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PAPER

EFFECTS OF ENRICHMENT WITH POLYPHENOLIC EXTRACTS FROM SARDINIAN PLANTS ON PHYSICO-CHEMICAL, ANTIOXIDANT AND MICROBIOLOGICAL PROPERTIES OF YOGURT

EFFETTO DELL'AGGIUNTA DI ESTRATTI POLIFENOLICI DI PIANTE DELLA FLORA SARDA SULLE PROPRIETÀ FISICO-CHIMICHE, ANTIOSSIDANTI E MICROBIOLOGICHE DEGLI YOGURT

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ABSTRACT

The effect of adding artichoke (*Cynara scolymus* L.), strawberry-tree fruit (*Arbutus unedo* L.) and cherry (*Prunus avium* L.) extracts was evaluated on the physico-chemical, antioxidant and microbiological properties of home-made yogurts. Yogurts, enriched with artichoke or red ripe strawberry-tree fruit extract, demonstrated high *in vitro*

RIASSUNTO

In questo lavoro è stato valutato l'effetto dell'aggiunta di estratti di carciofo (*Cynara scolymus* L.), frutti di corbezzolo (*Arbutus unedo* L.) e ciliegia (*Prunus avium* L.) sulle proprietà fisico-chimiche, antiossidanti e microbiologiche di yogurt preparati in laboratorio. Gli yogurt con estratti di parte edibile di carciofo o con frutti maturi di corbezzo-

- Key words: antioxidant properties, microbiological characteristics, vegetable extracts, yogurt -

antioxidant activity. Ten days after their preparation, no variations in the antioxidant components and antioxidant activity of the yogurts were observed. The enriched yogurts showed an increase in lactic acid and acetaldehyde. As regards microbial characteristics, there was a notable increase in the microbial count of Lactobacilli in yogurts with edible artichoke parts ($4.5x10^9$ cfu/g) and with strawberry-tree fruit extracts ($1.8x10^9$ cfu/g) during the three-week experimental period. During the same period persistence of Streptococci in yogurt with artichoke edible parts was observed until the end of the first week ($5.2x10^7$ cfu/g). Our results indicate that the enrichment of yogurts with Sardinian plant extracts can significantly improve the antioxidant activity of yogurt and in some cases the survival of its microbial flora.

lo dimostravano un'elevata attività antiossidante *in vitro*. Dieci giorni dopo la loro preparazione, gli yogurt mantenevano inalterato il contenuto in polifenoli e l'attività antiossidante e mostravano un significativo aumento nel contenuto di acido lattico e acetaldeide. Dopo sette giorni è stato osservato un incremento di Lactobacilli negli yogurt contenenti estratto di parte edibile di carciofo ($4,5x10^9$ cfu/g) e estratti di frutti di corbezzolo ($1,8x10^9$ cfu/g) ed una persistenza di Streptococchi negli yogurt contenenti estratto di parte edibile di carciofo ($5,2x10^7$ cfu/g). I risultati indicano che la preparazione di yogurt contenenti estratti di carciofo può migliorare significativamente la sopravvivenza della flora batterica solo per i primi 7 giorni e può potenziarne l'attività antiossidante.

INTRODUCTION

Yogurt is a well-known fermented dairy product obtained by the lactic acid fermentation of milk by the action of yogurt starter bacteria, *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. The role of these bacterial strains in yogurt production is primarily milk acidification by D- and L-lactic acid and synthesis of flavour compounds that contribute to the final aroma of the yogurt, such as volatile and non-volatile acids, carbonyl compounds (acetaldehyde or diacetyl) and miscellaneous products (SERRA *et al.*, 2009). Yogurt has long been recognised as a healthy food since the associated bacterial metabolism is responsible for the development in a yogurt of compounds that make it beneficial for human health. For example, 3-hydroxy-3-methylglutaric acid is known to be an antihypercholesterolemic product (HEPNER *et al.*, 1979) and β-galactosidase is indispensable to lactose digestibility, and antihypertensive peptides inhibiting angiotensin-I-converting enzyme (ACE) derived from casein hydrolysis (TAKANO, 2002; ASHAR and CHAND, 2003). Moreover, the contribution of yogurt bacteria to the improvement of intestinal microflora is widely recognised and yogurt consumption is associated with health benefits: for lactose intolerance, diarrhoeal diseases, inflammatory bowel diseases, *Helicobacter pylori* infection and allergies (ADOLFSSON *et al.*, 2004).

To meet consumer demands, yogurt is also produced in flavoured, supplemented and enriched forms. Flavouring can be carried out by addition of natural ingredients i.e. "berry" fruits such as strawberry, raspberry, bilberries, black-

berry, blackcurrant and cherry, well known sources of polyphenolic antioxidants (COÏSSON *et al.*, 2005). Supplementation with functional components (APOSTOLIDIS *et al.*, 2006) is carried out for various reasons: probiotic strains, such us *Lactobacillus* and *Bifidobacterium*, are added for their therapeutic properties in gastrointestinal disorders and their ability to improve immune functions (ISOLAURI, 2001; SAAVEDRA, 2001). Prebiotic oligosaccharides enhance the growth of probiotics in the yogurt environment; ω-3 long-chain fatty acids are precursors of important anti-thrombotic and anti-inflammatory molecules (MARCHIOLI *et al.*, 1999; ALBERT *et al.*, 2002); phytosterols and phytostanols help lower the absorption of cholesterol (RAMJIGANESH *et al.*, 2000); and, finally, plant polyphenols are added because of their well-known antioxidant activity (FUKUMOTO and MAZZA, 2000; SZETO *et al.*, 2002).

In terms of natural polyphenolics from dietary plants, there is an increasing evidence that a diet with an increased intake of these compounds is associated with reduced risk of cardiovascular diseases (YOCHUM *et al.*, 1999) and certain types of cancer (YANG *et al.*, 2001). The characterization and quantification of phenolic compounds present in typical Sardinian plants such as artichoke (*Cynara scolymus* L.) Spinoso Sardo variety, strawberry-tree (*Arbutus unedo* L.) fruits and cherries (*Prunus avium* L.) Bonnannaro variety and the *in vitro* evaluation of their benefits have been the focus of recent research (ALAMANNI and COSSU, 2003; ALAMANNI *et al.*, 2006). The results showed a high content of antioxidant polyphenolics whose activity was comparable, and in some cases higher, than well-known antioxidants such as beta-carotene, ascorbic acid and catechins.

The effect of adding strawberry-tree fruit and artichoke extracts on the viability of fermenting bacterial strains and a probiotic strain was evaluated in a previous investigation (PISU *et al.*, 2006); the results showed that the extracts had a positive action on the development of bacterial flora.

The aim of this research was to investigate the effect of enrichment with artichoke, strawberry-tree fruit and cherry extracts from Sardinian plants on the physico-chemical, antioxidant and microbiological characteristics of home-made yogurt, as compared to commercially produced yogurts.

MATERIALS AND METHODS

Extract preparation and determination of polyphenolic content

Fresh artichokes (*Cynara scolymus* L.), Spinoso Sardo variety, purchased from the local market with stalk and leaves, were subdivided into the edible part (EP) (consisting of internal bracts, cup, and the edible part of the stem) and the non-edible part (NEP) (consisting of the fibrous portions rich in chlorophyll, i.e. outer bracts, stem bark and leaves). Strawberry-tree (*Arbutus unedo* L.) fruits at two different stages of ripening, ripe (red fruit) and unripe (yellow fruit), were collected in the Sardinian mountains (Tempio Pausania, Sassari, Italy). Cherries (*Prunus avium* L.), Bonnannaro variety, were harvested in the Bonnannaro area (Sassari, Italy). Plants and fruits were stored at -20°C. The extracts were prepared by suspending 300 g of each plant, finely homogenized in a blender, in 300 mL of Milli-Q water and boiling them for 30 min. The suspensions were filtered and the filtrate was concentrated up to ~30 mL at 70°C and at reduced pressure. The residue obtained was dissolved in water to a final volume of 50 mL. All plant extracts were stored at 5°C until use.

The amount of total phenolics in the extracts was determined according to the Folin-Ciocalteu spectrophotometric

method (SINGLETON and ROSSI, 1965). The results are expressed as mg/mL of gallic acid equivalent (GAE) (Acros, Milan, Italy). The calibration curve was prepared using concentrations of gallic acid ranging from 5 to 50 μg/mL.

Preparation of yogurts containing polyphenolic extracts

Commercial whole fresh pasteurised bovine milk was mixed with a commercial natural bovine yogurt as a starter culture at 5, 10 and 20% (v/v) in order to determine the best conditions required to obtain a "home-made" yogurt. The mixtures were incubated at 45°C and the yogurt was taken out of the incubator when the pH dropped to approximately 4.5 (~6-7 hours). The yogurt was cooled to room temperature and stored at 4°C. Samples were collected after 1 day at 4°C and analysed for the viable counts of both *L. bulgaricus* and *S. thermophilus*.

To prepare yogurts enriched with vegetable and fruit extracts, aliquots of 45 mL of whole milk inoculated with natural yogurt as a starter (10% v/v) (percentage chosen on the basis of microbiological results) were transferred to sterile plastic containers. Appropriate amounts of each extracts were added to obtain the following polyphenolic concentrations: 0.05% (w/w) for artichoke yogurt (edible and non-edible parts), 0.05% (w/w) for strawberry-tree fruit yogurt (ripe and unripe) and 0.02% (w/w) for cherry yogurt (Table 1). Controls consist of unsupplemented yogurt samples.

Table 1 - Commercial and home-made yogurts assayed.

Home-made yogurt samples	Characteristics	Polyphenolic content % (w/w)
LW	unsupplemented yogurt (ctr)	
LE1	with edible artichoke part (EP) extract	0.05
LE2	with non edible artichoke part (NEP) extract	0.05
LE3	with ripe strawberry-tree fruit (red) extract	0.05
LE4	with unripe strawberry-tree fruits (yellow) extract	0.05
LE5	with cherry extract 0.02	
Commercial yogurt samples		
CW1	natural yogurt	
CW2	natural yogurt	
CW3	natural yogurt	
CW4	natural yogurt	
CW5	natural yogurt	
CW6	natural yogurt	
CW7	natural yogurt	
CW8	natural yogurt	
CE1	with Vit. C, D_3, E	
CE2	with Q10 factor and Vit. A, D_3, E	
CE3	*with blueberry/currant extract*	0.07*
CE4	with papaya/guava extract	0.07*

CW: Commercial natural; CE: Commercial enriched; LW: home-made natural; LE: home-made enriched; * reported on labels.

Commercial yogurt samples

Eight samples of natural bovine yogurt, and four samples of yogurt enriched with different antioxidant compounds and polyphenolic extracts, produced from whole bovine milk in different factories, were purchased one month before the expiry date at a local supermarket and stored at 4°C until used (Table 1).

Physico-chemical properties of yogurts

The pH of different yogurt samples was measured at 20°C by using a pH meter equipped with a specific electrode for semi-solid substances (Hanna FC200, Hanna Instruments, Milan, Italy).

The acidity of the yogurt was measured suspending 10 g of yogurt in 100 mL of water and titrating with a solution of 0.25 N NaOH, with phenolphthalein solution as indicator. Yogurt acidity is expressed in Soxhlet-Henkel degrees (SH°) and is reported for 100 g of yogurt according to the equation:

SH° = milliliters NaOH consumed/yogurt weight;

D- and L-lactic acid and acetaldehyde were dosed in yogurts using rapid UV-Kit enzymatic conventional methods (Megazyme International Ireland Limited, Bray, Co. Wicklow, Ireland) based on spectrophotometric detection of specific compounds.

Total polyphenolic content and antioxidant activity of the yogurt samples

One gram of yogurt was placed in a volumetric flask and diluted in a methanol/water (1:1 ratio) solution to 10 mL, it was then transferred to a plastic tube (15 mL) with a screw cap, shaken by vortex for 15 s and centrifuged at 4,000 rpm for 10 min. The total polyphenolic content was determined by the Folin-Ciocalteu method previously described and the results are expressed as micrograms of gallic acid equivalent (GAE) per gram of yogurt.

The antioxidant activity of the different yogurt samples was evaluated in terms of "free-radical-linked scavenging ability" by measuring the decoloration of a methanolic solution of the stable radical 1,1-diphenyl-2-picryl-hydrazyl (DPPH•) (Sigma-Aldrich, Milan, Italy) with a spectrophotometric test (VON GADOW *et al.*, 1997). The percentage of scavenging of the radical in the presence of the sample was calculated according to the following formula:

$$\text{Inhibition } \% = [(At_0 - At_{60})/At_0] \times 100$$

where At_0 is the absorbance of the control at 517 nm at time = 0 min and At_{60} is the absorbance of the DPPH-sample solution at the same wavelength after 60 min. The percentage inhibition data are expressed as micrograms of Trolox equivalents (TE) per gram of yogurt. The calibration curve had been prepared using concentrations of Trolox (Acros, Milan, Italy) between 1.0 and 10.0 μg/mL ($r^2 = 0.999$, $y = 2.351x + 0.443$).

The determination of the reducing ability of yogurt was carried out by using a method based on the ferric reducing ability power (FRAP) (BENZIE and STRAIN, 1996). At low pH, when a ferric-tripyridyltriazine (Fe^{3+}-TPTZ) (Acros, Milan, Italy) complex is reduced to the ferrous (Fe^{2+}) form, an intense blue colour develops with an absorption maximum at 593 nm. The data of absorbance obtained are expressed as micrograms of Trolox equivalents (TE) per gram of yogurt by calibration curve in a range from 1.0 to 12.0 μg/mL ($r^2 = 0.999$, $2.337x + 0.0098$).

Microbiological analysis

Aliquots of 1.0 g of each yogurt sample were weighed in sterile tubes and mixed with 100 mL of sterile phosphate saline buffer (pH 7.4; PBS) (Oxoid, Milan, Italy); serial tenfold dilutions were prepared using the same buffer. The selective enumeration of yogurt microorganisms was

performed by plating the dilutions of yogurt samples onto appropriate media. Viable counts of *Streptococcus thermophilus* were carried out on M17 agar (final pH 6.9±0.2) (Oxoid Milan, Italy) plates incubated aerobically for 48 h (TERZAGHI and SANDINE, 1975), while *Lactobacillus delbrueckii* subsp. *bulgaricus* was enumerated on MRS agar, final pH 6.2±0.2 (Oxoid, Milan, Italy) plates, incubated anaerobically for 48 h in the Gas Generating Kit Anaerobic System (Oxoid, Milan, Italy) (DAVE and SHAH, 1996). Bacterial counts of yogurt samples and controls were carried out at T_0 (24 h after yogurt manufacturing) and after 1, 2 and 3 weeks of refrigerated storage (4°C).

The percentile survival rate was calculated for each time with the following formula:

% = (bacterial number at T/bacterial number at T_0) x 100

Statistical analysis

Data reported in the tables and figures are the means of experiments repeated three times. Statistical analyses were conducted by GraphPad Prism 4 software (GraphPad Software Inc., San Diego, CA, USA). Correlations were obtained by Pearson correlation coefficient in bivariate correlations. Differences between means at the 5% ($p<0.05$) level were considered significant.

RESULTS

Total polyphenolic content of plant extracts

The total polyphenolic contents of the different fruits and plant extracts, expressed as mg/mL of gallic acid equivalents are reported in Table 2. As expected on the basis of the available literature (ALAMANNI and COSSU, 2003; ALARCAO-E-SILVA *et al.*, 2001; USENIK *et al.*, 2008), the polyphenolic content of the assayed extracts are quite different, ranging from 4.0 mg/mL (cherry extract) to 15.3 mg/mL (yellow strawberry-tree fruit extract).

Physico-chemical properties and antioxidant activity of natural yogurts

The baseline values of some chemical characteristics of commercial and homemade natural yogurts are reported in Table 3. L-lactic acid concentration and pH were comparable between the two types of yogurt; the L-lactic acid concentration was 3-5 times higher than D-lactic acid. Acetaldehyde levels were higher in commercial yogurts even though the high standard deviation (data not shown) demonstrates a great variability of this parameter (0.05 to 1.73 mg/g), probably due to the different geographical origins of the milk and/or the production process.

Good baseline correlations (r) were obtained between the polyphenolic content and the antioxidant activity of all the examined yogurts without any plant-based supplementation ($r = 0.771$ for DPPH test and $r = 0.827$ for FRAP test; $p<0.05$).

Physico-chemical properties and antioxidant activity of enriched yogurts

Enriched yogurts were prepared in the laboratory and analyzed 24 h after preparation, as previously described in

Table 2 - Total polyphenolic contents of artichoke, strawberry tree and cherry extracts, expressed as gallic acid equivalents (mg/mL).

Extract	Polyphenolic content (mg/mL±SD)
Artichoke (EP)	8.0±0.01
Artichoke (NEP)	6.7±0.04
Red strawberry-tree fruits	11.3±0.06
Yellow strawberry-tree fruits	15.3±0.03
Cherry	4.0±0.01

Mean±SD (standard deviation) of 3 determinations for each sample.

Table 3 - General features of commercial and home-made natural yogurts.

			Commercial* mean±SD	Home-made*
pH			4.3±0.26	4.4±0.11
Acidity		SH°	52.8±8.1	40.5±3.5
Lactic acid	D	mg/g	3.29±3.3	1.3±0.1
	L		9.47±2.2	9.8±0.14
Acetaldehyde		mg/g	0.54±0.53	0.34±0.04
Polyphenolic content		GAE (μg/g)	73.2±17.6	101.4±12.6
Antioxidant activity	DPPH test	TE (μg/g)	39.6±11.1	35.7±5.8
	FRAP test		31.1±21.9	50.6±6.7

*Mean±SD of 8 samples.

the experimental section. In Table 4 the results of home-made enriched yogurts (LE 1-5) are compared with four selected commercial enriched yogurts (CE 1-4).

Compared to the unsupplemented yogurt (LW), all of the home-made enriched yogurts had a lower pH and consequently a higher SH° acidity value, no variation in D- and L-lactic acid contents and a lower concentration of acetaldehyde.

pH and acidity values of enriched commercial yogurt were comparable to those of the unsupplemented yogurt, while in the CE2 sample (yogurt with Q10 factor and vitamin A, D, E) the L-lactic acid and acetaldehyde contents were higher.

The polyphenolic content and the antioxidant activities of enriched yogurt samples, commercial and home-made yogurts are compared in Fig. 1. In general, the antioxidant activities were quite similar for all of the yogurts examined with the exception of the LE3 and LE4 samples (enriched with red strawberry-tree fruit and yellow fruit extract, respectively) that showed the highest activity in the DPPH radical scavenging assay. Moreover, yogurt enriched with edible parts of artichoke (LE1) contained

Table 4 - Physico-chemical characteristics of commercial and home-made yogurts enriched with polyphenolic substances (mean±SD of 3 determinations for each sample).

Samples	pH	Acidity (SH°)	Lactic acid (mg/g)		Acetaldehyde (μg/g)
			D	L	
CE1	4.45±0.08	46.20±1.3	0.0±0.00	9.3±0.34	88.1±3.4
CE2	4.17±0.06	55.40±1.8	1.4±0.06	30.7±2.9	387.6±20.3
CE3	4.23±0.07	40.20±1.1	0.2±0.01	5.7±0.19	141.0±7.7
CE4	4.36±0.02	33.50±0.8	0.3±0.01	5.3±0.24	176.2±8.4
LW	4.4±0.03	40.5±1.5	1.3±0.04	9.1±0.39	343.9±18.6
LE1	3.8±0.04	76.6±3.7	1.4±0.05	9.2±0.41	121.8±6.8
LE2	3.8±0.07	69.9±2.4	1.7±0.08	9.6±0.65	103.6±5.5
LE3	3.8±0.08	70.0±3.1	1.4±0.10	9.4±0.55	172.6±7.0
LE4	3.7±0.05	63.7±2.1	1.1±0.09	9.6±0.47	246.7±13.8
LE5	3.8±0.06	63.9±2.9	1.9±0.11	8.9±0.38	105.7±7.1

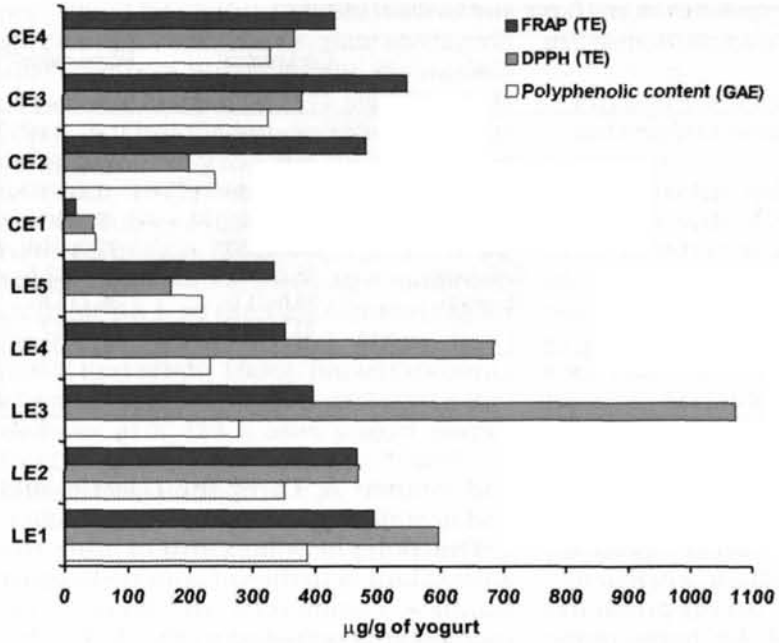

Fig. 1 - Antioxidant activities (expressed as Trolox equivalents, TE) and total polyphenolic content of commercial enriched yogurts and home-made enriched yogurts at T_0.

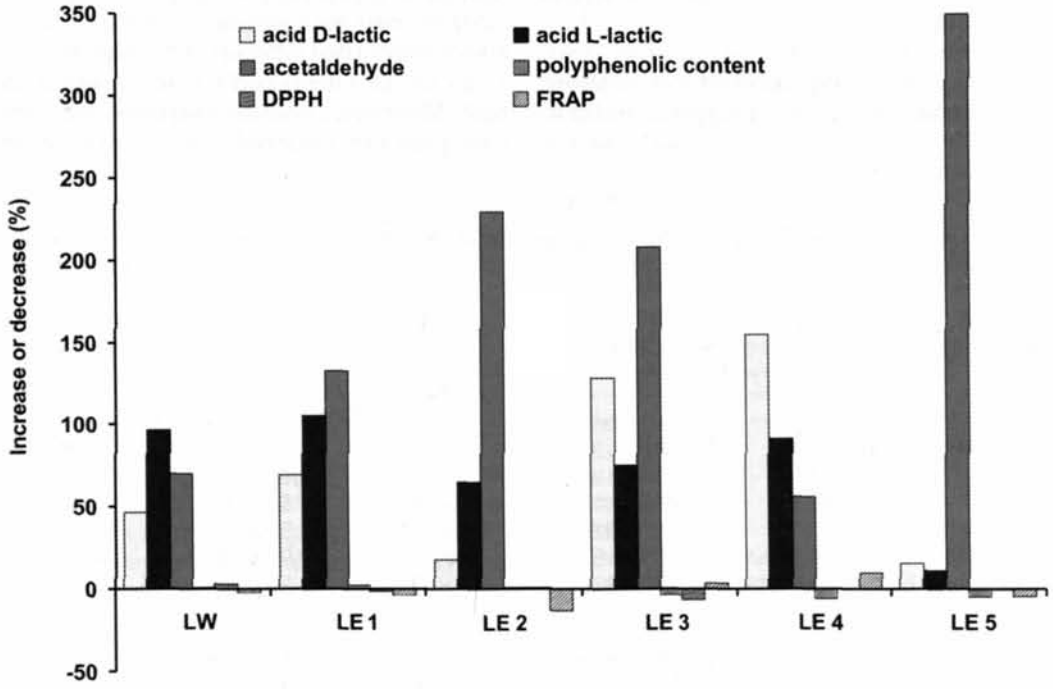

Fig. 2 - Characteristics of home-made yogurts: per cent increase or decrease of values after ten days.

a greater quantity of polyphenols and showed a higher antioxidant activity than commercial yogurts without any plant extract enrichment.

The variations in the physico-chemical characteristics, polyphenolic content and antioxidant activities of all of the home-made yogurts (both unenriched and enriched) were observed over a period of ten days. Results of these observations are reported in Fig. 2, where the increases or decreases (minus sign) in the values with respect to t_0 are reported as percentages. Notable increases were observed particularly in lactic acid (D and L) and acetaldehyde production; in particular there were marked increases in the D-lactic acid and L-lactic acid in yogurt containing strawberry-tree fruit extracts (LE4) and in yogurt enriched with edible artichoke parts (LE1). Acetaldehydes increased remarkably in several yogurts and especially in the sample enriched with cherry extract (LE4). After ten days, the antioxidant component levels were almost unchanged, and the antioxidant activity showed negligible variations.

Microbiological analysis

Bacteria were counted periodically in both the unsupplemented commercial and home-made yogurts. All the experiments were performed in triplicate and

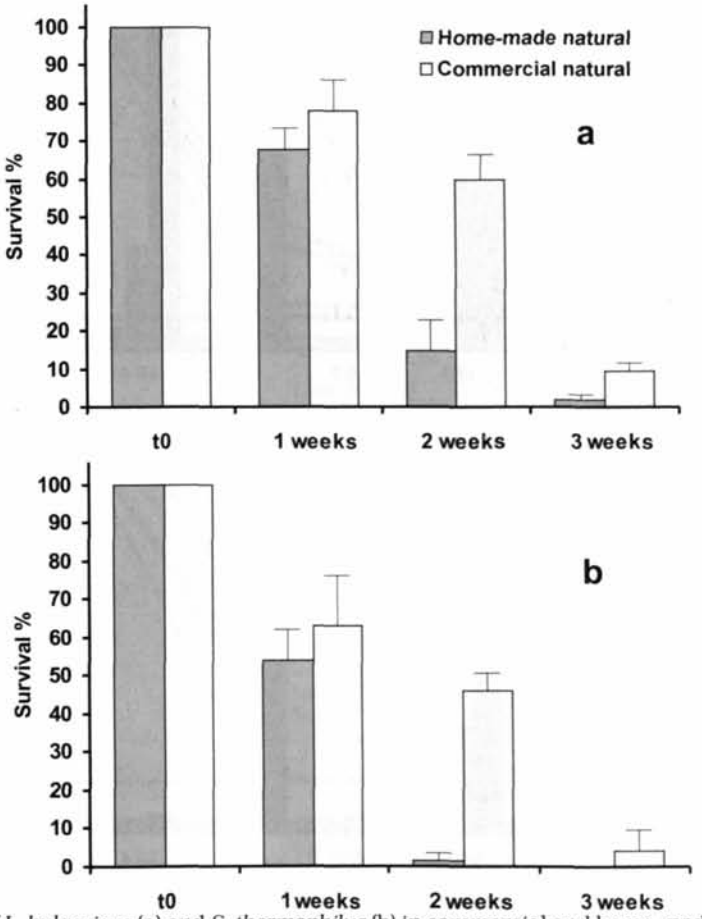

Fig. 3 - Viability of *L. bulgaricus* (a) and *S. thermophilus* (b) in commercial and home-made natural yogurt.

bacteria were also counted in triplicate for each sample. The results, expressed as % survival, are reported in Fig. 3.

In commercial natural yogurts, the initial cell counts were in the range of $2.6x10^9$ and $5.0x10^9$ cfu/g for *L. bulgaricus* and *S. thermophilus* respectively, and these numbers decreased steadily over the three-week experimental period.

Home-made yogurt samples were characterised by lower initial counts of both *L. bulgaricus* and *S. thermophilus* (ranges $3.5x10^8$ and $1.1x10^8$ cfu/g, respectively) and by a more marked decrease after the second week of storage. This might be due to the quality of milk used, to the yogurt used as an inoculum to produce home-made yogurt, which most likely was quite different if compared to the industrial starter, and also to the equipment and methodology of preparation.

The enriched yogurts showed an increasing trend in microbial counts when enriched with the edible artichoke extract (LE1) (Fig. 4): at time 0 both *L. bulgaricus* and *S. thermophilus* showed significantly higher numbers compared to

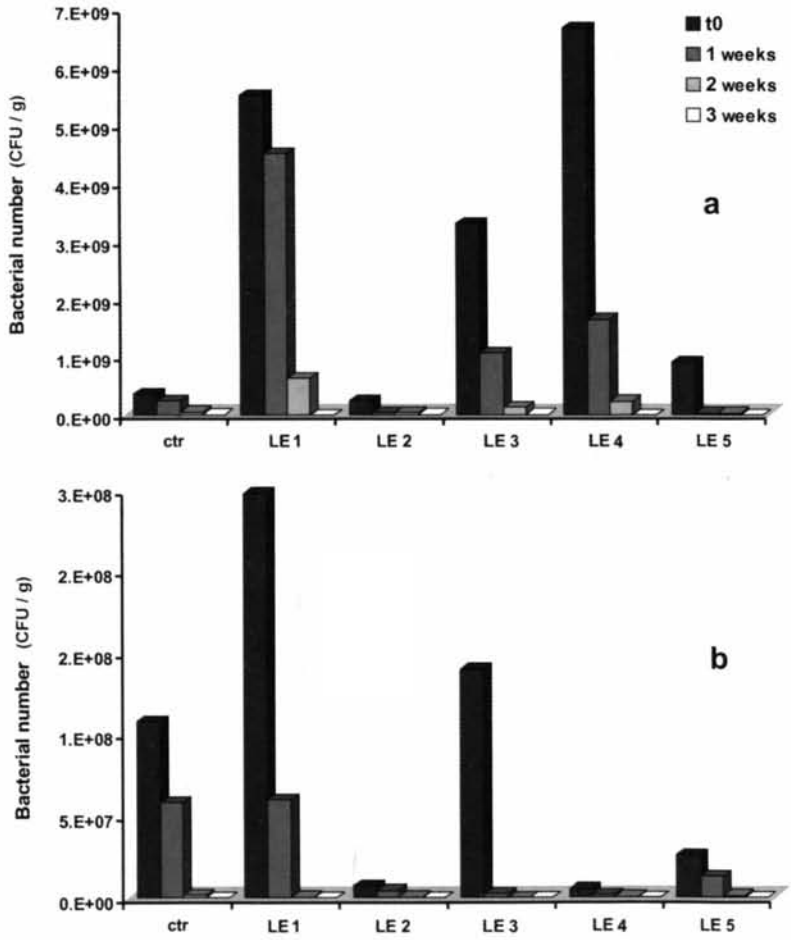

Fig. 4 - Survival of *L. bulgaricus* (a) and *S. thermophilus* (b) in home-made yogurt enriched with plant extracts over 3 weeks.

the controls. It is also noteworthy that this effect was not observed after the addition of non-edible artichoke parts (LE2). This result may be partly attributed to the presence of inulin, a well-known prebiotic polysaccharide (KRUSE *et al.*, 2005) in artichoke ED extracts. Moreover, at time zero a notable improvement of viable counts of lactobacilli was observed in yogurt enriched with unripe strawberry-tree extract (LE4) and an enhanced effect was observed after the addition of ripe strawberry-tree extract (LE3).

Fig. 5 shows the bacterial survival (expressed as percentage) in yogurts enriched with polyphenolic extracts in comparison with the control (LW) over the established period of time. As far as lactobacilli are concerned, the values for the survival after the first week were higher than the controls only in the presence of LE1 extract (85% and 70%, respectively), while the other extracts did not improve their viability. On the other hand, streptococci survival was positively affected by the presence of LE2 extract (65% viability vs 55%) after one week. The viabili-

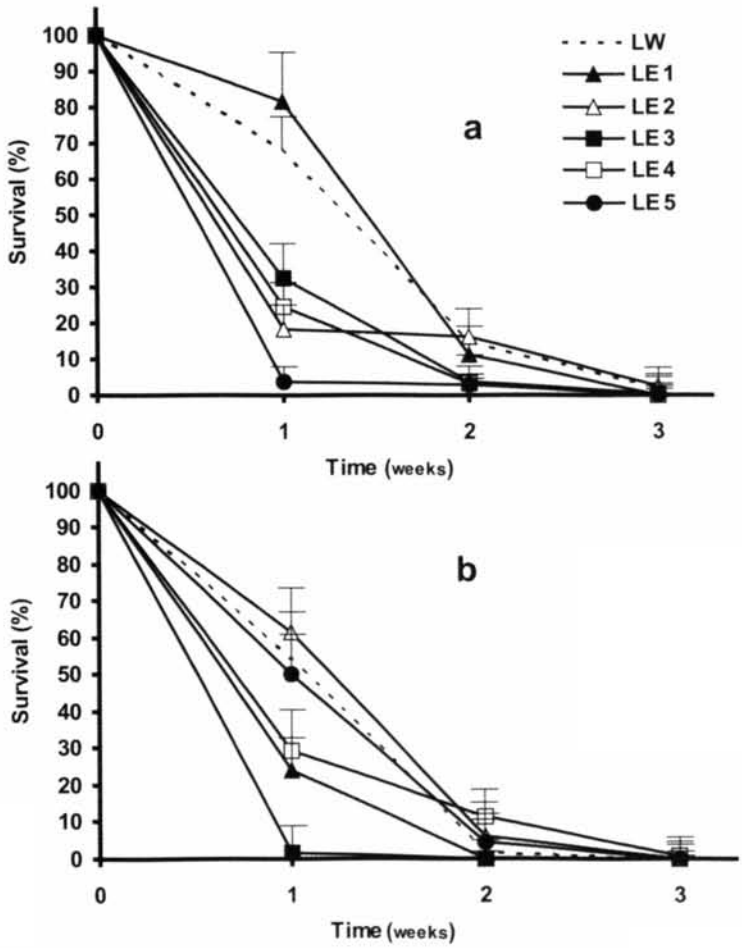

Fig. 5 - Evolution of *L. bulgaricus* (a) and *S. thermophilus* (b) in yogurts in the presence of polyphenolic extracts.

ty was not improved due to the extract at later times. At the second week, survival of the lactobacilli and streptococci was always less than 20%.

CONCLUSIONS

Commercial dairy yogurts and home-made dairy yogurts were quite comparable in terms of chemical-physical characteristics. Moreover, these properties were not significantly modified by supplementation with different edible plant extracts just before fermentation, except for a slight decrease of pH and increase of acidity in all the samples.

Enriched home-made yogurts showed antioxidant activities quantitatively comparable to those of commercial enriched yogurts; the yogurt with red strawberry-tree fruit extract was the most active in the DPPH assay.

After ten days, an increment in the lactic acid (D and L) and acetaldehyde production was observed in some samples of home-made yogurt, while variations in the antioxidant components were not observed and antioxidant activities were almost unchanged.

In terms of microbial activity over the experimental period of three weeks, a high microbial count was observed at time 0 after fermentation with lactobacilli and streptococci in yogurts enriched with strawberry-tree extract and with edible artichoke extract. Under these storage conditions these counts did not change significantly in yogurt enriched with edible artichoke parts for the first week of the experiment.

On the basis of these results the incorporation of selected edible polyphenolic extracts did not affect the chemical and microbiological characteristics of yogurts. Further considering that a regular intake of these dietary polyphenolic compounds is regarded as beneficial for human health, it can be concluded that the yogurts produced as in this study could be of potential interest for the design of probiotic yogurts with additional bioactive metabolites from edible sources and therefore more effective functional foods.

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