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RHEOLOGICAL, TEXTURAL, COLOR AND PHYSICO-CHEMICAL PROPERTIES OF SOME YOGURT PRODUCTS FROM THE SPANISH MARKET

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Abstract: *Yogurt is nowadays one of the most consumed fermented milk products in the world due to its benefits for the human body. The purpose of this work is to study the rheological, textural and color aspects of different types of yogurts from the Spanish market. For this study, two types of yogurt, blank yogurt and fruit yogurt respectively were selected; five samples for each type, each one with different concentration of total soluble content, fat content, protein and sugar content were analyzed. The study shows the existence of some correlations between some physico-chemical and textural parameters, so the highest adhesiveness and cohesiveness are reached by the sample with 10% fats, while the tension parameter is the highest for the sample with the lowest concentration of sugars, and the highest firmness is reached in the sample with the lowest concentration of fats. The color parameters are influenced by the presence of the food colorants, and their nature. The PCA made provides some explanation on the two components of 100% of the total variance and it was observed that the 2 types of yogurt are situated in different groups. The analysis of variance (ANOVA) conducted revealed that considering that a higher value of F-ratio means a more noticeable effect of the factor (type of yogurt) in a variable, the parameters tone and a^* were more distinguished by the type of yogurt.*

Keywords: yogurt, viscosity, consistency, luminosity, water activity

1. Introduction

Yogurt is produced by a fermentation process during which a weak protein gel develops due to a decrease in the pH of the milk. The pH of the milk is decreased due to the conversion of lactose to lactic acid by the fermentation culture bacteria. In the liquid milk, casein micelles are present as individual units. As the pH reaches pH 5.0, the casein micelles are partially broken down and become linked to each other under the form of aggregates and chains forming part of a three-dimensional protein matrix in which the liquid phase of the milk is immobilized.

This gel structure contributes substantially due to the overall texture and organoleptic properties of yogurt and gives rise to shear and time dependent viscosity [1].

Texture is one of the most important attributes used by consumers to assess food quality. Texture is one of the main characters that define the quality of yogurt. The most frequent defects related to yogurt texture that may lead to consumer rejection are apparent viscosity variations and the occurrence of syneresis [2].

Yogurt rheological characterization is required for product and process development and to ensure consumer acceptability [3]. This characterization can be made using either instrumental or sensory measurements.

The firmness of yogurt and the viscosity of just-stirred gel are greatly influenced by the amount of heat treatment the yogurt mix receives. Heating unfolds the globular whey proteins and exposes sulphydryl groups, which react with other sulphydryl groups and disulfides and induce linkages and protein-casein aggregates [4, 5].

The gel strength of yogurt is related to the cumulative effects of the chemical interactions. The binding of β-lacto globulin to the casein micelle seems to be responsible for the increase of gel strength [6, 7, and 8].

The purpose of this paper is to make a statistical analysis of the yogurt samples from the Spanish market keeping into account physico-chemical, rheological, textural and color parameters using ANOVA and PCA analysis, and to notice which parameters make the difference.

2. Materials and methods

2.1. Materials

For this study eight samples of yogurt were purchased from the Spanish market: sample 1 –Hacendado griego, sample 2 – Hacendado cremoso natural, sample 3 – Hacendado yogur natural, sample 4 – Hacendado sin grasa, sample 5 – Danone densa, sample 6 –Hacendado fresa 0% grasa, sample 7 –Activia con fresa, sample 8 – Hacendado yogur cremoso con fresa. The samples were divided into two main categories: natural yogurt (blank samples) and fruit yogurt, respectively. The samples had different physical chemical composition (different concentrations of sugar content, fat content and protein content, respectively).

2.2.Chemical analysis

Yogurts were analyzed for protein by the Kjeldahl method (SR ISO 17837:2009), fat by gravimetric method (SR EN ISO 1736:2009).

2.3. Color measurement

The color measurement was achieved with a Konica Minolta spectrophotometer CM 3500 d (Konica Minolta Business Technologies, Inc. Japan). The samples were fitted in plastic flask with 3.8 cm height and 6 cm diameter. To measure the reflected light, a diagram of 8 mm is opened. The reflection specters are registered and the CIELab parameters are calculated at a 100 angle, using the D65 light: L*(luminosity, between 0[black], at 100 [white]), a*(+a*[red], -a* [green]), b*(+b*[yellow], -b*[blue]) and h* [tone].

The color intensity C* is calculated with:

$$C^{*}=(a^{2}+b^{2})^{0.5} \qquad (1)$$

2.4. Texture

Yogurt samples were carefully scooped into acrylic cylindrical containers (70mm diameter 80mm height) with the help of a spatula to a depth of 50 mm.

Yogurt texture measurements were carried out with a Stable Micro Systems Texturometer model TA-XTplus (Texture Technologies Corp., White Plains, New York) with a 5 kg load cell.

A combination of back extrusion and texture profile analysis (TPA) was used. A 35mm diameter solid rod (A/BE35) was thrust into the cylindrical containers holding the test sample, so that the fluid flew upwards through the concentric annular space.

All determinations were carried out in duplicates. The positive area represents the consistency; the positive force represents the firmness, while the negative force and negative area represents the cohesiveness and the index of viscosity, respectively.

2.5. Rheological measurement

Viscosity measurements were carried out on the yogurt samples at room temperature (20^0C), with Haake RheoStress 1 rheometer, with control thermo bath, with a coaxial cylinder system. All the data were transformed using linear regression with the Herschkel Bulkley model:

$$\tau = \tau_0 + K \cdot \gamma^n \qquad (2)$$

where: τ- shear stress, Pa, τ_0 – coefficient, K – consistency, Pa·s^n, γ – shear rate, s^{-1}, n – flow index.

2.6. Water activity

The water activity of the yogurt samples was performed using the Fast Lab 2 water activity meter.

2.7. pH measurement

pH measurements were made with a Metler Toledo pH.-meter, at 20^0C.

2.7. Statistical analysis

An analysis of variance (ANOVA) (α=0.05) with least significant difference (LSD) test using Statgraphics Plus 5.1 was made for the data of physico-chemical, rheological, textural and color parameters. In addition to this, the data were analyzed by using multivariate techniques, applying the software Unscramble version 10.1 (CAMO Process AS, Oslo, Norway, 2005). The variables were weighted with the inverse of the standard deviation of all objects in order to compensate for the different scales of the variables. A Principal Components Analysis (PCA) was applied to describe the relation among the chemical, rheological, textural and color parameters.

3. Results and discussion

The samples submitted to this study presented a fat level between 0.1 and 10%, respectively, proteins between 3.3 and 5.2% respectively and sugar 3.90-17.10%. The pH value was in the acid region, while the water activity was ranged between 0.98-0.99.

The yogurt is a complex non-Newtonian fluid with a great quantity of water which influences the rheological and textural behavior. The different concentration of proteins, fats, sugars generated different rheological and textural data set.

The rheological data were transformed using the Herschkel Bulkley model, suitable for this type of fluid (R^2 of the model was between 0.95-0.99). The viscosity ranged between 0.35 and 0.90 Pa·s, respectively.

The sample with the highest content of fat exhibited the highest viscosity, while the samples with the highest content of sugars presented the lowest level of viscosity. The samples of fruit yogurt seem to have the same viscosity due to the presence of

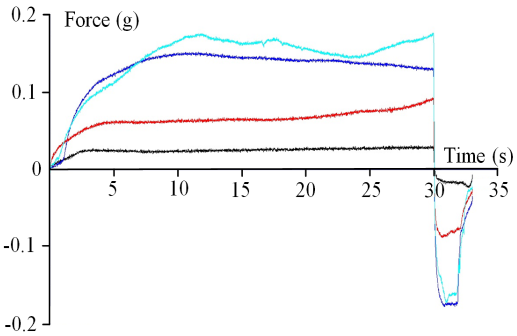

Fig.1. Textural profile of blank yogurt samples: black line sample 1, dark blue line sample 2, red line sample 3 and blue line sample 4

hydrocolloids used to stabilize fruit in the yogurt. The flow index, n, has an interesting evolution; it ranges between 0.04 and 0.6, placing yogurt in the class of the pseudo plastic fluids.

The sample with the highest content of fats and fat free samples presented the lowest flow index, while the fruit ones presented the highest flow index. The consistency index, K, is greater for the samples with a lot of fats or without fats, while the samples with fruits presented the lowest index.

The texture is a property of the foods that always is related to a chemical physical system that is a colloidal system formed by two non-miscible phases. In the figures 1 and 2 the textural grams of the yogurt samples subjected to the study are presented.

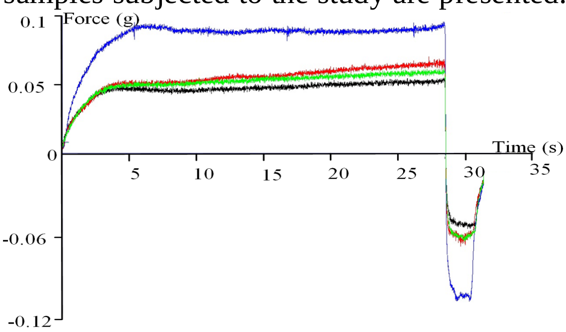

Fig.2 Textural profile of fruit yogurt samples, dark blue line sample 5, blue line sample 6, red line sample 7 and green line sample 8

It can be seen that in the case of blank samples, each one having a different textural behavior, while in the case of fruit yogurt there are three samples which do not have great differences in their behavior. That phenomenon could be generated by the presence of the same hydrocolloid in the composition of yogurt.

The textural parameters of the yogurt samples analyzed ranged in a large spectrum; adhesiveness from 0.05 to 0.35 g, cohesiveness from 0.79 to 3.90 g, tension from 0.01 to 0.05 g and firmness from 0.06 to 0.31 g.

It seems that there are some correlations between some physico-chemical parameters and textural ones, so the highest adhesiveness and cohesiveness is reached by the sample with 10% fats, while the tension parameter is the highest in the sample with the lowest concentration of sugars, and the highest firmness is got in the sample with the lowest concentration of fats.

The yogurt color was measured in the sense of lightness, red-green axis a^*, yellow-blue axis b^*, tone and color intensity. The lightness L^*(91.15) of the black samples are influenced by the content of fats, so the high lightness is achieved by the samples with the high percentage of fats, while the rest of the samples have the same level of this parameter. In the case of the fruit yogurt samples, the yogurt with 0.1% fat has the lowest level of lightness, while the fruit samples which have in their compositions anthocyans have the highest level of lightness (81.79). The samples with fruit have lower lightness than the blank yogurt due to the presence of food colorants (carmine and anthocyans).

Table.1
Physico- chemical, rheological, textural and color ANOVA of the yogurt samples

	Yogurt type		F ratio
	Blank (SD)	**Fruit (SD)**	
Physico- chemical parameters			
Proteins [g/100g]	3.95a(0.57)	4.5a(0.60)	4.58ns
Fats [g/100 g]	4.1a (3.70)	1.82a (1.14)	2.53ns
Sugars g/100 g]	5.8b (4.44)	12.05a (4.90)	7.82*
Fruits [g/ 100g]	0b (0)	7.35a (3.83)	29.4***
pH	4.21a (0.08)	4.26a (0.04)	2.08ns
a_w	0.87a (0.30)	0.98a (0)	0.9ns
Rheological parameters			
Viscosity [Pa·s]	0.51a (0.23)	0.54a (0.14)	0.11ns
n, flow index	0.18a (0.1)	0.37a (0.16)	2.82ns
K, consistency index [	166.53a (40.2)	16.23a (4.49)	4.59ns
Color parameters			
L* (Luminosity)	89.9a (3.87)	78.64b(3.11)	99.08***
a* (red-green axis)	-2.14b (0.51)	9.29a (2.3)	187.14***
b* (yellow-blue axis)	8.12a (2.14)	4.55b (1.96)	22.71***
C*(color intensity)	8.4b (1.35)	10.58a (1.70)	10.14**
h*(tone)	104.58a (31.37)	27.26b (13.24)	263.13***
Texture parameters			
Adhesiveness	0.22a (0.13)	0.17a (0.04)	1.39ns
Cohesiveness	2.74a (1.36)	1.84a (0.45)	3.09ns
Tension	0.018a (0.02)	0.006a (0)	2.67ns
Firmness	0.19a (0.09)	0.07b (0.02)	12.33**

Note: NS not significant (P<0.05), * P>0.05, ** P>0.01, *** P>0.001

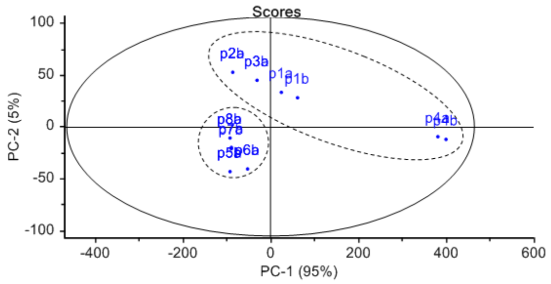

Fig.3 PCA scores of yogurt samples

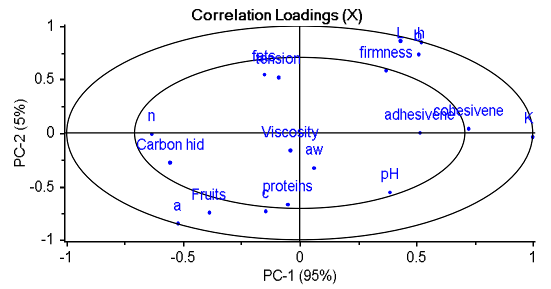

Fig.4 PCA loadings of the yogurt samples

In the case of a*, the blank samples are situated in the negative region (more towards green), while the fruit sample on the positive region (more towards red) due to the presence of red colorants. All the b* samples are situated in the positive region (more towards blue). The tone of the samples is higher for the blank samples without colorants, while color intensity is higher for the colored samples.

A PCA was conducted to evaluate the global effect of the type of yogurt (blank, fruit) on the physical chemical, textural, rheological and color, from a descriptive point of view. Figure 3 shows the sample scores and compound loadings of the PCA analysis performed. It was found, that two principal components (PCs) explained 100% of the total variance in the data set.

The PC1 explains 95% of the total variance and the PC2 explains 5%, one representing the fruit yogurt samples and the other one the blank samples.

The loadings of each parameter on the principal components show that the grouping of different type is primarily influenced by certain parameters. In the central ellipse the parameters (tension, fat content, adhesiveness, pH, a_w, protein content, viscosity, sugar content, flow index, firmness) could be seen which influence less the differential of the samples, while in the outer ellipse the parameters (consistency index, cohesiveness, luminosity, fruit content, a^*, b^*, tone, color intensity) with a higher influence.

In order to know if the differences observed among different yogurt types for each parameter are statistically significant, an analysis of variance (ANOVA) with one factor (type) was carried out (Table 1). It is known that if P-value from the ANOVA analysis is equal or superior to 0.05 there are not significant differences among types. Taking these differences into account for the physico-chemical, rheological, textural and color parameter and considering that a higher value of F-ratio means a more noticeable effect of the factor (type of yogurt) in a variable, tone and a^* were the parameters more affected by the type of yogurt.

4. Conclusion

The yogurt is a complex viscous food material due to the complexity of its nature and composition. Rheological behavior of yogurt is influenced by sugars, fats and water. It seems that fats and sugars have a different influence on the flow index; the fats reduced the index, while the sugars increased it. The study revealed the existence of some correlations between some respectively. There are two main differentiated groups of samples on the plot: physico- chemical parameters and textural parameters, so sugars and fats influenced more. The color parameters are influenced by the presence of the food from fruit addition, e.g. anthocyans, and its nature.

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