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Characterization and ranking of commercial vanilla flavoured set yoghurt marketed in Sri Lanka

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Abstract
Vanilla flavoured sweetened set yoghurt manufactured by few commercial scale processors dominates the yoghurt market in Sri Lanka. Despite the comparable production technologies, the quality of the final product differs widely in several aspects. Therefore, the present study was conducted to characterize and to rank the most preferred vanilla flavoured commercial set yoghurt brand marketed in Sri Lanka. Yoghurts from six popular commercial brands (Y_1, Y_2, Y_3, Y_4, Y_5, and Y_6) were purchased from two supermarkets. Compositional (total solid %, fat %, protein %, ash %, carbohydrate %), physicochemical (pH, titratable acidity) and physical (water-holding capacity, spontaneous whey syneresis, instrumental color and texture) properties were tested using standard procedures. Sensory properties (flavor, color and appearance, body & texture, acidity, over-all acceptability) were evaluated with 30 untrained panel of judges. Data were analyzed using SPSS (ver.20) except sensory data. Fuzzy toolbox from MATLAB computer software was used to analyze sensory data. Significant ($p<0.05$) variations were observed in the composition, physicochemical, physical and sensory parameters of different yoghurt brands. Highest water holding capacity and the lowest instrumental hardness value were reported by Y_3 and were observed to be significantly ($p>0.05$) different from other 5 brands. Spontaneous whey syneresis was negligible in all the commercial yoghurt brands. Significant ($p<0.05$) variations were observed in instrumental colour parameters of yoghurts and no relationship was observed with the preference. Brand Y_3 had the highest sensory acceptability, rated under the 'good' category whereas the lowest acceptability by Y_5 which was classified under 'satisfactory' category. Proximate composition of the most preferred yoghurt brand was observed to be 22.80±0.10% TS, 3.25±0.06% fat, 4.06±0.09% protein, 0.77±0.10% ash and 14.72±0.46 total carbohydrates with acceptable pH (4.09±0.06) and acidity (1.16±0.01% lactic acid). Overall sensory score of yoghurt samples has a significant ($p<0.05$) negative correlation with instrumental hardness (R^2 = 0.513) and storage period (R^2 = 0.791). The ranking of the yoghurts according to the overall sensory score were $Y_3 > Y_1 > Y_6 > Y_2 > Y_4 > Y_5$.

Keywords: Yoghurt, Characterization, Fuzzy logic, texture, MATLAB

1. Introduction

Yoghurt is well known for centuries as a dense nutritional source having therapeutic properties. It is a highly digestible fermented dairy product suitable for all age groups. Yoghurt is considered as a healthy food owing to the presence of live microbial cultures, higher digestibility and bioavailability of nutrients [1, 2]. It aids in weight control and can be recommended for people suffering from lactose intolerance, gastrointestinal disorders (such as inflammatory bowel disease and irritable bowel syndrome) and immune system related problems [2, 3]. There is an increasing trend/increased popularity of yoghurt consumption throughout the world. It was reported that the world market for yoghurt and fermented dairy products has developed dynamically during the last 25 years which could be observed both in the developed and in the emerging markets [4]. Yoghurt is the fastest growing dairy category in the world [5] and in the Sri Lankan market. It is especially due to the healthy image associated with yoghurt along with the availability of diversity of products. There is a significant diversity of yoghurts marketed [6] depending on the physical nature (set, stirred, drinking etc.), chemical composition (low fat, non-fat, regular/full fat), added flavours (vanilla strawberry, etc.) and therapeutic aspects (probiotic, prebiotic, antioxidant rich) etc. However, vanilla flavoured set yoghurt dominates the yoghurt market in Sri Lanka, despite of diversity of cultures, living standards, age-groups, gender etc. among consumers. Set style yoghurts are made by allowing incubation to occur directly in the retail packages [7]. There are two major categories of vanilla flavoured set yoghurts marketed in Sri Lanka according to the scale of manufacture i.e. large scale or commercial which is having island wide distribution and small scale having regional distribution.

Even though the yoghurt production procedure is fairly simple, the use of high technology can increase the efficiency of production while maintaining the quality and uniformity of the end product which is important with respect to consumer acceptance and market success. Commercial yoghurt manufactures are trying to build a persistent market for their end products. On the other hand, consumers are expecting maximum satisfaction for the money they spend. Therefore, the ultimate quality of the product is much more critical. Manufacturing procedure of commercial set yoghurt is similar with comparable production technologies. Nevertheless, the quality of the commercial vanilla flavoured set yoghurt marketed in Sri Lanka varies widely in several aspects. This could be attributable to various factors such as differences in raw materials, additives and manufacturing alternatives used. Hence, knowledge on the characteristic features of existing yoghurt is extremely important to further manipulate the production process in order to strengthen the industry and to offer a product that provides maximum satisfaction to the consumers. However, so far limited information is available on the quality aspects of set yoghurt marketed by commercial manufacturers in Sri Lanka [8]. Therefore, the main focus of this study was to characterize vanilla flavoured set yoghurt brands manufactured by large scale Island wide distributors on the basis of compositional, physical, physicochemical, textural and sensory properties. The information generated could be used by the dairy industry to understand the similarities and differences of the product from different manufacturers and to modify and further improve the product characteristics to meet consumers' criteria or expectations.

2. Materials and Methods

2.1 Set yoghurt samples

Six different commercial set yoghurt brands having island wide distribution and the highest market share were selected for the current study. Convenient sampling method was used and all the samples were purchased from 2 supermarkets in Kurunegala District, Sri Lanka. The yoghurt brands were named as Y_1, Y_2, Y_3, Y_4, Y_5, and Y_6. Care was taken to ensure that the yoghurts purchased were not closure to their expiration date; i.e. yoghurts were at the middle of their storage period. For each individual brand of yoghurt, only the packages with similar expiration date were selected to minimize possible variations.

Table 1: Main ingredients and nutritional facts* of commercial set yoghurt examined in the current study

Sample code	Main ingredients	Energetic value (Kcal /100 g)	Fat content (g/100 g)	Protein content (g/100g)	Carbohydrate content (g/100 g)	Calcium content (mg/100 g)
Y_1	Whole milk, gelatin, milk solids, flavours, sugar, yoghurt culture, INS 102, INS 122	102.5	3.1	3.6	14.8	150
Y_2	Fresh milk, gelatin, milk solids, flavours, sugar, yoghurt culture, INS 202	103	3.2	3.5	15.6	98.4
Y_3	Fresh milk, gelatin, milk solids, flavours, sugar, yoghurt culture, E 102, E 122	NA	NA	NA	NA	NA
Y_4	Fresh milk, gelatin, milk solids, flavours, sugar, yoghurt culture, E 110, E 102, E 202	103	3.0	3.7	12.0	NA
Y_5	Whole milk, gelatin, flavours, sugar, yoghurt culture	100	3.5	3.5	13.5	NA
Y_6	Fresh milk, gelatin, milk solids, sugar, flavor, yoghurt culture, INS 202, INS 100	102.8	3.1	3.6	14.8	NA

* Declared on the label All the purchased samples were transported to the laboratory by carefully placing them in an insulated box with ice packs. They were stored in a refrigerator maintained at 4±1°C throughout the testing period. The study was repeated three times. Table 1 shows the main ingredients and nutritional facts declared on the label of the commercial set yoghurt brands.

2.2 Proximate composition

The samples were well mixed and analyzed in triplicate to determine the proximate composition. Total solid content was determined by oven dry method [9]. Roese-Gottileb method was used to determine the fat content with some modifications as described in AOAC official methods of analysis [9]. Protein content was determined according to the method given by International Dairy Federation [10] and ash content by igniting the solid materials at 600°C in an electric muffle furnace [9]. Total carbohydrate content of the yoghurt samples was calculated by difference method {Carbohydrates % = TS% – (Fat % + Protein % + Ash %)}.

2.3 Physicochemical and physical properties

PH and Titratable acidity

Yoghurts (at half aged of their shelf life) were subjected to pH measurements by using a bench top pH meter (Agilent, 3200P) at 25°C after calibration with fresh pH 4.0 and 7.0 standard buffers. Titratable acidity (TA) was determined after thoroughly mixing the yogurt sample with 10 mL of warm distilled water and titrating with 0.1 N NaOH using 0.5 % phenolphthalein indicator.

Spontaneous whey syneresis

Aspiration method [11] was used to determine the spontaneous whey syneresis in undisturbed set yoghurt samples. Samples were taken out from the refrigerator (4±1°C) and weighed using an analytical balance. Then the samples were kept at approximately 45° angle for 2 h to allow the whey on the surface to gather on the side of the cup. Collected whey was drawn out by a needle connected to a graduated syringe and final weight of the yoghurt was taken. Spontaneous whey syneresis was expressed as a percentage of whey weight over the initial weight of the yoghurt (by deducting the cup weight).

Water holding capacity

Water holding capacity was determined using centrifugation method [12] with slight modifications. Ten grams of samples from each yoghurt brand were measured into pre-weighed centrifuge tubes and subjected to centrifugation at 1500×g for 10 min at 4°C. Weight of the expelled whey was recorded. Water holding capacity was calculated by using the following equation

$$\text{WHC}(\%) = \frac{\text{Weight of the native yoghurt} - \text{Weight of the discarded whey}}{\text{Weight of the native yoghurt}} \times 100 \quad (1)$$

Instrumental colour

Color of the set yoghurt samples were determined by using Lovibond Chroma meter (LC 100, RM 200). Samples were kept in ambient conditions for 30 min and then lids were removed. Chroma meter was placed on the surface of the yoghurt closer enough to get the readings and surrounding was covered to reduced disturbance by the ambient light. Care was taken not to touch the sample by the instrument while taking the readings. The color was expressed according to CIELAB system which measures the *L*, *a* and *b* values of the samples. *L* value indicates the lightness of the sample and it ranges from 0 to 100. A positive *a* value indicates the redness and negative *a* value indicates the greenness of the object. Similarly, *b* value represents the color ranging from yellow (+) to blue (-) [13].

Texture profile

The texture profiles of the selected yoghurt brands were analyzed in intact samples, which remained inside retail packages, to avoid any damages or alterations for the structure of the yoghurt gel. Texture profile analysis was implemented with a Brookfield CT3 texture analyzer (CTV 1.8 USA). This method was performed with slight modification of the method used previously [14]. The load cell was 4500 g and two sequential compressions were used with a cylindrical probe (25.4 mm diameter & 35 mm length). The probe penetrated 10 mm of the sample with 2 mm/s of pretest speed and 1 mm/s test speed. The texture profile was analyzed by exponent software which gives ultimate texture profile curves (force vs. time) of commercial yoghurts. To express the texture of yoghurt gels, following parameters were obtained; Hardness (maximum force in the first compression cycle), cohesiveness (inner gel strength i.e. A2/A1), adhesiveness (representing the work to pull the cylindrical probe i.e. based on A3), gumminess (product of hardness and cohesiveness) and chewiness (product of hardness, cohesiveness and springiness). Fig.1 shows the typical texture profile curve generate by a texture analyzer [15].

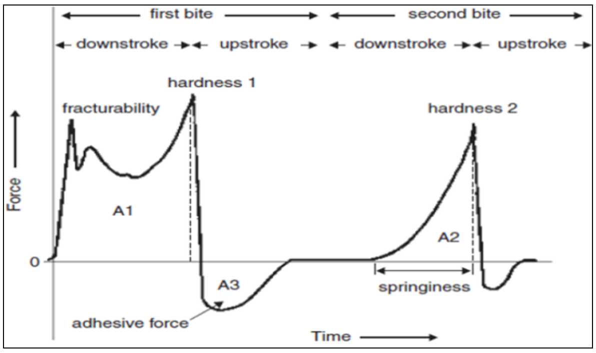

Fig 1: Typical texture profile curve generated by the texture analyzer [15]

2.5 Sensory evaluation

Sensory evaluation of the yoghurt brands were carried out by using untrained panel of 30 judges aged between 25 – 45 years old. Non-smoking healthy adults were selected from the Faculty of Agriculture premises, Mapalana for the sensory evaluation. Six individual sensory booths were prepared with supplements of samples, drinking water to wash off the mouth and evaluation sheet. The place was well ventilated and ample lightning was provided to eliminate disturbances from nuisance odors and inefficient light condition, respectively. Samples were kept 30 min in ambient conditions before serving for the panelists [16]. Six separate cylindrical cardboard containers/covers for each sensory booth were used to hide the brand names of the commercial samples and all the samples were labeled with random 3 digits. Panelists were advised to evaluate samples in quick manner but not in a hurry. Twenty minutes were provided for each panelist to complete the evaluation [16]. The sensory evaluation sheet used in the current study was prepared, so that the fuzzy decision making model could be used in the analysis.

2.6 Statistical analysis

Complete Randomized Design was used. The analysis of variance (ANOVA) procedure was carried out using SPSS ver. 20. When treatment effects were observed to be significant ($p<0.05$), means were separated using Turkey's test. Analysis of the sensory data was carried out by fuzzy logic modeling using MATLAB computer software.

3. Results and Discussion

3.1 Proximate composition and physicochemical properties of yoghurt

Table 2 shows the proximate chemical composition and the physicochemical properties of commercial vanilla flavoured set yoghurt brands tested. Significant ($p<0.05$) variations were observed in all the compositional parameters namely TS, protein, fat and total carbohydrate except ash percentage among the tested brands.

Table 2: Compositional and physicochemical properties* of commercial vanilla flavoured set yoghurt brands

Parameter	Commercial yoghurt brand					
	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
Composition (%)						
TS	21.32±0.44[a]	21.39±0.09[a]	22.80±0.10[b]	21.76±0.17[a]	22.36±0.16[b]	21.48±0.14[a]
Protein	3.80±0.08[bc]	3.61±0.17[ab]	4.06±0.09[c]	3.75±0.15[bc]	3.34±0.17[a]	3.75±0.14[bc]
Fat	3.05±0.74[ab]	3.02±0.53[ab]	3.25±0.60[c]	3.12±0.78[bc]	2.87±0.81[a]	3.07±0.15[ab]
Ash	0.72±0.01	0.87±0.95	0.76±0.09	0.83±0.06	0.83±0.09	0.85±0.06
Carbohydrate	14.14±0.28[a]	14.20±0.30[a]	15.10±0.46[bc]	14.13±0.37[a]	15.45±0.46[c]	14.28±0.33[ab]
Physicochemical properties						
pH	4.12±0.00[b]	4.03±0.04[a]	4.08±0.06[ab]	4.02±0.02[a]	4.10±0.01[ab]	4.03±0.00[a]
Titratable acidity (%LA)	1.03±0.01[a]	1.01±0.28[a]	1.15±0.00[c]	1.12±0.05[c]	1.07±0.01[b]	1.22±0.02[d]

* Mean ± SD of 4 replicates [a, b, c, d] Mean ± SD not sharing the same superscript in each row differ significantly (P<0.05).

Total solids percentage of Y_3 was observed to be the highest followed by Y_5 and were significantly ($p<0.05$) higher compared to the values observed in other yoghurt brands. The lowest TS percentage was observed in Y_1 and was fluctuated between 21.32±0.44-22.80±0.10% in the tested commercial yoghurt brands. Similarly, protein and fat percentages were also observed to be the highest in Y_3 and the values were 4.06±0.09 and 3.25±0.60%, respectively. According to the Sri Lanka Standards Institution (SLSI) requirements [17], the minimum fat percentage of yoghurt should be 3.0% and minimum milk solid nonfat percentage should be 8.0% and hence, the minimum TS would be 11.0%. All the tested brands of yoghurt satisfied SLSI requirements with respect to milk fat except brand Y_5, which was having 2.87±0.81% (Table 2), even though it is declared on the label as having 3.5% of fat (Table 1).

National and international standards are available for the minimum protein percentage of yoghurt e. g. minimum 2.7% [17, 18]; minimum 3.2% [19]. It was observed that all the tested commercial brands of yoghurt were having satisfactory level of protein percentage (>3.2%) that comply with national and international standards. Total carbohydrate % was observed to be the lowest in Y_4 while the highest in Y_5 and the variations observed could be due to different levels of additives, especially the sugar used in the manufacturing process. The ash% did not show any significant ($p>0.05$) deference among the tested yoghurt brands. The deviations in the values of compositional parameters may be due to the different raw materials and the levels used in standardization of the yoghurt mix by each manufacturer. Previous studies showed that the composition of yoghurt is highly depending on the type of milk and the processing conditions used in the manufacturing process [20, 7]. Apart from that, several authors agreed that the variations exist in the composition of commercial yoghurts [21, 22, 23].

Titratable acidity of tested commercial brands of yoghurts observed to be significantly ($p<0.05$) different and were between 1.03±0.01 - 1.22±0.02, where the highest TA was reported by Y_6 (Table 2). The acidity of yoghurt is a consequence of lactic acidification obtained at the end of the incubation and post acidification during the storage [24]. Conversion of lactose in to simple sugars and then to lactic acid by the starter culture microorganisms (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus)* used in the manufacturing process of yoghurt leads to the lactic acidification. There are numerous standards regarding the titratable acidity of yoghurts. According to the general standards for identity of fermented milk given by International Dairy Federation [25], final titratable acidity of a yoghurt should be 0.7% LA where as 0.9% LA is required according to Code of Federal Regulations of Food and Drug Administration [26] in Washington. Food Safety and Standard Authority in India [19] assigned to have titratable acidity of 0.85% to 1.2% LA during the storage of yoghurt. Apart from that, Codex Standards for fermented milks given by Food and Agriculture Organization [18] stated that yoghurt should have minimum titratable acidity of 0.6 expressed as percent lactic acid. In local context, it is recommended to have 0.8 to 1.25 percent lactic acid for yoghurts [17]. Tested brands of yoghurts were in the middle of their storage and the post acidification due to the continuous production of lactic acid by yoghurt starter microorganisms even under refrigerated storage conditions could be the reason for the observed higher acidity values as reported by several authors [24, 27, 28] in the past. The lactic acidification is influenced by various factors such as quality of the milk used [29], the starter culture strains and stain associations and incubation temperature used [24]. Post acidification is influenced by the storage temperature, storage time and the final fermentation pH [24]. Significant variations observed in the titratable acidity of the tested commercial yoghurt brands could be due to the above mentioned reasons. However, the values were within the acceptable level according to Sri Lankan Standards [17].

Reduction of pH of yoghurt is due to the increase of acidity. The pH of milk decreases towards the Iso-Electric Point of casein, 4.6 with the continuation of the lactic acid production. At this pH, milk starts to coagulate making a firm curd. This is because of the increase of the casein-casein attractions due to increased hydrophobic and electrostatic charge interactions [30]. Due to the acidification process, three dimensional network consisting of clusters and chains of caseins are formed [31]. According to SLSI requirements, yoghurt should have a pH of 4.5 [17]. It was observed that in all the commercial brands of yoghurt tested had less than pH 4.5 and were between 4.02±0.02 and 4.12±0.00 (Table 2). The highest pH was reported by Y_1 where as the lowest by Y_4. Significant ($p<0.05$) differences were observed in the pH of some of the tested yoghurt brands. Clear relationship was not observed between the TA and pH of yoghurts. The observed low pH values in commercial yoghurts could be attributable to the continuation of starter microbial activity during the storage of yoghurt. Increase of the acidity and the reduction of pH give yoghurt its characteristic tart flavor along with a preservative action [32].

3.2 Physical properties

Water holding capacity and whey syneresis

Water holding capacity is considered as an important physical parameter related to set style yoghurt. Water holding capacity is a measure of ability to retain water in the body of a yoghurt. Highest water holding capacity was reported by Y_3 (89.01±1.29%) which was observed to be significantly ($p>0.05$) different from other 5 brands. More than 14% higher WHC was observed in Y_3 compared to the brand Y_5 which was having the lowest WHC.

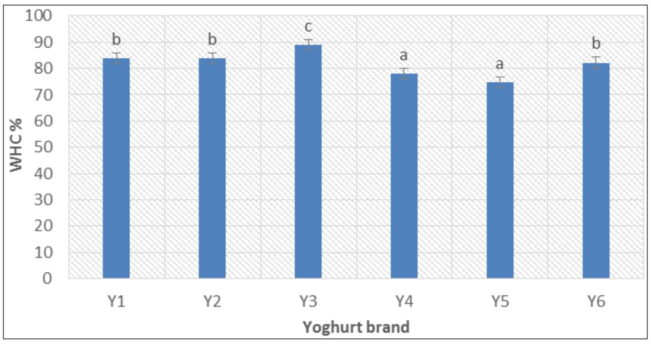

Fig 2: Water holding capacity of commercial vanilla flavoured set yoghurt brands

Water holding capacity of yoghurt can differ due to several factors such as origin of milk, homogenization procedure specifications, total solid content, protein and fat content, source of protein, selection of starter culture (either ropy or non-ropy) and processing conditions [33, 34] etc. Therefore, the significant ($p<0.05$) variations of the observed values of WHC of commercial yoghurts can be due to the differences in the ingredients and the manufacturing procedures used. The lowest WHC observed in yoghurt brand Y_5 can be associated with the lowest fat and protein content as shown in the table 02. Higher WHC is beneficial since it seems to reduce the whey syneresis which is an important aspect with respect especially to set yoghurt quality.

Syneresis or whey separation is considered as a defect in set yoghurt [35]. Syneresis is the extraction or expulsion of liquid from a gel [36]. Controlling of whey syneresis in set yoghurt is commonly achieved by fortification of yoghurt mix with skimmed milk powder and various other methods such as, addition of ultrafiltered skim milk retentate [37], whey protein concentrates [38], whey protein isolates [39] use of specialized starter cultures [11], different stabilizing agents [40, 41] etc. as reported in previous studies. Spontaneous whey syneresis measured in undisturbed yoghurt is almost negligible in all the commercial brands tested. Application of various methods to control whey syneresis by commercial yoghurt manufacturers including addition of milk solids and gelatin as declared on the label (Table 1) could be attributable for this observation.

Instrumental color

Colour plays a significant role in food choice and food acceptance by the consumers. Tested commercial brands of vanilla flavoured set yoghurts showed a significant ($p<0.05$) variation with respect to instrumental colour parameters as shown in the Table 3. Highest L (lightness) value was observed in the brand Y_6, whereas the lowest in Y_3. However, all the yoghurt brands can be considered as light because, the L values observed in the studied commercial yoghurts were greater than 50 [42].

Table 3: Instrumental colour of commercial vanilla flavoured set yoghurt brands

Commercial yoghurt brand	*L**	*a**	*b**	Hue angle	Chroma value
Y_1	79.30 ± 0.72^c	0.76 ± 0.05^b	17.13 ± 0.57^f	87.40 ± 0.36^e	17.26 ± 0.06^f
Y_2	82.36 ± 0.32^d	4.16 ± 0.20^f	12.10 ± 0.10^c	71.70 ± 0.10^a	12.46 ± 0.23^c
Y_3	75.23 ± 0.41^a	1.30 ± 0.00^c	15.13 ± 0.15^d	85.30 ± 0.26^d	15.20 ± 0.10^d
Y_4	78.16 ± 0.50^{bc}	1.70 ± 0.00^d	16.70 ± 0.00^e	84.23 ± 0.57^c	16.66 ± 0.11^e
Y_5	77.23 ± 0.25^b	2.13 ± 0.05^e	9.53 ± 0.05^b	77.83 ± 0.57^b	9.56 ± 0.11^b
Y_6	83.00 ± 0.10^d	-0.76 ± 0.05^a	7.76 ± 0.05^a	95.56 ± 0.57^f	7.76 ± 0.05^a

Mean±SD of 3 replicates a, b, c, d, e, f Mean ± SD not sharing same superscript in each column differ significantly ($P<0.05$)

Highest redness (a*) and yellowness (b*) values were observed in Y_2 and Y_4, respectively. Further, brand Y_6 showed a negative a* value indicating its greenish colour. According to the label information given (Table 1), commercial yoghurts were added with permitted food colours such as INS 100 (curcumin), INS 102 (tatrazine), INS 122 (Azorubine), E 110 (sunset yellow) etc. and preservatives (INS 202). However, commercial brands Y_2 and Y_5 were not reported with added food colours according to the label information given. Even though, yoghurt brand Y_3 having lowest lightness value obtained the highest consumer preference according to the fuzzy logic modeling, a clear relationship was not observed in between the colour parameters and the acceptability of yoghurts by the consumers. Other quality parameters such as texture, absence of whey syneresis, good flavour etc. is equally important for the consumer acceptability of set yoghurt.

Textural attributes

Texture is an important indicator for set yoghurt quality. Yoghurt texture can be evaluated by a sensory panel as well as instrumentally. However, sensory evaluation of texture is a subjective method and depends greatly on the evaluator unless extensive training is provided. Currently, instrumental texture analysis is extensively used due to the feasibility, reliability of the results, cost effectiveness and time saving. Texture is defined primarily as the response of the tactile senses to physical stimuli that result from contact between some part of the body and the food [15]. Simply, texture profile analysis is a process which imitates the physical breakdown of the food material inside the mouth. Hardness at cycle 1 and 2 represent the hardness of two bites inside the mouth during the consumption of the product [15].

Table 4 shows the results of the texture profile analysis of commercial brands of vanilla flavoured set yoghurts. Mentioned texture parameters have been chosen in order to interpret a meaningful results related to the nature of the product. Significant ($p<0.05$) variations were observed in texture parameters of commercial vanilla flavoured set yoghurt brands except adhesiveness and cohesiveness (Table 4).

Table 4: Textural attributes of commercial vanilla flavoured set yoghurt brands

Texture parameter	Commercial set yoghurt brand					
	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
Hardness (g) at Cycle 1	233.3 ± 2.3^a	210.0 ± 1.0^a	85.0 ± 1.8^b	166.7 ± 2.9^a	170.0 ± 2.7^a	188.3 ± 1.6^a
Adhesiveness (mJ)	3.1 ± 1.3^a	3.4 ± 1.0^a	2.0 ± 1.2^a	2.8 ± 1.3^a	2.6 ± 0.5^a	2.7 ± 1.8^a
Hardness (g) at Cycle 2	173.3 ± 1.6^c	175.0 ± 1.0^c	61.7 ± 0.8^a	125.0 ± 0.5^b	148.3 ± 1.2^{bc}	148.3 ± 0.3^{bc}
Cohesiveness	0.4 ± 0.3^a	0.4 ± 0.04^a	0.4 ± 0.1^a	0.4 ± 0.1^a	0.4 ± 0.2^a	0.4 ± 0.2^a
Gumminess (g)	98.3 ± 1.7^b	87.5 ± 1.4^b	31.1 ± 1.9^a	61.3 ± 1.6^{ab}	100.0 ± 2.3^b	84.3 ± 2.2^b
Chewiness (mJ)	9.1 ± 1.6^b	8.5 ± 1.5^b	2.8 ± 0.9^a	5.7 ± 1.7^{ab}	8.1 ± 1.8^b	6.5 ± 2.8^{ab}

Mean±SD of 4 replicates a, b, c Mean ± SD not sharing same superscript in each row differ significantly ($P<0.05$)

Hardness is the most important parameter for evaluation of yoghurt texture which is regarded as the force required to attain a certain deformation and is considered as a measure of firmness of the yogurt [43]. Significantly ($p<0.05$) less hardness value was observed in the commercial yoghurt brand Y_3, which is mostly accepted by the sensory evaluation panel. When the tested yoghurt composition is concerned, Y_3 had the highest amount of total solids, proteins and fat (Table 2). Previous studies reported that the sensory and texture properties of cultured milk products are positively influenced by the fat content [44, 45, 7] even though the protein has a negative effect at higher levels [37]. Therefore, it can be stated that, high fat (comply with SLS) level of Y_3, compared to the other commercial brands, could be positively contributed to have a consumer preferred smooth textured set yoghurt.

3.3 Sensory evaluation

According to fuzzy logic modeling process results, highest similarity values for commercial brands Y_1, Y_2, Y_3, Y_4 and Y_6 has been reported under scale factor 'Good', as shown in the Table 5 and therefore, overall sensory quality of those brands could be considered as 'Good'. The commercial brand Y_5 has been categorized in to 'satisfactory' category according to similar reasoning. As shown in the Table 5, according to the similarity values, order of ranking of commercial vanilla flavored set yoghurt brands were $Y_3 > Y_1 > Y_6 > Y_2 > Y_4 > Y_5$, respectively.

Table 5: Similarity values of quality attributes of commercial set yoghurt brands obtained through sensory evaluation

Scale factor	Similarity values of commercial set yoghurt brands					
	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
Not satisfactory	0	0	0	0	0.0287	0
Fair	0.0770	0.1475	0.0849	0.1844	0.3902	0.1176
Satisfactory	0.4696	0.6293	0.0760	0.7154	1.0966	0.5650
Good	0.9697	0.9411	0.9754	0.9019	0.8468	0.9416
Very good	0.7573	0.5290	0.7762	0.3767	0.0414	0.5686
Excellent	0.2167	0.0709	0.3336	0.0307	0	0.0814

Fuzzy logic modeling has been employed for the sensory evaluation of commercial food products such as Jam [46], mango drinks [47], coffee products [48] etc. successfully during the past.

3.4 Correlations observed
Hardness showed a negative correlation (R^2 = 0.513) with the overall sensory score of the commercial yoghurt brands. Accordingly, yoghurt brand Y_3 which is having lowest hardness showed the highest acceptability. Even though the relationship was not so prominent, it could be considered in product improvements. Measurements of physical properties such as texture, guides in predicting the sensory attributes of a product [15]. Based on these measurements, the process and/or the formula for a given product may be changed in order to produce a finished product that falls within the range of textural parameters that can establish acceptable sensory quality to the consumer. Sometimes these measurements are employed to establish a quality grade used to set a price for the product. When considering about a product like set yoghurt both sensory and textural properties are equally important in the perspective of consumer acceptance [49]. Hence, above revealed relationship is needed to be prioritized in production process of set yoghurts. Apart from that, a Strong negative correlation (R^2=0.791) was observed between sensory score and the storage period of set yoghurts, which indicate the freshness of yoghurt as an important factor even though it is within its shelf life. This is supported by the conclusions made in a previous study [50] regarding sensory acceptability of yoghurts over the storage period and storage temperature. According to them, this sensory acceptability behavior is exhibited due to development of undesirable characters of the product during storage period.

4. Conclusion
Commercial vanilla flavoured set yoghurts examined in the current study showed considerable variations with respect to composition, physicochemical, physical and sensory characteristics. Spontaneous whey syneresis, which is considered as a major defect in set yoghurt was observed to be negligible in any of the tested commercial yoghurt brands. Highest water holding capacity and lowest instrumental hardness value was reported by brand Y_3 which is having the highest sensory acceptability according to the fuzzy logic modeling. All the yoghurt brands except one was comply with SLSI standards with respect to the fat content. Overall sensory score of yoghurt brands has a significant (*$p<0.05$*) negative correlation with instrumental hardness (R^2 = 0.513) and storage period (R^2 = 0.791). The ranking of the yoghurts according to the overall sensory score were $Y_3 > Y_1 > Y_6 > Y_2 > Y_4 > Y_5$.

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