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Preliminary assessment of a yoghurt-like product manufactured from hazelnut slurry: Study using response surface methodology

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ABSTRACT

The aim of this study was to evaluate the possibility of using hazelnut slurry in manufacture of yoghurt. A yoghurt-like product was prepared from hazelnut slurry fortified with skimmed milk powder. The effects of the total solids content of the hazelnut slurry (TSCHS, 8–16 g 100 g^{-1}) and the content of milk powder (CMP, 6–9 g 100 g^{-1}) on the proximate composition, physicochemical and sensorial properties, fatty acid composition, total phenolic content (TPC) and antioxidant activity of the product were evaluated using response surface methodology. Both the TSCHS and the CMP had a significant effect on the total solids content, *b* value, syneresis, palmitic and oleic acid content, and FRAP value. Only the TSCHS showed a significant effect on the protein and fat content, *a* value, water-holding capacity, TPC and ABTS values. Only the CMP showed a significant effect on the carbohydrate and ash content and the acidity. The characteristics of the product generally appeared to be compatible with those of yoghurt. The product was rich in unsaturated fatty acids. Therefore, using hazelnut slurry in manufacture of yoghurt may be proposed to enhance the health benefits of yoghurt.

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1. Introduction

Yoghurt, a fermented milk product, is one of the most popular dairy products worldwide because of its nutritional and health benefits. Yoghurt is a rich source of carbohydrate (lactose), protein (casein), fat, vitamins (B vitamins) and minerals (calcium and phosphorus). Yoghurt is an easily digestible product because milk protein, carbohydrate and fat are hydrolysed during fermentation. Yoghurt includes lactic acid bacteria, which have health-promoting properties or therapeutic effects on gastrointestinal functions and diseases, including lactose intolerance, diarrhoea, colon cancer and inflammatory bowel disease. Yoghurt is known to improve bone health and to help control body weight (Adolfsson, Meydani, & Russell, 2004; Mckinley, 2005). Yoghurt is generally manufactured from dairy milk, especially cow's milk. Many attempts have been made to produce yoghurt from plant milk including soy milk (Granata & Morr, 1996; Rinaldoni, Campderros, & Padilla, 2012), mango-soy milk (Kumar & Mishra, 2004), corn milk (Supavititpatana, Wirjantoro, Apichartsrangkoon, & Raviyan, 2008) and peanut milk (Isanga & Zhang, 2009).

Hazelnuts are important in human nutrition and health because of their composition of protein, carbohydrates, lipids, vitamins, minerals, dietary fibres, tocopherols, phytosterols, squalene, and phenolic compounds (Alasalvar, Shahidi, Liyanapathirina, & Ohshima, 2003). Epidemiological studies have shown that nut consumption is associated with a lower risk of coronary heart disease. Nut consumption has also been shown to help prevent sudden cardiac death, hypertension, gallstone disease, high blood cholesterol and high blood pressure (Ros, 2010). Hazelnut slurry is produced by soaking hazelnuts (roasted or unroasted) in water, grinding the nuts in water and then filtering the slurry. Hazelnut slurry may provide the same potential health benefits as hazelnuts. Hazelnut slurry is rich in monounsaturated fatty acids (mainly oleic acid) and phytosterols (mainly β-sitosterol) and contains antioxidant compounds.

Hazelnut slurry may be used in the manufacture of yoghurt to enhance the health benefits of yoghurt. The aim of this study was to evaluate the possibility of using hazelnut slurry in manufacture of yoghurt. The effect of the ingredients on the characteristics of the product was analysed using response surface methodology.

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2. Material and methods

2.1. Chemicals

All chemicals and solvents (analytical grade or HPLC grade) were obtained from Merck (Darmstad, Germany). FAME mix, ABTS, TPTZ and gallic acid were purchased from Sigma-Aldrich (St. Louis, MO, USA).

2.2. Materials

Hazelnuts (Tombul cultivar) were obtained from an orchard in Giresun province (Turkey). Skimmed milk powder (Pınar Co., Izmir, Turkey) was purchased from a local market. Skimmed milk powder had protein (36 g 100 g^{-1}) and carbohydrate (52 g 100 g^{-1}) as the main constituents. The starter culture (Chr. Hansen FD DVS YC-X16, Chr. Hansen A/S, Horsholm, Denmark) was obtained from a local distributor.

2.3. Hazelnut slurry preparation

Shelled hazelnuts were roasted at 140 °C for 15 min in an oven. The roasted hazelnuts were soaked in water for 12 h. After filtration and washing, the hazelnuts were ground with water in a blender (Waring laboratory blender, Conair Corporation, Stamford, CT, USA) for 2 min. The slurry was filtered through a double-layered cheesecloth.

One batch of the hazelnut slurry was prepared and the total solids content of the batch was determined. When hazelnuts were ground with water (1:3) in a blender, the obtained hazelnut slurry had approximately 24 g 100 g^{-1} of total solids content. It had 11.6 g of fat, 7.4 g of carbohydrate and 4.6 g of protein as the main constituents. The batch was diluted with water to obtain the targeted levels of total solids.

2.4. Yoghurt manufacture

The skimmed milk powder was dissolved in the hazelnut slurry at 43 °C, stirring for 40 min. The milk was homogenised with a homogeniser (Daihan WiseTisHG-15A, Daihan Scientific Co., Seoul, South Korea) and pasteurised at 90 °C for 20 min. After cooling to 43 °C, the starter culture (3 mL 100 g^{-1}) was added to the pasteurised milk. The milk inoculated with the starter culture was incubated at 43 °C for 4–4.5 h until a pH of about 4.6–4.7 was attained. The yoghurt was stored at 4 °C overnight prior to analysis.

2.5. Proximate composition

The moisture, protein, fat and ash content of the samples were determined in accordance with the AOAC methods. The oven method was used for the moisture content, the Kjedahl method for the protein content (factor: 6.38), the Gerber method for the fat content, and the dry burning method for the ash content. Total carbohydrates were calculated by subtracting the total percentages of moisture, protein, fat and ash from 100.

2.6. Physicochemical properties

The pH of the sample was measured with a pH meter (Hanna HI 2210, Smithfield, RI, USA). The acidity of the sample was determined by the alkali titration method. Colour properties (*L*, *a*, and *b* values) were measured with a chromometer (Konica Minolta CR-400, Japan). The syneresis was measured by using 10 g of yoghurt spread on a filter paper (Whatman No. 1) in a beaker. The beaker was held at 4 °C for 5 h, and the liquid collected was weighed. The water-holding capacity was determined with the centrifuge method. The yoghurt sample (10 g) was stored at 4 °C for 24 h, and then the tubes were centrifuged at 5000 × *g* for 20 min at 4 °C. The whey separated from the samples was weighed.

2.7. Fatty acid composition

The fatty acid composition was determined according to the analytical methods previously described (Ilyasoglu, 2013). The determination of the fatty acid composition was carried out by gas chromatography with flame ionisation detection (GC-FID). Fatty acid methyl ester (FAME) was injected into a Shimadzu GC-2010 Plus gas chromatograph (Shimadzu Corporation, Japan) equipped with a flame ionisation detector, a split/splitless injector and a long capillary column (0.25 mm × 0.20 μm × 60 m, Teknokroma TR-CN100, Teknokroma Anlitica, Barcelona, Spain). The oven temperature program was as follows: the initial temperature of the column was 90 °C, held for 5 min, followed by a 10 °C/min ramp to 240 °C, and held for 20 min. The carrier gas was helium at a flow rate of 1 mL/min, the split ratio was 50:1, and the injection quantity was 1 μL. The identification of FAMEs was performed by using a standard FAME reference mixture. The peak areas were computed by the integration software, and fatty acids were given in percentages relative to the total fatty acid content.

2.8. Total phenolic content

The samples (2 g) were extracted with 5 mL of methanol (70%) for one hour in an ultrasonic bath and centrifuged for 10 min. After filtration, the residue was re-extracted with 5 mL of methanol (70%). The combined methanol extracts were stored at −18 °C until analysis. The total phenolic content (TPC) was estimated using the Folin-Ciocalteu method. A total of 0.1 mL of the extract solution was mixed with 0.50 mL of diluted Folin-Ciocalteu reagent, 0.4 mL of sodium carbonate (1 M) and 4 mL of distilled water. The absorbance of the mixture was measured at 760 nm after 1 h. The calibration curve was prepared with standard gallic acid ranging from 0 to 200 mg/mL. The TPC was expressed as mg of gallic acid equivalents (GAEs) per kg of the sample.

2.9. ABTS radical scavenging activity

For the ABTS assay, the ABTS stock solution was prepared by reacting 7 mmol/L of ABTS with 2.45 mmol/L of potassium persulphate solution. The solution was then left in the dark at room temperature for 16 h. The stock solution was diluted with ethanol to reach an absorbance of 0.70 (±0.02) AU at 734 nm. A total of 50 μL of the extract was mixed with 1500 μL of $ABTS^{+}$ solution, and the absorbance was measured at 734 nm after 6 min. The results were expressed as micromoles of trolox per kg of the sample.

2.10. Ferric reducing antioxidant power assay

For the ferric reducing antioxidant power (FRAP) assay, fresh FRAP reagent was prepared by mixing the following solutions (10:1:1): acetate buffer solution (pH = 3.6), TPTZ solution in 40 mmol/L HCl (10 mmol/L) and $FeCl_3$ (20 mmol/L) solution. A total of 50 μL of the extract was mixed with 1500 μL of FRAP reagent, and the absorbance was measured at 595 nm after 20 min. The results were expressed as micromoles of trolox per kg of the sample.

2.11. Microbiological analyses

A check of starter culture in the samples was performed immediately after the completion of fermentation and during four

weeks of storage at 4 °C. The samples (10 g) were diluted with sterile peptone water (0.1 g 100 mL^{-1}, 90 mL), and serial dilutions were prepared. Starter culture cells were counted using pour plate technique. Enumerations of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* colonies were carried out in M17 agar (Merck) under aerobic condition and MRS agar (Merck) under unaerobic condition for 37 °C for 48 h, respectively. Cell count was expressed as colony forming units per gram (cfu g^{-1}) of the product.

2.12. Sensorial properties

The appearance, consistency, odour, taste and overall acceptability of the samples were analysed after overnight storage. The samples (25 g) put in the cups were coded randomly with three digit random number and served to the panellists in booths. The ten panellists (students of department of nutrition and dietetics) having knowledge of sensory analysis were selected. They evaluated the samples using a 9-points scale. The sensory scores ranged from 1 (dislike extremely) to 9 (like extremely). Water was given to the panelists to rinse their mouth between the samples.

2.13. Experimental design

A two-factor and five-level central composite design was used for the response surface methodology studies. Table 1 presents the independent variables and the experimental design. The two factors selected were the total solids content of the hazelnut slurry (TSCHS), (8–16 g 100 g^{-1}) and the content of milk powder (CMP) in slurry (6–9 g 100 g^{-1}).

2.14. Statistical analysis

The regression analyses, statistical significance, analysis of variance (ANOVA) and response surfaces were analysed using Modde 9.1 software (Umetrics, MKS Instruments Inc., Sweden).

3. Results and discussion

3.1. Proximate composition

The total solids, protein, fat, carbohydrate and ash content of the product was determined (Table 2). The effects of two variables, the TSCHS and the CMP, on these parameters can be visualised using contour plots. It can be seen from Fig. 1 that the proximate composition of the product was affected by the TSCHS and the CMP used in the manufacture of the product. The analysis of variance was applied to determine the significance of the effect of the variables on the responses. The regression coefficients and the *p*-values of the variables are presented in Table 3. Both variables influenced the total solids content of the product, with positive linear effects observed. The total solids content of the product increased with increasing TSCHS and CMP (Fig. 1a). Only TSCHS had a significant effect on the protein and fat content, and a linear effect was observed. The protein and fat content increased with increasing TSCHS (Fig. 1b and c). Only CMP had a significant impact on the carbohydrate and ash content of the product, with a linear effect observed. The carbohydrate and ash content of the product increased with increasing CMP (Fig. 1d and e). Only the TSCHS influenced the energy value of the product, and a linear effect was observed. An increase in the TSCHS resulted in a rise in the energy value (Fig. 1f). The model equations for the responses could be derived by using the regression coefficients of the factors (Table 3). The R^2 values of the responses explained by the models were 0.99, 0.98, 0.88, 0.85, 0.78 and 0.99 for the total solids ($p < 0.05$), fat ($p < 0.05$), protein ($p < 0.10$), carbohydrate ($p < 0.10$) and ash ($p < 0.20$) content and the energy value ($p < 0.05$), respectively. The lack of fit values ($p > 0.05$) revealed that the models were convenient for the prediction.

The addition of the milk powder enhanced the total solids, carbohydrate and ash content of the product. The increase in the total solids content of the product can be attributed to the high solids content of the milk powder (>90 g 100 g^{-1}). The high lactose content of the milk powder may explain the increase in the carbohydrate content. Milk powder is rich in minerals, especially calcium and phosphorus, and this may account for the increase in the ash content. The total solids, protein and fat content and the energy value of the product increased with an increase in the level of the TSCHS. The increase in the total solids content of the product may be related to the amount of total solids of the hazelnut slurry used in the study. The increase in the total solids content of the hazelnut slurry may enhance the protein and the fat content of hazelnut slurry, and this may lead to an increase in the protein and fat content, and the energy value of the product.

Yoghurt has 15.1–23 g 100 g^{-1} of total solids matter, 0.7–3 g 100 g^{-1} of fat, 4.1–5.7 g 100 g^{-1} of protein and 7.5–7.8 g 100 g^{-1} of carbohydrate, depending on the type (Tamime & Robinson, 1999). The total solids content of the product at the studied variable levels was compatible with the yoghurt. The fat content of the product was higher than that of the yoghurt because hazelnut slurry contains more fat (>4 g 100 g^{-1}) than cow's milk (0.1–3.9 g 100 g^{-1}). However, the carbohydrate content of the product generally appeared to be lower than that of the yoghurt. This finding may be related to the high lactose content of cow's milk, and the absence of lactose in hazelnut slurry. The protein content of the product generally was similar to that of the yoghurt. The ash content of the product was in the range of values reported for the yoghurt. The energy value of the product was higher than that of the yoghurt (234.3–330.5 kJ 100 g^{-1}). The higher energy value may be related to the high fat content of the product.

Table 1
Central composite design for the manufacture of a yoghurt-like product from hazelnut slurry.

Experiment	Codified		Total solids content of hazelnut slurry (g 100 g^{-1})	Content of milk powder in slurry (g 100 g^{-1})
	X_1	X_2		
1	−1	−1	8	6
2	−1	1	8	9
3	1	−1	16	6
4	1	1	16	9
5	0	0	12	7.5
6	−1.41	0	6.4	7.5
7	1.41	0	17.8	7.5
8	0	−1.41	12	5.4
9	0	1.41	12	9.6
10	0	0	12	7.5

3.2. Physicochemical properties

The physiochemical properties of the product, including its pH, acidity, colour values, syneresis and water-holding capacity were determined (Table 2). Neither the TSCHS nor the CMP variable had a significant effect on the pH value of the product (Table 3). The acidity value of the product was influenced only by CMP, with a linear effect observed. The acidity of the product increased with increasing CMP (Fig. 2a). Both variables influenced the colour values of the product. Only the TSCHS had a significant impact on the *a* value, with a linear effect observed. An increase in the TSCHS resulted in an increase in the *a* value (Fig. 2b). Both variables had a significant impact on the *b* value, whereas they had no significant

Table 2
Characteristics of a yoghurt-like product from hazelnut slurry.

Proximate composition and energy value						
Experiment	Total solids (g 100 g^{-1})	Protein (g 100 g^{-1})	Fat (g 100 g^{-1})	Carbohydrate (g 100 g^{-1})	Ash (g 100 g^{-1})	Energy value (kJ 100 g^{-1})
1	13.30	3.49	4.1	5.08	0.68	295.8
2	15.91	4.81	4.4	5.90	0.85	343.1
3	21.16	5.73	9.8	4.94	0.72	546.0
4	23.08	5.63	8.9	7.72	0.91	556.1
5	17.76	4.44	6.0	6.59	0.72	401.7
6	12.48	2.94	3.0	5.95	0.58	261.9
7	22.69	5.01	9.6	7.32	0.76	567.8
8	16.02	3.70	6.0	5.76	0.55	384.9
9	19.04	5.58	5.5	7.08	0.85	420.2
10	17.86	4.63	5.8	6.69	0.71	409.2

Physicochemical properties							
Experiment	pH	Acidity (g 100 g^{-1})	*L* value	*a* value	*b* value	Syneresis (g 100 g^{-1})	WHC[a] (g 100 g^{-1})
1	4.60	0.45	88.33	−2.22	8.30	49.11	47.41
2	4.74	0.58	88.69	−2.42	8.89	40.47	49.59
3	4.73	0.49	88.59	−1.92	9.70	39.16	57.01
4	4.79	0.59	87.60	−2.13	10.77	37.55	49.21
5	4.58	0.51	86.87	−2.31	9.91	40.79	43.88
6	4.56	0.49	88.15	−2.67	8.16	43.64	45.78
7	4.77	0.53	88.31	−2.01	9.89	39.10	57.05
8	4.51	0.42	86.73	−2.17	9.41	46.87	45.88
9	4.53	0.61	85.07	−2.00	10.46	39.21	44.34
10	4.52	0.53	85.66	−2.27	9.91	41.14	43.11

Sensorial properties					
Experiment	Appearance	Consistency	Odour	Taste	Overall accetability
1	4.5	5.2	4.3	4	4.5
2	3.9	3.3	4.2	4	3.8
3	6	5.9	4.9	5.5	6
4	3.9	3.7	4	3.4	3.5
5	4.9	6.0	5.0	4.1	4.8
6	6.2	6.5	5.8	5.7	5.9
7	4.8	6.1	4.8	3.8	4.9
8	5.4	4.7	4.4	3.9	4.8
9	6.4	6.3	5.1	5.8	6.5
10	5.2	5.6	4.7	4.0	5

Fatty acid composition (g 100 g^{-1})					
Experiment	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid
1	5.20	2.34	84.59	6.93	0.10
2	5.27	2.36	84.44	6.89	0.11
3	4.93	2.28	85.15	6.86	0.11
4	4.92	2.26	85.15	6.92	0.11
5	4.94	2.22	85.25	6.95	0.11
6	5.40	2.19	84.15	6.92	0.10
7	4.94	2.10	85.19	7.04	0.10
8	4.99	2.20	84.95	7.05	0.11
9	5.05	2.19	84.97	7.06	0.11
10	4.96	2.21	85.21	6.94	0.11

Total phenolic content and antioxidant activity			
Experiment	Total phenolic content (mg kg^{-1})	ABTS (μmol kg^{-1})	FRAP (μmol kg^{-1})
1	84.32	277.78	218.18
2	92.27	338.89	261.36
3	144.55	461.11	272.73
4	172.95	583.33	377.27
5	159.32	458.33	304.55
6	76.36	194.44	163.64
7	118.41	358.33	286.36
8	145.68	427.78	334.09
9	190.01	555.56	395.45
10	178.64	541.66	350.00

[a] WHC; water holding capacity.

effect on the *L* value. Positive linear and negative quadratic effects of the TSCHS and a positive linear effect of the CMP on the *b* value of the product were observed. The *b* value increased with increasing TSCHS until the midpoint of the response surface was attained. Further increases slightly increased the *b* value. An increase in the CMP resulted in an increase in the *b* value (Fig. 2c). Both variables showed significant effects on the syneresis, with negative linear effects observed. The interaction term of the variables had a

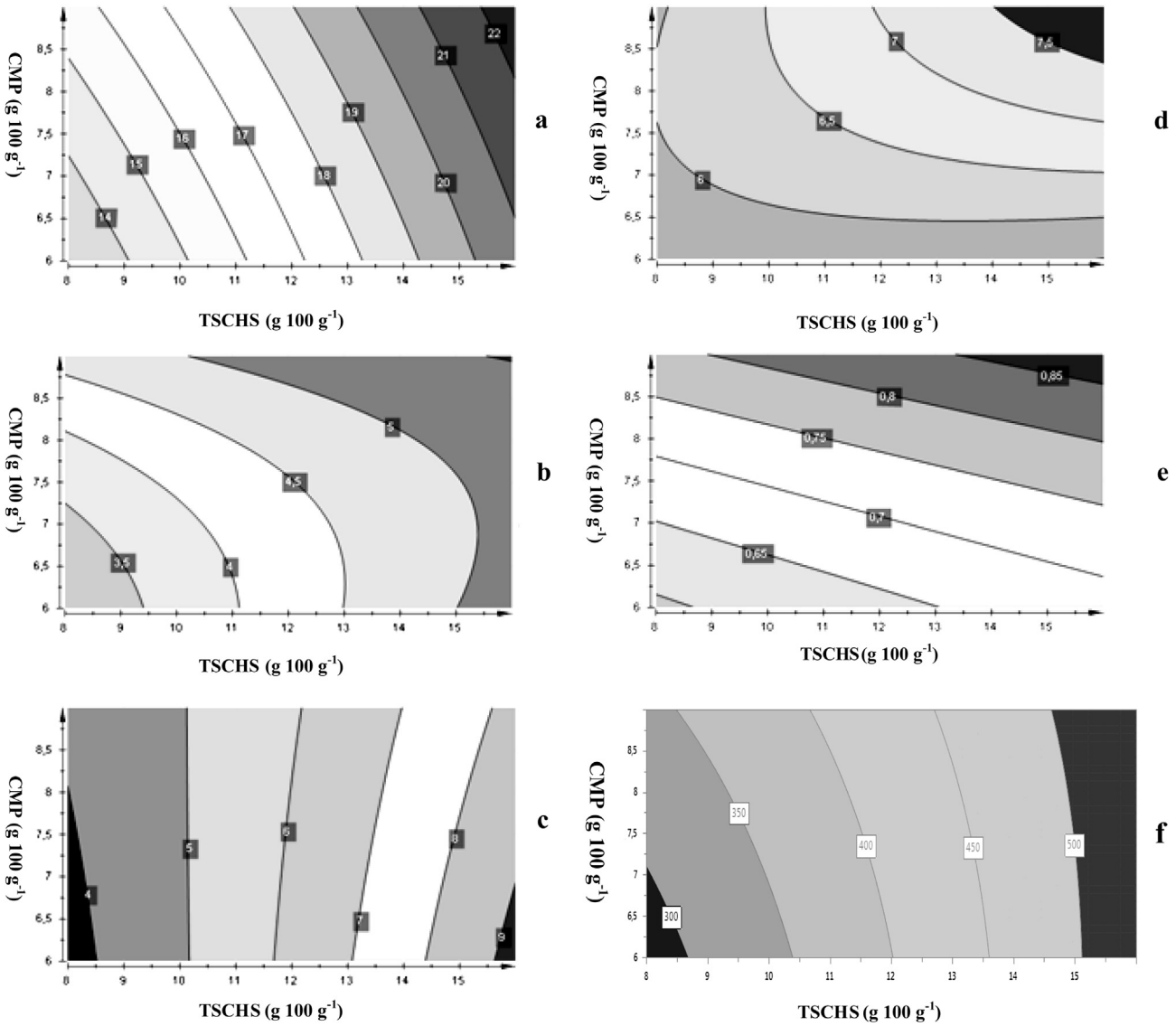


Fig. 1. Contour plots of proximate composition and energy value (total solid content of the hazelnut slurry (TSCHS) and content of the milk powder (CMP) a) total solid content b) protein content c) fat content d) carbohydrate content e) ash content f) energy value.

positive impact on the syneresis. An increase in the TSCHS led to a decrease in the syneresis until the midpoint of the response surface was attained. However, further increases in the TSCHS slightly decreased the syneresis. The syneresis decreased with increasing CMP (Fig. 2d). Only the TSCHS had a significant effect on the water-holding capacity, and positive linear and quadratic effects of the TSCHS on the water-holding capacity were observed. The water-holding capacity of the product increased with increasing TSCHS after the midpoint of the response surface was attained. The R^2 values of the responses explained by the models were 0.98, 0.84, 0.99, 0.95 and 0.91 for the acidity ($p < 0.05$), a ($p < 0.10$) and b ($p < 0.05$) values, syneresis ($p < 0.05$) and water holding capacity ($p < 0.05$), respectively. The lack of fit values ($p > 0.05$) revealed that the models were convenient for the prediction.

The addition of the milk powder enhanced the acidity and the b values and decreased the syneresis. The increase in the acidity value of the product may be related to the buffering action of the additional proteins, carbohydrate and other milk powder constituents (Tamime & Robinson, 1999). The casein content increased with an increase in the level of the milk powder, and this may have resulted in a reduction in the syneresis (Fiszman, Lluch, & Salvador, 1999). The light yellow colour of the milk powder may enhance the b value. The TSCHS enhanced the a and b values, possibly due to the colour properties of the hazelnut slurry. An increase in the TSCHS decreased the syneresis and increased the water-holding capacity of the product. The components of hazelnut slurry may have a stabiliser effect, and hazelnut slurry proteins may have a higher water-holding capacity.

The acidity value of the product was lower than that of the yoghurt (>0.6 g 100 g^{-1}), a finding that may be attributed to the low lactose content of the hazelnut slurry fortified with skimmed milk powder. The product exhibited a lower L value and higher a, and b values compared to the yoghurt. The syneresis level of the product ranged from 37.5 to 49.1 g 100 g^{-1}, which were similar to that of the yoghurt (40–51 g 100 g^{-1}). The water-holding capacity of the product ranged from 43.1 to 57.1 g 100 g^{-1}. These values were higher than that of the yoghurt (40 g 100 g^{-1}) (Riener, Noci, Cronin, Morgan, & Lyng, 2010). The higher values may be related to the greater water-holding capacity of proteins in hazelnut slurry compared with proteins in cow's milk. The water holding capacity

Table 3
Regression coefficients and *p*-values.

Proximate composition and energy value												
Factor	Total solids		Protein		Fat		Carbohydrate		Ash		Energy value	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept	17.822	**0.001**	4.478	**0.001**	6.067	**0.001**	6.557	**0.001**	0.727	**0.001**	413.425	**0.001**
TSCHS (L)	3.473	**0.001**	0.706	**0.014**	2.300	**0.001**	0.427	0.078	0.042	0.197	105.478	**0.001**
CMP (L)	1.038	**0.006**	0.455	0.055	−0.148	0.462	0.641	**0.024**	0.093	**0.026**	15.665	0.066
TSCHS (Q)	0.073	0.776	−0.088	0.696	0.261	0.316	−0.102	0.673	−0.002	0.956	5.672	0.506
CMP (Q)	0.046	0.857	0.219	0.357	−0.003	0.988	−0.180	0.470	0.009	0.806	2.233	0.788
TSCHS × CMP	−0.158	0.574	−0.294	0.262	−0.324	0.253	0.467	0.125	−0.001	0.999	−11.2061	0.248

Physicochemical properties														
Factor	pH		Acidity		*L* value		*a* value		*b* value		Syneresis		WHC[a]	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept	4.550	**0.001**	0.520	**0.001**	86.265	**0.001**	−2.290	**0.001**	9.915	0.001	40.965	**0.001**	43.492	**0.001**
TSCHS (L)	0.056	0.155	0.013	0.060	−0.071	0.847	0.180	**0.016**	0.675	**0.001**	−2.273	**0.005**	2.965	**0.017**
CMP (L)	0.027	0.450	0.059	**0.001**	−0.351	0.367	−0.020	0.677	0.371	**0.002**	−2.485	**0.004**	−0.919	0.288
TSCHS (Q)	0.078	0.122	−0.001	0.863	1.148	0.056	−0.013	0.822	−0.410	**0.003**	0.039	0.943	4.086	**0.012**
CMP (Q)	0.013	0.746	0.001	0.863	0.113	0.806	0.100	0.147	−0.006	0.936	0.782	0.203	1.283	0.242
TSCHS × CMP	−0.018	0.700	−0.006	0.360	−0.300	0.551	−0.002	0.972	0.107	0.202	1.562	**0.047**	−2.217	0.091

Sensorial properties										
Factor	Appearance		Consistency		Odour		Taste		Overall acceptability	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept	5.005	**0.001**	5.480	**0.001**	4.477	**0.001**	4.294	**0.001**	4.851	**0.001**
TSCHS (L)	−0.099	0.825	−0.032	0.954	−0.085	0.731	−0.168	0.687	−0.114	0.812
CMP (L)	−0.010	0.982	−0.032	0.955	−0.032	0.896	−0.027	0.947	−0.016	0.974
TSCHS (Q)	−0.015	0.979	0.128	0.854	0.097	0.751	0.023	0.964	0.003	0.996
CMP (Q)	0.142	0.801	−0.296	0.676	−0.161	0.605	0.117	0.820	0.112	0.851
TSCHS × CMP	−0.320	0.600	−0.001	0.998	−0.189	0.571	−0.503	0.385	−0.351	0.588

Fatty acid composition										
Factor	Palmitic acid		Stearic acid		Oleic acid		Linoleic acid		Linolenic acid	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept	4.947	**0.001**	2.219	**0.001**	85.202	**0.001**	6.492	**0.001**	0.109	**0.001**
TSCHS (L)	−0.149	**0.001**	−0.034	0.357	0.327	**0.001**	0.016	0.633	0.001	0.306
CMP (L)	0.014	**0.047**	0.003	0.942	−0.039	0.165	0.001	0.967	0.001	0.609
TSCHS (Q)	0.096	**0.001**	−0.002	0.957	−0.231	**0.001**	−0.009	0.823	−0.003	0.058
CMP (Q)	0.029	**0.010**	0.019	0.663	−0.099	**0.026**	0.024	0.553	0.001	0.526
TSCHS × CMP	−0.019	**0.047**	−0.006	0.894	0.018	0.593	0.021	0.639	−0.002	0.149

Total phenolic content and antioxidant activity						
Factor	Total phenolic		ABTS		FRAP	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept	158.664	**0.001**	489.044	**0.001**	328.630	**0.001**
TSCHS (L)	25.732	**0.019**	80.266	**0.010**	42.441	**0.005**
CMP (L)	14.290	0.103	44.623	0.061	23.948	**0.034**
TSCHS (Q)	−27.186	**0.032**	−85.366	**0.017**	−49.245	**0.006**
CMP (Q)	2.277	0.801	8.342	0.718	13.392	0.229
TSCHS × CMP	5.504	0.576	17.215	0.495	9.437	0.402

Bold values indicate significant factors at $p < 0.05$.
[a] L; linear, Q: quadratic, WHC; water holding capacity.

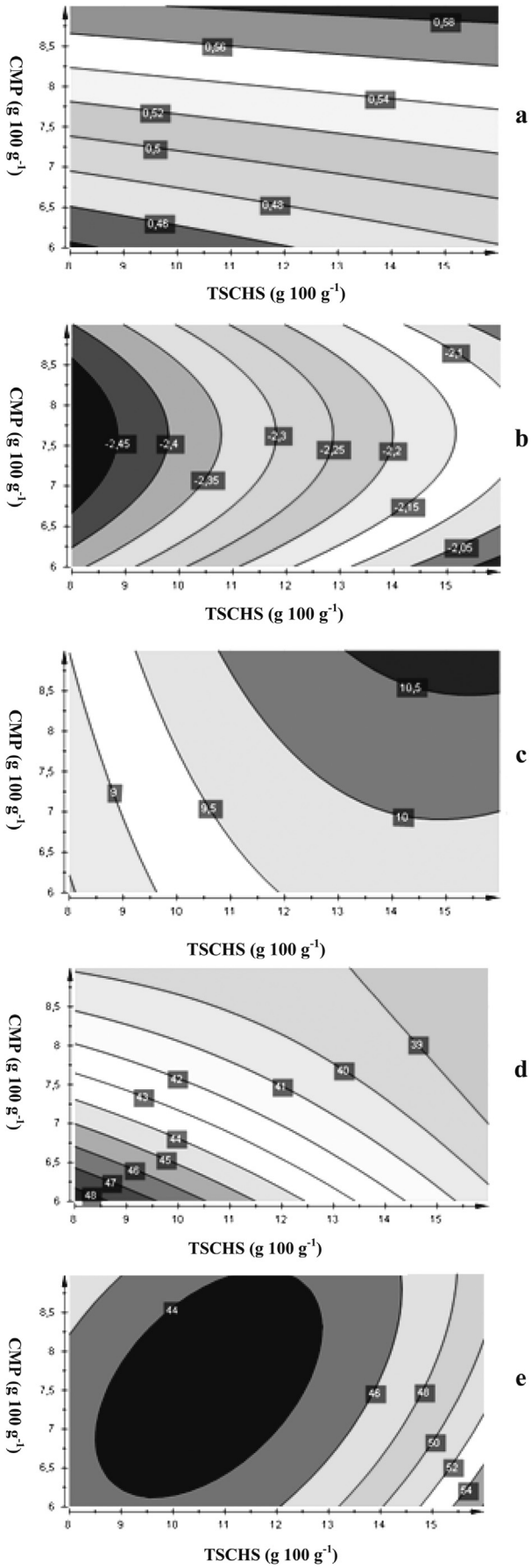
of food proteins is known to be influenced by the composition, conformation, and surface characteristics of the proteins (Barbut, 1999).

3.3. Sensorial properties

The regression coefficients and the *p*-values of both the variables are presented in Table 3. They indicate that the TSCHS and the CMP at the studied levels did not influence the sensory properties of the product. The sensory scores for the appearance, consistency, odour and taste attributes of the product seemed to be within the commercially acceptable range (4–9) suggested for yoghurt in the Karl Ruher 9-point scheme (Tamime & Robinson, 1999).

3.4. Fatty acid composition

Oleic acid was the most abundant fatty acid detected in the product followed by linoleic, palmitic and stearic acid. The regression coefficient and the *p*-values of the variables are presented in Table 3. They indicate that both the TSCHS and the CMP had a significant effect on the palmitic acid and oleic acid content of the product. Negative linear and positive quadratic effects of the TSCHS and positive linear and quadratic effects of the CMP on the palmitic acid content were observed. The palmitic acid content decreased with increasing TSCHS until the midpoint of the response surface was attained. However, further increases in the TSCHS slightly changed the palmitic acid content. The palmitic acid content slightly changed with increasing CMP (Fig. 3a). Positive linear and



negative quadratic effects of the TSCHS and a negative quadratic effect of the CMP on the oleic acid content were observed. The oleic acid content increased with increasing TSCHS until the midpoint of the response surface was attained. However, further increases in the TSCHS slightly changed the oleic acid content. The oleic acid content slightly changed with an increase in the CMP (Fig. 3b). Both variables showed no significant effect on the stearic, linoleic, and linolenic acid content. The R^2 values of the models were 0.99, and 0.99 for the palmitic, and oleic acid content ($p < 0.05$), respectively. The lack of fit values ($p > 0.05$) revealed that the models were convenient for the prediction.

The fatty acid composition of the product was similar to that of hazelnut oil (Crews et al., 2005). The product was richer in unsaturated fatty acids (mainly oleic acid) and contained a lower amount of saturated fatty acid compared to the yoghurt. The yoghurt contained a greater quantity (more than 50 g per 100 total fatty acids) of saturated fatty acids (mainly palmitic, stearic and myristic acid) (Junior et al., 2012). The type of dietary fat consumed influences plasma cholesterol levels. Saturated fatty acids are known to increase the serum concentrations of total, low-density lipoprotein and high-density lipoprotein (HDL) cholesterol and the cholesterol/HDL ratio (Ros, 2010). Replacing saturated fatty acids with unsaturated fatty acids may reduce the risk of cardiovascular diseases. Fatty acids present in nuts are known to be important in preventing the development of cardiovascular diseases (Ros & Mataix, 2006). The current findings suggest that using hazelnut slurry in manufacture of yoghurt may enhance the potential health benefits of yoghurt, especially in terms of cardiovascular health.

3.5. Total phenolic content and antioxidant activity

It can be seen from Table 3 that only the TSCHS affected the TPC. The antioxidant activity of the product was determined using two in vitro assays (Table 2). Only the TSCHS affected the ABTS values, whereas both variables had a significant effect on the FRAP values (Table 3). Positive linear and negative quadratic effects of the TSCHS on the TPC and ABTS values were observed. The TPC and ABTS values of the product increased with an increase in the TSCHS until the midpoint of the response surface was attained. However, further increases in the TSCHS had a slight impact on the TPC and ABTS values (Fig. 4a and b). Both linear and quadratic effects of the TSCHS on the FRAP value were observed, whereas only a linear effect was observed for the CMP. An increase in the TSCHS led to a rise in the FRAP value until the midpoint of the response surface was attained. However, further increases in the TSCHS slightly changed the FRAP value. With respect to the CMP, the FRAP value increased in accordance with an increase in the CMP (Fig. 4c). The R^2 values of the models were 0.89, 0.93, and 0.96 for the TPC, ABTS and FRAP values ($p < 0.05$), respectively. The lack of fit values ($p > 0.05$) revealed that the models were convenient for the prediction.

The addition of the milk powder increased the FRAP value, possibly as a result of its protein composition (36 g/100 g). Peptides released during the fermentation may show antioxidant properties (Farvin, Baron, Nielsen, & Jacobsen, 2010). Whey and casein hydrolysates have been reported to prevent lipid oxidation in muscle foods. Peptides may inhibit oxidative reactions by inactivating of prooxidative metals (Elias, Kellebery, & Decker, 2008). Casein-phosphopeptides have been reported to possess metal chelating activity (Power, Jakeman, & FitzGerald, 2013). Increasing the level

Fig. 2. Contour plots of physicochemical properties (total solid content of the hazelnut slurry (TSCHS) and content of the milk powder (CMP) a) acidity b) *a* value c) *b* value d) syneresis e) water-holding capacity.

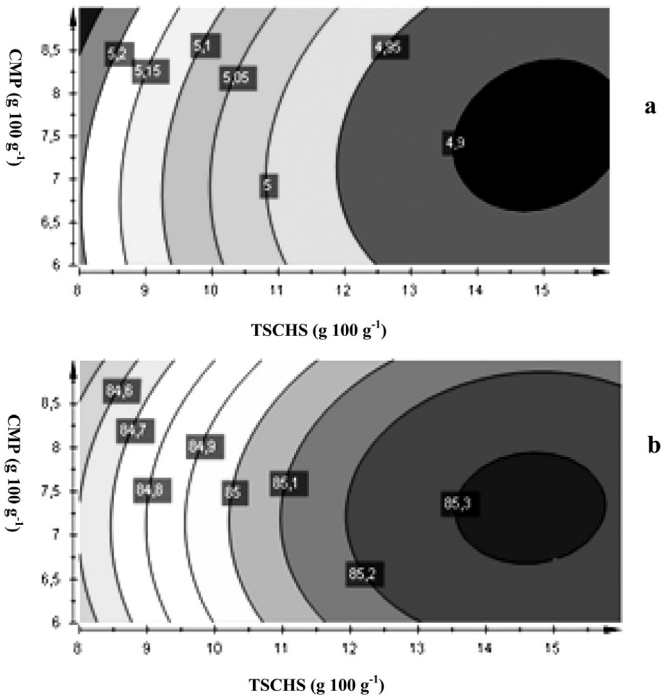


Fig. 3. Contour plots of fatty acid composition (total solid content of the hazelnut slurry (TSCHS) and content of the milk powder (CMP) a) palmitic acid b) oleic acid.

of the TSCHS enhanced the TPC and the antioxidant activity of the product. The amount of antioxidant compounds in hazelnut slurry may be increased by increasing the level of total solids. The TPC and antioxidant activity of the hazelnut kernels were studied by Oliveria et al. (2008). They reported that the extracts of the hazelnut kernels showed a concentration-dependent activity. The sample having a higher TPC exhibited a higher antioxidant activity.

The fortification of yoghurt with plant extracts has been extensively studied (Chouchouli et al., 2013; Jimenez, Murcia, Parras, & Martinez-Tome, 2008; Najgebauer-Lejko, Sady, Grega, & Walczycka, 2011). The TPC of the product was higher compared to that of yoghurt fortified with grape seed. The product had the antioxidant capacity as yoghurts fortified with grape seed, lemon and green tea. Thus, hazelnut slurry may be alternative option to the use of plant extract in order to increase potential health benefits of yoghurt.

3.6. Viability of starter culture

The products were stored at 4 °C for 4 weeks, and the number of starter cultures were determined at the end of fermentation and 1st, 2nd, 3rd, and 4th week. The number of starter cultures significantly increased in the first week ($p < 0.05$) and then slightly changed (data not shown). At the end of fermentation, the products contained *L. bulgaricus* and *S. thermophilus* colonies, ranging from 2.36 to 6.55 log cfu g^{-1}, and from 2.50 to 7.53 log cfu g^{-1}, respectively. After 4 weeks of storage at 4 °C, *L. bulgaricus* and *S. thermophilus* colonies varied from 4.57 to 4.90 log cfu g^{-1}, and from 7.39 to 8.72 log cfu g^{-1}, respectively. Yoghurt should contain abundant and viable starter cultures at the time of consumption. Our findings showed that the viability of the starter cultures continued during cold storage and the products had high number of starter cultures more than 10^7 cfu g^{-1} of *S. thermophilus* and 10^4 cfu g^{-1} of *L. bulgaricus* after 4 weeks of cold storage. It can be

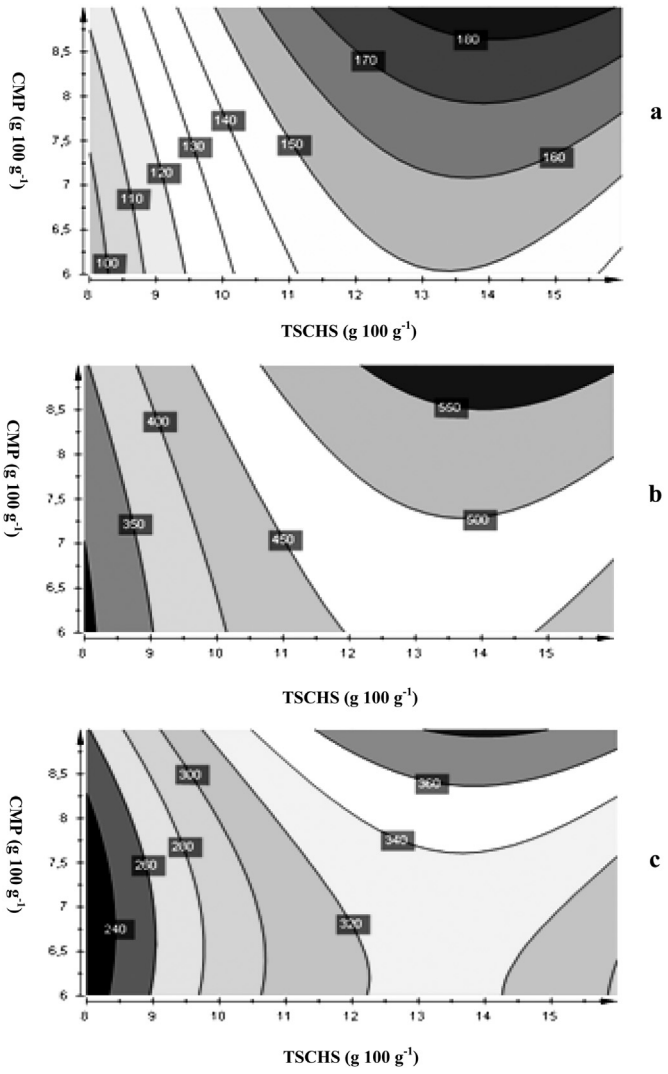


Fig. 4. Contour plots of total phenolic content, and antioxidant activity (total solid content of the hazelnut slurry (TSCHS) and content of the milk powder a) TPC b) ABTS c) FRAP.

interpreted that a yoghurt-like product manufactured from hazelnut slurry may meet the criterion suggested for yoghurt.

4. Conclusion

The nutritional composition and physicochemical properties of the yoghurt-like product manufactured from hazelnut milk slurry appeared to be compatible with that of yoghurt. The product may be superior to yoghurt in terms of its fatty acid composition and TPC. The product may be an alternative option for yoghurt manufacturer. The proximate composition, physicochemical properties, fatty acid composition and antioxidant capacity of the product were influenced by the ingredients at the studied levels. Further studies should focus on optimizing the ingredients levels for targeted product types.

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