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EFFECT OF ADDITION OF STARCHES OF DIFFERENT BOTANICAL ORIGIN ON THE TEXTURE AND RHEOLOGICAL PROPERTIES OF SET-STYLE YOGHURTS**

D. Najgebauer-Lejko[1]*, M. Sady[1], T. Grega[1], B. Faber[1], J. Domagała[1], B. Machaczka[1]

[1]Department of Animal Products Technology, Faculty of Food Technology, Agricultural University of Krakow, 31-149 Kraków, ul. Balicka 122, Poland
* Corresponding author: dnajgebauer-lejko@ar.krakow.pl
** Original scientific paper

Abstract: The aim of the present study was to estimate an effect of addition of different native starches i.e.: potato, maize, waxy maize and tapioca on the textural (Texture Profile Analysis) and rheological properties (apparent dynamic viscosity, flow curves) of set-style cow's yoghurts. All analyses were done on fresh yoghurts and after 1 and 3 weeks of storage at 4°C in three series. Introduction of all starches to the yoghurt formula resulted in higher viscosity and improvement of all textural parameters except hardness. Addition of maize starch caused the highest apparent viscosity value and waxy maize starch supplementation led to the lowest hardness. Also the shape of flow curves was highly affected by the kind of starch added to the processing milk. Generally, maize and waxy maize starch additives resulted in higher values of shear stress when compared to the plain yoghurt, whereas yoghurt supplemented with potato starch demonstrated lower values of that parameter.

Key words: yoghurt, starch, texture, rheological properties

Introduction and literature review

Rheological studies are performed as quality control tool in dairy plants and as a technique for scientists to investigate the structure of the product (*Tunick,* 2000). From a rheological point of view yoghurt is considered as viscoelastic, pseudoplastic fluid exhibiting time depended and shear thinning behaviour. According to *Beal et. al.* (1999) the development of viscosity in yoghurt is influenced by the type of starter culture, incubation temperature, final fermentation pH and storage time. Other factors that highly affect rheological properties of yoghurt are: the total solids level, fat content, processing (heat treatment, homogenization, stirring) and presence of stabilizers added to the processing milk *(Gün and Işıklı,* 2007*; Tamime and Robinson,* 1999*)*.

Starch is often invited into the yoghurt milk mixture because of its excellent gelling properties as well as low cost and availability. Worldwide starch is produced from many plant sources which can be divided into: grains, tubers and roots. Generally, maize (corn in US) is the major source of this polysaccharide (over 80% of global production) and is mainly produced in the US, whereas wheat and potato dominate in Europe market and the production of root starch – tapioca (other names: cassava, manioc) is concentrated in Southeast Asia and South America (*Berghtaller,* 2004). Waxy maize, tapioca and potato starches are the most frequently used starches in food systems. Starches of different botanical origin are characterized with different composition (protein, fat, minerals content, amylose to amylopectin ratio) as well as physicochemical and technological properties (gelatinization temperature, water binding capacity, solubility, viscosity …etc.) (*Swinkles, 1985; Röper,* 1996). The aim of the present study was to investigate how starches of different botanical origin, namely: potato, maize, waxy maize and tapioca, influence the rheological and textural properties of set-style non-fat yoghurt.

Materials and methods

Yoghurts were made from skim cow's milk supplemented with skim milk powder to average protein content of 5,44-5,76% and with 1,5% additive of either potato (PS), maize (MS), waxy maize (WMS) or tapioca starch (TS). Milk without starch fortification was used as a control (called natural yoghurt). The yoghurt manufacture included: milk centrifugation, addition of skim milk powder and starch, homogenization (60°C, 6MPa), pasteurization, cooling to 44°C and inoculation with 2% of YC-180 DVS culture (Chr. Hansen), incubation to 4,7 pH, cooling and storage at 4°C.

All samples were subjected to the Texture Profile Analysis (TPA) using TA-XT2 texture analyzer (Stable Micro System - Haslemere, Surrey, England). Penetrometric test was done using a conical probe of 20 mm. in diameter and 40 mm in height which penetrate undisturbed cups of yoghurt to a depth of 25 mm at the rate of 1 mm/s. As a result a plot of force vs. time was obtained for each sample. The following factors were determined on the basis of TPA analysis: hardness [N], adhesiveness [|N·m|], cohesiveness and gumminess [N]. All analyses were run in three series, in the 1st, 7th and 21st day of cold storage at 4°C Rheological properties of yoghurts were measured by means of rotational rheometer Rheotest RV2 (VEB MLW Medingen, Germany) at 10°C. Obtained results were subjected to statistical analysis with Statistica 6 (StatSoft) software. An effect of starch additive and time of storage was estimated on the basis of two-way analysis of variance and the differences between arithmetic means of results were determined based on Duncan test at the significance levels of $p \leq 0,05$ and $p \leq 0,01$.

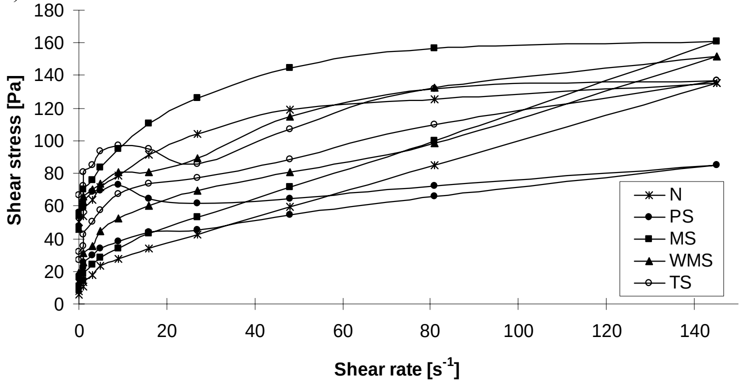
Results of investigations and discussion

*Alfonso and Maia (*1999*)* reported that during the storage time viscosity of yoghurts increases due to syneresis, protein hydration and production of exopolisaccharides. In the conducted study some enhancement of consistency was observed during the whole storage period for WMS yoghurts and after 7 days in the case of natural and PS fermented milks (table 1 and 2). On the contrary, the negative affect of storage time was noticed for TS fortified product. Apparent dynamic viscosity of examined yoghurts was also highly influenced by the kind of starch additive. The most positive effect, visible as growths in viscosity along with storage time, was observed for the MS (maize starch) and WMS (waxy maize starch) fortified yoghurts. It is worth to notice that WMS additive resulted in the highest value of this parameter at the end of storage period.

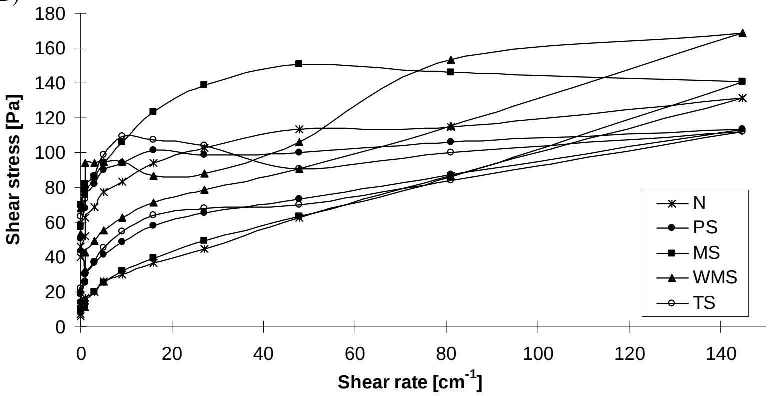
Flow curves (shear rate vs. shear stress) of examined yoghurts are presented in the Figure 1A-C. They differ from one another in the shape, area of a hysteresis loop, values of shear stress for the same shear rates and in the inclination angle. Analysis of flow curves revealed that yoghurt supplemented with MS was characterized with the highest values of shear stress and simultaneously with the greatest area between “up” and “down” lines of flow curves. According to *Kessler* (1998) and *Schramm* (1998) the area of a hysteresis loop is related to the energy needed to break down gel structure. It means that yoghurt with MS required the highest values of shear stress to damage curd structure but on the other hand it underwent shear thinning at higher extent. The opposite trend was observed in the case of fermented milk supplemented with potato starch (PS), which needed lower values of shear stress to break down but was less susceptible to shear thinning (narrow area enclosed by the “up-down” flow curves).

Figure 1. Flow curves of yoghurt: N - natural, PS - with potato starch, MS - with maize starch, WMS - with waxy maize starch, TS – with tapioca starch, 1 day after production (A), 7 days after production (B) and 21 days after production (C)

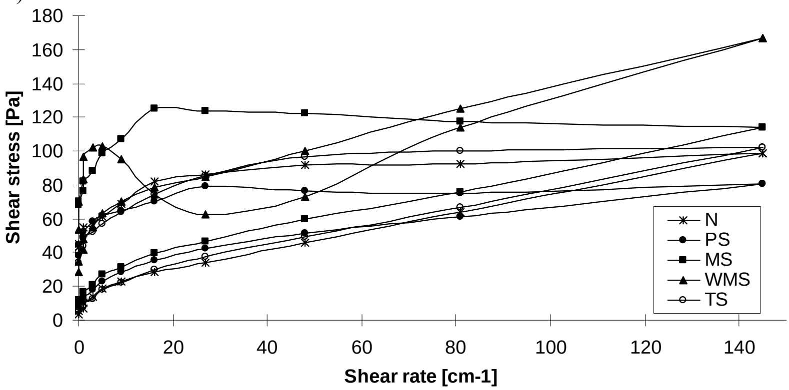
A)



B)



C)



Some differences in the shape and area of tixotropic loops were observed along with storage time. The greatest changes were observed for yoghurt with addition of WMS, especially after 2 weeks of storage when the "up" line of a flow curve connected with increasing values of shear rate crossed down the "down" line related to decreasing shear rates. Small area of hysteresis loops as well as a high angle of curve inclination suggest that the WMS supplementation affected in the most positive way the resistance of yoghurt stored for 7-21 days to shear thinning.

The results of TPA assessment and two-way analysis of variance for TPA are presented in Table 1 and 2.

Table 1. Texture Profile Analysis (TPA) as affected by the kind of starch additive and time of storage

Y. kind	Storage t. [days]	Hardness [N]	Adhesiveness $\times 10^{-3}$ [|N·m|]	Cohesiveness [-]	Gumminess [N]	Viscosity [Pa·s]
N	1	1,08 ± 0,10	3,05 ± 0,06	0,35 ± 0,05	0,34 ± 0,02	8,77 ± 1,16
	7	1,35 ± 0,01	8,16 ± 0,75	0,43 ± 0,04	0,58 ± 0,06	9,27 ± 0,33
	21	1,51 ± 0,02	7,04 ± 0,18	0,35 ± 0,02	0,52 ± 0,03	6,62 ± 0,99
PS	1	1,13 ± 0,06	3,98 ± 0,04	0,32 ± 0,06	0,39 ± 0,03	9,52 ± 0,74
	7	1,11 ± 0,09	5,81 ± 0,09	0,48 ± 0,03	0,54 ± 0,03	10,43 ± 1,79
	21	1,65 ± 0,11	4,51 ± 1,92	0,45 ± 0,02	0,74 ± 0,05	7,23 ± 2,06
MS	1	1,13 ± 0,00	7,21 ± 0,16	0,54 ± 0,02	0,56 ± 0,08	10,51 ± 0,91
	7	1,29 ± 0,15	8,12 ± 0,88	0,49 ± 0,03	0,63 ± 0,10	11,81 ± 3,63
	21	1,46 ± 0,17	9,08 ± 0,02	0,40 ± 0,07	0,65 ± 0,08	11,86 ± 2,73
WMS	1	0,98 ± 0,00	8,01 ± 1,29	0,57 ± 0,02	0,56 ± 0,02	8,94 ± 0,99
	7	0,97 ± 0,04	6,41 ± 1,35	0,57 ± 0,03	0,53 ± 0,04	10,51 ± 0,91
	21	1,17 ± 0,06	8,96 ± 1,35	0,57 ± 0,08	0,70 ± 0,05	12,91 ± 2,32
TS	1	1,17 ± 0,06	5,75 ± 0,08	0,61 ± 0,03	0,40 ± 0,08	12,58 ± 1,99
	7	1,30 ± 0,39	8,83 ± 1,25	0,50 ± 0,16	0,36 ± 0,00	7,78 ± 0,83
	21	1,49 ± 0,09	13,03 ± 0,23	0,55 ± 0,21	0,68 ± 0,18	7,12 ± 1,43

Legend: N- natural yoghurt (without starch), PS - yoghurt with potato starch, MS – yoghurt with maize starch, WMS – yoghurt with waxy maize starch, TS – yoghurt with tapioca starch.

Generally, starch contributed to greater adhesiveness, cohesiveness and gumminess of examined yoghurts, whereas the hardness of PS, MS, WMS and TS yoghurts was at the same or slightly lower level when compared to the natural one (Table 2). It is consistent with results obtained by *Rawson and Marshall* (1997) who stated that exopolysaccharides produced by ropy strains contribute in a greater extent to adhesiveness but the protein matrix is more responsible for hardness. Hardness of examined yoghurts was affected by either starch additive and time of storage. The highest values for all products were observed 21 days after manufacturing. It was found that fermented milk fortified with WMS had the softest structure and was simultaneously characterized with the highest cohesiveness which was at the same level during the whole storage period.

Table 2. Least square means for the parameters of textural assessment in yoghurts in relation to their composition and time of storage.

Factor	Kind of starch additive					Time of storage [days]		
	N	PS	MS	WMS	TS	1	7	21
Hardness [N]	1,32 A	1,30 B	1,29 C	1,05 ABCD	1,32 D	1,10 Aa	1,20 aB	1,47 AB
Adhesiveness ×10^3 [│N·m│]	4,72 ABC	4,77 DEF	8,14 AD	7,79 BE	9,21 CF	4,79 AB	7,47 Aa	8,52 Ba
Cohesiveness	0,38 ABa	0,42 CD	0,48 ab	0,57 Abc	0,55 BD	0,48	0,49	0,47
Gumminess [N]	0,48 ABa	0,56 ab	0,61 AC	0,60 BD	0,48 CDb	0,45 A	0,53 A	0,66 A
Viscosity [Pa s]	8,22 AB	9,06 a	11,40 Aab	10,79 B	9,16 b	10,07	9,96	9,15

N – natural yoghurt, PS – yoghurt with potato starch, MS - yoghurt with maize starch, WMS - yoghurt with waxy maize starch, TS - yoghurt with tapioca starch.
A, B, C, D, E, F – values in rows followed by the same letters are significantly different at $p \leq 0,01$;
a, b, c – values in rows followed by the same letters are significantly different at $p \leq 0,05$;

The greatest variations of TPA parameters between 1 and 21 day of storage were stated for yoghurts with: PS (hardness – Δ +0,51 N; cohesiveness - Δ +0,13; gumminess - Δ +0,35 N) and TS (adhesiveness - Δ +7,28 · 10^{-3} │N·m│). Textural properties of PS supplemented yoghurt were also the most closed to that obtained for the product without any starch additive.

Conclusion

1. Yoghurt fortified with various starch additives were more viscous and had softer gel structure than the natural yoghurt with no starch supplementation.
2. On the basis of flow curves analysis it was stated that yoghurt with waxy maize starch was the most resistant to shear thinning after 1 week and 3 weeks of cold storage and higher shear stress values were needed to break down its structure. Additionally TPA analysis revealed that it was

characterized with high values of cohesiveness unchangeable during the whole storage period.

3. Among all investigated native starches waxy maize starch can be recommended as the best starch for set-style yoghurt stabilization during cold storage for a period of 7-21 days.

UTICAJ DODAVANJA SKROBA RAZLIČITOG BOTANIČKOG POREKLA NA REOLOŠKE OSOBINE I STRUKTURU JOGURTA

D. Najgebauer-Lejko, M. Sady, T. Grega, B. Faber, J. Domagała, B. Machaczka

Rezime

Cilj ovog istraživanja je ocena dodavanja različitih skrobova na senzorne osobine kao i na reološke i osobine teksture, strukture jogurta. Jogurti su proizvedeni od obranog kravljeg mleka uz dodatak mleka u prahu i jednog od skrobova: krompirni skrob, kukurzni, amilopektinski skrob i skrob tapioke. Standardizovano (0,05% masti, 5,5% proteina), pasterizovano i homogenizovano mleko je ukiseljeno jogurt kulturom DVS tipa (YC-180, Chr. Hansen) do 4,7 pH. Analiza sastava je rađena korišćenjem Texture Profile Analysis (TPA) analizatorom strukture TA-XT2 (Stable Micro System). Reološka merenja (očigledna dinamička viskoznost, krive toka) su urađena pomoću rotacionog reometra– Rheotest RV2. Sve analize su urađene na svežim jogurtima i nakon 1 i 3 nedelje skladištenja u frižideru na 4°C u tri serije.

Uvođenje svih skrobova je dovelo do povećanja viskoznosti I poboljšanja svih parametara structure osim čvrstoće. Dodavanje kukuruznog skroba je izazvalo najveću očiglednu viskoznost, a najslabiju čvrstoću je imao jogurt koji je dopunjen amilopektinskim skrobom. Takođe, oblik krivih toka je bio pod jakim uticajem vrste skroba dodatog tokom prerade mleka. Generalno, kukuruzni i amilopektinski skrob su rezultirali u višim vrednostima za stress sečenja u poređenju sa običnim jogurtom, dok je jogurt sa dodatkom krompirovog skroba pokazao niže vrednosti za ovaj parametar. Takođe, fermentisano mleko uz dodatak amilopektinskog skroba je bilo

manje osetljivo/podložno tanjenju nakon 7-21 dana skladištenja u hladnom prostoru.

Na osnovu sprovedenog ispitivanja može se preporučiti amilopektinski skrob kao najbolji prirodni skrob za stabilizaciju jogurta tokom perioda skladištenja u hladnom prostoru od 7 do 21 dana.

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