Research Article

pISSN: 2345-5357
eISSN: 2423-4214

OPEN ACCESS

APPLIED FOOD BIOTECHNOLOGY, 2022, 9 (2):91-102
Journal homepage: www.journals.sbmu.ac.ir/afb

High-Methoxyl Apple Pectin Improves Rheological Properties and Storage Stability of the Flavored Probiotic Yogurt Drinks, Compared to Pomegranate Pectin

Bahareh Sarmadi[1†], Parang Nikmaram[2†], Amir Mohammad Mortazavian[1*], Hossein Kiani[2*] Mohammad Mousavi[2], Elham Khanniri[1], Reza Mohammadi[3] Adriano G da Cruz[4]

1-Department of Food Technology, Faculty of Nutrition Sciences and Food Technology/National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran
2-Department of Food Science, Engineering and Technology, Bioprocessing and Biodetection Lab, College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran
3-Department of Food Science and Technology, School of Nutritional Sciences and Food Technology, Kermanshah University of Medical Sciences, Kermanshah, Iran
4-Department of Food, Federal Institute of Science and Technology of Rio de Janeiro, Rio de Janeiro, RJ, Brazil

Abstract

Background and Objective: Use of pectin has attracted interests in food and nutraceutical industries, owing to its positive effects on stability of dairy drinks and potential health benefits to humans. Furthermore, demands for the production of stable fermented milk drinks during storage period is high. Therefore, the aim of this study was to assess effects of apple and pomegranate pectins as stabilizers on various characteristics of probiotic yogurt drinks.

Material and Methods: Apple and pomegranate pectins at concentrations of 0-0.5% (w v^{-1}) were added to the probiotic yogurt drinks containing 2% of inulin and 12% of pomegranate juice. Then, rheological behavior, particle size distribution and stability of probiotic yogurt drinks were studied during storage.

Results and Conclusion: Control (treatments with no pectin addition) and probiotic yogurt drinks containing pomegranate pectin (0.1-0.5%) showed Newtonian flow behavior and liquid-like behavior over the frequency range. Probiotic yogurt drinks with apple pectin included shear-thinning flow behavior, gel-like network at low frequencies and mean size particle of 50 µm. The highest G' and G" and stabilities during the storage were achieved in samples containing 0.5% of apple pectin. Results demonstrated that apple pectin included great potentials to be used in industrial production of probiotic yogurt drinks as it improved rheological properties and storage stability of the products. Therefore, use of 0.5% apple pectin is suggested in fermented milk drinks.

Conflict of interest: The authors declare no conflict of interest.

Article Information

Article history:
- Received 6 Feb 2022
- Revised 6 Feb 2022
- Accepted 13 Feb 2022

Keywords:
- Apple pectin
- Probiotic yogurt drink
- Pomegranate pectin
- Stabilizer

Corresponding author:
Amir Mohammad Mortazavian: Department of Food Technology, Faculty of Nutrition Sciences and Food Technology/National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran
mortazvn@sbmu.ac.ir
Hossein Kiani: Department of Food Science, Engineering and Technology, Bioprocessing and Biodetection Lab, College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran
hokiani@ut.ac.ir
[†]These authors contributed equally to this word as the first author: Bahareh Sarmadi, Parang Nikmaram

How to cite this article

Sarmadi B, Nikmaram P, Mortazavian AM, Kiani H, Mousavi M, Khanniri E, Mohammadi R, Cruz AGd. High-Methoxyl Apple Pectin Improves Rheological Properties and Storage Stability of the Flavored Probiotic Yogurt Drinks, Compared to Pomegranate Pectin. Appl Food Biotechnol. 2022; 9 (2): 91-102. http://dx.doi.org/10.22037/afb.v9i2.37565

1. Introduction

Flavored probiotic yogurt drinks (PYDs) are popular acidified milk drinks. They may be manufactured using various formulations but are commonly produced by adding lactic acid starters and/or probiotic bacteria to ferment and acidify milk. Furthermore, PYDs are blended with fruit-based mixtures [1]. For nutritional purposes, food and dairy products have been fortified with probiotic bacteria and fruit pulp/juices, which include outstanding markets. Therefore, PYDs are healthy products because of probiotics and the metabolites formed during fermentation, including bran-

ched-chain fatty acids, amines, phenolic compounds and vitamins [2].

One of the issues linked to these products is the sedimentation of aggregated proteins and large fruit particles [3]. Casein micelles are stable in sub-micrometer particles at the natural milk pH (~6.6) [4]. However, the pH of yogurt drinks falls to 3.4-4.6 due to the fermentation and addition of acid juices, resulting in instability of the micelles [5]. Therefore, a three-dimensional (3-D) network of irreversibly aggregated caseins is formed at pH 4.6, the casein micelle isoelectric point. This aggregation leads to phase separation in these products [6]. In addition, processing operations such as thermal treatment, dilution and storage may contribute to the acceleration of the protein aggregation [7]. The most effective method to solve the instability problem of dairy drinks includes use of stabilizers; from which, pectin has been shown as a good choice [8]. Pectin includes a complex structure, consisting majorly of alpha (1→4) links between the galacturonic acid units [9]. The galacturonic acid units can be non-esterified or esterified with methyl ester groups, showing various degrees of esterification (DE). Pectins with DE higher than 50% are known as high methoxyl pectins (HMP), while those with less than 50% are known as low methoxyl pectins (LMP). The HMP are stabilizers commonly used to decrease phase separation in acidified dairy drinks [9]. Common sources of pectin are apple and citrus peels. However, pomegranate peels may be addressed as novel pectin sources [10]. Prevention of particle sedimentation by HMP can be explained via various mechanisms. First, negatively charged pectin molecules can entirely cover the positively charged caseins by linking to the calcium ions or charged peptides [11]. Therefore, they can decrease attraction forces between the particles by steric repulsions and prevent flocculation, sedimentation and phase separation in PYDs [12, 13]. In addition, pectin molecules can form a weak gel network and prevent sedimentation of casein particles by creating a multi-layer biopolymer matrix with them [14]. This weak gel is strong enough to overcome the gravity force and prevent collision and sedimentation of the suspended casein particles [15]. Moreover, pectin can provide stability by increasing viscosity of the continuous phase, decreasing effects of gravity based on the Stokes' law.

Up-to-date, studies have carried out to stabilize plain acidified dairy drinks using various types of pectin [6,16,17]. To the best of the authors' knowledge, stabilization of PYD blended with fruit juice has not been investigated. Therefore, the major objective of this study was to investigate effects of various concentrations of pomegranate and apple HMP on physical and rheological properties of PYDs containing fruit juices (pomegranate juice), prebiotic ingredients and probiotic bacteria. Rheological properties, viscosity, phase separation and particle size distribution were carried out to provide further information on the stabilization mechanisms.

2. Materials and Methods

2.1. Materials

Pomegranate and apple peels were provided by a local market, dried at room temperature and milled using Polymix M20 Universalmuhle (Kinematica, Switzerland) Grinding Mill. Pectin extraction was carried out using citric acid (pH, 2.5; temperature, 88 °C; extraction time, 120 min) [10]. Briefly, 5 g of pectin were extracted from 170 g of pomegranate and apple peel powders. Degrees of pectin esterification extracted from pomegranate and apple peels were 65 and 72.35%, respectively, by drawing a calibration curve using pectin standards with known DE values according to Pereira et al. [10]. Characteristics of the pectins are reported in Table 1.

2.2. Sample preparation

Yogurt samples were prepared according to Nikmaram et al. by mixing nonfat reconstituted skim milk powder (8.5% w w^{-1}), inulin (2% w w^{-1}) and pomegranate juice (12% w w^{-1}) [1,18]. Fermentation phase was carried out using probiotic culture (*L. acidophilus* LA- 5 and *L. casei* 431; Chr. Hansen A/S, Hørsholm, Denmark) at 37 °C. The resulting yogurt (pH 4.8) was diluted with distilled water and pectin solutions to achieve a final total solid content (TSC) of 8.6% (w w^{-1}). This was mixed (Janke and Kunel RW 20 DZM Mixer, IKA) and homogenized at 45 atmospheric bars (APV1000 Laboratory Homogenizer, Denmark). Pectin was used at concentrations of 0, 0.1, 0.2, 0.3, 0.4 and 0.5% w v^{-1}.

Pectin solutions used in PYD were prepared by gradually adding the powder into cold distilled water with intensive stirring (Janke and Kunel RW 20 DZM Mixer, IKA) and then dissolving at 70 ˚C for 20 min using shaker water bath [9]. Solutions were cooled down to ambient temperature (25-30 ˚C) and added to partially diluted PYD portions. Preparations were stored at 4 ˚C until use.

Table 1. Characterization of the apple and pomegranate pectins*

Pectins				Neutral sugars (wt%)					
	Mw (kDa)	DE (%)	GalA (%)	Rha	Ara	Glc	Gal	Xyl	Man
AP	145.70	72.35	54.60	2.28	3.21	12.62	4.52	1.60	0.32
PP	130.20	65.00	69.20	1.85	3.86	21.56	3.49	0.51	0.14

*AP= Apple pectin, PP= Pomegranate pectin, Mw= molecular weight, DE= Degree of esterification, GalA= galacturonic acid, Rha= rhamnose, Ara= arabinose, Glc= glucose, Gal= galactose Xyl= xylose, Man= mannose

2.3. Viscosity measurement

Viscosity measurement of the fresh samples was carried out at 25 ˚C ±2 using viscometer (Brookfield DV II, LV Viscometer, USA) equipped with ULA spindle as described by Joudaki et al. [13]. Torque values were selected between 10 and 100%.

2.4. Rheometry

Rheological properties of the PYDs were assessed using Bohlin Gemini 200 Rheometer (Malvern Instruments, Worcestershire, UK) in a controlled rate mode. For each experiment, approximately 2 ml of the fresh samples were transferred onto the rheometry device plate. The geometry device included a cone with an angle of 4 °C and a diameter of 40 mm (4/40). Temperature was adjusted to 20 ˚C ±0.2 and PYDs were held on a plate for 10-15 min before analysis for temperature stabilization between the sets. Initially, Stress amplitude sweep was carried out to specify the linear viscoelastic behavior region at 10% strain. Then, oscillatory measurements were carried out at frequencies ranging 0.1-10 Hz to assess dynamic rheological properties, including storage (G') and loss (G") moduli.

2.5. Particle size analysis

Particle size distribution of the fresh samples was assessed using light scattering and Mastersizer 2000S Instrument (Malvern Instruments, UK) equipped with quartz cell and laser beam with λ of 634 nm. Refractive indices used for the particles and solvent were 1.5 and 1.33, respectively. Analysis was based on the principles of Fraunhofer [19]. Size distribution was characterized by volumetric percentage and carried out at room temperature.

2.6. Phase separation assessment

Tubes (2 cm in diameter and 12 cm in height) containing 20 ml of each preparation were stored at 4 ˚C for 15 days to assess phase separation and sedimentation. Volume of the separated serum at the upper phase was measured after 1 and 15 days of cold storage [20]. Samples with serum separation of less than 5% were considered as stable samples.

2.7. Statistics

Duncan's test was used to report significant differences ($p < 0.05$) between the mean values using SAS Software V.9.1 (SAS, 2004). All measurements were carried out in triplicate.

3. Results and Discussion

3. Results and Discussion

3.1. Viscosity

Figure 1 illustrates the flow behavior curves of PYDs stabilized with AP (Fig. 1a) and PP (pomegranate pectin) (Fig. 1b).

Treatments formulated with AP showed shear thinning behaviors. Wang et al. showed that the reaction between HMP and casein formed gel structures; in which, gel strength increased with pectin concentration [17]. However, network might be disrupted at higher shear rates. Therefore, shear-thinning behavior in PYD could be linked to the rupture of structure with increased shear rates. Shear-thinning behavior in fermented dairy drinks might be advantageous due to decreases in apparent viscosity in the mouth, inducing a desirable mouthfeel [21].

Linear relationships between the shear stress and shear rate were detected for the samples containing PP and control PYD (Fig. 1b). Viscosity of the control PYD was 2.2 mPa s^{-1}, which was close to a plain Doogh based on the results by Hasheminya et al. [22]. Viscosity values of the samples containing PP at 0.1, 0.2, 0.3, 0.4 and 0.5% were 2.56, 2.86, 3.16, 3.82 and 4.48 mPa s^{-1}, respectively. Therefore, the best rheological model to describe their behavior included the Newtonian model. In addition, several studies have shown that fermented milk drinks such as Ayran and Doogh demonstrate Newtonian behaviors [23]. In the present study, viscosity was enhanced by increasing PP concentration. Higher numbers of the pectin molecules were present to cover the casein micelles, possibly increasing interactions with water molecules and thus altering the fluid resistance to flow [24]. Figure 2 illustrates apparent viscosity (η) against pectin concentration (%) at shear rate of 50 s^{-1} for the samples containing 0.1, 0.2, 0.3, 0.4 and 0.5% of pectin and the control samples. Apparent viscosity of the PYD stabilized with various levels of pectin increased with increasing pectin concentrations ($p < 0.05$). However, effects of AP on the apparent viscosity of PYD were more significant than effects of PP ($p < 0.05$). These results indicated that HMP pectin could decrease weak gel structure formations; similar to the results reported for doogh and other acidified dairy drinks [13,14]. Koksoy and Kilic showed that the apparent viscosity of Ayran increased progressively from 27 to 50 mPa when the HMP content (DE was not assessed) increased from 0.25 to 0.5% at a shear rate of 55 s^{-1} [21]. Furthermore, Jensen et al. demonstrated that the viscosity of acidified dairy drinks increased sharply by HMP (DE = 72.6%) addition [25]. At higher concentrations of added pectin, further pectin molecules might be available to interact with casein particles and entrap them inside the pectin network, resulting in physical stability due to the restricted movement of these particles. In this study, AP included further suggested effects, which could be linked to the characteristics of the pectin such as the higher DE.

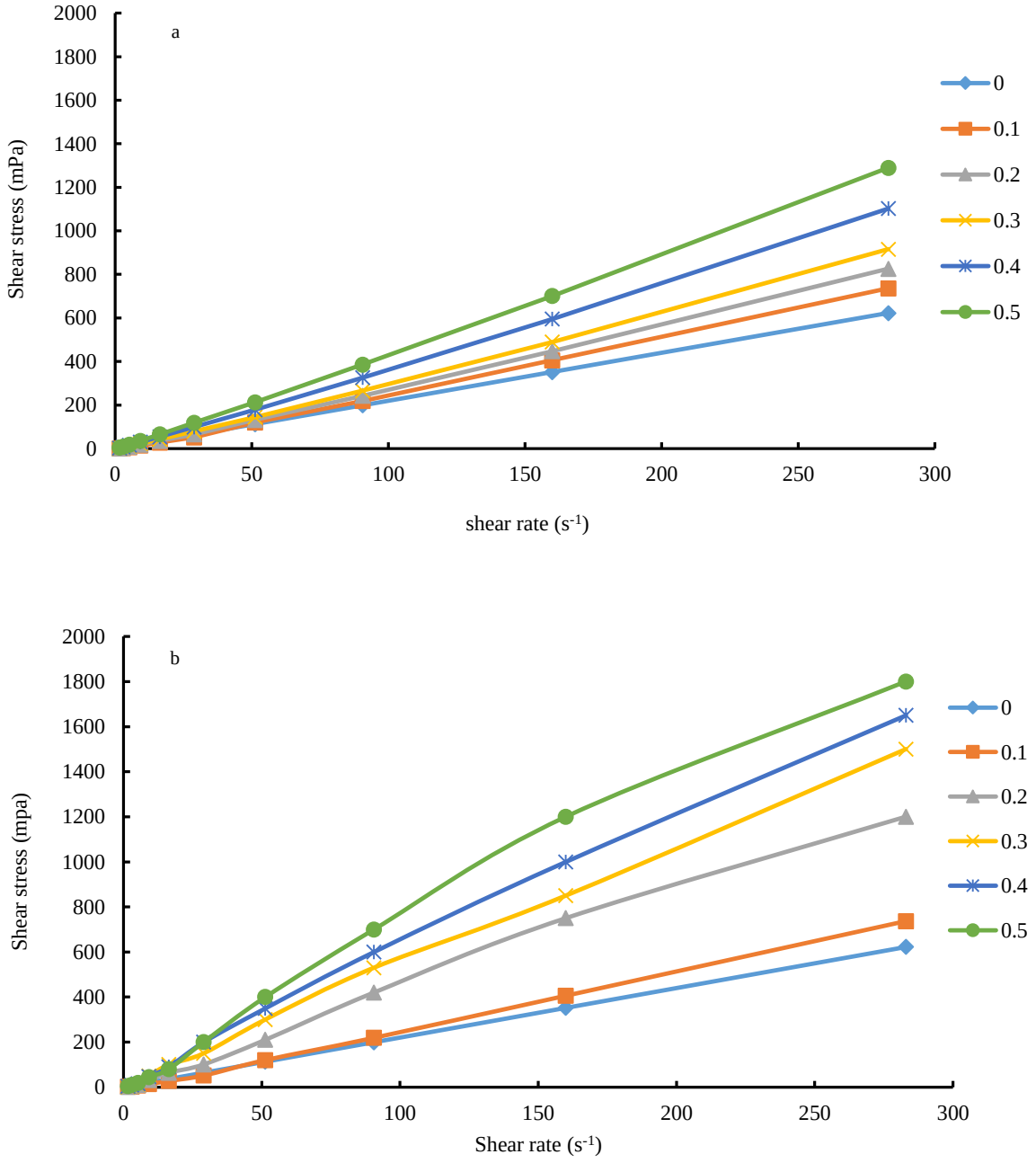

Figure 1. Changes in shear stress (mPa) of the probiotic yogurt drinks at various concentrations (% w v^{-1}) of apple pectin (a) and pomegranate pectin (b) as a function of shear rate (s^{-1}).

In fact, AP with higher DE could make further bonds with the casein micelle surface. Possibly for this reason, it was more effective in preventing casein-casein aggregation in PYD during storage. Based on the Stoke's law, increases in PYD viscosity could play important roles in decreased precipitant formation since samples containing AP demonstrated higher viscosity rates than samples prepared with PP. Based on the characteristics of the two pectin, AP included a higher molecular weight than that PP did, affecting viscosity [26].

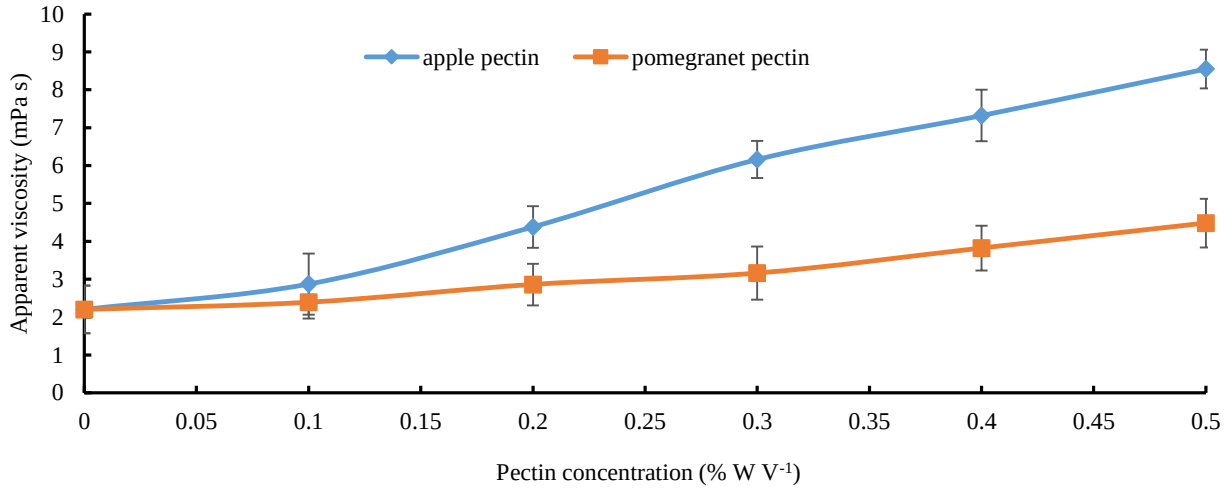

Figure 2. Apparent viscosity (at shear rate of 50 s^{-1}) of the probiotic yogurt drinks stabilized by various concentrations of apple pectin (♦) and pomegranate pectin (■). Different letters indicate significant differences at $p < 0.05$.

3.2. Oscillatory characteristics

Changes in elastic modulus (G') and viscous modulus (G") as a function of the frequency were observed in preparations containing various pectin contents (Figs. 3 and 4). All preparations were highly dependent on the frequency in the linear viscoelastic region at fixed stress (Fig. 3 (a,b,c,d,e,f)). In addition, PYD containing AP could be addressed as a viscoelastic material. Based on Fig. 3a, PYD with no AP addition showed similar G' and G" values and changes in G' and G" over the frequency range were almost equal. Hence, the control PYD showed a liquid-like behavior. The G' and G" values increased as AP concentration increased from 0.1 to 0.5%. The storage modulus (G') was consistently higher than the loss modulus (G") at lower frequencies in AP added samples. Therefore, 3-D network formations were seen in all the preparations with AP addition. At a specific point, two curves crossed over and G" values became higher than G' values, illustrating ruptures of the constructed pectin-protein network started at the crossover point. For the preparations containing AP, trend of the changes in G' and G" values was different and G" included a sharper ascending trend. Such observations indicated formation of a weak gel-like network after pectin addition to the samples [8]. The two G' and G" moduli represented two regions when the frequency changed; a plateau curve was reported in the first region. In the second region, moduli were strictly dependent on the frequency. In the first region, higher values of G' were observed with minor changes in the two moduli. This region could be attributed to the pectin-protein 3-D network created by the electrostatic interactions of these molecules [27]. Moreover, slight increases in G' and G" values with increasing frequency in this region could be explained due to the network deficiency such as dangling of polymer chain ends and trapped entanglements and loops [28]. However, the two moduli started to increase and G" was higher than G', resulting in viscous behaviors at higher frequencies. This region could be associated to the rupture of the pectin-protein network lost at higher shear rates. The two areas of behavior were observed for all AP added samples and they were more distinguishable at higher pectin concentrations. When the pectin concentration increased, rupture of the structure occurred at higher frequencies, indicating the formation of stronger networks. Frequencies, at which, the rupture occurred respectively included 24.21, 24.21, 27.66, 31.03 and 32.84 (Hz) for the samples containing 0.1, 0.2, 0.3, 0.4 and 0.5% AP, showing further effective protein stabilization rates at higher quantities of pectin. Rheological behaviors of the samples containing PP (Fig. 4 (b,c,d,e,f) were similar to those of the control (Fig. 4a). Therefore, liquid-like (not gel behavior) behaviors were seen in all preparations containing PP, as similarities between the G' and G" values indicated that the gel structure was not formed even at higher PP contents (0.5%).

3.3. Particle size distribution

Particle size analysis is a valuable tool for studying electrostatic complexes between the proteins and polysaccharides [29]. Particle size distribution of the samples is shown in Fig. 5 (a,b).

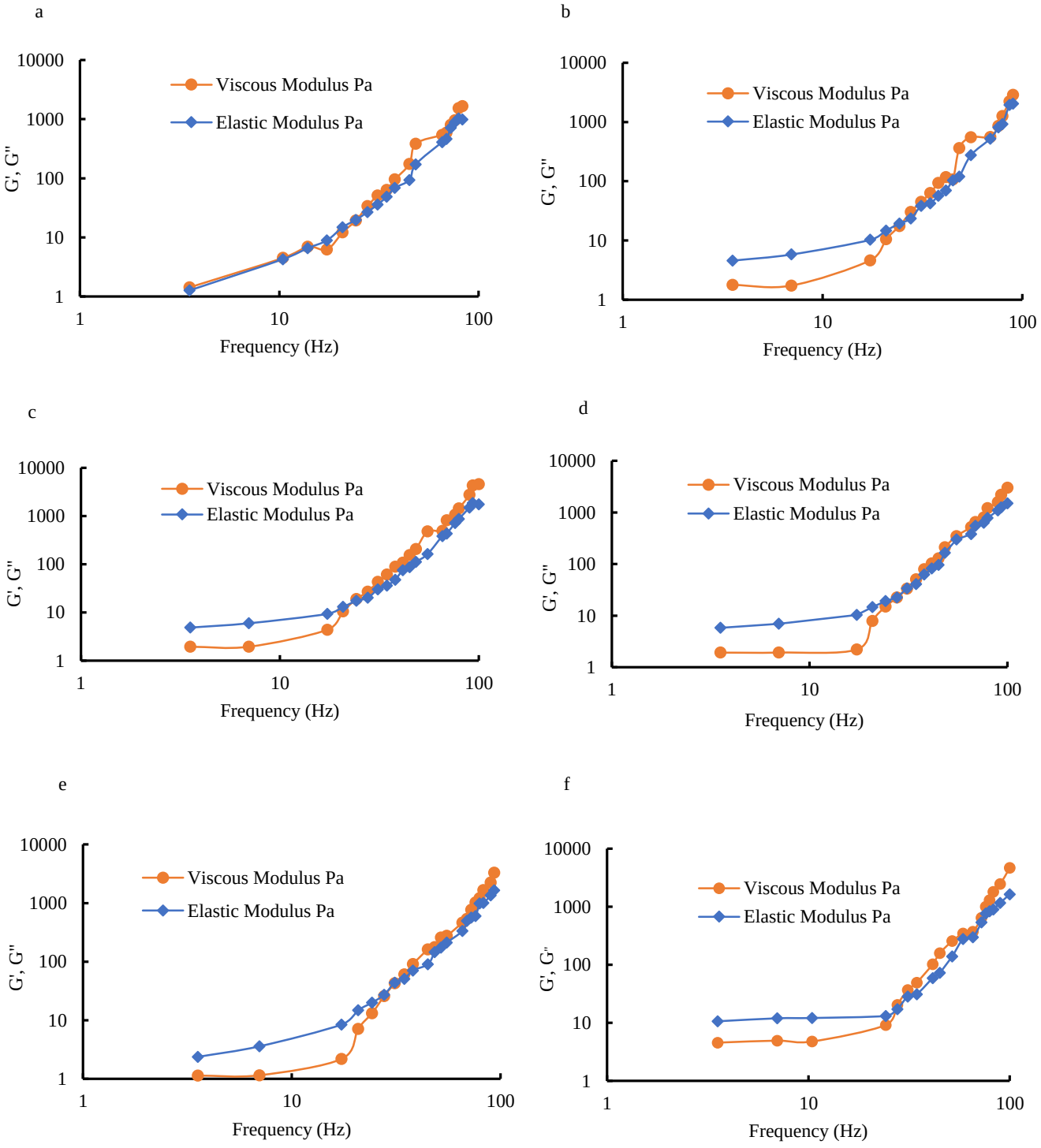

Figure 3. The G' and G" changes in probiotic yogurt drinks with no added apple pectin (a) and with 0.1 (b), 0.2 (c), 0.3 (d), 0.4 (e) and 0.5% (f) of apple pectin w v^{-1}.

Akkerman et al. stated that the average casein micelle size of four cow milk was 112.13 nm; however, the particle size increased after heat treatment (141 ℃ for 4 s). These results were linked to the heat process, causing whey proteins to denature and form complexes on the surface of the caseins [12]. In the current study, particle sizes for the detected particles in the control PYD were 200–2000 µm, which were greater than those of the non-heat treated milk of the former study. Particle size distribution of the AP preparations varied and extended to 100 µm, while their average diameter was 50 µm.

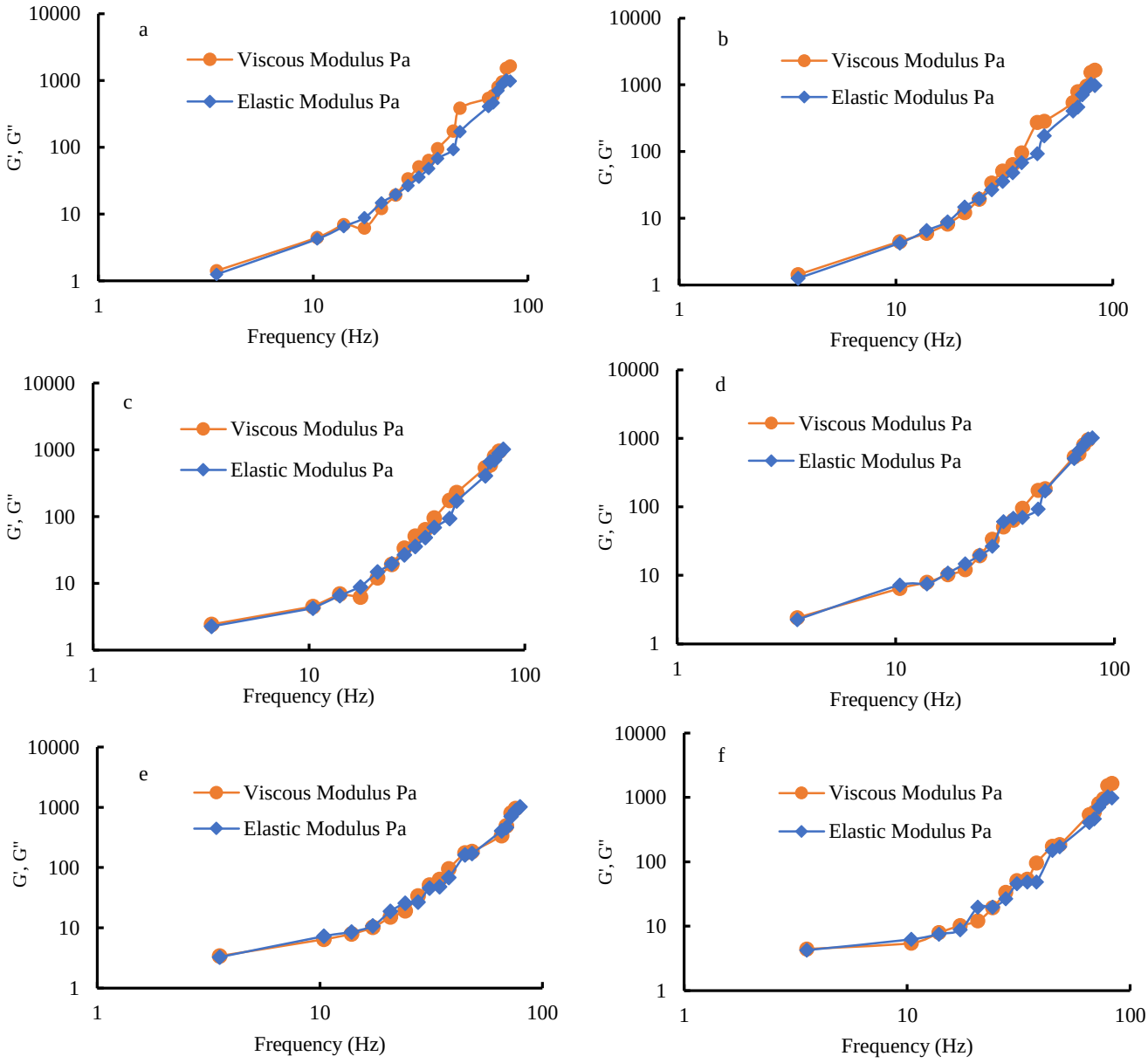

Figure 4. The G' and G" changes in probiotic yogurt drinks without pomegranate pectin (a) addition and with pomegranate pectin addition of 0.1 (b), 0.2 (c), 0.3 (d), 0.4 (e) and 0.5 % w v^{-1} (f).

Various AP levels included similar effects on the particle size distribution. However, preparations containing 0.5% of AP included the narrowest diagram, indicating particle size uniformity. A small aggregate population with a diameter higher than 100 µm was reported in distributions of 0.1 and 0.2% of AP, possibly because low pectin to cover the positively charged caseins lead to bridging flocculation [30]. Similar large aggregates were seen by Bourriot et al. in a mixture of micellar casein with guar gum [31]. This phenomenon was linked to decreased casein flocculation. Increases in size of the particles could be attributed to increases in the number of stable electrostatic associations between the pectin and the casein fragments [9].

Particle size distribution of the PYDs containing PP revealed that the particle size was not affected by higher PP levels and induced lower particle aggregation, compared to the control samples (less than 50 µm). Moreover, particle size distribution in the control PYD was wider than that in preparations containing pectin. Jensen et al. demonstrated that the particle size distribution ranged 5-15 µm in acidified dairy drinks with no pectin addition. Monomodal distributions were seen in PYD with or without pectin addition, possibly due to the aggregated casein micelles [25].

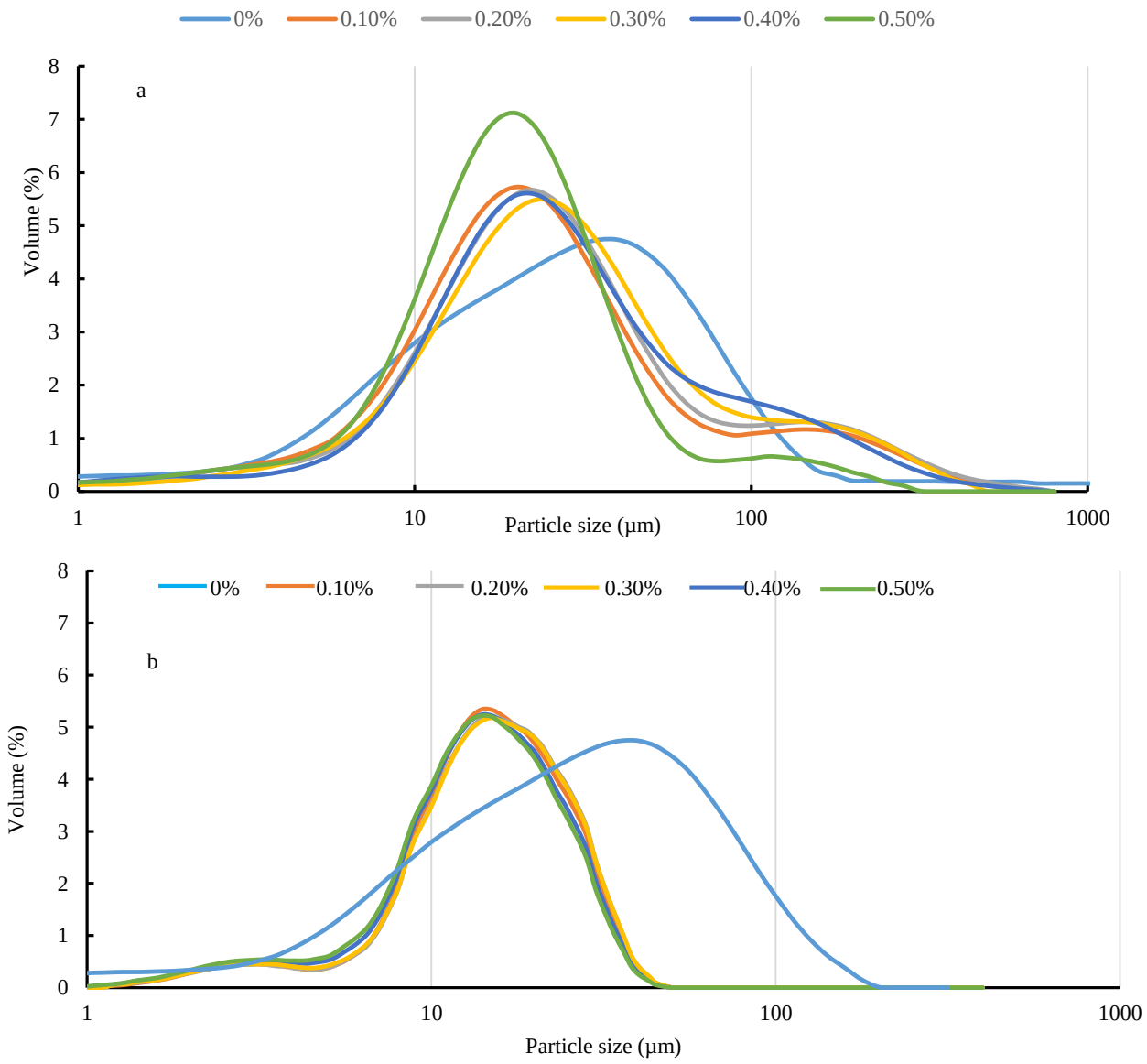

Figure 5. Particle size distribution of the probiotic yogurt drinks containing various concentrations of apple pectin (a) and pomegranate pectin (b).

3.4. Phase separation

In Fig. 6, the photographs of PYDs with pectin addition can be seen after 1 and 15 days of cold storage (4 °C). Samples without stabilizers and with 0.1 and 0.2% of AP were separated into two layers. In the control drink, a translucent upper layer (serum) and a dense opaque lower layer (sediment) were detected. By the end of Day 15 of storage, the translucent serum phase (upper layer) was still detectable in the control sample, representing more than 80% of the total volume (Fig. 6b). This behavior seemed completely consistent with progressive sedimentation of the individual fragments of acid-casein gels [9]. Particle sedimentation into a dense lower layer was not observed in samples containing high levels of AP (0.3, 0.4 and 0.5%) on Day 1 of storage (Fig. 6a). Over a 15-day storage time, samples with higher levels of AP addition preserved their stabilities (Fig. 6b). It was reported that adding 0.1 and 0.2% of AP were inadequate for preventing phase separation during the storage (15 days). This instability was possibly connected with the occurrence of bridging flocculation on partially covered casein particles by pectin [32,33]. Therefore, low levels of AP could not create enough electrostatic and steric repulsion for the dispersion stabilization. Yuliarti et al. reported that the phase separation was prevented by addition of HMP (DE = 70%) at a concentration of 0.8% (w w^{-1}) in acidified milk beverages during storage for seven days [34]. In contrast, Koksoy and Kilic reported that 0.5% of HMP (unspecified DE) decreased but did not prevent the phase separation in Ayran [21].

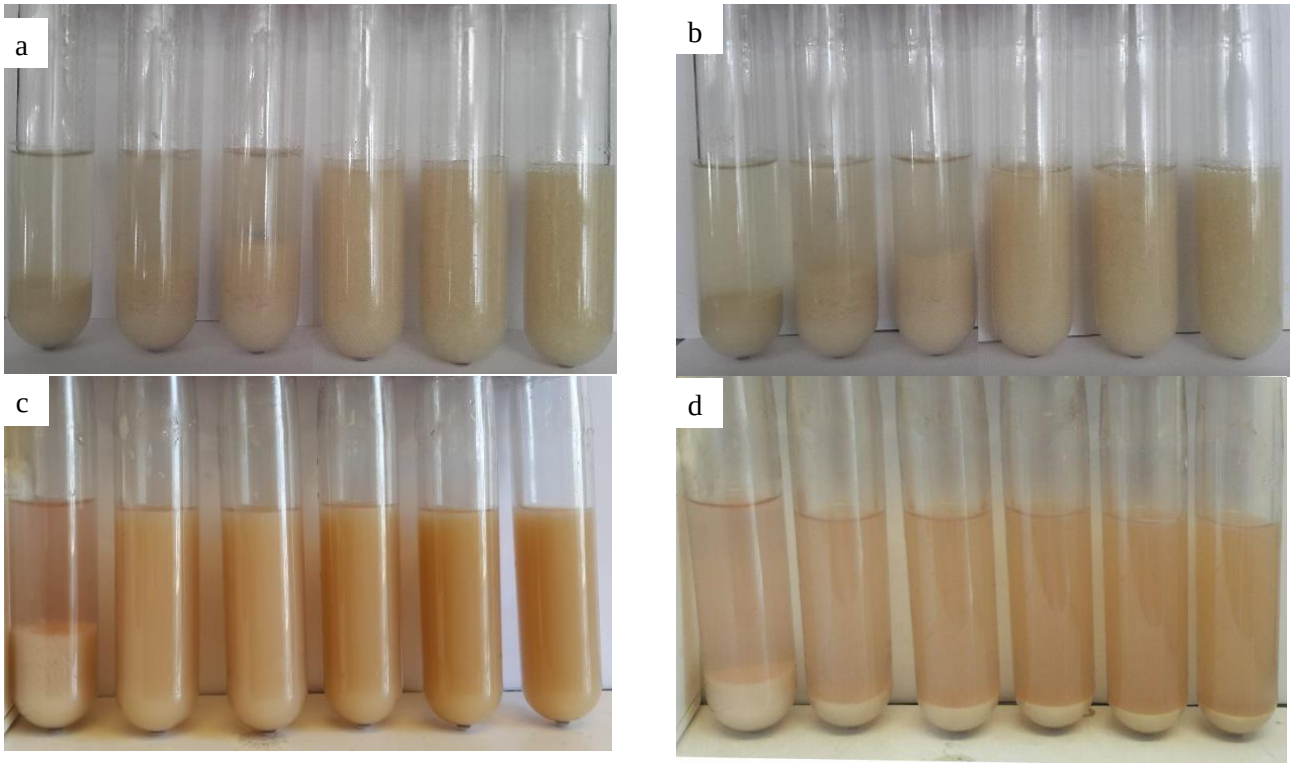

Figure 6. Images of probiotic yogurt drinks preparations with 0, 0.1, 0.2, 0.3, 0.4 and 0.5% of apple pectin after 1 (a) and (b) 15 days of cold storage (4 ˚C) and those with 0, 0.1, 0.2, 0.3, 0.4 and 0.5% pomegranate pectin at 1 (c) and 15 (d) days of cold storage (4 ˚C). Tubes are present in increasing form left to right, based on the pectin concentration.

Tromp et al. showed that 0.3% of pectin (DE = 72.2%) was necessary to produce a stable system containing 8.5% of milk solids and lower pectin content did not stabilize the product [14]. Therefore, the biopolymer needed to stabilize the beverage depended on the degree of polymerization and its interactions with the food components [3].

The translucent serum layer in samples with high AP levels may majorly be characterized by liquid release after the gel network contraction, which is expressed as syneresis instead of sedimentation since syneresis occurs most often in concentrated emulsions [27]. After initial rapid sedimentation, it is estimated that the acid-casein particles in the lower layer reassociate to provide a cross-linked network and form further particle-particle junctions, leading to fluid expression by gel contraction [9]. Overall, three types of junctions may be suggested in PYDs: (a) acid-casein particles in the control PYD; (b) pectin-casein connections (protein-polysaccharide complexes), resulting in bridging between the casein particles; and (c) pectin molecules forming a "weak gel-like structure," resisting to flow (viscosity) and network contraction (syneresis) [9].

Preparations containing 0.1-0.5% of PP showed no sedimentation on Day 1 of storage (Fig. 6c), unlike the control samples where the phase separation was seen. However, samples with PP addition could not preserve the stability for up to 15 days of cold storage and the particles sedimented into the lower layer (Fig. 6d).

In addition, the upper layer of these samples containing PP presented significant turbidity due to the suspended protein particles. Therefore, PP partially stabilized casein fragments because the pectin-protein connections were not possibly strong enough to preserve PYD stabilization until the storage time.

In general, samples with 0.3% of AP addition included the minimum concentration needed to stabilize the PYD, while 0.5% of PP was still insufficient for the stabilizing of casein particles in PYD (Fig. 6). This difference in the necessary quantity of pectin for the stabilization might be caused by various charges (DE), molecular weight and size of pectin. When pectin molecules included fewer dissociated carboxylic groups, they became less charged and fewer sites were available for the interactions with casein particles. Therefore, their tendency to be adsorbed onto the casein particle surface decreased [30]. Therefore, it has been suggested that the PP was less charged (DE) than AP. Then, it possibly included a lower ability for the adsorption onto casein particles.

4. Conclusion

Demands for the production of stable fermented milk drinks during storage is high. In the current study, apple and pomegranate pectins as bioactive polysaccharides were used to stabilize probiotic yogurt drinks. Experiments revealed that the stabilization of PYD by pectin depended on the concentration and DE of pectins. Although PP and AP were

considered as high methoxyl pectins, AP (higher DE) performed better than PP in PYD stabilization, possibly due to the higher overall negative charges. The oscillatory rheometry showed liquid-like behaviors in all samples containing PP. However, gel-like networks in PYD samples containing AP were seen, which could be broken at higher frequencies. The frequency limit, at which the gel network rupture occurred, increased with higher AP levels and was correlated with the PYD stability. In general, use of AP is recommended to improve quality attributes of the acidified dairy drinks. However, further studies are necessary to investigate effects of apple pectin on the characteristics of various fermented milk drinks as well as human gastrointestinal diseases.

5. Acknowledgements

Research reported in this publication was supported by the Elite Researcher Grant Committee under award number [958307] from the National Institutes for Medical Research Development (NIMAD), Tehran, Iran. The authors appreciate ZAMZAM Co., Tehran, Iran, for offering experimental device services.

6. Conflict of Interest

The authors report no conflicts of interest.

References

1. Nikmaram P, Mousavi SM, Kiani H, Emamdjomeh Z, Razavi SH, Mousavi Z. Modeling the effect of inulin, pH and storage time on the viability of selected lactobacillus in a probiotic fruity yogurt drink using the monte carlo simulation. J Food Qual. 2016; 39 (4): 362-369.
http://doi.org.10.1111/jfq.12202

2. Verbeke KA, Boobis AR, Chiodini A, Edwards CA, Franck A, Kleerebezem M, Nauta A, Raes J, Van Tol E, Tuohy KM. Towards microbial fermentation metabolites as markers for health benefits of prebiotics. Nutr Res Rev. 2015; 28(1): 42-66.
http://doi.org.10.1017/S0954422415000037

3. Guimaraes JT, Silva EK, Costa ALR, Cunha RL, Freitas MQ, Meireles MAA, Cruz AG. Manufacturing a prebiotic whey beverage exploring the influence of degree of inulin polymerization. Food Hydrocoll. 2018; 77: 787-795.
http://doi.org.10.1016/j.foodhyd.2017.11.02

4. Khanniri E, Sohrabvandi S, Masomeh Arab S, Shadnoush M, Mortazavian AM. Effects of stabilizer mixture on physical stability of nonfat Doogh, an Iranian traditional drink. Koomesh 2017; 19(1): 144-153.

5. Hashemi K, Hosseini E. The stabilizing and prebiotic potential of water-soluble phase of bitter almond gum exudate in probiotic yogurt drink. Carbohydr Polym. 2021; 255: 117395.

http://doi.org.10.1016/j.carbpol.2020.117395

6. Khanniri E, Yousefi M, Khorshidian N, Sohrabvandi S, Mortazavian AM. Development of an efficient stabiliser mixture for physical stability of nonfat unfizzy doogh. Int J Dairy Technol. 2019; 72(1): 8-14.
http://doi.org/10.1111/1471-0307.12554

7. Laurent MA, Boulenguer P. Stabilization mechanism of acid dairy drinks (ADD) induced by pectin. Food Hydrocoll. 2003; 17(4): 445-454.
http://doi.org.10.1016/s0268-005x(03)00028-6

8. Krongsin J, Gamonpilas C, Methacanon P, Panya A, Goh SM. On the stabilisation of calcium-fortified acidified soy milks by pomelo pectin. Food Hydrocoll. 2015; 50: 128-136.

9. Kiani H, Mousavi ME, Razavi H, Morris ER. Effect of gellan, alone and in combination with high-methoxy pectin, on the structure and stability of Doogh, a yogurt-based Iranian drink. Food Hydrocoll. 2010; 24(8):744-754.
http://doi.org.10.1016/j.foodhyd.2010.03.016

10. Pereira PHF, Oliveira TIS, Rosa MF, Cavalcante FL, Moates GK, Wellner N, Waldron KW, Azeredo HM. Pectin extraction from pomegranate peels with citric acid. Int J Biol Macromol. 2016; 88: 373-379.
http://doi.org.10.1016/j.ijbiomac.2016.03.074

11. Nakamura A, Yoshida R, Maeda H, Corredig M. The stabilizing behaviour of soybean soluble polysaccharide and pectin in acidified milk beverages. Int Dairy J. 2006; 16(4): 361-369.
http://doi.org.10.1016/j.idairyj.2005.01.014

12. Akkerman M, Johansen LB, Rauh V, Sørensen J, Larsen LB, Poulsen NA. Relationship between casein micelle size, protein composition and stability of UHT milk. Int Dairy J. 2021;112:104856.
http://doi.org.10.1016/j.idairyj.2020.104856

13. Joudaki H, Mousavi M, Safari M, Razavi SH, Emam-Djomeh Z, Gharibzahedi SMT. Scrutinizing the different pectin types on stability of an Iranian traditional drink "Doogh". Int J Biol Macromol. 2013; 60: 375-382.
http://doi.org.10.1016/j.ijbiomac.2013.06.034

14. Tromp RH, De Kruif CG, Van Eijk M, Rolin C. On the mechanism of stabilisation of acidified milk drinks by pectin. Food Hydrocoll. 2004; 18(4): 565-572.
http://doi.org.10.1016/j.foodhyd.2003.09.005

15. Miquelim JN, Lannes SCS, Mezzenga R. pH Influence on the stability of foams with protein-polysaccharide complexes at their interfaces. Food Hydrocolloids. 2010; 24(4): 398-405.
http://doi.org.10.1016/j.foodhyd.2009.11.006

16. Cai Z, Wu J, Du B, Zhang, H. Impact of distribution of carboxymethyl substituents in the stabilizer of carboxymethyl cellulose on the stability of acidified milk drinks. Food Hydrocoll. 2018; 76: 150-157.
http://doi.org.10.1016/j.foodhyd.2016.12.034

17. Wang X, Kristo E, LaPointe G. Adding apple pomace as a functional ingredient in stirred-type yogurt and yogurt drinks. Food Hydrocoll. 2020;100: 105453.
http://doi.org.10.1016/j.foodhyd.2019.10545

18. Nikmaram P, Mousavi SM, Emam-Djomeh Z, Kiani H, Razavi SH. Evaluation and prediction of metabolite production, antioxidant activities and survival of Lactobacillus casei 431 in a pomegranate juice supplemented yogurt drink using support vector regression. Food Sci Biotechnol. 2015; 24(6): 2105-2112.
http://doi.org.10.1007/s10068-015-0279-5

19. Huang X, Kakuda Y, Cui W. Hydrocolloids in emulsions: Particle size distribution and interfacial activity. Food Hydrocoll. 2001; 15(4-6): 533-542.
http://doi.org.10.1016/s0268-005x(01)00091-1

20. Azarikia F, Abbasi S. On the stabilization mechanism of Doogh (Iranian yoghurt drink) by gum tragacanth. Food Hydrocoll. 2010; 24(4): 358-363.
http://doi.org. 10.1016/j.foodhyd.2009.11.001

21. Koksoy A, Kilic M. Use of hydrocolloids in textural stabilization of a yoghurt drink, ayran. Food Hydrocoll. 2004; 18(4): 593-600.
http://doi.org.10.1016/j.foodhyd.2003.10.002

22. Hasheminya SM, Ehsani MR, Dehghannya J. Production of a fiber-enriched pasteurized and non-pasteurized fermented acidified drink using gellan. Food Biosci. 2013; 3: 29-35.
http://doi.org.10.1016/j.fbio.2013.05.002

23. Kiani H, Mousavi SMA, Emam-Djomeh Z. Rheological properties of Iranian yoghurt drink, Doogh. Int J Dairy Sci. 2008; 3(2): 71-78.

24. Azary Z, Nasirpour A. Effect of whey protein concentrate, pH and salt on colloidal stability of acid dairy drink (Doogh). Int J Dairy Technol. 2018; 71(1): 198-207.
http://doi.org.10.1111/1471-0307.12371

25. Jensen S, Rolin C, Ipsen R. Stabilisation of acidified skimmed milk with HM pectin. Food Hydrocoll. 2010; 24(4): 291-299.
http://doi.org.10.1016/j.foodhyd.2009.10.004

26. Wang X, Chen Q, LuX. Pectin extracted from apple pomace and citrus peel by subcritical water. Food Hydrocoll. 2014; 38: 129-137.
http://doi.org.10.1016/j.foodhyd.2013.12.003

27. Dickinson E. Stability and rheological implications of electrostatic milk protein-polysaccharide interactions. Trends Food Sci Technol. 1998; 9(10): 347-354.
http://doi.org. 10.1016/S0924-2244(98)00057-0

28. Ross-Murphy SB. Structure-property relationships in food biopolymer gels and solutions. J Rheol. 1995; 39(6): 1451-1463.
http://doi.org. 10.1122/1.550610

29. Gorji EG, Mohammadifar MA, Ezzatpanah H. Influence of gum tragacanth, *Astragalus gossypinus*, addition on stability of nonfat Doogh, an Iranian fermented milk drink. Int J Dairy Technol. 2011; 64(2): 262-268.
http://doi.org.10.1111/j.1471-0307.2010.00658.x

30. Liu J, Nakamura A, Corredig M. Addition of pectin and soy soluble polysaccharide affects the particle size distribution of casein suspensions prepared from acidified skim milk. J Agric Food Chem. 2006; 54(17): 6241-6246.
http://doi.org.10.1021/jf060113n

31. Bourriot S, Garnier C, Doublier JL. Micellar-casein-κ-carrageenan mixtures. I. Phase separation and ultrastructure. Carbohydr Polym. 1999; 40(2):145-157.
http://doi.org.10.1016/S0144-8617(99)00044-2

32. De Kruif C, Tuinier R. Polysaccharide protein interactions. Food Hydrocoll. 2001;15(4-6): 555-563.

http://doi.org.10.1016/S0268-005X(01)00076-5

33. Maroziene A, De Kruif C. Interaction of pectin and casein micelles. Food Hydrocoll. 2000; 14(4): 391-394.
http://doi.org.10.1016/S0268-005X(00)00019-9

34. Yuliarti O, Mei KH, Ting ZKX, Yi KY. Influence of combination carboxymethylcellulose and pectin on the stability of acidified milk drinks. Food Hydrocoll. 2019; 89: 216-223.
http://doi.org.10.1016/j.foodhyd.2018.10.040

Research Article
pISSN: 2345-5357
eISSN: 2423-4214
OPEN ACCESS

APPLIED FOOD BIOTECHNOLOGY, 2022, 9 (2): 91-102
Journal homepage: www.journals.sbmu.ac.ir/afb

پکتین سیب متوکسیل بالا در مقایسه با پکتین انار، خواص رئولوژی و پایداری نوشیدنی ماست زیست‌یار[1] طعم‌دار را بهبود می‌بخشد.

بهاره سرمدی[1†]، پرنگ نیک مرام[2†]،امیر محمد مرتضویان[1*]، حسین کیانی[2*]، محمد موسوی[2]، الهام خان‌نیری[1]، رضا محمدی[3]، آدریانو کروز[4]

۱-گروه علوم و صنایع غذایی، دانشکده علوم تغذیه و صنایع غذایی، انستیتو تحقیقات تغذیه‌ای و صنایع غذایی کشور، دانشگاه علوم پزشکی شهید بهشتی، تهران، ایران.
۲- گروه علوم، مهندسی و صنایع غذایی، آزمایشگاه فرآیند زیستی و تشخیص زیستی، پردیس کشاورزی و منابع طبیعی، دانشگاه تهران، کرج، ایران.
۳- گروه علوم و صنایع غذایی، دانشکده علوم تغذیه و صنایع غذایی، دانشگاه علوم پزشکی کرمانشاه، کرمانشاه، ایران.
۴- گروه غذا، موسسه فدرال علم و فناوری ریو دو ژانیرو، ریو دو ژانیرو ، برزیل.

تاریخچه مقاله
دریافت ۶ فوریه ۲۰۲۲
داوری ۶ فوریه ۲۰۲۲
پذیرش ۱۳ فوریه ۲۰۲۲

واژگان کلیدی
- پکتین سیب
- نوشیدنی ماست زیست‌یار
- پکتین انار
- پایدارکننده

***نویسندگان مسئول**

امیر محمد مرتضویان
گروه علوم و صنایع غذایی، دانشکده علوم تغذیه و صنایع غذایی/ انستیتو تحقیقات تغذیه و صنایع غذایی کشور، دانشگاه علوم پزشکی شهید بهشتی، تهران، ایران.
mortazvn@sbmu.ac.ir

حسین کیانی
گروه علوم، مهندسی و صنایع غذایی، آزمایشگاه فرآیند زیستی و تشخیص زیستی، پردیس کشاورزی و منابع طبیعی، دانشگاه تهران، کرج، ایران.
پست الکترونیک:
hokiani@ut.ac.ir

[†]این نویسندگان به عنوان نویسنده اول در این کار ، مشارکت یکسان داشته اند : بهاره سرمدی ، پرنگ نیک مرام

چکیده

سابقه و هدف: استفاده از پکتین در صنایع غذایی و غذادارو، به‌دلیل اثرات مثبت آن بر پایداری نوشیدنی‌های لبنی و همچنین فواید بالقوه آن برای سلامتی انسان مورد توجه قرار گرفته است. همچنین، تقاضا برای تولید نوشیدنی‌های شیر تخمیر شده پایدار در طول زمان نگهداری زیاد است. بنابراین، هدف از این مطالعه بررسی اثرات پکتین‌های سیب و انار به‌عنوان پایدارکننده بر خواص نوشیدنی ماست زیست‌یار بود.

مواد و روش ها: پکتین‌های سیب و انار در غلظت‌های ۰/۵-۰ درصد ($w\ v^{-1}$) به نوشیدنی ماست زیست‌یار حاوی ٪۲ اینولین و ٪۱۲ آب انار اضافه شد. سپس، رفتار رئولوژیک، توزیع اندازه ذرات و پایداری نوشیدنی‌های ماست زیست‌یار در طول زمان نگهداری مورد بررسی قرار گرفت.

یافته‌ها و نتیجه‌گیری: نمونه شاهد (تیمار بدون افزودن پکتین) و نوشیدنی‌های ماست زیست‌یار حاوی پکتین انار (٪۰/۵-۰/۱) رفتار جریان نیوتنی و رفتار شبه سیال را در محدوده فرکانس نشان دادند. ویژگی نوشیدنی‌های ماست زیست‌یار حاوی پکتین سیب شامل رفتار جریان شل‌شونده با برش، شبکه شبه ژل در فرکانس‌های پایین و متوسط اندازه ذرات ۵۰ µm بود. بالاترین G' و G" و پایداری در طول دوره نگهداری در نمونه‌های حاوی ٪ ۰/۵ پکتین سیب به‌دست آمد. نتایج نشان داد که پکتین سیب، از آنجا که خواص رئولوژیکی و پایداری انباری را بهبود می‌بخشد، پتانسیل بالایی برای استفاده در تولید صنعتی نوشیدنی‌های ماست زیست‌یار دارد. بنابراین، استفاده از ٪ ۰/۵ پکتین سیب در نوشیدنی‌های شیر تخمیر شده پیشنهاد می‌شود.

تعارض منافع: نویسندگان اعلام می‌کنند که هیچ نوع تعارض منافعی مرتبط با انتشار این مقاله ندارند.

[1] Probiotic