Assessment of technological characteristics of non-fat yoghurt manufactured with prebiotics and probiotic strains

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Abstract Microbiological, physicochemical, aroma and organic acid characteristics of non-fat yoghurt incorporated with β -glucan and probiotic *Lactobacillus plantarum* strains (AB6-25, AC18-82 and AK4-11) combination as adjunct culture were investigated during a 21 day storage period at 4 °C. Four treatment yoghurts contained 0.25, 0.5, 1 and 1.5 % β -glucan. Treatments also included probiotic combination and commercial culture. Treatments were compared with three controls produced containing commercial culture, commercial culture and probiotic combination, and commercial culture, *Lactobacillus acidophilus* and inulin. The results indicated that β -glucan promote the viability of lactobacilli. However, the addition of β -glucan (except 0.25 %) resulted in enhanced syneresis ($P<0.05$). In general, the use of 0.25 % β -glucan had no significant effect on pH, fat, protein and organic acid content of non-fat yoghurt. The results obtained from this research demonstrated that the use of 0.25 % β -glucan has no adverse effect on the characteristics of non-fat yogurt produced with probiotic combination.

Keywords β -glucan · Non-fat yoghurt · Probiotic · *Lactobacillus plantarum*

Introduction

Functional foods are edibles which besides their initial function (satiation and nutrition) also provide health benefits to the consumer. Functional foods must fulfill the following requirements: they must consist of natural components, not a tablet or powder; they can and should be consumed as part of the daily meals; their special regulations lie in the regulation of the particular process ongoing in the human organism. The best-known examples of functional foods are fermented milks and yoghurts containing a special kind of bacterium that positively affects human intestines (Havrlentová et al. 2011).

There has been an increasing interest in the production of synbiotic fermented milk products especially yoghurt and numerous studies have focused on using *Lactobacillus acidophilus* strains and inulin for yoghurt production. However, there is a lack of information about using β -glucan and other starter cultures for the production of fermented milk products (Zekovic et al. 2005). It has been suggested that oats, particularly soluble fibre fraction β -glucan, play a significant role in human physiological processes (Jenkins et al. 2002; Tungland 2003). β -glucan is added in the formulation of functional and nutraceutical foods to improve the texture of extruded foods, as non-caloric thickeners and stabilizers in the manufacture of low-fat products such as ice creams and yoghurts (Brennan et al. 2002). Cereal β -glucan also could play multiple roles as fat mimetics which are substances that imitate organoleptic or physical properties of triglycerides (Akoh 1998). Consumption of low or non-fat dairy products has increased in recognition thanks to their health benefits, and the health problems of consumers (Kucukoner and Haque 2003). Yogurt is one of the most popular of these dairy-fermented products and is popularly consumed in many societies. Yogurt by itself has been recognized by the medical profession as a healthy food for both adults and children, due

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to health benefits from high levels of proteins, calcium and vitamins (Sahan et al. 2008).

The objective of this study was to determine the effects of adjunct probiotic *Lactobacillus plantarum* strains and oat based β -glucan in synbiotic functional non-fat yoghurt. The yoghurts were evaluated with respect to their microbiological, physicochemical properties, aroma compounds and organic acid profiles.

Materials and methods

Materials

The microorganisms, used in this study for preparation of *L. plantarum* combination including *L. plantarum* AB6-25, AC18-82 and AK4-11 were previously isolated from human sources (Başyigit Kılıç and Karahan 2010) and some probiotic and technological properties of the strains were also determined previously (Başyigit Kılıç et al. 2012). The freeze-dried (DVS) starter cultures and the milk were obtained from Çavuşoğulları Dairy Factory (Burdur, Turkey). The probiotic strain *L. acidophilus* LMG 11472 was obtained from the BCCM/LMG culture collection in Gent, Belgium. The commercial oat β -glucan (PROMOAT soluble oat fibre) and inulin (Orafti, HPX) were provided by Güler Kimya (Istanbul, Turkey) and Artisan Gıda (Istanbul, Turkey), respectively.

Yoghurt manufacture

The yoghurt was produced at the Department of Dairy Products, Vocational School of Education, Mehmet Akif Ersoy University, Turkey. Production was carried out using skim milk. The fat and milk solids-not-fat level in the standardized milk was % 0.1 and % 8.90, respectively. In this research, seven different groups of yoghurt were produced. Control 1 (C1) was produced using DVS starter culture (2 %), control 2 (C2) was produced using DVS starter culture (1 %) and *L. plantarum* combination (10^7 – 10^8 CFU ml⁻¹), control 3 (C3) was produced using DVS starter culture (1 %), *L. acidophilus* LMG 11472 (10^7 – 10^8 CFU ml⁻¹), and inulin (2 %). Group C3 was added to the study to compare the treatment groups with mostly known synbiotic yoghurt formula. All the treatment groups (T) were produced by using the DVS starter culture (1 %) and *L. plantarum* combination (10^7 – 10^8 CFU/ml). Oat β -glucan was added into the T1, T2, T3 and T4 groups at the levels of 0.25, 0.5, 1.0 and 1.5 %, respectively.

Standardized milk was supplemented with inulin and oat β -glucan for yoghurt production, as has been described previously. Milk for each group was heated to 60–75 °C and homogenized by an Ultra Turrax homogenizer (Sintcrusher M, Heidolph, Germany) for 15 s for dispersion of β -glucan

and inulin. Milk was then pasteurized at 85 °C for 15 min and cooled to 44 °C. The inoculated groups were dispensed into presterilized glass containers, incubated at 42 °C until the pH reached 4.50, cooled to 4 °C and stored for 3 weeks. The yoghurt samples were subject to microbiological and physicochemical analysis at time intervals of 1, 7, 14 and 21 days. All yoghurt trials were repeated twice.

Microbiological analysis of yoghurts

Microbiological analyses were carried out at the 1st, 7th, 14th and 21st days of storage. The preparation of the samples and dilutions for microbiological examinations was performed according to IDF standard 122C. Total mesophilic aerobic bacteria, mould and yeast and lactobacilli were counted. All analyses were performed in duplicate. The number of *L. plantarum* strains was also determined on *L. plantarum* selective agar (LPSM) at 37 °C for 48 h (Bujalance et al. 2006). M17 agar (Merck, Germany) was used to determine the viability of starter cultures for *Streptococcus salivarius* subsp. *thermophilus*. The plates were incubated at aerobic conditions for 48 h at 37 °C. *L. delbrueckii* subsp. *bulgaricus* was counted on reinforced clostridia agar (RCA) at pH 5.3 and anaerobic incubation (GasPak System-OXOID) at 42 °C for 48 h (Vasiljevic et al. 2007).

Physicochemical analysis of yoghurts

The yoghurt groups were analyzed in duplicate for their dry matter (DM), fat, protein, titratable acidity (TA), pH and syneresis. DM content was determined by gravimetric method via oven drying in a laboratory oven BINDER GmbH (Germany), at 105 °C (Anonymous 1981). Fat content was determined using the Gerber method (British Standard Institution 1955). Total nitrogen was measured via the micro-Kjeldahl method (IDF 1962). Titratable acidity (TA) was determined by titrating 10 mL sample with 0.1 M NaOH; phenolphthalein was used as an indicator. The extent of syneresis during cold storage of yoghurt groups was determined using the method of Keogh and O’Kennedy (1998) with some modifications (Purwandari et al. 2007). For this purpose 20 g samples were centrifuged (NF 400, Nüve, Turkey) at 700 g for 10 min. The weight of the drained liquid was recorded and related to the initial weight of yoghurt. The degree of syneresis was expressed as a percentage.

Determination of aroma compounds

Aroma compounds analyses were carried out by GC/MS chromatography of yoghurt samples on the 1st and 21st days of storage. A fused silica SPME fiber CAR/PDMS was used to determine the headspace-solid phase microextraction. Two grams of yoghurt samples were transferred into headspace

vials and sample vials were incubated at 40 °C for 15 min, after which the fiber was inserted directly into the vial and the fiber remained inside the sample for 15 min at 40 °C. Afterwards, the fiber was withdrawn and transferred into the injection port of the GC. Desorption time was set to 1 min while the temperature of the injection port was set to 250 °C.

GC/MS analysis was performed with GC 17A QP 5050 GC/MS (Shimadzu, Japan). Helium was used as the carrier gas. The MS operating conditions were: Ionization voltage 70 eV, ion source EI, ion source temperature 250 °C. The following GC operating conditions were used: a 50 m×0.32 mm I.D., 1.2 µm film thickness column Cp WAX 52 CB; a flow rate of 1.5 mL min⁻¹; the injection port set at 250 °C the temperature program began at 40 °C for 3 min; increased 4 °C min⁻¹ up to 230 °C; stayed at 230 °C for 10 min identification of components was carried out by means of commercial libraries (Wiley, Nist and Tutor).

Determination of organic acids

Determination of organic acids was carried out in yoghurt samples on the 1st and 21st days of storage. Sample preparations were made as described by Alhendawi et al. (1997) with slight modifications. A 20 µL of the diluted solution was injected into the HPLC system (Shimadzu, Japan) equipped with a Prodigy ODS (2) (250×4.6 mm) 5 µ column. The mobile phase consisted of 1 % acetonitrile/ 99 % 0.05 M KH₂PO₄ at pH 2.5, and the flow rate was 0.8 mL min⁻¹. To prepare a standard solution, stock solutions (1000 ppm) of organic acids were prepared in the mobile phase. Standard solutions of each organic acid were made in the mobile phase by appropriate dilutions (formic acid 145 mg L⁻¹, pyruvic acid 3.5 mg L⁻¹, lactic acid 3174 mg L⁻¹, acetic acid 102.8 mg L⁻¹).

Statistical analysis

The complete experiment was repeated twice. Data was subject to Tukey's test for pairwise comparisons between means by using SPSS 16.0 (SPSS, Chicago, IL, USA). Values of $P \leq 0.05$ were considered to be statistically significant.

Results and discussion

Microbiological characteristics of non-fat yoghurts

Table 1 shows the viable counts of *L. plantarum*, *Str. salivarius* subsp. *thermophilus* and *L. delbrueckii* subsp. *bulgaricus* in yoghurts during the refrigerated storage. The initial viable count of *L. plantarum* was determined to be at the level of 8 log₁₀ CFU g⁻¹. The viable count was almost stable in C2 and T1 groups and a slight decrease was observed in the rest of the groups during the 21 days of storage. Several

Table 1 Effect of storage period on viability of *L. plantarum* and yoghurt cultures (*L. delbrueckii* subsp. *bulgaricus* and *Str. salivarius* subsp. *thermophilus*) in yoghurt groups (CFU g⁻¹)*

Culture/Group	Period of storage (day) Log ₁₀ CFU g ⁻¹			
	1	7	14	21
<i>L. plantarum</i>				
C1	<1	<1	<1	<1
C2	8.61	8.40	8.63	8.69
C3	<1	<1	<1	<1
T1	8.60	7.95	8.56	8.61
T2	8.50	8.00	7.73	7.95
T3	8.39	7.92	7.63	8.01
T4	8.77	8.39	8.29	8.62
Standard error	0.21			
<i>Str. salivarius</i> subsp. <i>thermophilus</i>				
C1	8.43	8.23	8.27	8.16
C2	8.47	8.39	8.45	8.34
C3	8.28	8.23	8.23	8.24
T1	8.45	8.32	8.49	8.28
T2	8.41	8.22	8.30	8.42
T3	8.24	8.27	8.23	8.23
T4	8.42	8.46	8.49	8.32
Standard error	0.06			
<i>L. delbrueckii</i> subsp. <i>bulgaricus</i>				
C1	7.84	7.30	6.81	6.27
C2	7.08	7.42	7.08	6.89
C3	8.02	8.05	8.15	7.78
T1	7.44	7.33	6.91	6.64
T2	7.50	7.55	7.00	7.09
T3	7.20	7.22	7.04	6.57
T4	7.33	7.32	6.98	6.59
Standard error	0.25			

*No statistical difference among the count of bacteria

reports pointed out the ability of selected probiotic and yoghurt strains to utilize β-glucan (Snart et al. 2006; Gee et al. 2007). Our findings were also consistent with the results given by Jaskari et al. (1998) regarding the promotion of growth by β-glucan and the viability of LAB. Our previous study (Başyigit Kılıç and Akpınar 2013) showed that the addition of 0.5 and 1 % β-glucan in regular yoghurt had effected the growth of *L. plantarum* strains. However, the added concentration of β-glucan had no effect ($P > 0.05$) on the viable cell counts of LAB and *L. plantarum* in non-fat yoghurts.

The viable counts of *L. delbrueckii* subsp. *bulgaricus* in general decreased slightly but nonsignificantly in all groups after 21 days of storage. It has been previously reported that the addition of inulin had a substantial positive effect on the performance of selected *Lactobacillus* strains (Donkor et al. 2007). In our research, the highest viable counts were

determined in group C3 at the end of 21 days storage at 4 °C. Therefore, it may be concluded that the addition of inulin had a substantial positive effect on the growth of *L. delbrueckii* subsp. *bulgaricus*. Vasiljevic et al. (2007) found that *L. delbrueckii* subsp. *bulgaricus* and *Str. salivarius* subsp. *thermophilus* appeared unaffected by the addition of prebiotics during cold storage, although slight but not significant increase in cell concentration was observed with inulin addition. There were minimal differences in the viability of *Str. salivarius* subsp. *thermophilus* amongst groups in our study. The viable counts of the bacteria were determined above $8 \log_{10}$ CFU g⁻¹ during 21 days of storage period. Similar to our findings, Vinderola et al. (2000) found that *Str. salivarius* subsp. *thermophilus* counts were at least 1 log higher than those for *L. delbrueckii* subsp. *bulgaricus* in yoghurts produced with the direct inoculation of starter culture.

Physicochemical characteristics of non-fat yoghurts

The effects of reducing the fat content and adding inulin and β -glucan in different concentrations into the yoghurt formula increased the amount of DM %. While the lowest DM % was observed in the groups C1 and C2 as 8.60 and 8.62 at the beginning of the storage, the highest DM % (10.01) was determined in group C3 (inulin added group) after 21 days storage, and there was also non-significant increase in DM % related to the added level of the β -glucan concentrate during the storage period. The protein content of the yoghurts remained nearly constant for C1, C2, T1, T2 and T4 groups during the 21 days storage period (Table 2). The protein content decreased from 3.15 to 2.69 at the end of the 21 days storage for group C3, however this change was not

Table 2 Protein content (%) of the yoghurts during the storage period

Yoghurts*	Days			
	1	7	14	21
C1	2.94 ^{aA}	3.30 ^{aA}	2.97 ^{abA}	2.91 ^{abA}
C2	2.59 ^{aA}	3.03 ^{aA}	2.69 ^{bcA}	2.79 ^{abA}
C3	3.15 ^{aA}	3.18 ^{aA}	3.11 ^{abA}	2.69 ^{bA}
T1	3.10 ^{aA}	2.99 ^{aA}	3.23 ^{aA}	3.03 ^{abA}
T2	2.97 ^{aA}	2.98 ^{aA}	3.12 ^{abA}	2.74 ^{bA}
T3	2.57 ^{aB}	3.06 ^{aAB}	2.49 ^{cB}	3.40 ^{aA}
T4	2.92 ^{aA}	3.25 ^{aA}	3.22 ^{aA}	3.19 ^{abA}
Standard error	0.15			

* Different small letter superscripts depict the statistical difference within in a column indicate significant difference ($P < 0.05$) among the yoghurt groups, different capital letter superscripts depict the statistical difference within a row indicate significant difference ($P < 0.05$) for the same yoghurt at different storage days

significant ($P > 0.05$). A significant increase was observed only in group T3 from 2.57 to 3.40 within days 1 and 21 ($P < 0.05$). Sahan et al. (2008) determined that, while, the addition of 0.25 or 0.5 % β -glucan composite into the skim milk somewhat increased the total solid content in the yoghurts, fat and protein contents did not differ significantly. TA values as % lactic acid for 1st day ranged from 0.55 to 0.83 %. The TA values of T3 and T4 groups were significantly lower than other groups. TA values increased slightly for all groups during the storage. TA values for day-21 ranged from 0.69 to 0.91 %. It was reported by many researchers that, depending on the starter and adjunct cultures used in the yoghurt production and the enzymes produced by these cultures TA% may increase during the storage period (Atamer et al. 1986). Following the inoculation of the cultures, the initial pH of milk decreased to 4.5 within 3.5–4 h at 42 °C incubation for all yoghurt groups. pH values for day-1 in yoghurt groups ranged from 4.33 (C1) to 4.56 (T3). There was a slight decrease during 21 days refrigerated storage but these differences were not significantly important ($P > 0.05$), though lactic acid (%) increased slightly for all groups. The changes in TA% and pH in yoghurts are illustrated in Figs. 1 and 2, respectively. Vinderola et al. (2000) determined that the pH values decreased approximately by 0.5 units during the storage period for reduced-fat yoghurts. A pH decrease of approximately 0.14–0.27 units has been determined in our study for non-fat yoghurts. Guven et al. (2005) reported that use of inulin as a fat replacer did not significantly affect the pH values. Sahan et al. (2008) also indicated that pHs of the non-fat yoghurts decreased during the storage period.

In our study, at the beginning of the storage, the highest syneresis was determined in groups T2, T3 and T4 groups, which were produced with β -glucan ($P < 0.05$). While there was a decrease in C1, C2, C3 and T1 groups after a 21 day storage period, the amount of whey removed was almost

Fig. 1 The TA% changes in yoghurts during the storage period

Fig. 2 The pH changes in yoghurts during the storage period

constant for T2, T3 and T4 groups. The syneresis determined in non-fat yoghurts was higher than the syneresis reported for regular yoghurt in our previous study (Başığit Kılıç and Akpınar 2013). The syneresis levels of yoghurts during the storage period have been shown in Fig. 3. By contrast, Fernandez-García & McGregor (1997) showed that increasing the levels of β -glucan concentrate in low-fat yoghurt, led to decreasing levels of syneresis. This variation in results could be due to the diversity found in cereal β -glucan structures that are important in determining their physical properties, such as the molecular weight, the distribution of cellulose oligomers and the ratio of β -(1, 4) to β -(1, 3) linkages in the polysaccharide chain (Lazaridou and Biliaderis 2007).

Aroma compounds

The acetaldehyde, acetone, diacetyl and acetoin contents obtained from 1st and 21st days of storage are presented in Table 3. In this study, acetaldehyde was not determined in the C2 and yoghurt groups produced with β -glucan. The highest acetaldehyde content was determined for the 21 day of the storage in group C1 and C3 as 9.28 and 8.73 $\mu\text{g g}^{-1}$, respectively. Only the C3 group, produced with inulin had acetaldehyde on the 1st day of the

Fig. 3 The syneresis (%) levels of yoghurts during the storage period

storage. The production of acetaldehyde appeared to be strain specific. The rate and amount of acetaldehyde depends on the strain and growth condition. There are also some other factors effecting the acetaldehyde formation. Threonine aldolase is the major enzyme activity involved in acetaldehyde production in the yogurt bacterium *S. thermophilus* (Chaves et al. 2002). In this research the concentration of l-threonine did not investigated and it is hard to discuss the reason of no acetaldehyde formation in samples.

Contrary to our results, Guven et al. (2005) determined that, set-type low-fat control yoghurt had higher acetaldehyde values in comparison with inulin-added samples after both 7 and 15 days of storage. However, in yoghurts while the diacetyl was not observed in group C2 on day 1 and 21, an increase was observed only in C1 group and the diacetyl content decreased for the rest of the groups after 21 d storage. Ozer et al. (2007) and Güler et al. (2009) did not determine diacetyl in yoghurts. There were significant differences in acetone concentrations in yoghurts ($P < 0.05$). In our previous studies, we determined the content of the acetaldehyde in pure cultures of *L. plantarum* AB6-25, AK4-11 and AC18-82 as 3.38, 1.68 and 12.52 $\mu\text{g g}^{-1}$, respectively (Başığit Kılıç et al. 2012, unpublished data).

It was observed that the acetone concentrations of yoghurts decreased in C1, T2 and T4 groups in day 21. Kaminarides et al. (2007) determined that the levels of acetone increased significantly after 21 days' storage in the yoghurts produced from milk with 6.6, 3.8 and 2.3 % fat apart from that in low fat yoghurt made from milk with 0.9 % fat. The volatile compounds had a wide variation in yoghurts. Kneifel et al. (1992) and Xanthopoulos et al. (1994) showed that the levels of acetaldehyde (2.0 to 41.0 mg kg^{-1}), diacetyl (0.2 to 2.3 mg kg^{-1}), acetoin (2.2 to 28.2 mg kg^{-1}) and acetone (1.8 to 3.4 mg kg^{-1}), and butanone-2 (0.1–0.6 mg kg^{-1}) in their samples. Previous studies indicated that the levels of diacetyl ranged from less than 1 mg kg^{-1} (Kneifel et al. 1992; Ligor et al. 2008) up to more than 40 mg kg^{-1} (Macciola et al. 2008).

Organic acid profile

Concentrations of formic, pyruvic, lactic and acetic acid in yoghurt samples are presented in Table 4. The results of our study indicated that lactic acid was the major organic acid in non-fat yoghurts. It was shown that during storage acidity of yoghurts increased in concern of pH level. The lactic acid concentration increased on the 21st day for all groups except group C2. This phenomenon is commonly known and it is a result of acidifying microflora activity (Tamime and Robinson 1999). Akin (1997) determined the lactic acid concentration of milk fermented with yoghurt starter cultures and *L. acidophilus* as 8538 and 9060 mg kg^{-1} , respectively. During yoghurt storage, the decrease in lactose concentrations

Table 3 The acetaldehyde, acetone, diacetyl and acetoin contents obtained from 1st and 21st days of the storage of yoghurts ($\mu\text{g g}^{-1}$)*

Yoghurts	Acetaldehyde		Acetone		Diacetyl		Acetoin	
	1. day	21. day	1. day	21. day	1. day	21. day	1. day	21. day
C1	ND [‡]	9.28 ^A	4.21 ^{aB}	2.96 ^{bC}	ND	6.12	2.38 ^{bG}	6.96 ^{aD}
C2	ND	ND	–	1.33 ^F	ND	ND	7.13 ^{aE}	7.20 ^{aC}
C3	4.3 ^b	8.73 ^{aB}	0.90 ^{bF}	2.10 ^{aD}	1.43 ^D	ND	9.21 ^{aB}	8.46 ^{bB}
T1	ND	ND	2.43 ^{bC}	3.06 ^{aB}	0.95 ^E	ND	8.30 ^{bC}	8.84 ^{aA}
T2	ND	ND	1.45 ^{aE}	0.87 ^{bD}	3.12 ^C	ND	7.61 ^{aD}	6.01 ^{bE}
T3	ND	ND	1.90 ^{bD}	3.43 ^{aA}	8.49 ^A	ND	4.53 ^{bF}	5.57 ^{aF}
T4	ND	ND	5.60 ^{aA}	2.06 ^{bE}	4.78 ^B	ND	12.37 ^{aA}	4.89 ^{bG}

*Different small letter superscripts depict the statistical difference within in a column indicate significant difference ($P<0.05$) for the same yoghurt at different storage days. Different capital letter superscripts depict the statistical difference within a row indicate significant difference ($P<0.05$) among the yoghurt groups

[‡] ND not determined

was generally accompanied by proportional increases in lactic, acetic and propionic acid concentrations (Laye et al. 1993). Similar to results of Guler (2007) a significant increase in acetic acid content in all groups has been observed during refrigerated storage in this study. Kaminarides et al. (2007) also determined at high concentration of acetic acid in four yoghurts with different fat concentrations, which increased significantly during yoghurt storage.

The lowest formic, acetic and lactic acid levels were found in group C1. Our previous study (Başıyigit Kılıç and Akpınar 2013) showed that β -glucan addition slightly decreased the levels of formic and lactic acid in regular yoghurt. However, this effect was not observed in non-fat yoghurts produced with β -glucan in this study. The results showed that pyruvic acid content in yoghurts was very low compared with that of other organic acids. Akin (1997) found the pyruvic acid as 39 mg kg^{-1} in yoghurts produced with yoghurt starter cultures. While the pyruvic acid content of the C3 and T3 groups increased at the end of the storage period, significant decreases were observed in the rest of the groups. Fernandez-Garcia and McGregor

(1994) also observed a decreasing trend in the content of pyruvic acid in plain yoghurt when stored at 4°C for 4 weeks.

Conclusion

Improving the health potential of yoghurt has become a popular field. The result of this study showed the potential for the production of synbiotic non-fat yoghurt involving probiotic *L. plantarum* strains and prebiotic ingredients. Yoghurts with β -glucan showed positive effects in terms of lactic acid content and pH reduction. However, at the beginning of the storage, the syneresis was higher in the 0.50, 1.0 and 1.5 % β -glucan added groups. It was observed that β -glucan promotes growth and viability of LAB. The yoghurts produced using *L. plantarum* combination as adjunct culture exhibited good microbiological and physicochemical properties. However, some process modifications in β -glucan containing yoghurt production may be required to prevent

Table 4 The formic acid, pyruvic acid, lactic acid and acetic acid contents obtained from 1st and 21st days of the storage of yoghurts ($\mu\text{g g}^{-1}$)[‡]

Yoghurts	Formic acid		Pyruvic acid		Lactic acid		Acetic acid	
	1. day	21. day	1. day	21. day	1. day	21. day	1. day	21. day
C1	205.2 ^{bG}	581.5 ^{aA}	8.1 ^{aB}	6.6 ^{bD}	7359.8 ^{bG}	16440.8 ^{aB}	113.5 ^{bG}	365.9 ^{aG}
C2	454.7 ^{aA}	337.0 ^{bE}	10.3 ^{aA}	7.1 ^{bB}	17191.2 ^{aA}	15393.9 ^{bD}	505.2 ^{bA}	701.1 ^{aB}
C3	311.1 ^{bE}	400.2 ^{aB}	7.5 ^{bD}	8.2 ^{aA}	10101.3 ^{bF}	14533.6 ^{aF}	286.1 ^{bE}	557.0 ^{aF}
T1	354.9 ^{bC}	361.7 ^{aC}	6.4 ^{aF}	6.1 ^{bG}	13648.7 ^{bB}	16678.9 ^{aA}	380.3 ^{bC}	638.0 ^{aE}
T2	333.7 ^{bD}	352.3 ^{aD}	7.4 ^{aE}	6.2 ^{bF}	13151.1 ^{bD}	15841.4 ^{aC}	376.5 ^{bD}	644.9 ^{aD}
T3	297.1 ^{bF}	317.8 ^{aF}	6.3 ^{bG}	6.8 ^{aC}	11185.8 ^{bE}	14060.7 ^{aG}	222.4 ^{bF}	690.1 ^{aC}
T4	394.3 ^{aB}	296.3 ^{bG}	7.8 ^{aC}	6.5 ^{bE}	13236.5 ^{bC}	15269.0 ^{aE}	414.9 ^{bB}	798.9 ^{aA}

[‡] Different capital letter superscripts depict the statistical difference within in a column indicate significant difference ($P<0.05$) among the yoghurt groups. Different small letter superscripts depict the statistical difference within a row indicate significant difference ($P<0.05$) for the same yoghurt at different storage days

quality defects such as syneresis. Further studies will be conducted to determine the effects of β -glucan on yoghurts produced with different milk types.

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