Development of fermented skimmed milk fortified with yellow sweet potato (*Ipomoea batatas* L.) with prebiotic and antioxidant activity

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Summary

The research was conducted to develop functional fermented milk by using yellow sweet potato (*Ipomoea batatas* L.) as a prebiotic and antioxidant agent. Fermented milk treatments were manufactured from skimmed milk using a probiotic culture (*Lactobacillus acidophilus* La5) and were fortified with sweet potato powder at levels of 15 g·l^{-1}, 35 g·l^{-1} and 55 g·l^{-1}. At day 1 and after 14 days of cold storage, fermented milk treatments were evaluated for viability of probiotic bacteria, viscosity, water-holding capacity (*WHC*), total phenolic compounds (*TPC*), total carotenoids (*TC*), antioxidant activity (*AA*) and sensory as well as texture profile attributes. Fortification with sweet potato powder stimulated the growth of probiotic bacteria. The bacterial counts in control fermented milk and fortified by 55 g·l^{-1} sweet potato powder were 7.74 log CFU·g^{-1} and 10.28 log CFU·g^{-1}, respectively. The addition of sweet potato powder enhanced viscosity and *WHC* in all treatments. High *TPC*, *TC* and *AA* were observed in fermented milk with added sweet potato powder, and the effect of the fortification was found to depend on its concentration. The results indicated that fortification with sweet potato powder improved the textural profile, particularly at concentrations of 35 g·l^{-1}and 55 g·l^{-1}. After 14 days of storage, viscosity, *AA*, firmness and adhesiveness increased. Sensorically, all fermented milk treatments were acceptable.

Keywords

sweet potato; fermented milk; probiotic; prebiotic; antioxidant activity

Functional foods are a class of food respecting the consumers' demand for not only eating but also for protection against various chronic diseases. Various functional foods contain probiotic bacteria, prebiotics or a combination of them, which plays a role in promoting health of consumers [1]. Various fermented milk products are considered functional dairy products due to their nutritional, therapeutic and probiotic impacts such as antimicrobial, anticancer and cholesterol reduction activities as well as immune system stimulation [2].

Probiotics have been classically defined as living microorganisms that are intended to have health effects when applied to the body in a proper amount. These microorganisms should be present in the fermented milk products at viable counts of 7–9 log CFU·ml^{-1} during all food processing phases and should be able to survive in the gastrointestinal tract [3]. *Lactobacillus, Bifidobacterium, Lactococcus, Pediococcus, Bacillus* and some yeast strains are the major groups of probiotic microorganisms. Prebiotics are non-digestible food ingredients that stimulate the activity of probiotics that ultimately supply health benefits to the consumer or host [4]. The world prebiotic market is expected to reach 7.8 billion US dollars (6500 million EUR) in 2022, being driven by the increasing request from the food industry sector [1]. Fortification of milk using prebiotics such as soya flour or lentil flour to manufacture a functional fermented milk was investigated in various studies [5–7].

One of the world's most important vegetable crops is sweet potato (*Ipomoea batatas* L.),

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being ranked as the seventh major food crop in the world. Sweet potato is the fifth-largest fresh-weight food crop in developing countries, being grown in over 100 developing countries [8]. Sweet potato is an advantageous crop from the points of view of economy as well as health. It contains carbohydrates, proteins, dietary fibres, vitamins and minerals. In addition, it is rich in bioactive components such as carotenoids and phenolic compounds, which contribute to the positive health effects including antioxidant, antidiabetic and anti-obesity activities [9].

Consumption of whole-fat fermented dairy products has decreased in recent years particularly in the case of people suffering from chronic diseases. However, milk fat plays a main role in the flavour and texture of fermented dairy products. Thus, the decrease in milk fat in fermented dairy products leads to their weak body, poor texture and whey separation [10]. Accordingly, because of the high nutritional value of sweet potato and insufficient information on supplementation of fermented milk products with sweet potato, the purpose of this study was to evaluate the fortification of fermented milk with sweet potato as a prebiotic and antioxidant agent.

MATERIALS AND METHODS

Materials

Cows' milk was obtained from Dairy Technology Unit of Cairo University (Giza, Egypt). It was defatted and heat-treated at 90 °C for 10 min.

Skimmed milk powder was provided by Arla Foods (Viby, Denmark).

The yellow sweet potato was cultivated in El-Minia governorate (Egypt), thrived during summer season and purchased from the local market in Giza (Egypt). The sweet potato was picked out according to absence of physical defects or damage, and based on uniformity in appearance.

Commercial strain *Lactobacillus acidophilus* La5 was obtained from MIFAD - Misr Food Additives (Cairo, Egypt).

Chemicals were obtained from Sigma-Aldrich (St. Louis, Missouri, USA). The culture media de Man, Rogosa and Sharpe (MRS) agar, violet bile glucose agar and oxytetracycline-glucose-yeast extract agar were obtained from Lab M (Heywood, United Kingdom).

Preparation of sweet potato powder

The sweet potato was washed, peeled, cut into slices with thickness 2–3 mm and dried in an oven at 40 °C. The dried sweet potato slices were grinded into powder and sieved by a 60 mm mesh sieve to gain powder of uniform particle size.

Fermented milk manufacturing

Four treatments of fermented milks were manufactured in the laboratory from skimmed milk. Skimmed milk was supplemented with skimmed milk powder 10 $g\cdot l^{-1}$ and divided into four portions.

The first portion (treatment 1, control) was heat-treated for 10 min in a water bath at 90 °C, then was cooled to 37 °C and *Lb. acidophilus* La5 culture was added at 2 % (v/v).

A preliminary study was conducted to identify the appropriate sweet potato concentration considering no gel formation during milk heating and the selected concentrations of sweet potato were 15 $g\cdot l^{-1}$, 35 $g\cdot l^{-1}$ and 55 $g\cdot l^{-1}$.

The second, third and fourth portions of skimmed milk (treatments 2, 3 and 4, respectively) were fortified with sweet potato powder at levels of 15 $g\cdot l^{-1}$, 35 $g\cdot l^{-1}$ and 55 $g\cdot l^{-1}$, respectively and were heat-treated for 10 min in a water bath at 90 °C, then were cooled to 37 °C and *Lb. acidophilus* La5 culture was added at 2 % (v/v) .

Samples of all treatments were incubated at 37 °C for 4.5–6 h until fermentation and subsequently were stored at 4–6 °C for 14 days.

Preparation of water-soluble extract from fermented milk samples

Water-soluble extracts of fermented milk used for determination of total phenolics, total carotenoids and antioxidant activity assays were prepared according to Abd El-Fattah et al. [11]. In screw-cap tubes, 10 g of fermented milk samples was added to 40 ml of distilled water. The mixture was homogenized followed by retaining at 40 °C for 1 h. The homogenate was then centrifuged at 10 000 ×*g* for 30 min and the resultant supernatant was collected and kept at –80 °C for analysis within one week.

Chemical and physico-chemical parameters

The chemical composition of sweet potato powder and skimmed milk were determined using standard AOAC methods [12]. AOAC method 947.05 was used for determination of titratable acidity (*TA*), 925.23 for total solids, 991.20 for proteins and 923.03 for ash of fermented milk [12]. The crude fibre of fermented milk samples was estimated as described by Mbaeyi-Nwaoha et al. [13].

Viscosity

The apparent viscosity of fermented milk was determined with a Brookfield digital rotational viscometer model DV-II+ (Brookfield Engineering, Middleboro, Massachusetts, USA) using a spindle No. 5. A reading of apparent viscosity in centipoises was recorded from the viscometer's digital output.

Water-holding capacity

Twenty grams of fermented milk were centrifuged at 5 000 ×g for 10 min at 20 °C. The clear whey was separated and measured out. The water-holding capacity (WHC) was estimated according to Eq. 1 and expressed in percent:

$$WHC = \left(F - \frac{CE}{F}\right) \times 100 \quad (1)$$

where F is weight of fermented milk and CE is weight of separated clear whey (in grams).

Microbiological analysis

Lactobacillus acidophilus, coliform bacteria and total moulds and yeasts were cultivated on MRS agar, violet bile glucose agar and oxytetracycline-glucose-yeast extract agar media, respectively. Their counts were enumerated according to the standard methods for the examination of dairy products [14].

Total phenolic compounds and total carotenoids

Total phenolic compounds (TPC) and total carotenoids (TC) were determined spectrophotometrically according to Perna et al. [15] and Xavier et al. [16] using UV-Visible spectrophotometer Jenway (Cole-Parmer, Stone, United Kingdom). Content of TPC was expressed as milligrams of gallic acid equivalents (GAE) per kilogram of sweet potato powder or fermented milk. Content of TC was expressed as grams per kilogram of sweet potato powder or fermented milk.

Phenolic compounds in sweet potato powder

Determination of phenolic compounds was carried out by high-performance liquid chromatography (HPLC) using an Agilent 1260 infinity HPLC system (Agilent Technologies, Santa Clara, California, USA). Separation was carried out using a Zorbax Eclipse plus C18 column (100 mm × 4.6 mm, particle size 5 μm; Agilent Technologies). The detection wavelength was set at 284 nm and the column temperature was kept at 30 °C.

Antioxidant activity of fermented milk

The radical-scavenging activity of fermented milk was evaluated using 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) inhibition assay as described by Abd El-Fattah et al. [11]. One millilitre of DPPH (0.1 mmol·l^{-1}) was mixed with 1 ml supernatant. The mixture was shaken and allowed to stand at room temperature for 30 min. Absorbance of the obtained mixture was estimated at 517 nm. Instead of the sample, distilled water was utilized as a blank. The DPPH radical-scavenging activity (AA) was calculated using the following equation and expressed in percent:

$$AA = \frac{(A_0 - A_s)}{A_0} \times 100 \quad (2)$$

where A_0 is the absorbance of blank and A_s is the absorbance of water-soluble extract.

Texture profile analysis

The textural attributes of fermented milk were evaluated using the textural analyser, B type (Cometech Testing Machines, Taichung, Taiwan). A back-extrusion cell with a compression disc (35 mm diameter) was utilized. Two cycles were applied to 25 % of sample depth at a constant crosshead velocity of 1 mm·s^{-1} and then returned. From the texture profile analysis, the values of firmness, gumminess, chewiness, adhesiveness, cohesiveness and springiness were deduced.

Sensory evaluation

Twenty staff members from Dairy Science Department of Cairo University (Giza, Egypt) and Dairy Technology Department of Agricultural Research Center (Giza, Egypt) used a quality score card for flavour (50 points), body and texture (40 points) and appearance (10 points) evaluation of fermented milk treatments.

Statistical analysis

All results are means of three separate replicates and were displayed as mean ± standard deviation. Data were analysed statistically utilizing analysis of variance (ANOVA) by MSTAT-C software (Michigan State University, East Lansing, Michigan, USA). Differences between means were considered significant at 95% (P < 0.05) confidence level.

RESULTS AND DISCUSSION

Basic chemical and microbiological composition

The chemical composition of skimmed milk and sweet potato is presented in Tab. 1. Control fermented milk (treatment 1) contained 141 ± 5 g·kg^{-1} total solids, 43.3 ± 2.5 g·kg^{-1} total protein and 10 ± 1 g·kg^{-1} ash compared to those of other treatments (148.8 ± 10.35 g·kg^{-1} total solids, 44.8 ± 5.3 g·kg^{-1} total protein, and 10.78 ± 1 g·kg^{-1} ash). Fermented milk in all treatments was free

Tab. 1. Chemical composition of skimmed milk and sweet potato powder.

Component	Skimmed milk	Sweet potato powder
Total solids [g·kg^{-1}]	95.0 ± 1.0	930.0 ± 11.2
Protein [g·kg^{-1}]	34.1 ± 0.3	74.0 ± 1.0
Fat [g·kg^{-1}]	0.0	13.0 ± 0.1
Carbohydrate [g·kg^{-1}]	51.1 ± 0.1	759.5 ± 12.3
Ash [g·kg^{-1}]	8.8 ± 0.1	29.9 ± 0.6
Crude fibre [g·kg^{-1}]	–	43.6 ± 0.2
Total phenolic compounds [mg·kg^{-1}]	–	30190 ± 89
Total carotenoids [g·kg^{-1}]	–	41.78 ± 0.75

Values are means ± standard deviation (n = 3). Total phenolic compounds are expressed as grams of gallic acid equivalents.

from moulds, yeasts and coliform bacteria on the first day of manufacturing and at the end of the cold storage period as well.

Titratable acidity and *Lb. acidophilus* counts

The results of *TA* and *Lb. acidophilus* counts (Tab. 2) showed that fermented milk in treatments 2, 3 and 4 had a significantly higher *TA* and *Lb. acidophilus* counts on the first day and at the end of the storage period than the fermented milk in treatment 1. The significant increase in *TA* of fermented milk in treatments 2, 3, and 4 might have been due to the high viable *Lb. acidophilus* counts and the production of lactic acid. This observation is positive as Korbekandi et al. [17] reported that the health effects of probiotic dairy products rely on the counts of active bacteria cells at consumption. Hence, it is essential to administer adequate amounts of a high survival rate of the probiotics through the shelf life of the product [18]. The results of Tab. 2 show that *Lb. acidophilus* exhibited positive growth with fortification of fermented milk with sweet potato, which might have been due to the prebiotic effect of dietary fibre of sweet potato. Our results revealed that sweet potato contained 43.6 g·kg^{-1} crude fibre (Tab. 1), and this increased the content of crude fibre in the fermented milk, thus, enhancing the growth of the culture.

In this regard, the content of crude fibre of 49 sweet potato kinds was previously found to range between 34.5 g·kg^{-1} and 63.6 g·kg^{-1} [19]. Robinson [20] reported that pectin, cellulose, lignin and hemicellulose are considered as dietary fibre in sweet potato. Furthermore, Suryadjaja [21] found that sweet potato contains potential prebiotics such as oligosaccharides, one of which is raffinose. Mikasari and Ivanti [22] reported that oligosaccharides of sweet potato act as a prebiotic and support the growth of lactobacilli.

In our study, after 14 days of cold storage, there was no difference in the counts of *Lb. acidophilus* between all treatments except treatment 2, which showed a significant decrease in the counts of *Lb. acidophilus*. The viable probiotic *Lb. acidophilus* counts exceeded the recommended level of 10^6 CFU·g^{-1} in all treatments during the storage period of up to 14 days. Fermented milk (treatment 4) had significantly higher viable counts of *Lb. acidophilus* (10.28 log CFU·g^{-1}) com-

Tab. 2. Titratable acidity, *Lb. acidophilus* counts and crude fibre content of fermented milk treatments.

Parameter	Storage period [d]	Fermented milk				*LSD*
		T1	T2	T3	T4	
Titratable acidity [%]	1	0.65 ± 0.01 ^{f}	0.69 ± 0.01 ^{e}	0.75 ± 0.01 ^{d}	0.79 ± 0.01 ^{c}	0.01
	14	0.79 ± 0.01 ^{c}	0.80 ± 0.01 ^{bc}	0.81 ± 0.01 ^{b}	0.91 ± 0.01 ^{a}	
La5 counts [log CFU·g^{-1}]	1	7.74 ± 3.51 ^{e}	8.51 ± 0.16 ^{c}	8.86 ± 2.53 ^{b}	10.28 ± 1.03 ^{a}	0.10
	14	7.67 ± 2.31 ^{e}	8.39 ± 1.48 ^{d}	8.90 ± 2.06 ^{b}	10.26 ± 1.46 ^{a}	
Crude fibre [g·kg^{-1}]	1	–	0.40 ± 0.09 ^{c}	1.53 ± 0.40 ^{b}	2.40 ± 0.30 ^{a}	0.40
	14	–	0.70 ± 0.05 ^{c}	1.30 ± 0.50 ^{b}	1.70 ± 0.10 ^{b}	

Values are mean ± standard deviation.
T1 – control, T2 – fermented milk fortified with 15 g·l^{-1} sweet potato, T3 – fermented milk fortified with 35 g·l^{-1} sweet potato, T4 – fermented milk fortified with 55 g·l^{-1} sweet potato.
La5 – *Lb. acidophilus* La5, *LSD* – least significant difference.

pared to those of other treatments. This could be supposedly attributed to the stimulatory effect of sweet potato on *Lb. acidophilus* growth.

Viscosity and water-holding capacity

Viscosity and *WHC* are important parameters when assessing the fermented milk quality. The values of viscosity and *WHC* (Fig. 1) indicated that the fortification of fermented milk with sweet potato led to a significant increase in the viscosity and *WHC* of all treatments compared to treatment 1 (control). At the end of the cold storage period, the viscosity of all treatments significantly increased, while the values of *WHC* were stable with no significant variations in all treatments except treatment 1 that exhibited a significant decline in the *WHC* value. These results suggest that sweet potato had a positive effect on the water retention and viscosity of fermented milk. In this respect, Saleh et al. [23] found that the addition of sweet potato starch to set yogurt significantly increased viscosity and significantly decreased wearing-off. This might be due to the mechanism of starch gelatinization at the first step of yogurt making. Starch is composed of amylopectin molecules that have a high-water binding ability; thus, it can increase the viscosity of the yogurt [24].

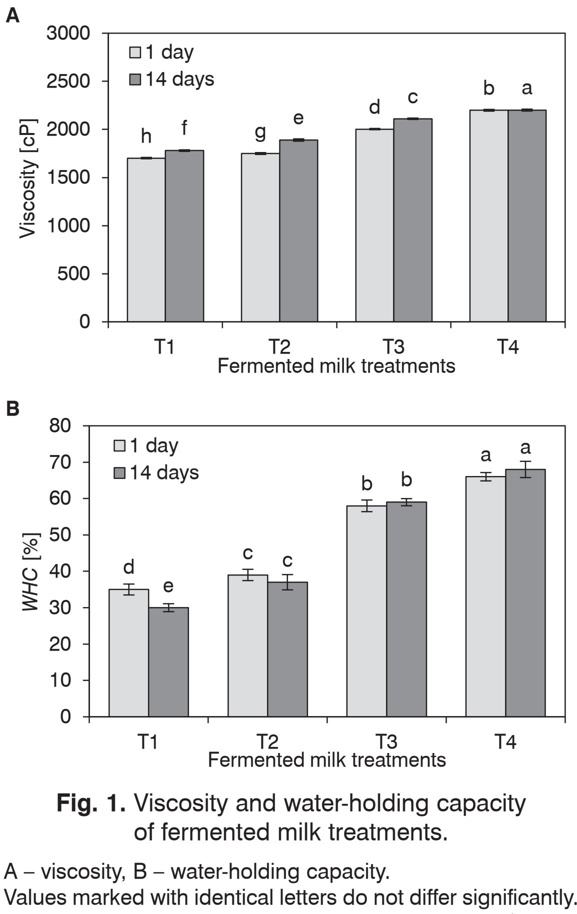

Fig. 1. Viscosity and water-holding capacity of fermented milk treatments.

A – viscosity, B – water-holding capacity.
Values marked with identical letters do not differ significantly.
T1 – control, T2 – fermented milk fortified with 15 g·l^{-1} sweet potato, T3 – fermented milk fortified with 35 g·l^{-1} sweet potato, T4 – fermented milk fortified with 55 g·l^{-1} sweet potato.
WHC – water-holding capacity.

Bioactive components and antioxidant activity

The results on *TPC*, *TC* and *AA* are shown in Fig. 2. *TPC* of fermented milk (control) ranged from 5.2 mg·kg^{-1} to 7.2 mg·kg^{-1} (expressed as GAE) and *TC* ranged between 0.310 g·kg^{-1} and 0.176 g·kg^{-1} on day 1 and after 14 days of cold storage, respectively. In this respect, Baba et al. [25] found that *TPC* of plain yogurt was 17.2–18.7 mg·kg^{-1} (expressed as GAE) during 21 days of refrigerated storage.

Fermented milk (control) significantly exhibited the lowest *AA* on day 1 and after 14 days of cold storage compared to other fermented milk treatments. *AA* of the control fermented milk might rely on fermentation of milk with *Lb. acidophilus* La5 that can produce antioxidant peptides by proteolysis of milk. These results are in agreement with those of Abd El-Fattah et al. [11].

The highest levels of *TPC*, *TC* and *AA* were noticed for treatment 4, either on day 1 or after 14 days of cold storage. These results could be explained by the fortification of fermented milk with sweet potato that contained 30 190 mg·kg^{-1} (expressed as GAE) of *TPC* and 417.8 g·kg^{-1} of *TC* (Tab. 1). Our findings indicated that *TPC* and *TC* were primary contributors to their radical-scavenging activity. These results are consistent with the findings of Teow et al. [26].

By HPLC analysis, 16 phenolic compounds were identified in sweet potato powder (Fig. 3). Phenolic acids such as vanillic acid, pyrogallol, catechol, gallic acid, ferulic acid, ellagic and cinnamic acid, and flavonoids derivatives such as quercetin and myricetin were recognized. The sweet potato powder contained the highest amounts of vanillic acid (64.81 mg·kg^{-1}), pyrogallol (10.49 mg·kg^{-1}), catechol (9.66 mg·kg^{-1}) and *p*-hydroxybenzoic acid (5.18 mg·kg^{-1}; data not shown). Various previous studies reported that phenolic acids, such as vanillic acid, exhibited strong antioxidant, cardioprotective, hepatoprotective and anti-apoptotic activities [27]. Furuno et al. [28] and Siger et al. [29] reported that pyrogallol, ferulic and *p*-coumaric acids possessed high antioxidant and antibacterial activities. Besides, quercetin is known to exhibit multifaceted biological and therapeutic effects including antioxidative, anticancer, antimicrobial, anti-inflammatory, cardioprotective and hepatoprotective activities [30].

Our results showed that the period of cold

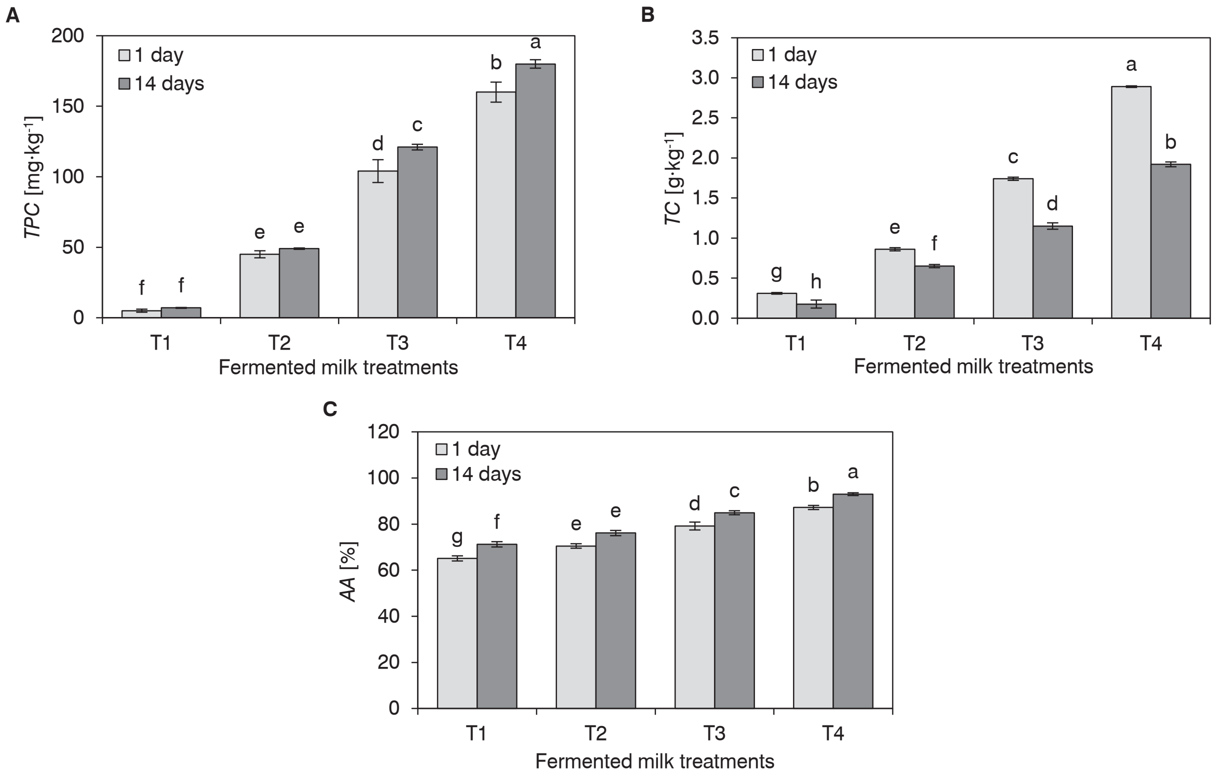

Fig. 2. Total phenolic compounds, total carotenoids and antioxidant activity of fermented milk treatments.

A – total phenolic compounds, B – total carotenoids, C – antioxidant activity.
Values marked with identical letters do not differ significantly.
T1 – control, T2 – fermented milk fortified with 15 g·l^{-1} sweet potato, T3 – fermented milk fortified with 35 g·l^{-1} sweet potato, T4 – fermented milk fortified with 55 g·l^{-1} sweet potato.
TPC – total phenolic compounds (expressed as grams of gallic acid equivalents), *TC* – total carotenoids, *AA* – antioxidant activity.

storage had a significantly negative effect on *TC* of all treatments. This was in agreement with results of GAD et al. [31], who found that the concentration of carotenoids in all yogurt treatments gradually decreased during the cold storage, which may be owing to their degradation. FIEDOR and BURDA [32] reviewed that carotenoids are scavengers of various reactive oxygen species and very efficient quenchers of singlet oxygen. At the end of cold storage, *AA* was significantly enhanced in all treatments in our study. This affirmed that proteolytic activity of *Lb. acidophilus* may involve the milk protein breakdown to different extents and hence may release a broad range of peptides that act as

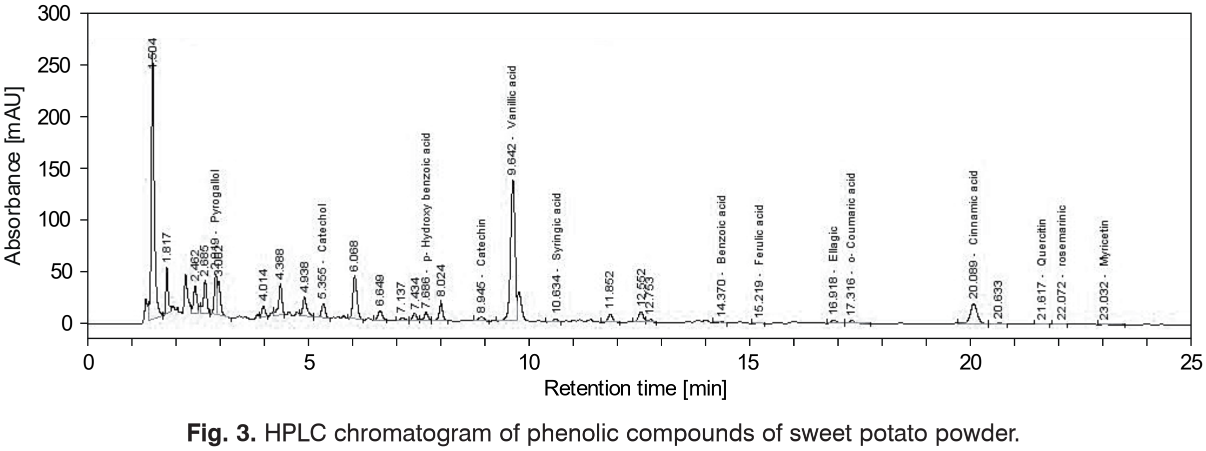

Fig. 3. HPLC chromatogram of phenolic compounds of sweet potato powder.

electron donors and could convert free radicals to more stable compounds [33].

Texture profile analysis

It is well known that texture has a vital role in the quality of fermented dairy products and is quite affected by their composition. Tab. 3 presents data on changes in texture attributes of the fermented milk treatments evaluated by texture profile analysis. Compared to control fermented milk (treatment 1), the addition of sweet potato powder led to a significant increase in fermented milk firmness, springiness and cohesiveness, particularly at the addition level of 35 $g \cdot l^{-1}$ and 55 $g \cdot l^{-1}$ of sweet potato (treatments 3 and 4). However, adhesiveness, gumminess and chewiness exhibited the opposite behaviour. The increase in firmness could be due to the relation between firmness and water binding, as it is known that sweet potato can bind water. This result is inharmonious to the results of *WHC* and viscosity. The protein-polysaccharide interactions and coagulation as well as aggregation behaviour have a significant effect on rheological properties and physical stability of multi-component food systems [23, 34]. At the end of cold storage, firmness and springiness of fermented milk increased significantly in treatments 1 and 4, while adhesiveness increased significantly in all treatments. On the other hand, cohesiveness of fermented milk decreased significantly in all treatments, while gumminess and chewiness did not change significantly. In this respect, SALEH et al. [23] observed that sweet potato starch increased the hardness and decreased

Tab. 3. Textural profile analysis of fermented milk treatments.

Properties	Storage period [d]	Fermented milk				*LSD*
		T1	T2	T3	T4	
Firmness [N]	1	0.44 ± 0.01 e	0.79 ± 0.11 cd	0.98 ± 0.11 bc	1.13 ± 0.15 b	0.21
	14	0.74 ± 0.08 d	0.98 ± 0.15 bc	1.01 ± 0.12 b	1.37 ± 0.16 a	
Adhesiveness [$N \cdot s^{-1}$]	1	0.35 ± 0.00 d	0.32 ± 0.00 de	0.29 ± 0.00 e	0.04 ± 0.01 g	0.05
	14	0.71 ± 0.00 a	0.65 ± 0.00 b	0.43 ± 0.00 c	0.23 ± 0.01 f	
Cohesiveness	1	0.62 ± 0.02 b	0.60 ± 0.00 b	0.59 ± 0.05 b	0.69 ± 0.01 a	0.05
	14	0.51 ± 0.01 c	0.50 ± 0.04 c	0.62 ± 0.04 b	0.63 ± 0.01 b	
Gumminess [N]	1	0.786 ± 0.170 a	0.593 ± 0.109 b	0.429 ± 0.011 bcd	0.283 ± 0.010 d	0.168
	14	0.897 ± 0.150 a	0.586 ± 0.101 b	0.472 ± 0.010 bc	0.338 ± 0.010 cd	
Springiness	1	0.719 ± 0.010 e	0.846 ± 0.010 de	1.047 ± 0.080 c	1.470 ± 0.141 b	0.165
	14	0.757 ± 0.090 e	0.990 ± 0.101 cd	1.140 ± 0.121 c	1.680 ± 0.110 a	
Chewiness [N]	1	1.16 ± 0.19 ab	0.83 ± 0.12 c	0.43 ± 0.01 de	0.24 ± 0.01 f	0.18
	14	1.19 ± 0.14 a	0.99 ± 0.12 bc	0.54 ± 0.01 d	0.25 ± 0.01 ef	

Values are mean ± standard deviation. Values in the same column or row for each parameter with identical superscript letters do not differ significantly.
T1 – control, T2 – fermented milk fortified with 15 $g \cdot l^{-1}$ sweet potato, T3 – fermented milk fortified with 35 $g \cdot l^{-1}$ sweet potato, T4 – fermented milk fortified with 55 $g \cdot l^{-1}$ sweet potato.

Tab. 4. Sensory evaluation of fermented milk treatments.

Attributes	Number of points	Storage period [d]	Fermented milk				*LSD*
			T1	T2	T3	T4	
Body and texture	40	1	28.33 ± 2.88 e	33.33 ± 2.30 cd	34.90 ± 0.22 bcd	36.31 ± 1.68 abc	3.24
		14	32.47 ± 2.53 d	35.08 ± 1.56 abcd	36.81 ± 1.30 ab	38.27 ± 0.96 a	
Flavour	50	1	28.77 ± 2.40 e	33.80 ± 3.02 d	44.80 ± 1.40 ab	43.73 ± 2.98 ab	4.78
		14	38.43 ± 3.05 cd	41.44 ± 3.49 bc	45.31 ± 1.03 ab	46.43 ± 3.54 a	
Appearance	10	1	7.66 ± 0.57 c	7.66 ± 0.57 c	8.21 ± 1.21 bc	9.84 ± 0.47 a	1.31
		14	8.21 ± 1.21 bc	9.47 ± 0.50 ab	9.10 ± 1.01 ab	9.55 ± 0.95 a	
Overall acceptability	100	1	65.65 ± 1.21 g	75.00 ± 1.21 f	88.70 ± 1.00 c	88.40 ± 0.86 c	1.45
		14	78.41 ± 0.62 e	84.84 ± 0.68 d	90.39 ± 0.17 b	93.58 ± 0.28 a	

Values are mean ± standard deviation. Values in the same column or row for each parameter with identical superscript letters do not differ significantly.
T1 – control, T2 – fermented milk fortified with 15 $g \cdot l^{-1}$ sweet potato, T3 – fermented milk fortified with 35 $g \cdot l^{-1}$ sweet potato, T4 – fermented milk fortified with 55 $g \cdot l^{-1}$ sweet potato.

the adhesiveness and cohesiveness of yogurt. However, the gumminess was not affected in that study.

Sensory evaluation

The sensory attributes of the fermented milk products may be affected by the addition of functional ingredients that could lead to a decrease in the consumer acceptability. Therefore, it is necessary to evaluate the changes in the sensory properties of fermented milk when using the sweet potato. The results in Tab. 4 demonstrate an improvement in the sensory attributes of the functional fermented milk as a result of fortification with the sweet potato. Significant increase was observed in the body and texture (36.31), flavour (43.73), appearance (9.84) and overall acceptability (88.40) of fermented milk in treatment 4 compared to 28.33, 28.77, 7.66 and 65.65, respectively, in treatment 1 (control). These results are consistent with those observed by SALEH et al. [23] who noticed that the sensory viscosity, texture and overall acceptability of yogurt supplemented with sweet potato starch were significantly higher than those of the control yogurt. Furthermore, COLLINS et al. [35] found that the addition of sweet potato purée to fermented milk contributed to an increase in firmness, yellow colour, flavour, and overall acceptability. After 14 days of storage, a similar trend was found in all fermented milk treatments.

CONCLUSIONS

This work aimed to develop functional fermented milk with a high content of viable probiotic bacteria and with high antioxidant activity, using addition of sweet potato powder. The fortification of the fermented milk by sweet potato enhanced the population of probiotic *Lb. acidophilus* culture through the cold storage period. Viscosity, *WHC*, *TPC*, *TC* and *AA* of fermented milk were improved using the addition of sweet potato. Furthermore, the supplementation with sweet potato enhanced the texture profile properties of the fermented milk. The cold storage had a positive effect on viscosity, *TPC* and *AA* of the fermented milk. Liking responses of assessors showed a high overall acceptability score of the fermented milk with sweet potato addition, particularly at levels 35 $g \cdot l^{-1}$ and 55 $g \cdot l^{-1}$. Generally, sweet potato can be further developed as a sustainable component for various value-added fermented dairy products with improved functionality and to boost human health.

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