

**Original Article**

Comparative Effects of Iranian Native and Commercial Probiotic Incorporation on Rheological Behavior and Syneresis Characteristics of Yogurts

Somayeh Heydari¹, Seyed Ebrahim Hosseini*², Amir M. Mortazavian*³, Salman Taheri⁴

1- PhD Student, Department of Food Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran

2- Associate Professor, Department of Food Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran

3- Professor, Faculty of Nutrition and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran

4- Associate Professor, Chemistry and Chemical Engineering Research Center of Iran, Tehran, Iran

Received: February 2021

Accepted: May 2021

ABSTRACT

Background and Objectives: The aim of the present study was to investigate effects of incorporating Iranian native and commercial probiotic strains (*Lactobacillus acidophilus*, *Lactobacillus casei* and *Bifidobacterium lactis*) on the rheological and syneresis properties of yogurts.

Materials and Methods: Samples were heated (90 °C, 15 min) after reconstituting in milk (13% SNF). After cooling down, the starter culture and probiotics were incorporated. Incubation was carried out at 42 °C until the pH decreased to 4.5. Syneresis was assessed based on Amatayakul *et al.* method. Rheological characteristics were assessed using dynamic oscillation (strain sweep and frequency sweep) and rotation assays.

Results: Results revealed significant improvement in characteristics of the probiotic yogurts, compared to the control sample. Based on the results of rheological assessments, yogurts showed viscoelastic behaviors. In general, yogurts containing the native strain of *L. acidophilus* provided further desirable rheological and syneresis characteristics.

Conclusions: Therefore, it is strongly recommended to use native Iranian *L. acidophilus* in probiotic yogurt production.

Keywords: *Bifidobacterium*, *Lactobacillus*, Yogurt, Rheological characteristics

Introduction

There are direct relationships between food and health, popularizing functional food consumption world (1, 2, 3). According to Food and Agriculture Organization/World Health Organization (FAO/WHO), probiotics are live microorganisms with beneficial health effects as administered in sufficient amounts. In fact, viability is a critical factor for considering a microorganism as a probiotic. However, it has been reported that dead cells and cell metabolites can include health benefits (4). These effects, known as core benefits, include regulation of intestinal transit, normalization of perturbed microbiota, turnover of enterocytes, competitive exclusion of pathogens, colonization resistance with neurological, immunological and endocrinological effects as well as production of short-chain fatty acids and various bioactive compounds (5). Proteolytic activities of probiotics and prebiotics can affect sensory and rheological characteristics

of the food products. Therefore, consumption of fermented dairy products (containing living bacteria) such as probiotic yogurts shows beneficial effects on human health. Yogurt is a unique carrier for probiotic bacteria. It includes nice texture and organoleptic characteristics, high nutritional values and excellent adaptability. *Lactobacillus* spp. and *Bifidobacterium* spp. are known as the most common commercial probiotics used in yogurt production (6, 7). Various factors affecting probiotics in yogurts, including food matrices, production procedures and storage conditions (oxygen extent, pH, temperature, inoculation rate, time and packaging materials) (8). Changes in yogurt characteristics such as viscosity can occur as a result of alteration in protein proportions and ion contents even as total protein and fat are adjusted to a fixed extent as well as changes in process and storage conditions (9).

*Address for correspondence: Seyed Ebrahim Hosseini¹ and Amir M. Mortazavian²

¹Associate Professor, Science and Research Branch, Islamic Azad University, Tehran, Iran. ebhoseini@srbiau.ac.ir

²Professor, Faculty of Nutrition and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran. mortazvn@sbmu.ac.ir

Mousavi *et al.* (2019) reported that survival of *Lactobacillus acidophilus* and texture and organoleptic characteristics of the flaxseed enriched probiotic yogurts are affected by the proportion of flaxseed and storage time. Furthermore, addition of flaxseed to probiotic yogurts caused a higher growth rate of *Lactobacillus acidophilus* (up to 8.82 CFU/ml), compared to the control sample (6.87 CFU/ml). Flaxseed enhanced the yogurt viscosity, hardness, cohesiveness, gumminess and water holding capacity (WHC). However, decreases in yogurt syneresis and adhesiveness were seen (10). Sarwar *et al.* (2019) assessed physicochemical and microbiological characteristics of the produced synbiotic yogurt by probiotic yeast of *Saccharomyces boulardii* in combination with inulin (1–2% w/v). Microrheological analysis showed that the values of G_0 and G'' slightly decreased by the addition of inulin. Physicochemical parameters such as pH, acidity and protein content were in the normal range (similar to the control), while the fat content of the synbiotic yogurt significantly decreased. Addition of 1% inulin in yogurt formulation decreased the yogurt syneresis and preserved the viability of *S. boulardii* after storage for 28 days. Inulin improved the texture (dense, compressed and homogeneous structure), organoleptic characteristics and the survival of *S. boulardii* with a viable count of higher than 6.0 log CFU/g in the yogurt, as generally needed for probiotics. There is no evidence assessing rheological characteristics and syneresis of the probiotic yogurts using various Iranian native probiotics. Therefore, the aim of this study was to assess effects of Iranian native probiotic strains in comparison with commercial strains on the rheological and syneresis characteristics of the yogurt.

Materials and Methods

Probiotic strains and starter culture: Commercial lyophilized starter culture (*Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus thermophilus*) as well as commercial probiotic strains (*Lactobacillus acidophilus* LA-5, *Lactobacillus casei* 431 and *Bifidobacterium lactis* BB-12) were supplied by Chr. Hansen A/S, Horsholm, Denmark. Iranian native probiotic strains were purchased from TakGene, Tehran, Iran. Yogurt cultures and probiotic strains were stored at -18 °C according to the manufacturer's instructions.

Production of set yogurts: In this study, various probiotic yogurt treatments were used, including yogurt bacteria (Y-C) as control, yogurt bacteria and native strain of *L. acidophilus* (YLA_n), yogurt bacteria and native strain of *L. casei* (YLC_n), yogurt bacteria and native strain of *B. lactis* (YBL_n), yogurt bacteria and commercial strain of *L. acidophilus* (YLA_c), yogurt bacteria and commercial strain of *L. casei* (YLC_c), and yogurt bacteria and commercial

strain of *B. lactis* (YBL_c). All samples were prepared using potable water and reconstituted skim milk powder (Pegah Dairy Industry, Tehran, Iran). Samples were heated (90 °C, 15 min) after reconstituting in milk (13% SNF). After cooling down (44 °C ±1), starter cultures and probiotics were incorporated. Then, incubation was carried out at 42 °C until pH decreased to 4.5 ±0.01 from 6.41 ±0.03. Samples were cooled down and stored at 5 °C for 28 days.

Rheological assessment: Rheological behaviors of the prepared samples were studied using dynamic oscillation and rotation shear assays and rheometer (MCR301, Anton-Paar, GmbH, Graz, Austria) vane geometry. All experiments were carried out at 20 °C ±1. The strain sweep assay was carried out (strain range of 0.01–1000% at fixed 1 Hz) to investigate limiting values of the linear viscoelastic range (LVE), structural strength (G' at LVE), cross over ($G' = G''$) and resistance to mechanical force or yield stress (τ_y as an indicator of structural strength) (12). In frequency sweep assays, the frequency ramp ranged 0.01–100 Hz. Rheological parameters, including elastic modulus (G'), viscous modulus (G''), damping factor ($\tan\delta = G''/G'$), complex modulus (G^*) and “ a ” and “ b ” factors were estimated (13,14). Rotation shear assays were carried out in two intervals as described by Donmez *et al.* (2017) and Norouzebeigi *et al.* (2020) with modifications as follows: the first interval for 10 s at a steady shear rate of 200 rps to achieve a better homogenization and create a similar beginning status for all treatments and the second interval at a shear rate of 0.5–300 rps to achieve apparent viscosity (15,16). Data were properly fitted with the power-law model and assessed using Rheoplus Software v3.21 (Anton Paar, Graz, Austria).

Syneresis assessment: Level of the spontaneous syneresis in undisturbed set yogurt was assessed according to Amatayakul *et al.* (2006). First, the cup of set yogurt was weighed at 4 °C (W_1). Then, yogurt was stored at an angle of nearly 45° to collect the separated whey on the side of the cup. A needle was used to remove the separated whey. Weight of the yogurt cup was recorded (W_2). To prevent further leakage of whey from the gel, the entire assay was carried out within 10 s. The syneresis was expressed using Eq. 1 (17):

$$\text{Syneresis (\%)} = W_2/W_1 \times 100 \quad (1)$$

Statistical analysis: All experiments were carried out in triplicate. Results were statistically analyzed using completely randomized design at a confidence level of 0.95. Curve Expert v.6, SPSS v.24 and Excel 2013 were used to carry out statistical and regression analyses.

Results

Rheological characterization

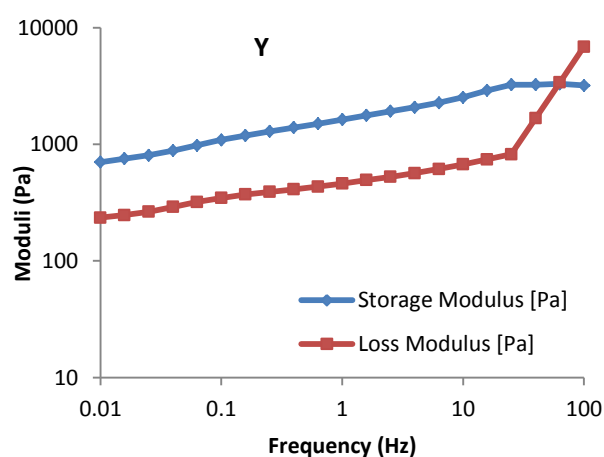
Frequency scan assay: Figure 1 (a–g), showed changes in the storage modulus of the various samples at a frequency of 0.01–100 Hz. Results of the frequency scanning assay are represented in Table 1. It was detected that the elastic modulus of all treatments was higher than the viscous modulus. Storage module (elastic component) and drop modulus (viscous component) showed similar frequency dependences. Furthermore, samples showed various elasticities and poor viscoelastic gel characteristics (Fig. 1H); as Hassan *et al.* (2003) reported (18). Similar rheological behaviors were observed in all samples. However, significant differences were seen between the elastic components of the Iranian and commercial probiotic strains. Generally, YLan and YLac samples showed the highest and the lowest elastic components, respectively. Increases in elastic components of all samples were seen at higher frequencies; as shown by Blisto *et al.*, 2017, and

Costa *et al.*, 2019 (21, 22). Figure 1i represents elastic and viscous components of the samples at various frequencies. Therefore, addition of probiotic bacteria changed the firmness of yogurt. Compared to the control, YLan sample included the highest elasticity and viscosity, while YLac sample showed the lowest values.

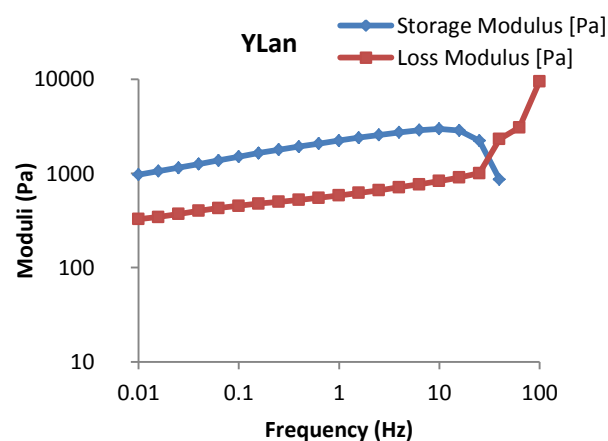
Table 1. Textural attributes of various yogurt samples

Treatments	a	b	R ²	tanδ
Y-C	1658 ^c	0.193 ^a	0.98	0.310 ^a
YLA _n	2205 ^a	0.167 ^d	0.99	0.294 ^d
YLA _c	1294 ^g	0.164 ^d	0.99	0.293 ^d
YLC _n	1938 ^b	0.171 ^c	0.99	0.300 ^c
YLC _c	1542 ^f	0.168 ^{cd}	1.00	0.301 ^c
YBL _n	1781 ^d	0.180 ^b	0.99	0.304 ^b
YBL _c	1871 ^c	0.179 ^b	0.98	0.301 ^c

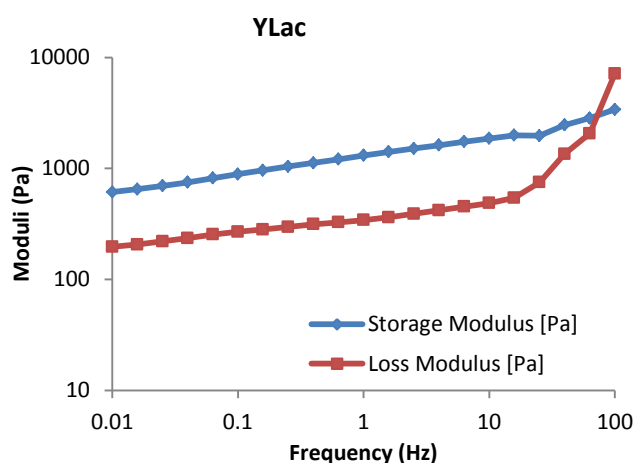
*Means in a column with different small letters represent significant differences ($P < 0.05$).



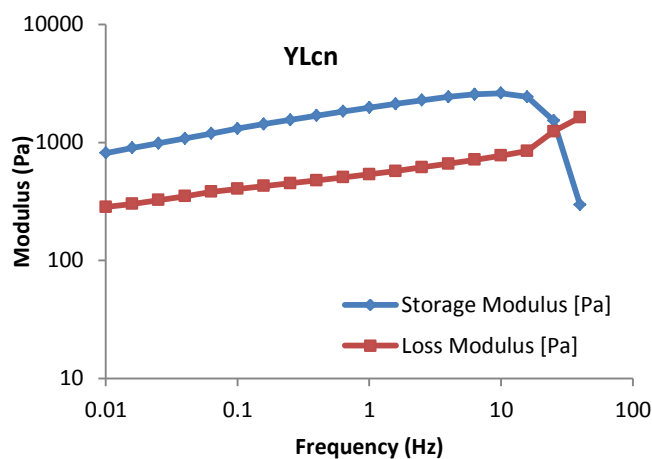
(a)



(b)



(c)



(d)

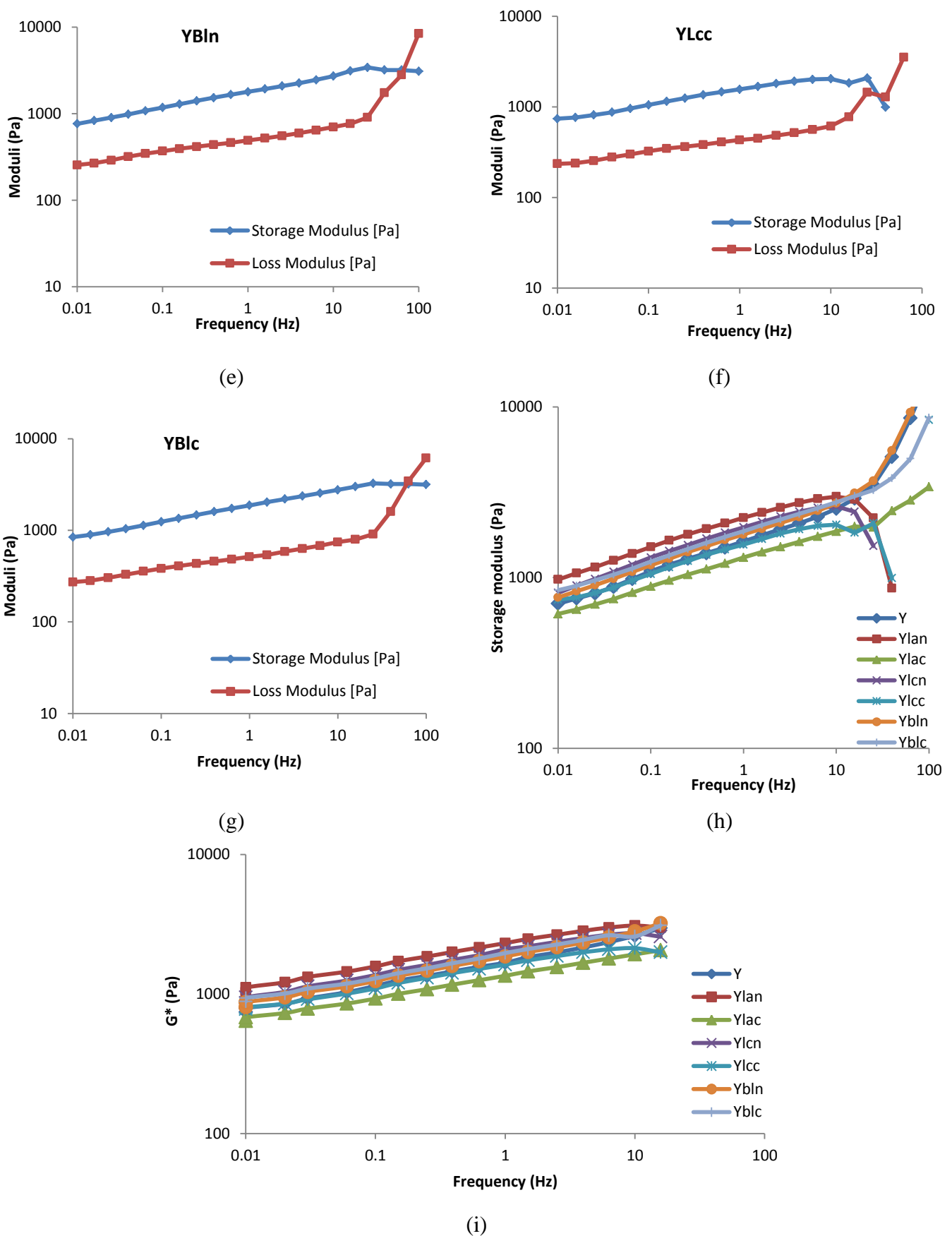


Figure 1. Storage and loss moduli of various yogurt samples Treatments: Y–C, yogurt bacteria; YLA_n, yogurt bacteria and native *Lactobacillus acidophilus*; YLA_c, yogurt bacteria and commercial *Lactobacillus acidophilus*; YLC_n, yogurt bacteria and native Iranian *Lactobacillus casei*; YLC_c, yogurt bacteria and commercial *Lactobacillus casei*; YBL_n, yogurt bacteria and native Iranian *Bifidobacterium lactis*; and YBL_c, yogurt bacteria and commercial *Bifidobacterium lactis*

As shown in Table 1, $\tan\delta$, “a” and “b” values of the samples were significantly various ($p < 0.05$). The Y-C included the highest “b” value while YBL_n and YBL_c showed the lowest value. The YL_{a_n} and YL_{a_c} included the highest and the lowest “a” values, respectively. Based on the viscoelastic materials, higher “b” values show the viscoelastic behavior of the gel-like structures and a further sensitivity to mechanical stresses. In power-law, the higher “a” (y-intercept) values refer to stronger gel structures. The YL_{a_n} and YL_{a_c} samples included the highest and the lowest “a”, respectively. The higher $\tan\delta$ refers to the lower strength of the gel structure. Ratio of the viscous components was higher than elasticity. YL_{a_c} and YL_{a_n} included the highest and the lowest values of $\tan\delta$, respectively.

Strain scan assay results: Intersection of the elastic and viscous components is considered as the elastic boundary (Table 2). The sample structure breaks and begins to flow; as Meyer *et al.* (2011) reported. Values of the elastic and viscous components were similar. Intersection of the elastic component and the viscosity (over cross) were significantly various in various samples ($p < 0.05$). Moreover, YLC_n and YL_{a_c} included the highest and the lowest elastic ranges, respectively. Based on the results from the strain scan assay (Table 2), the YL_{a_c} sample included the lowest structural strength (elastic modulus in the range linear viscoelasticity). Considering G^* , “a”, “b” and $\tan\delta$, the YL_{a_n} sample showed the highest structural strength. Table 2 shows significant differences between the stress levels of the samples corresponding to the end of the linear region ($p < 0.05$). Higher levels of this parameter demonstrate

higher structural stabilities and stronger gel structures. Stress is the minimum necessary force to flow the sample (24). In fact, YL_{a_n} included the highest limit stress representing that a further mechanical force was needed to follow (12). Apparent viscosity of the samples (at a constant stress point) was shown in Fig. 2. Samples Y and YL_{a_n} showed the lowest and the highest apparent viscosities, respectively. These results revealed effects of the probiotic bacteria on the yogurt texture. Figure 2 represents significant improvements in apparent viscosity of the probiotic yogurt, compared to the control (25).

Table 2. Rheological characteristics of the control and prepared yogurt samples

Treatments	Storage modulus (Pa)	Cross over (Pa)	Tau (y) (Pa)
Y-C	1661.03 ^e	124.00 ^b	6.20 ^d
YL _{a_n}	2187.94 ^a	121.00 ^c	8.34 ^a
YL _{a_c}	1284.84 ^e	106.00 ^d	4.90 ^f
YLC _n	1988.76 ^b	170.66 ^a	7.39 ^b
YLC _c	1550.66 ^f	121.07 ^c	5.91 ^e
YBL _n	1776.95 ^d	121.60 ^c	6.63 ^c
YBL _c	1859.77 ^c	121.68 ^{bc}	6.21 ^d

*Values with different letters in each column are significantly different ($p < 0.05$).

Syneresis characteristics: Table 3 illustrates syneresis assessment results of the samples. Significant differences were seen in the syneresis levels of various yogurts ($p < 0.05$). In general, YL_{a_n} and YL_{a_c} showed the lowest and the highest synereses, respectively. Levels of YL_{a_n}, YLC_n and YBL_c samples were statistically similar ($p > 0.05$). However, syneresis of YL_{a_c} was 62.34% higher than that of YL_{a_n}.

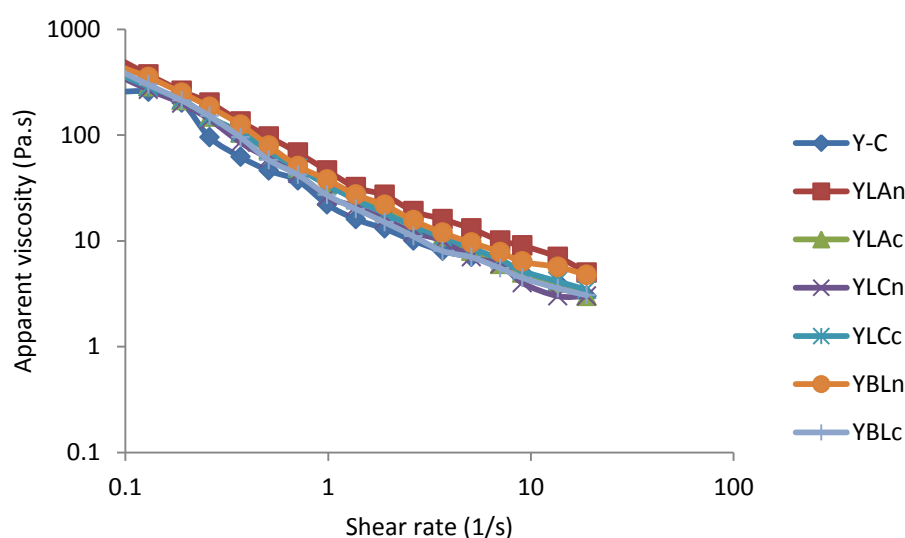


Figure 2. Apparent viscosity of various yogurt samples

Discussion

Rheological characterization

Frequency scan assay: Results were similar to reported results by Hasan *et al.* in 2003 and KrivoroTova *et al.* in 2017 (18, 19). Use of higher frequencies caused increases in elasticity and viscosity of the sample components. Elastic and viscous components reached the intersection point; therefore, all samples showed the flow point. In viscoelastic region, all samples showed linear behaviors (such as solid). Before the flow point, the elastic component was higher than the elastic component. After the linear viscoelastic range, the viscosity component was higher and the samples showed quasi-liquid behaviors. These results were similar to those by Zargaran *et al.* (2013). As Costa *et al.* (2019) described, the higher complex modulus caused further firmness in the treated yogurt rather than the control.

Strain scan assay results: Costa *et al.* (2019) reported that limit stresses generally existed despite an interactive structure or cross-linking and probiotic bacteria seemed to amplify these linkages (22). Decreases in apparent viscosity were possibly linked to the effects of the bacterial enzymes on the casein micelle matrix (Ariana and McGrew, 2007). Type of the fiber and storage time are factors affecting apparent viscosity of the samples (26). Ariana and McGraw (2007) reported insignificant differences between the apparent viscosity of yogurt samples containing inulin and oligofructosis. Yogurt is a pseudoplastic product (Costa *et al.*, 2019), meaning that increases in shear stress lower its viscosity. In the current study, YLan and Y showed the highest and the lowest apparent viscosities, respectively. This demonstrated the effects of probiotics on strengthening the gel network and improving the viscosity (22).

Syneresis characteristics: In this study, consistencies were reported between the results of the syneresis and the rheological characteristics of the yogurt samples. Gel structure of the samples with higher elastic modulus and yield stress was further compact. It brought higher serum maintenance and lower syneresis (27,9,28). Compared to the probiotic samples, incorporating inactivated probiotic cells into yogurts caused lower syneresis and higher WHC (12). Brennan and Tudorica (2008) reported that yogurt syneresis was affected by the milk fat content. They also stated that the fat globules decreased the casein aggregation, improved the three-dimensional (3D) network and produced further compact structures (29). Amatayakul *et al.* (2006) reported that the yogurt syneresis decreased by

increases in total solids and use of extracellular polymeric substance-producing starter cultures (17). These dissimilar syneresis results could be attributed to use of various total solid levels (13%) in this study (30,31). Total solids extended and starter culture types affected whey separation of the yogurt. Increases in total solid contents promoted the gel network stability and density. Moreover, water was delimited rather tightly, causing higher firmness (21). Fortifying milk protein network with skim milk powder, whey protein isolate and sodium caseinate is effective in decreasing or preventing yogurt syneresis (29). Donmez *et al.* (2017) investigated that green tea and green coffee powders (rich in polyphenols) improved set yogurt whey separation and its rheological characteristics (16). Parvarei *et al.* (2021) compared addition of probiotics and paraprobiotics to the greatest mean pH drop rate, mean acidity increase rate, mean redox potential increase rate, final acidity and final redox potential in yogurts containing inactivated *L. acidophilus* (added before fermentation). Samples containing *L. acidophilus* and *B. lactis* included the highest acetaldehyde contents. After 28 days, samples containing paraprobiotics (*L. acidophilus*) included the highest lactic acid levels. The *L. acidophilus* showed greater effects on acetaldehyde generation in yogurts after 28 days of storage. Addition of paraprobiotics increased viability of the starter cultures. Moreover, incorporation of inactivated probiotic cells into yogurts decreased the syneresis and increased the WHC (32).

Conclusion

Results of this study revealed that the probiotic strains significantly affected syneresis and rheological characteristics of the yogurts. Native and commercial probiotic strains were effective in strengthening the casein network and yogurt structure as well as decreasing the syneresis. Therefore, use of the Iranian native *L. acidophilus* strain is recommended in probiotic yogurt production as it provides better rheological and syneresis characteristics after fermentation. Further studies are needed to assess effects of other Iranian native probiotic strains on rheological and syneresis characteristics of the yogurts during fermentation and storage.

Financial disclosure

The authors declared no financial interest.

Funding/Support

This work was not financially supported.

References

- Karaca O. B, Güzeler N, Tangüler H, Yaşar K, & Akın M. B. Effects of apricot fibre on the physicochemical characteristics the sensory properties and bacterial viability of nonfat probiotic yoghurts. *Foods*. 2007; 8, 1–15.
- Khorshidian N, Yousefi M, Shadnoush M, & Mortazavian A. M. An overview of β -Glucan functionality in dairy products. *Current Nutrition & Food Science*. 2018; 14, 280–292.
- Wang Y, Zhou J, Xia X, Zhao, Y, & Shao W. Probiotic potential of *Lactobacillus paracasei* FM-LP-4 isolated from Xinjiang camel milk yoghurt. *International Dairy Journal*. 2018; 62, 28–34.
- FAO, WHO. Guidelines for the evaluation of probiotics in food. Food and Agriculture Organization and World Health Organization, London. 2002.
- Scourboutakos MJ, Franco-Arellano B, Murphy SA, Norsen S, Comelli EM, L'Abbe´ MR. Mismatch between probiotic benefits in trials versus food products. *Nutrients*. 2017.
- Alizadeh Khaledabad M, Ghasempour Z, Moghaddas Kia E, Rezazad Bari M, and Zarrin R. Probiotic yoghurt functionalised with microalgae and Zedo gum, chemical, microbiological, rheological and sensory characteristics. *International Journal of Dairy Technology*. 2017; 73(1): 67-75.
- Lucatto J.N, da Silva- Buzanello R.A, de Mendonça S.N.T.G, Lazarotto T.C, Sanchez J.L, Bona E. and Drunkler D.A. Performance of different microbial cultures in potentially probiotic and prebiotic yoghurts from cow and goat milks. *International Journal of Dairy Technology*. 2019.
- Norouzbeigi S, Vahid-Dastjerdi L, Yekta R, Farhoodi M, Mortazavian AM. Effects of using different O₂ scavengers on the qualitative attributes of bifidus yogurt during refrigerated storage. *Food Research International*. 2020:109953.
- Keogh M, O'Kennedy B. Rheology of stirred yogurt as affected by added milk fat, protein and hydrocolloids. *Journal of food science*. 1998; 63(1):108-12.
- Mousavi M, Heshmati A, Garmakhany A. D, Vahidinia A, Taheri M. Optimization of the viability of *Lactobacillus acidophilus* and physico-chemical, textural and sensorial characteristics of flaxseed-enriched stirred probiotic yogurt by using response surface methodology. *Food Science and Technology*. 2019: Vol.102 pp.80-88 ref.36.
- Sarwar A, Aziz T, Al-Dalali S, Zhao X, Zhang J, Din J, Chen Ch, And Yang Z. Physicochemical and Microbiological Properties of Synbiotic Yogurt Made with Probiotic Yeast *Saccharomyces boulardii* in Combination with Inulin. *Journal MDPI*. 2019.
- Balaghi S, Mohammadifar MA, Zargaraan A, Gavlighi HA, Mohammadi M. Compositional analysis and rheological characterization of gum tragacanth exudates from six species of Iranian Astragalus. *Food Hydrocolloids*. 2011; 25(7):1775-84.
- Heydari S, Amiri- Rigi A, Ehsani MR, Mohammadifar MA, Khorshidian N, Koushki MR, et al. Rheological behaviour, sensory properties and syneresis of probiotic yoghurt supplemented with various prebiotics. *International Journal of Dairy Technology*. 2018;71:175-84.
- Mariotti M, Lucisano M, Pagani MA, Ng PK. The role of corn starch, amaranth flour, pea isolate, and Psyllium flour on the rheological properties and the ultrastructure of gluten-free doughs. *Food Research International*. 2009;42(8):963-75.
- Norouzbeigi S, Vahid-Dastjerdi L, Yekta R, Farhoodi M, Mortazavian AM. Effects of using different O₂ scavengers on the qualitative attributes of bifidus yogurt during refrigerated storage. *Food Research International*. 2020:109953.
- Dönmez Ö, Mogol BA, Gökmen V. Syneresis and rheological behaviors of set yogurt containing green tea and green coffee powders. *Journal of dairy science*. 2017; 100(2):901-7.
- Amatayakul T, Sherkat F, Shaha N. Syneresis in se yogurt as affected by EPS stater culture and levels of solids. *International Journal of dairy technology*. 2006: 59(3): 216-221.
- Hassan A.N, Ipsen R, Janzen T, and Qvist K.B. Microstructure and rheology of yogurt made with cultures differing only in their ability to produce exopolysaccharides. *Journal of dairy science*. 2003; 86(5), pp.1632-1638.
- KrivoroTova T, SereiKaiTe J. and GlibowSKI P. Rheological and textural properties of yogurts enriched with Jerusalem artichoke flour. 2017.
- Zargaraan A, Omarae Y, Rastmanesh R, Taheri N, Fadavi G, Fadaei M, Mohammadifar MA. Rheological characterization and cluster classification of Iranian commercial foods, drinks and desserts to recommend for esophageal dysphagia diets. *Iranian journal of public health*. 2013; Dec;42(12):1446.
- Belsito P.C, Ferreira, M.V.S, Cappato L.P, Cavalcanti R.N, Vidal V.A.S, Pimentel T.C, Esmerino E.A, Balthazar C.F, Neto R.P.C, Tavares M.I.B, and Zacarchenco P.B. Manufacture of Requeijão cremoso processed cheese with galactooligosaccharide. *Carbohydrate Polymers*. 2017:174, pp.869-875.
- Costa M.F, Pimentel T.C, Guimaraes J.T, Balthazar C.F, Rocha R.S, Cavalcanti R.N, Esmerino E.A, Freitas M.Q, Raices R.S, Silva M.C, and Cruz A.G. Impact of prebiotics on the rheological characteristics and volatile compounds of Greek yogurt. *LWT*. 2019;105, pp.371-376.
- Meyer D, Bayarri S, Tárrega A, Costell E.. Inulin as texture modifier in dairy products. *Food Hydrocolloids*, 2011: 25 (8), pp.1881-1890.
- Zhou M, Parkhurst A.M, Voss H.K, Weller C.L. Estimating rheological properties of yogurt using different versions of the Freundlich model and design matrices. 2004.
- Aryana K.J, McGrew P. Quality attributes of yogurt with *Lactobacillus casei* and various prebiotics. *LWT-Food Science and Technology*. 2007: 40(10), pp.1808-1814.
- Staffolo M.D, Bertola N, Martino M. Influence of dietary fiber addition on sensory and rheological properties of yogurt. *International Dairy Journal*. 2004:14(3), pp.263-268.
- Beheshtipour H, Mortazavian A, Mohammadi R, Sohrabvandi S, Khosravi- Darani K. Supplementation of *Spirulina platensis* and *Chlorella vulgaris* algae into probiotic fermented milks. *Comprehensive Reviews in Food Science and Food Safety*. 2013;12(2):144-54.
- Steffe JF. Rheological methods in food process engineering. Freeman press. 1996.
- Brennan CS, Tudorica CM. Carbohydrate- based fat replacers in the modification of the rheological, textural and sensory quality of yoghurt: comparative study of the utilisation of barley beta- glucan, guar gum and inulin. *International journal of food science & technology*. 2008; 43(5):824-33.

30. Aryana KJ, McGrew P. Quality attributes of yogurt with *Lactobacillus casei* and various prebiotics. *LWT-Food Science and Technology*. 2007; 40(10):1808-14.
31. Soni R, Jain NK, Shah V, Soni J, Suthar D, Gohel P. Development of probiotic yogurt: effect of strain combination on nutritional, rheological, organoleptic and probiotic properties. *Journal of Food Science and Technology*. 2020: 1-13.
32. Molaee Parvarei M, Fazeli M.R, Mortazavian A.M, Sarem Nezhad S, Mortazavi S.A, Golabchifar A.A. Khorshidian, N. Comparative effects of probiotic and paraprobiotic addition on microbiological, biochemical and physical properties of yogurt. *Food Research International*. 2020:110030.