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INFLUENCE OF CITRUS FIBRE ADDITION ON TEXTURAL AND RHEOLOGICAL PROPERTIES OF YOGURT

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Abstract: *The aim of this study is to evaluate the influence of citrus fibre addition (0, 0.25, 0.5 and 1%, respectively) on the textural and rheological properties of yogurt samples (7.5% dry matter, 10% dry matter and 12.5% dry matter). The rheological properties of the samples were investigated using a Brookfield viscometer, while the textural properties were measured using a Mark-10 texture-meter. The textural properties analysed were: hardness (H), cohesiveness (Co), springiness (S), gumminess (G) and chewiness (Ch). The principal component analysis was conducted based on the dry matter content, fibre content and rheological (viscosity) and textural properties (hardness (H), cohesiveness (Co), springiness (S), gumminess (G) and chewiness (Ch)) using Unscrambler X 10.1 (CAMO, Norway). The two components (PC1 and PC2) explained 100% of the variations in the data set. It can be observed that the samples were placed into three main different groups based on the dry matter concentration.*

Keywords: *yogurt, citrus fibre, physical properties, principal component analysis*

1. Introduction

Yogurt, according to the Codex Alimentarius standard for fermented milks [1], is a form of fermented milk that contains symbiotic cultures of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp.*Bulgaricus* that “shall be viable, active and abundant in the product to the data of minimum durability” [2].
The rheology, function and composition of ingredients are important for a food product engineer as well as quality control, and design of process equipment [3-5].
Dietary fiber is a common component of food products which consists of variety of polysaccharides such as cellulose, hemicelluloses, pectin, β-glucans, gums and lignin [6] and those are taken as foods due to their beneficial effects on food nutritional properties [7].
The dietary fiber are recommended to be consumed due to their significant role in the prevention, reduction and treatment of chronic diseases such as bowel, gastrointestinal disorders, obesity, diabetes, cardiovascular disease, cancer and also promoting physiological functions including reduction in blood cholesterol level and glucose attenuation [8-10].
Citrus fruits (*Citrus hystrix* and *Citrus maxima*) are one of the most consumed fruits all over the world. Citrus fruits contain vitamins (e.g. A, B and C), minerals, dietary fibers, secondary metabolites (e.g. phenolics, flavonoids, limonoids and carotenoids) [11].
The citrus fiber addition into food products have many benefits as: in the meat product will improve the oxidative stability and prolong their shelf life by preventing the lipid peroxidation due to the presence of associated bioactive compounds

*i.e.*polyphenols [12] and also decrease the residual nitrite level [13,14]. The citrus fiber products have many applications because of its neutral color, taste and odor [15].

The aim of this study is to evaluate the influence of citrus fiber addition on the rheological and textural properties of yogurt.

2. Materials and methods

Materials

Milk with different dry matters (7.5, 10 and 12.5% respectively), DI PROX 975 lactic culture and citrus fiber from Enzymes &DerivatesCostisa, Romania, were used.

Yogurt preparation

The milk sample was pasteurized and then cold up to 42 °C prior to lactic culture inoculation. The samples were kept at 42 °C till the desired pH was achieved. The citrus fiber was added into the samples in different concentrations (0, 0.25%, 0.5% and 1.0%, respectively), mixed and then kept for 24 h at 4 °C.

Rheological properties measurement

Viscosity measurements were carried out on the yogurtsamples at ambient temperature (4 °C), with a Brookfield viscometer (Brookfield Engineering Inc, Model RV- DV II Pro+) at 1, 2, 5, 10 , 20 and 100 rpm with RV spindle (RV3, RV4, RV5, RV6 type). The spindle nose was used in accordance with the sample nature to get all readings within the scale.

The samples in 300 mL of beaker with a 8.56 cm diameter (according to the Brookfield requests) were kept in a thermostatically controlled water bath for about 10 min before measurements in order to attain desirable temperature of 25^0C.

First measurements were taken 2 min after the spindle was immersed in each sample, so as to allow thermal equilibrium in the sample, and to eliminate the effect of immediate time dependence.

All data were then taken after 40 s in each sample. Each measurement was duplicated on the sample.

The obtained empirical data were converted using the Mitschka relationships to shear rate and shear stress. The shear rate versus shear stress data were interpreted using the power law expression

$$\sigma = k \cdot \gamma^n \qquad (1)$$

where:

σ – shear stress (N/m^2),

γ is the shear rate (s^{-1}),

n is the flow behaviour index, *k* is the consistency index (Ns^n/m^2).

The values for the flow behaviour index n, were obtained from plots of log shear stress versus log rotational speed; the slope of the line (if the dependence is sufficiently close to a linear one) is simply equal to the flow index of the fluid, *n*.

The shear stress is calculated using the next equation:

$$\tau_i = k_\tau \cdot \alpha_i \cdot C \qquad (2)$$

where:

τ_i – shear stress ($dyne/cm^2$)

k_τ= 0.119, this constant is for the spindle nos 2

α_i – torque dial, %

C – 7,187 dyne/cm for RV viscometer

The shear rate is calculated using the next equation:

$$\gamma_i = k_\gamma(n) \cdot N_i \qquad (3)$$

where:

γ_i – shear rate, s^{-1}

$k_\gamma(n)$– constant, depends by the value of n

N_i – rotational speed, rpm.

Texture properties measurement (TPA)

The TPA was carried out at 4 °C with Mark 10 Texture Analyzer (Mark 10 Corporation, USA) equipped with a 50 mm disc probe, the flask diameter was 70 mm. The TPA was operated at a constant speed of 150 mm/min, until a depth of 12.5 mm (the yogurt column had 25 mm). The TPA can offer a great number of texture parameters, as: hardness (H), viscosity (V), adhesion (A), cohesiveness (Co), springiness (S), gumminess (G) and chewiness (Ch) [16].

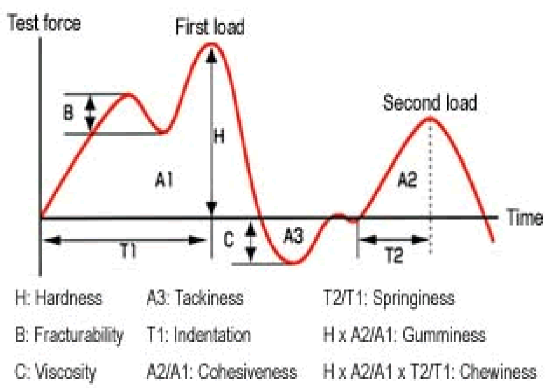

Fig.1. Texture profile [16]

Statistical analysis

The principal component analysis has been made up using the Unscrambler X 10.1 software (Camo, Norway).

3. Results and discussions

The rheological and textural parameters of the 12 samples are presented in Table 1. In Figure 2 is presented the viscosity evolution of a yogurt sample with shear rate. It can be observed a pseudoplastic evolution of the viscosity (the viscosity is decreasing with the increasing of the shear rate). In figure 3 is presented the texture profile of one yogurt sample.

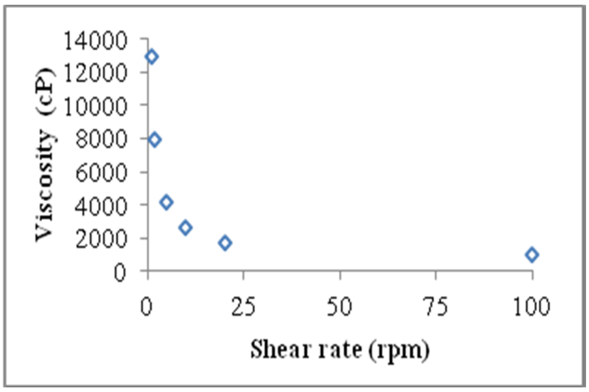

Fig.2. Yogurt sample rheological profile (P9)

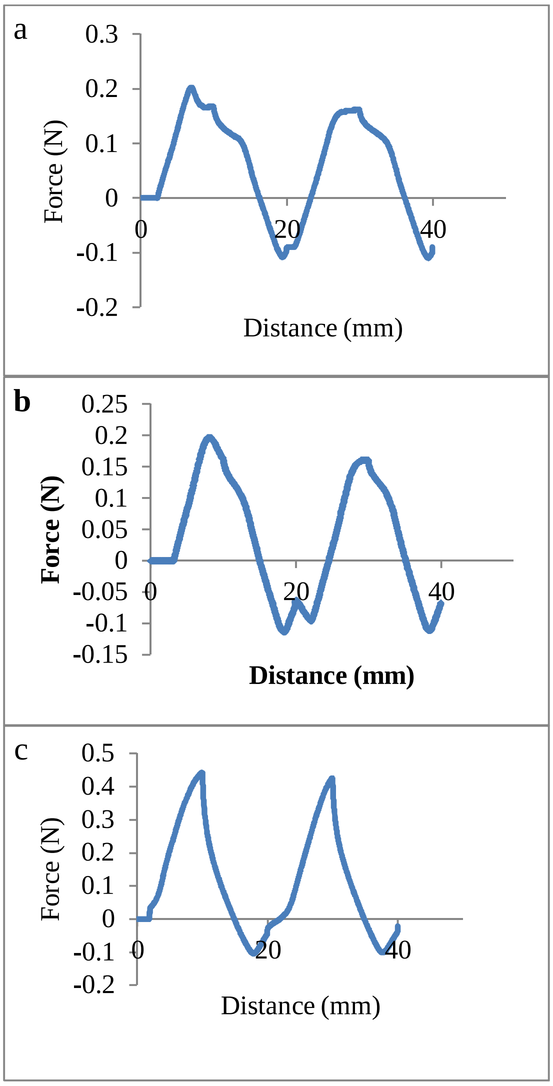

Fig.3. Yogurt sample texture profiles: a- P4, b-P6 and c- P9

Table 1.

Rheological and textural parameters of the yogurt samples

Sample	S.U.%	F %	H	Co	G	S	Gu	V(cP)
P1	7.5	0	0.240±0.002	0.87±0.01	0.26±0.02	1.05±0.01	0.34±0.01	390±11
P2	7.5	0.25	0.220±0.002	0.88±0.06	0.24±0.01	1.00±0.02	0.21±0.02	360±12
P3	7.5	0.5	0.196±0.001	0.71±0.01	0.27±0.02	1.01±0.01	0.15±0.01	355±11
P4	7.5	1	0.202±0.005	0.84±0.02	0.23±0.01	1.40±0.03	0.39±0.03	390±14
P5	10	0	0.208±0.004	0.86±0.05	0.24±0.03	0.97±0.02	0.19±0.01	310±11
P6	10	0.25	0.196±0.010	0.78±0.01	0.25±0.01	0.99±0.01	0.20±0.04	270±14
P7	10	0.5	0.182±0.012	0.96±0.04	0.18±0.02	1.00±0.02	0.21±0.01	250±16
P8	10	1	0.186±0.013	0.85±0.01	0.21±0.01	1.24±0.02	0.24±0.02	340±14
P9	12.5	0	0.442±0.015	0.85±0.03	0.51±0.03	0.98±0.01	1.03±0.01	970±15
P10	12.5	0.25	0.334±0.014	0.90±0.01	0.37±0.01	1.01±0.02	0.53±0.02	1500±13
P11	12.5	0.5	0.352±0.012	0.91±0.02	0.38±0.04	1.18±0.02	0.82±0.02	1740±12
P12	12.5	1	0.338±0.010	0.86±0.01	0.39±0.01	1.20±0.01	0.82±0.02	1834±14

DM-dry mater, F – fibre content, H – hardness, C – cohesiveness, G- gumminess, S-springiness, Gu-guminess, V- viscosity

According to the data presented in Table 1, it can be observed that: sample P9 has the highest hardness and the P7 the smallest one; in the case of cohesiveness the highest one can be observed in the case of sample P7 while P3 has the smallest one.

The yogurt gumminess is strongly influenced by the total soluble content and fibre concentration (the highest gumminess can be observed in the case of sample P12).

The combination of milk with 10% dry matter with 1% citrus fibre generated the yogurt with the highest elasticity.

The sample with the highest chewiness was P9 which is made from milk with 12.5% dry matter without fibre addition.

Regarding the rheological properties it can be observed an increase in viscosity with increasing the dry matter content and citrus fiber concentrations.

Citrus fibers are rich in pectin products. The pH of the yogurt, pectin, casein micelles are both substantially negatively charged.

Depending on the position of a system in relation to the phase diagram, there is a competition between the kinetics of phase separation due to the presence of polysaccharides and the induced gelation by the enzymes. For low levels of pectin (maximum 1 %) syneresis is less in the gel and the gel strength had increased by the addition of polysaccharides.

In the Table 2 is presented the Pearson correlation coefficients of the physicochemical properties of yogurt. It can be observed that is a strong positively correlation between the dry mater and hardness (r = 0.731**), gumminess (r = 0.674*), chewiness (r = 0.718**) and viscosity (r = 0.798**).

Another positively correlation can be observed between fibre content and springiness (r = 0.832**). The hardness is correlated positively with gumminess (r = 0.981**), chewiness (r = 0.954**) and viscosity (r = 0.798**). The gumminess is correlated positively with chewiness (r = 0.929**) and viscosity (r = 0.756**), while chewiness is correlated positively with viscosity (r = 0.812**).

Table 2.

Pearson correlation of physicochemical properties of yogurt

	DM	F	H	C	G	S	Gu	V
DM	1	0.025	0.731**	0.375	0.674*	-0.061	0.718**	0.798**
F		1	0.204	0.053	0.200	0.832**	0.022	0.175
H			1	0.227	0.981**	0.070	0.954**	0.798**
C				1	0.038	0.038	0.260	0.273
G					1	0.089	0.929**	0.756**
S						1	0.174	0.186
Gu							1	0.812**
V								1

DM-dry mater, F – fibre content, H – hardness, C – cohesiveness, G- gumminess, S-springiness, Gu-guminess, V- viscosity, * Significant correlations at a 0.01 level, ** Significant correlations at a 0.05 level

The principal component analysis was conducted to evaluate the global effect of the addition of citrus fibre on physicochemical properties of yogurt, from a descriptive point of view. In the Figures 4 and 5 are presented the scores and compound loadings of PCA analysis performed. It was found that the two principal components (PCs) explained 100% of the variations in the data set. The PC1 explains 99% of the variability and the PC2 explains 1%. It can be observed that the samples P5, P6, P7 and P8 are forming a group; another group is formed by the samples P9, P10, P11, P12 and the last one by the samples P1, P2, P3 and P4. The main characteristic of these groups is the dry mater concentration. Regarding the correlation loadings, the gumminess has the lowest influence on the scores. The samples viscosity and the dry mater (TSS) have the highest influence on the loadings.

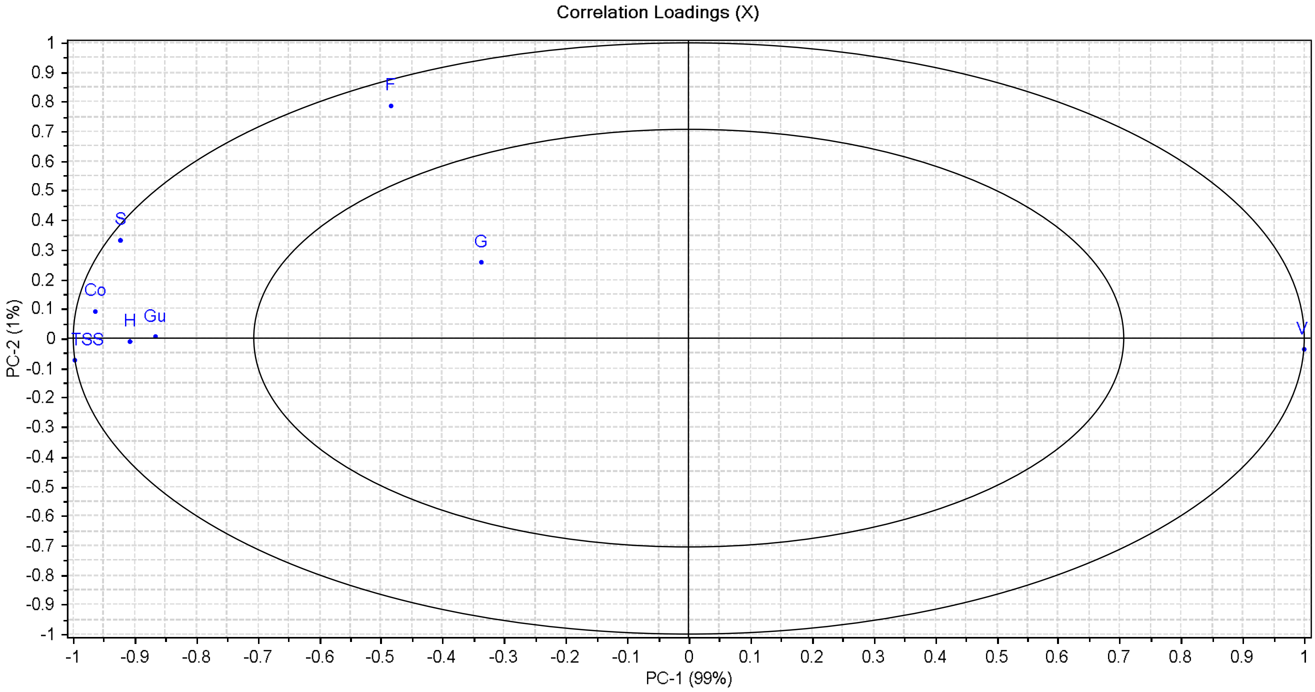

Fig. 4 Principal component analysis – correlation loadings between rheological and textural parameters

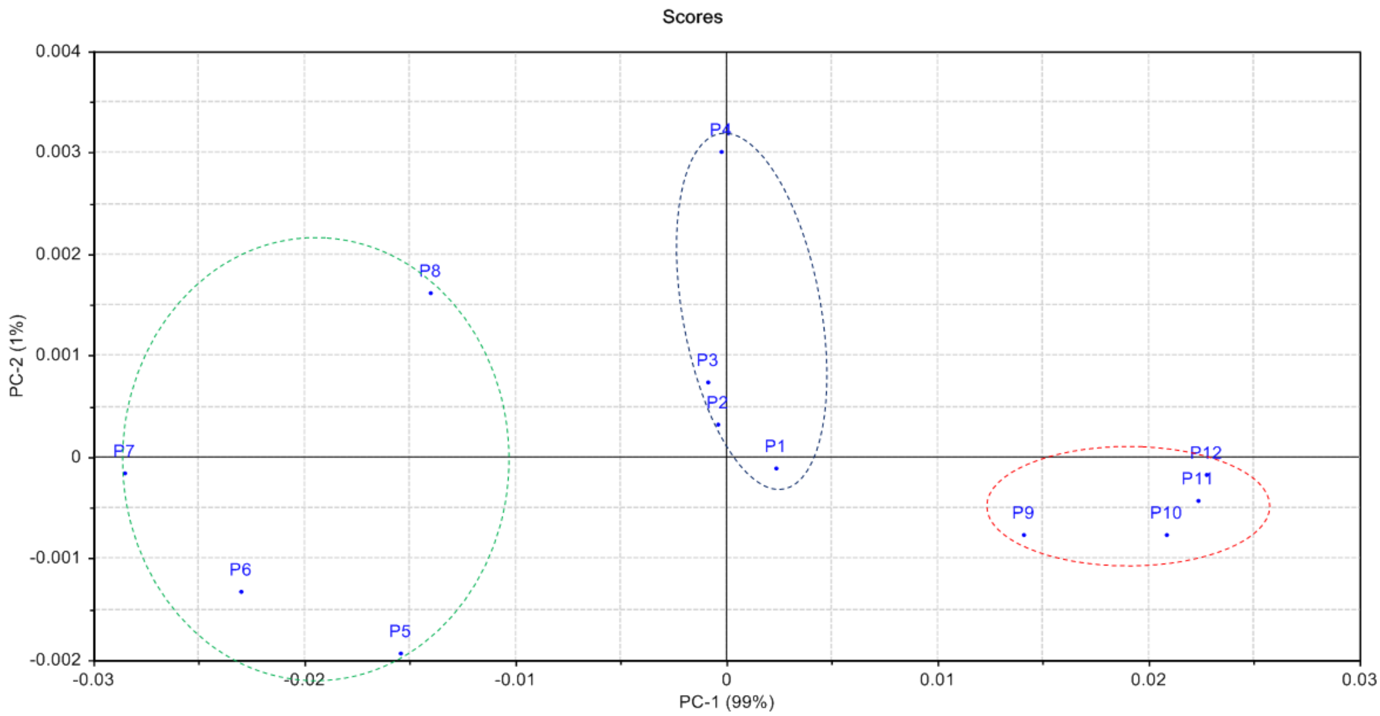

Fig. 5 Principal component analysis – correlation loading between yogurt samples formulations

4. Conclusions

The citrus fiber addition into yogurt sample has a positively influence on the rheological and textural properties of yogurt samples.
The principal component analysis conducted revealed three main groups; the sample dividing into the three main groups was based on the dry matter concentration. Viscosity and dry matter content has the high influence on the PCA projection, while the gumminess the lowest one. The highest positively correlation was observed between hardness and gumminess (r = 0.981**).

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