for the adhesiveness of yogurt made with skim milk powder (15.1 mJ on day 28) [26]. Cohesiveness indicates structural integrity and is often discussed in terms of bond strength [26]. The addition of whey increased the cohesiveness of the FYS (Figure 2). The highest cohesiveness level was related to FYS (0.895), and the lowest level was related to CYS (0.735). Adhesiveness results were statistically

[DOI: 10.22034/FSCT.21.150.139]

significant only on day 7 (P<0.05). Similarly, the addition of liquid milk whey to yogurt formulations contributed to higher cohesiveness in yogurt samples [8]. In another study conducted by Henriques et al. (2013), the addition of LWPC had no impact on the cohesiveness of medium-fat yogurt [7]. Gumminess is the force required to break down a semi-solid material so that it is ready to swallow and relies on firmness and cohesiveness attributes [27]. Yogurt samples with the addition of whey (FYS) demonstrate lower levels of gumminess than CYS. Adhesiveness results were not statistically significant during storage (P>0.05). The gumminess values of the sample decreased in the first week and increased in the following weeks. Similarly, a previous study found that the addition of liquid milk whey to the yogurt formulation contributed to lower gumminess in yogurt samples [8]. The springiness of a material refers to its ability to revert back to its original state after being deformed, and this characteristic is influenced by various factors, including heat treatment, protein interaction, elasticity, and the extent of protein unfolding [28]. A stronger gel structure can be attributed to heightened cohesiveness and springiness [5]. The lowest springiness value was found in the control sample CYS (36.33 mm). The results for springiness were not statistically significant during storage (P>0.05). Gahurie et al. (2019) showed that the addition of wheat germ and strawberry had no effect on the springiness of yogurt [21]. Stability constitutes a crucial determinant of the physical attributes of a product, subject to the influence of diverse variables encompassing the quantity of solid material, protein concentration, thermal treatment, homogenization, stirring temperature and pH, starter bacteria, acidity levels, exopolysaccharide type and quantity, bacterial protolithic activity, and storage conditions [21].

3.3. Sensory evaluation

The sensory evaluation results of yogurt samples containing 25% LW during 21 days of storage in the refrigerator are shown in Figure 3. The results showed that except for the appearance, color, and aroma of yogurt, the type of yogurt and storage time had a significant effect on the other evaluated features (P<0.05). By adding 25% LW to the yogurt formulation, the consistency and taste characteristics of the yogurt decreased significantly on days 14 and 21. The scores for the appearance and color characteristics of yogurt with LW were higher during the first week, but the consistency score was lower than that for the control sample during storage.

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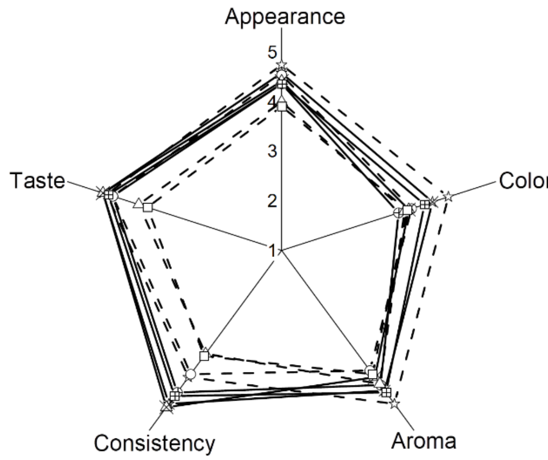

Figure 3. Sensory attributes of yogurts during storage: CYS = conventional yogurt with strawberries (-☆-, day 1; -⊕-, day 7; -△-, day 14; -⊞-, day 21); FYS = functional yogurt with strawberries (☆, day 1; ○, day 7; △, day 14, □, day 21)

The acceptability of the yogurt samples was calculated by assigning each sensory attribute a coefficient of importance (Figure 4). Higher acceptability scores were found for the control and functional yogurt samples during the first week of storage (P>0.05). The acceptability score of the yogurt with LW decreased in the following weeks compared with that of the control yogurt (without LW) (P<0.05). However, yogurt samples containing LW had an acceptable sensory score, and the panelists gave acceptable scores to the mentioned sample. The acceptability scores of the CYS and FYS samples on the final day of storage were 4.55 and 3.87, respectively.

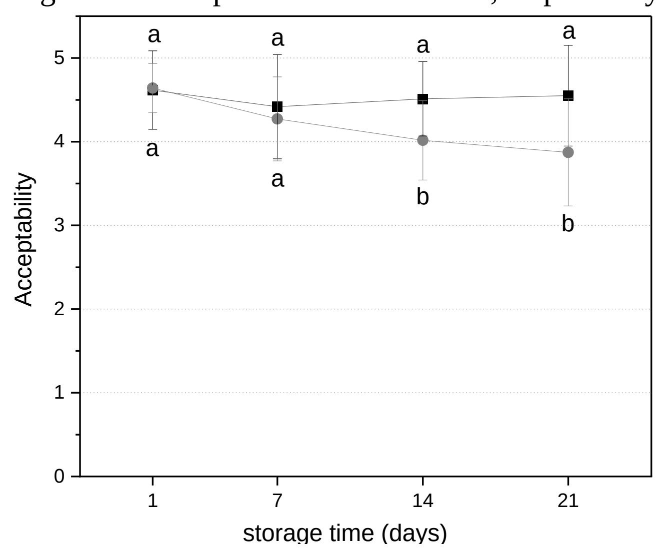

Figure 4. The overall weighted acceptability of yogurts (means $\pm SD$). CYS = conventional yogurt with strawberries (■); FYS = functional yogurt with strawberries (●). The mean values in the graph indicated by different letters indicate significant differences (P<0.05). Error bars represent the standard deviation (SD) of the mean of twelve panellists (N=12).

Janiaski et al. (2016) reported that strawberry-flavored yogurt with liquid whey was as acceptable as low-fat fermented or reconstituted whey beverages [4].

[DOI: 10.22034/FSCT.21.150.139]

Strawberry-flavored yogurt with liquid whey showed differences only in viscosity and smoothness of mouth-coating (P<0.05). Probiotic yogurt with strawberries and whey showed that viscosity on day 15 of storage of samples with the addition of 20% of whey compared with the control samples was not statistically significant (P>0.05), whereas the addition of 35% whey was statistically significant (P<0.05) [29].

The descriptive sensory evaluation of yogurt samples (CYS and FYS) during storage is shown in Figure 5. Distribution of strawberries scored higher on FYS only on day 7 (P>0.05). The results of this study indicated that the addition of whey had no effect on mold development in yogurt samples. The whey separation attribute of yogurt with LW on day 21 compared with the score of control yogurt was statistically significant (P<0.01). The obtained results are consistent with both the syneresis index and the sensory attribute of consistency. The results indicate a low score for milk odor during storage (P>0.05). The fermentation odor score was higher in FYS, but the difference was not statistically significant (P>0.05).

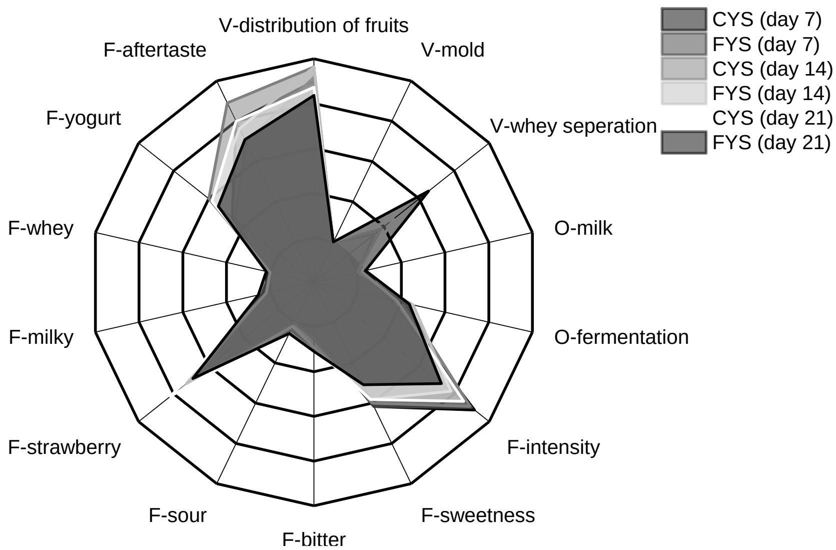

Figure 5. Sensory results from the quantitative descriptive analysis of yogurt samples: CYS = conventional yogurt with strawberries; FYS = functional yogurt with strawberries of 14 major attributes. V = visual; O = odor; F = flavor

During storage, the control and functional yogurt samples had similar scores for flavor intensity, sweetness, bitterness, sourness, milky taste, and strawberry taste (P>0.05). The whey was tasted on day 21 in the yogurt with LW (P>0.05). According to the sensory evaluation, CYS received higher scores for yogurt taste and aftertaste attributes. Janiaski et al. (2016) found that the use of natural ingredients, such as fruit pulp, was not essential for developing the sensory characteristics of strawberry-flavored yogurts and whey beverages with liquid whey [4]. It was preferable to use liquid preparations to add an artificial strawberry taste and aroma instead of preparations with suspended particles. The results of the descriptive sensory evaluation revealed that the LW formulation had similar flavor and taste profiles, indicating that the addition of

[DOI: 10.22034/FSCT.21.150.139]

LW is appropriate for producing functional yogurt with strawberries.

4-Conclusion

This research was conducted to investigate the effect of adding liquid whey in the formulation of yogurt on the textural and sensory characteristics of the product during 21 days of storage at 4 to 8 °C. The results of this research showed that the yogurt samples containing liquid whey had higher syneresis than the control sample (without liquid whey). However, the results showed that the type of yogurt had no significant effect on hardness, gumminess, or springiness except for adhesiveness and cohesiveness on days 1 and day 7 of storage, respectively. The scores of sensory characteristics of taste and consistency of yogurt samples containing whey were significantly lower than those of the control samples on days 14 and 21. However, yogurt samples containing liquid whey had an acceptable sensory score, and the panelists gave an acceptable average score for these samples. Therefore, because several beneficial properties of liquid whey are known, and by using it to produce functional yogurt, we aim to promote environmental friendliness and healthy foods.

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