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# Preliminary investigation of yoghurt enriched with hazelnut milk

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**Abstract**

The present work aimed to investigate the use of hazelnut milk (HM) with dairy milk in the preparation of yoghurt. Cow milk (CM) mixed with HM (75:25, v/v) was used as the raw material for HM-enriched yoghurt (HMEY). The control sample was prepared with CM only. The proximate composition, physicochemical and sensorial properties, and fatty acid and sterol compositions were determined. The proximate composition of the HMEY samples was found to be compatible with dairy yoghurt. The HMEY samples were rich in monounsaturated fatty acids (mainly oleic acid), whereas the control sample had a higher level of saturated fatty acids. The HMEY samples had a lower cholesterol content than the control sample. They also contained phytosterols (mainly β-sitosterol). These findings reveal that HM might have a potential in yoghurt manufacturing, and that the use of HM might enhance the health benefits of yoghurt especially in sustaining cardiovascular health.



## Introduction

Yoghurt, a fermented milk product, provides nutritional and health benefits. It is rich in macronutrients (casein and lactose) and micronutrients (B vitamins, calcium and phosphorus). Lactic acid bacteria exhibiting health-promoting properties are used in yoghurt production as starter cultures. These bacterial species are known to enhance humans' gastrointestinal functions (Adolfsson *et al*., 2004; Mckinley, 2005).

Although cow milk (CM) is generally used in yoghurt production, alternative food resources have also been investigated. Soy, corn, peanut and coconut milk have been used to produce yoghurt (Granata and Morr, 1996; Kumar and Mishra, 2004; Supavititpatana *et al*., 2008; Isanga and Zhang, 2009; Yakoob *et al*., 2012). Hazelnut milk (HM) may also be utilised to produce yoghurt. HM can be obtained by soaking and wet-grinding hazelnut kernels, and then filtrating the slurry. HM contains macronutrients and micronutrients, and is rich in monounsaturated fatty acids (mainly oleic acid). Previously, the HM fortified with skimmed milk powder was used as a raw material in yoghurt production (Ilyasoglu *et al*., 2015). However, the utilisation of HM and dairy milk mixture in the production of yoghurt has not been attempted.

The present work was therefore aimed to evaluate the possibility of using HM with dairy milk in yoghurt production. CM mixed with HM (75:25) was used in the production of yoghurt. Two formulations of HM-enriched yoghurt were prepared with skimmed CM and semi-fat CM. The characteristics of the developed products were compared to the control yoghurt made from pure CM.

## Materials and methods

### *Chemicals*

All chemicals and solvents were obtained from Merck (Darmstad, Germany). Fatty acid methyl ester (FAME) mix was purchased from Sigma-Aldrich (St. Louis, MO, USA).

### *Materials*

Hazelnuts (Tombul cultivar) were obtained from an orchard in Giresun Province, Turkey. Skimmed milk powder, skimmed milk, and semi-fat milk (Pinar Co., Izmir, Turkey) were purchased from a local market. The starter culture (Chr. Hansen FD DVS YC-X16, Chr. Hansen A/S, Horsholm, Denmark) was obtained from a local distributor.

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*Hazelnut milk preparation*

Hazelnut kernels were oven-roasted at 140°C for 15 min. The roasted hazelnuts were then soaked in water (1:6) 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.

*Yoghurt preparation*

HM, skimmed milk and semi-fat milk were used in the production of HM-enriched yoghurt (HMEY). HMEY1 and HMEY2 were prepared from HM and skimmed milk fat (25:75) and from HM and semi-fat milk (25:75), respectively. The control samples, CMY1 and CMY2, were prepared from the skimmed milk and semi-fat milk, respectively. Skimmed milk powder (4 g/100 g) was added to enhance the total solids of the products. Skimmed milk powder was dissolved in the HM and CM mix at 43°C under stirring for 40 min. The milk was homogenised with a homogeniser (Daihan WiseTisHG-15A, Daihan Scientific Co., Seoul, South Korea) and pasteurized at 90°C for 20 min. After cooling to 43°C, the starter culture (3 mL/100 g) 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 4.6-4.7 was obtained. The yoghurt was stored at 4°C overnight prior to analysis.

*Proximate composition*

The moisture, protein, fat and ash contents of the yoghurt samples were determined in accordance with the AOAC methods (AOAC, 2006). The total carbohydrates were calculated by subtracting the total percentages of moisture, protein, fat and ash from 100.

*Physicochemical properties*

The pH of the yoghurt samples was measured with a pH meter (Hanna HI 2210, Smithfield, RI, USA). The acidity of the samples was determined by the alkali titration method.

The colour properties ($L^*$, $a^*$, and b* values) of the yoghurt samples were measured using a chromameter (Konica Minolta CR-400 Series, Japan) to determine the whiteness ($L^*$), redness/greenness ($a^*$), and yellowness/blueness (b*) values of the yoghurt samples. The whiteness index was calculated according to the following equation :

$$\text{Whiteness index (WI)} = 100-((100-L^*)^2 + a^{*2} + b^{*2})^{0.5}$$

The syneresis and water-holding capacity of the yoghurt samples were determined in accordance with the method previously described by Ilyasoglu *et al*. (2015).

The viscosity of the yoghurt samples was determined at 4°C using a rheometer (Anton Paar, MCR 102, Germany) equipped with a 35 mm parallel plate and a 1 mm gap setting. The viscosity of the samples was determined as a function the of shear rate at a range of 1-100/s.

*Fatty acid composition*

The fatty acid composition of the yoghurt samples was determined according to the analytical methods previously described by Ilyasoglu *et al*. (2015). Briefly, 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).

*Total sterol content*

The total sterol content of the yoghurt samples was determined according to a modified DGF official method (Ilyasoglu, 2013). Briefly, the samples were injected in to a Shimadzu GC-2010 Plus gas chromatograph equipped with a flame ionisation detector, a split/splitless injector, and a capillary column (0.22 mm × 0.22 μm × 30 m, Teknokroma TRB-Sterol).

*Sensorial properties*

The appearance, consistency, odour, taste, and overall acceptability of the yoghurt samples were analysed following overnight storage. The samples (25 g) were put into cups and coded randomly with three digit random numbers and served to the panellists in booths. Twenty panellists with knowledge of sensory analysis were selected. They evaluated the samples using a 9-point Hedonic scale at a range of 1 (extremely dislike) to 9 (extremely like). Water was given to the panellists to rinse their mouth between tasting each sample.

*Microbiological analysis*

The starter culture counts of the yoghurt samples were determined immediately after the completion of fermentation and during four weeks of storage at 4°C. Briefly, the samples (10 g) were diluted with sterile peptone water (0.1 g/100 mL, 90 mL), and serial dilutions were prepared. Starter culture cells were counted using the pour-plate technique. Enumerations of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* colonies were conducted

in M17 agar (Merck, Germany) under an aerobic condition and in MRS agar (Merck, Germany) under an anaerobic condition, both at 37°C for 48 h. The cell counts were expressed as Colony Forming Units per gram (CFU/g) of the product.

*Statistical analysis*

One-way ANOVA was used to compare the characteristics of the milk and yoghurt samples. Triplicate analysis was performed, and the mean values and standard deviations were calculated. The SPSS 17.0 software (IBM, New York, USA) was used for data analysis.

## Results and dıscussıon

*Proximate composition*

The total solids, protein, fat, carbohydrate. and ash content of the HMEY yoghurts (HMEY1 and HMEY2), control yoghurts (CMY1 and CMY2), CM and HM are shown in Table 1. HMEY2 had higher levels of total solids, protein and fat than CMY2 ($p < 0.05$) and, had a lower level of carbohydrate. HMEY1 had a higher amount of fat and total solids than CMY1 ($p < 0.05$). These findings might be related to the composition of HM and CM. HM exhibited higher levels of fat and total solids and a lower level of carbohydrate than CM.

Table 1. Proximate compositions (g/100 g) and physicochemical properties of milk and yoghurt samples.

| Proximate composition of milk samples (g/100 g) | | | |
|---|---|---|---|
| Properties | CM1 | CM2 | HM |
| Protein | 3.15 ± 0.09$^{a}$ | 3.23 ± 0.02$^{a}$ | 3.01 ± 0.34 $^{a}$ |
| Fat | – | 1.45 ± 0.07$^{b}$ | 6.6 ± 0.30$^{a}$ |
| Carbohydrate | 5.18 ± 0.24$^{a}$ | 4.09 ± 0.25$^{a}$ | 1.94 ± 0.30$^{b}$ |
| Ash | 0.69 ± 0.02$^{a}$ | 0.67 ± 0.02$^{a}$ | 0.29 ± 0.02$^{b}$ |
| Total solids | 9.02 ± 0.10$^{b}$ | 9.44 ± 0.58$^{b}$ | 11.84 ± 0.01$^{a}$ |

| Proximate composition of yoghurt samples (g/100 g) | | | | |
|---|---|---|---|---|
| Properties | CMY1 | CMY2 | HMEY1 | HMEY2 |
| Protein | 4.39 ± 0.08$^{ab}$ | 3.57 ± 0.04$^{c}$ | 4.08 ± 0.10$^{b}$ | 4.61 ± 0.33$^{a}$ |
| Fat | – | 1.3 ± 0.10$^{b}$ | 1.1 ± 0.10$^{b}$ | 2.6 ± 0.30$^{a}$ |
| Carbohydrate | 6.93 ± 0.15$^{b}$ | 7.24 ± 0.10$^{a}$ | 6.39 ± 0.10$^{b}$ | 5.48 ± 0.39$^{c}$ |
| Ash | 0.82 ± 0.06$^{a}$ | 0.79 ± 0.06$^{a}$ | 0.70 ± 0.08$^{b}$ | 0.79 ± 0.06$^{a}$ |
| Total solids | 12.14 ± 0.11$^{d}$ | 12.90 ± 0.07$^{b}$ | 12.27 ± 0.01$^{c}$ | 13.48 ± 0.16$^{a}$ |

| Physicochemical parameters of milk samples | | | |
|---|---|---|---|
| Properties | CM1 | CM2 | HM |
| pH | 6.82 ± 0.01$^{b}$ | 6.78 ± 0.01$^{c}$ | 6.93 ± 0.01$^{a}$ |
| Acidity (g/100 g) | 0.15 ± 0.01$^{a}$ | 0.15 ± 0.01$^{a}$ | 0.03 ± 0.00$^{b}$ |
| Colour values | | | |
| *L** | 75.54 ± 0.09$^{c}$ | 85.69 ± 0.01$^{a}$ | 84.35 ± 0.01$^{b}$ |
| *a** | -5.85 ± 0.01$^{c}$ | -4.48 ± 0.01$^{b}$ | -0.73 ± 0.01$^{a}$ |
| *b** | -0.50 ± 0.03$^{c}$ | 5.36 ± 0.02$^{b}$ | 9.98 ± 0.02$^{a}$ |

| Physicochemical parameters of yoghurt samples | | | | |
|---|---|---|---|---|
| Properties | CMY1 | CMY2 | HMEY1 | HMEY2 |
| pH | 4.72 ± 0.02$^{a}$ | 4.61 ± 0.01$^{a}$ | 4.58 ± 0.02$^{a}$ | 4.60 ± 0.02$^{a}$ |
| Acidity (g 100g-1) | 0.70 ± 0.08$^{a}$ | 0.68 ± 0.09$^{a}$ | 0.71 ± 0.02$^{a}$ | 0.68 ± 0.03$^{a}$ |
| Colour values | | | | |
| *L** | 84.26 ± 0.07$^{d}$ | 86.26 ± 0.01$^{b}$ | 85.30 ± 0.012$^{c}$ | 87.05 ± 0.02$^{a}$ |
| *a** | -3.70 ± 0.11$^{d}$ | -3.55 ± 0.01$^{c}$ | -2.64 ± 0.06$^{b}$ | -2.48 ± 0.01$^{a}$ |
| *b** | 9.46 ± 0.11$^{b}$ | 9.80 ± 0.01$^{a}$ | 9.81 ± 0.05$^{a}$ | 9.83 ± 0.07$^{a}$ |
| WI | 81.20 ± 0.16$^{d}$ | 82.75 ± 0.01$^{b}$ | 82.15 ± 0.02$^{c}$ | 83.55 ± 0.02$^{a}$ |
| Synerisis (%) | 34.45 ± 1.53$^{b}$ | 29.83 ± 0.95$^{c}$ | 40.01 ± 1.99$^{a}$ | 37.33 ± 0.67$^{b}$ |
| WHC (%) | 29.74 ± 1.29$^{b}$ | 40.37 ± 2.02$^{a}$ | 32.47 ± 3.81$^{b}$ | 38.39 ± 3.96$^{a}$ |

CM1: skimmed milk, CM2: semi-fat milk, HM: hazelnut milk, CMY1: control yoghurt from skimmed milk, CMY2: control yoghurt from semi-fat milk, HMEY1: yoghurt from skimmed milk and hazelnut milk, HMEY2: yoghurt from semi-fat milk and hazelnut milk, WHC: water-holding capacity, WI: whiteness index. Different letters indicate significant difference between columns ($p < 0.05$)

The protein, carbohydrate and fat levels of HMEY were compatible with the values reported for commercial yoghurt (Tamime and Robinson, 1999). These findings reveal that HMEY could provide macronutrients similar to commercial yoghurt.

*Physicochemical properties*

The physiochemical properties of the yoghurt samples, including pH, acidity, colour, syneresis and water-holding capacity are also shown in Table 1. The pH and acidity values of the HMEY samples were close to those of CMY ($p > 0.05$). The HMEY samples showed higher $L^*$ and a* values than the CMY samples ($p < 0.05$). These findings might be related to the colour difference observed between HM and CM. HM exhibited higher values of $L^*$ and a* than CM. The syneresis level of the HMEY samples was higher than that of the CMY samples ($p < 0.05$). Syneresis is a result of the loss of yoghurt gel to retain the serum phase (Vital *et al*., 2015). Yoghurt gel firmness is related to the milk protein (Sah *et al*., 2016). Higher syneresis values might be associated with the lower content of milk protein in the HMEY samples as compared to those in the CMY samples. The water-holding capacity (WHC) showed no significant difference between the HMEY and CMY samples ($p > 0.05$).

Viscosity can be considered as an important property affecting the texture of foods. HMEY1 exhibited a higher viscosity value than CMY1 when the shear rate was at a range of 1-10/s (Figure 1). However, the viscosity values of both yoghurt samples showed similar values when the shear rate was at range of 10-100/s (Figure 1). The HMEY2 sample showed lower viscosity values than CMY2. These findings might be related to the lower WHC value of the HMEY2 sample than that of CMY2. A high WHC value can enhance curd stability, and increase viscosity value (Srısuvor *et al*., 2013). The viscosity values of the yoghurt samples exhibited a decreasing trend when the shear rate increased from 1/s to 100/s. This result indicates a shear-thinning behaviour that might be explained by the reduced viscosity through the breakdown of the gel structure. Shearing might break the casein strand and reduce the size of the aggregates. Consequently, viscosity can be decreased with increasing shear rate (Isanga and Zhang, 2009).

*Fatty acid composition*

The fatty acid compositions of HMEY1, HMEY2, CMY2, HM and CM are presented in Table 2. Oleic acid was the most abundant fatty acid detected in HMEY1 and HMEY2. HMEY1 showed a higher level of oleic acid than HMEY2 ($p < 0.05$). The HMEY samples also contained palmitic, stearic and linoleic acids as their main fatty acids. HMEY2 had higher contents of palmitic and stearic acids than HMEY1 ($p < 0.05$). Myristic acid was also detected in HMEY2. Palmitic, oleic, stearic and myristic acids were the main fatty acids found in CMY2. The HMEY samples were rich in monounsaturated fatty acids (MUFAs), whereas the CMY sample contained a higher amount of saturated fatty acids (mainly palmitic, stearic and myristic acids). These findings could be related to the higher content of oleic acid

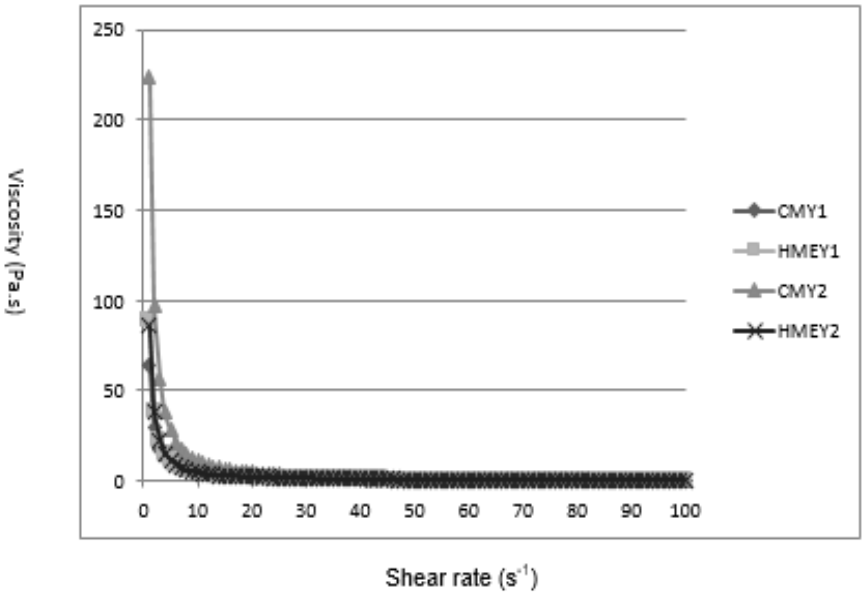


Figure 1. Viscosity values as a function of shear rate. CMY1: control yoghurt from skimmed milk, CMY2: control yoghurt from semi-fat milk, HMEY1: yoghurt from skimmed milk and hazelnut milk, HMEY2: yoghurt from semi-fat milk and hazelnut milk.

Table 2. Fatty acid compositions (g/100 g) and sterol compositions (mg/100 g) of cow milk (CM), hazelnut milk (HM), cow milk yoghurt (CMY), and hazelnut milk enriched yoghurt (HMEY).

| Fatty acid composition (g/100 g) of milk samples | | |
|---|---|---|
| Fatty acid | CM2 | HM |
| Butyric (C4:0) | 2.21 ± 0.08 | ND |
| Caproic (C6:0) | 1.52 ± 0.01 | ND |
| Caprylic (C8:0) | 0.93 ± 0.01 | ND |
| Capric (C10:0) | 2.19 ± 0.01 | ND |
| Lauric (C12:0) | 2.75 ± 0.02 | ND |
| Myristic (C14:0) | 11.16 ± 0.02 | ND |
| Myristoleic (C14:1) | 0.29 ± 0.01 | ND |
| Palmitic (C16:0) | 34.42 ± 0.09$^{a}$ | 4.22 ± 0.02$^{b}$ |
| Palmitoleic (C16:1) | 0.13 ± 0.01$^{a}$ | 0.12 ± 0.01$^{a}$ |
| Stearic (C18:0) | 13.45 ± 0.01$^{a}$ | 2.34 ± 0.05$^{b}$ |
| Oleic (C18:1) | 27.28 ± 2.08$^{b}$ | 80.03 ± 0.09$^{a}$ |
| Linoleic (C18:2) | 2.52 ± 0.18$^{b}$ | 12.67 ± 0.03$^{a}$ |
| Linolenic (C18:3) | 0.25 ± 0.01$^{a}$ | 0.12 ± 0.02$^{b}$ |

| Fatty acid composition (g 100 g$^{-1}$) of yoghurt samples | | | |
|---|---|---|---|
| Fatty acid | CMY2 | HMEY1 | HMEY2 |
| Butyric (C4:0) | 2.16 ± 0.04$^{a}$ | ND | 0.66 ± 0.02$^{b}$ |
| Caproic (C6:0) | 1.46 ± 0.01$^{a}$ | ND | 0.42 ± 0.05$^{b}$ |
| Caprylic (C8:0) | 0.91 ± 0.01$^{a}$ | ND | 0.26 ± 0.02$^{b}$ |
| Capric (C10:0) | 2.19 ± 0.01$^{a}$ | ND | 0.62 ± 0.05$^{b}$ |
| Lauric (C12:0) | 2.79 ± 0.01$^{a}$ | ND | 0.76 ± 0.04$^{b}$ |
| Myristic (C14:0) | 11.43 ± 0.04$^{a}$ | ND | 2.97 ± 0.15$^{b}$ |
| Myristoleic (C14:1) | 0.30 ± 0.01 | ND | ND |
| Palmitic (C16:0) | 35.01 ± 0.22$^{a}$ | 4.90 ± 0.09$^{c}$ | 12.70 ± 0.10$^{b}$ |
| Palmitoleic (C16:1) | 0.14 ± 0.01$^{a}$ | 0.16 ± 0.02$^{a}$ | 0.12 ± 0.01$^{a}$ |
| Stearic (C18:0) | 13.88 ± 0.09$^{a}$ | 2.54 ± 0.05$^{c}$ | 5.38 ± 0.11$^{b}$ |
| Oleic (C18:1) | 25.98 ± 0.27$^{c}$ | 79.10 ± 0.32$^{a}$ | 65.53 ± 1.20$^{b}$ |
| Linoleic (C18:2) | 2.05 ± 0.01$^{c}$ | 12.52 ± 0.09$^{a}$ | 10.29 ± 0.02$^{b}$ |
| Linolenic (C18:3) | 0.26 ± 0.02$^{a}$ | 0.15 ± 0.01$^{b}$ | 0.14 ± 0.01$^{b}$ |

| Sterol composition (mg/100 g) of milk samples | | |
|---|---|---|
| Sterol | CM2 | HM |
| Cholesterol | 339.85 ± 13.02 | ND |
| Campesterol | ND | 4.52 ± 0.55 |
| Stigmasterol | ND | 0.50 ± 0.03 |
| Clerosterol | ND | 0.49 ± 0.04 |
| β-sitosterol | ND | 65.32 ± 1.57 |
| Δ5-avenasterol | ND | 2.29 ± 0.29 |
| Δ7-stigmasterol | ND | 0.33 ± 0.01 |
| Δ7-avenasterol | ND | 0.27 ± 0.02 |
| Total phytosterol | ND | 73.73 ± 2.64 |

| Sterol composition (mg/100 g) of yoghurt samples | | | |
|---|---|---|---|
| Sterol | CMY2 | HMEY1 | HMEY2 |
| Cholesterol | 379.34 ± 12.88$^{a}$ | 99.23 ± 4.57$^{b}$ | 137.61 ± 6.42$^{b}$ |
| Campesterol | ND | 5.48 ± 0.33$^{a}$ | 4.64 ± 0.74$^{a}$ |
| Stigmasterol | ND | 0.54 ± 0.03$^{a}$ | 0.49 ± 0.07$^{a}$ |
| Clerosterol | ND | 0.42 ± 0.06$^{a}$ | 0.56 ± 0.07$^{a}$ |

Table 2. (Cont.)

| | | | |
|---|---|---|---|
| β-sitosterol | ND | 75.81 ± 4.31[a] | 55.84 ± 3.17[b] |
| Δ5-avenasterol | ND | 1.65 ± 0.16[a] | 0.56 ± 0.11[b] |
| Δ7-stigmasterol | ND | 0.85 ± 0.09[a] | 0.86 ± 0.21[a] |
| Δ7-avenasterol | ND | 0.41 ± 0.09[a] | 0.23 ± 0.03[a] |
| Total phytosterol | ND | 85.16 ± 3.37[a] | 63.18 ± 2.50[b] |

CM2: semi-fat milk, HM: hazelnut milk, CMY2: control yoghurt from semi-fat milk, HMEY1: yoghurt from skimmed milk and hazelnut milk, HMEY2: yoghurt from semi-fat milk and hazelnut milk, ND: not detected. Different letters indicate significant difference between columns ($p < 0.05$)

in HM and the higher content of saturated fatty acids in CM. The effect of dietary fat on the plasma cholesterol level depends on the type of fat. Saturated fatty acids increase the serum concentrations of total, LDL, and HDL cholesterol, whereas unsaturated fatty acid reduce the LDL cholesterol level and increase the HDL cholesterol level (Orsavova *et al*., 2015). Therefore, an increase in the intake of unsaturated fatty acids has been suggested to reduce the risk of cardiovascular diseases. Using HM in the yoghurt production could enhance the MUFA (mainly oleic acid) content. Therefore, the product developed in the present work might provide potential health benefits, especially in maintaining cardiovascular health.

*Sterol composition*

The sterol compositions of the HMEY1, HMEY2, CMY2, HM and CM2 are presented in Table 2. The CMY2 sample contained more than 300 mg/100 g cholesterol. The HMEY samples had a lower cholesterol cholesterol content than the CMY2 sample ($p < 0.05$). The cholesterol content of HMEY1 was lower than that of HMEY2. These findings indicated that the addition of HM to CM reduced the cholesterol level of yoghurt. The HMEY samples also contained phytosterols. β-sitosterol was the main phytosterols detected in the HMEY samples, followed by campesterol. Phytosterols are known to show beneficial effects on cardiovascular health. They inhibit the absorption and synthesis of cholesterol (Ras *et al*., 2016). The presence of phytosterols in HMEY might enhance the potential health benefits of yoghurt.

*Sensorial properties*

The sensorial properties of HMEY and CMY are presented in Table 3. The appearance, odour, taste and overall acceptability scores of HMEY1 were significantly lower than those of the CMY1 ($p < 0.05$). The consistency score presented no significant difference between HMEY1 and CMY1 ($p > 0.05$). HMEY2 showed lower odour, taste and overall acceptability scores than CMY2 sample ($p < 0.05$). The appearance and consistency scores showed no significant difference between HMEY2 and CMY2 ($p > 0.05$). The lower scores of the HMEY samples might be explained by their distinct aroma. The panellists stated that their aroma was not similar to that of commercial yoghurts. The aroma of hazelnut could have led to the low taste and odour scores. Thus, the overall acceptability scores of the HMEY samples were lower than those of the CMY samples. HMEY2 exhibited higher scores than HMEY1. This result suggests that HMEY2 could be more acceptable than HMEY1 by potential consumers.

Table 3. Sensorial properties of yoghurt samples

| Properties | CMY1 | CMY2 | HMEY1 | HMEY2 |
|---|---|---|---|---|
| Appearance | 5.7 ± 1.4[a] | 6.3 ± 1.3[a] | 4.6 ± 2.0[b] | 5.9 ± 1.8[a] |
| Consistency | 6.1 ± 1.6[a] | 6.5 ± 1.8[a] | 5.0 ± 1.8[a] | 5.7 ± 2.1[a] |
| Odour | 5.7 ± 1.5[a] | 6.0 ± 1.7[a] | 3.6 ± 1.6[b] | 4.5 ± 1.6[b] |
| Taste | 4.1 ± 1.7[a] | 5.8 ± 2.0[a] | 3.1 ± 1.6[b] | 3.7 ± 1.7[b] |
| Overall acceptability | 4.7 ± 1.4[b] | 6.0 ± 1.7[a] | 3.3 ± 1.3[c] | 4.3 ± 1.6[b] |

CMY1: control yoghurt from skimmed milk, CMY2: control yoghurt from semi-fat milk, HMEY1: yoghurt from skimmed milk and hazelnut milk, HMEY2: yoghurt from semi-fat milk and hazelnut milk. Different letters indicate significant difference ($p < 0.05$)

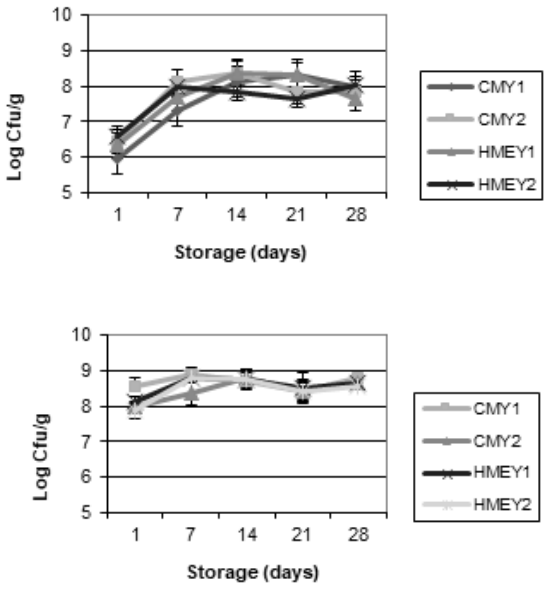


Figure 2. (a) The changes in the L. bulgaricus counts (log CFU/g), and (b) The changes in the S. thermophilus counts (log CFU/g). CMY1: control yoghurt from skimmed milk, CMY2: control yoghurt from semi-fat milk, HMEY1: yoghurt from skimmed milk and hazelnut milk, HMEY2: yoghurt from semi-fat milk and hazelnut milk

*Starter culture count*

The developed products and control samples were stored at 4°C for 28 days, and the starter culture counts were determined. Figure 2 shows the changes in the starter culture counts during storage. A significant increase in the starter culture count was observed in the first week ($p < 0.05$), and then the number slightly changed. Yoghurt should have a viable starter culture of more than 107 CFU/g at the time of consumption (Codex, 2003). Our results showed that the developed products contained a viable starter culture similar to the control yoghurts. Therefore, the developed product might meet the criterion suggested for yoghurt.

## Conclusion

The use of HM with dairy milk demonstrated in the present work has improved both the fatty acid and sterol compositions of yoghurt. The HMEY samples had higher levels of unsaturated fatty acids, mainly MUFAs. Moreover, they had lower contents of cholesterol and contained phytosterols. These properties might make them superior over CM yoghurt. Therefore, HM might be proposed as an alternative raw material for yoghurt production to enhance the health benefits of yoghurt, especially those related to cardiovascular health. As HM reduced the sensory scores of the yoghurt, flavouring agents should be used to improve its sensorial acceptability in future development.

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