# Effects of fat content on selected qualitative parameters of a fermented coconut "milk" beverage

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**Summary**
The aim of the study was to determine the effects of coconut fat content on selected parameters of a fermented coconut "milk" beverage stored for 28 days at 6 °C. Two variants of coconut beverages were prepared, namely, the low-fat (containing 20 g·kg$^{-1}$ fat) and the full-fat (containing 150 g·kg$^{-1}$ fat), obtained by addition of raw „organic" coconut oil. Raw "organic" coconut oil is rich in saturated fatty acids, mainly lauric and myristic acids (51.3 % and 15.6 % of total fatty acids, respectively). The sterol profile of the raw coconut oil indicated the presence of β-sitosterol (274.2 mg·kg$^{-1}$), Δ5-avenasterol (159.8 mg·kg$^{-1}$), stigmasterol (89.9 mg·kg$^{-1}$) and campesterol (40.5 mg·kg$^{-1}$). The populations of lactic acid bacteria (> 6 log CFU·ml$^{-1}$), bifidobacteria (> 6 log CFU·ml$^{-1}$) and pH (in range of 4.17–4.50) of the fermented coconut beverages did not depend on the fat content. The two variants of coconut beverages differed significantly in hardness, adhesiveness and syneresis, but did not differ in consistency visually.

**Keywords:**
raw coconut oil; sterol profile; fermentation; coconut "milk"; texture

Coconut "milk" is obtained from the coconut pulp, the main ingredient of which is fat. A fresh coconut contains about 33 % of coconut oil containing more than 90 % of saturated fatty acids. It is rich in saturated medium-chain fatty acids with a chain length from 6 to 12 carbon atoms, which were reported to exhibit various health-promoting effects [1–3]. Moreover, instead of being bound in lipoproteins, saturated medium-chain fatty acids are directly metabolized in the liver and converted mainly to energy [3]. Hence, coconut "milk" is often recommended in various dietary programs. Though fat is the main ingredient of coconut "milk", it also contains carbohydrates and aromatic compounds, though at lower contents. These features make coconut "milk" a popular ingredient of culinary dishes in many cuisines of the world, and a plant alternative to dairy products, in the form of e.g. fermented and unfermented coconut beverages. A coconut drink has a high nutritional value and a characteristic taste as well as aroma that are appealing to consumers. In addition, it offers a technological value as a food ingredient, e.g. as a fat or milk substitute, an emulsifier, or a stabilizer [4].

Vegetable beverages are products that are increasingly available on the market. They are usually obtained by aqueous extraction of selected seeds or nuts. Current trends in the utilization of coconut "milk" also include the production of fermented beverages, including "functional" beverages. "Functional" beverages provide the human body with many desirable nutrients or bioactive compounds, such as antioxidants, dietary fibre, live cells of lactic acid bacteria or probiotics, prebiotics, proteins, peptides, unsaturated fatty acids, omega-3 and omega-6 unsaturated fatty acids, stanols, minerals, and vitamins, for example. Lactic acid bacteria and bifidobacteria are widely used for fermentation of cereal-based beverages

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(e.g. oats, rice), legume-based beverages (e.g. soybeans, beans, peas), vegetable-based beverages (e.g. potatoes), seed-based beverages (e.g. flax, hemp) and nut-based beverages (e.g. almonds, coconut). Vegetable substitutes for yogurts and kefirs traditionally produced on a milk basis, are produced from these raw materials. The production of such "functional" beverages may include an increase in nutritional value resulting from the presence of bioactive compounds such as plant sterols. The fermented coconut beverages may become the future for „functional" beverages. This direction of coconut "milk" application is a part of the food trend for the production of vegan food as well as food containing live lactic acid bacteria or probiotic microorganisms.

The aim of this study was to determine the effects of coconut fat on selected parameters of fermented coconut beverages. The fat content of commercially available coconut "milk" varies between 140 $g \cdot kg^{-1}$ and 250 $g \cdot kg^{-1}$ [3]. Hence, we decided to analyse two samples with different fat contents that was regulated by the addition of raw coconut oil to the sample.

## MATERIALS AND METHODS

### Preparation of fermented coconut "milk" beverages with different fat contents

Two variants of a coconut beverage were prepared, namely, low-fat (containing 20 $g \cdot kg^{-1}$ fat) and full-fat (containing 150 $g \cdot kg^{-1}$ fat). Both beverages were based on a commercial coconut "milk" beverage (Bjorg, Lyon, France) containing water, coconut (66 $g \cdot kg^{-1}$), cane sugar, guar gum and sea salt. The declared fat content of this beverage was 20 $g \cdot kg^{-1}$.

In order to increase fat content and obtain a full-fat coconut beverage sample, an appropriate amount of raw "organic" coconut oil (Diet Food Mipama, Opatówek, Poland) containing pure coconut fat was added to the base product. Our previous study (unpublished data) had shown that a combination of native wheat starch and agar can perfectly stabilize the fermented coconut "milk". Therefore, a mixture containing native wheat starch (Polmarkus, Pyskowice, Poland) and agar (Agnex, Białystok, Poland) was used to stabilize both beverages (full-fat and low-fat ones).

Our previous work had also shown (unpublished data) that the optimal proportion of both compounds that provided better stability was 10 $g \cdot kg^{-1}$ and 1 $g \cdot kg^{-1}$ (in the case of a full-fat coconut beverage) and 10 $g \cdot kg^{-1}$ and 3 $g \cdot kg^{-1}$, respectively (in the case of a low-fat coconut beverage). These contents are in line with guidelines of the Regulation (EC) No 1333/2008 on food additives [5]. Briefly, a mixture containing the stabilizing substances was added to the sample, which was thoroughly homogenized with a kitchen blender BlendForce 2 BL435831 (Tefal, Rumilly, France) for 20 min.

Later, both beverages were pasteurized at 85 °C for approximately 10 min and then cooled to the fermentation temperature of 45 °C.

To facilitate the initiation of the fermentation process, 30 $g \cdot kg^{-1}$ of food-grade glucose (Agnex) was added to both beverages prior to pasteurization. A probiotic vegan starter YO-MIX 205 LYO (DuPont Danisco, Copenhagen, Denmark), containing *Streptococcus thermophilus*, *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Lactobacillus acidophilus* and *Bifidobacterium lactis* was used at a dose of 40 $g \cdot kg^{-1}$. Then, the samples were poured into 170 ml glass jars with metal caps and placed in a laboratory incubator at 45 °C for 5 h to allow the fermentation process.

Afterwards, the jars were transferred to a refrigerator and stored at 6 °C for 28 days. The samples of fermented coconut beverages were analysed after 0, 1, 2, 3 and 4 weeks. The experiments were carried out in duplicate.

### Determination of fatty acids and sterols

The fatty acid profile and sterol content in the samples were determined using gas chromatography combined with mass spectrometry (GC-MS Q2010; Shimadzu, Kyoto, Japan). Sample preparation and chromatographic analysis for the determination of the fatty acid profile were carried out according to Derewiaka et al. [6] and those for sterols according to Derewiaka et al. [7]. The chromatographic column for the determination of the fatty acid profile was BPX70 (30 m length, 0.25 mm internal diameter, 0.25 $\mu$m film thickness, Shim-Pol A. M. Borzymowski, Warsaw, Poland) and for sterols DB5ms (30 m length, 0.25 mm internal diameter, 0.25 $\mu$m film thickness, Shim-Pol A. M. Borzymowski). Analyses were carried out in triplicate.

### Starter bacteria population

The microbiological evaluation was done by calculating the number of microbial cells used as a starter population by using the plate method described previously by Ziarno et al. [8]. De Man, Rogosa and Sharpe (MRS) agar (Merck, Darmstadt, Germany) was used to determine the counts of lactobacilli. MRS with clindamycin-ciprofloxacin (MRS-CC) agar was used to determine the counts of *Lb. acidophilus*. M17 agar (Merck)

was used to determine the counts of streptococci. Bifidus selective medium (BSM) agar (Sigma-Aldrich, Saint Louis, Missouri, USA) with a selective BSM supplement (Sigma-Aldrich) was used to determine the counts of bifidobacteria. The inoculated plates were incubated at 37 °C for 72 h under anaerobic conditions (for lactobacilli, *Lb. acidophilus* and bifidobacteria) or aerobic conditions (for streptococci). After incubation, all the colonies were counted, and the average final result was provided as a logarithm of colony forming units per millilitre. The analysis was performed in triplicate.

### pH value

pH value was determined with a pH-meter (model CP-505; Elmetron, Zabrze, Poland), providing read out to the second decimal point, and by the application of the temperature compensation strategy. The analysis was performed in triplicate. The results were read with an accuracy of 0.01 unit.

### Determination of texture and syneresis

The samples were first evaluated visually for appearance regarding consistency (density, thickness, consistency, homogenity, presence of clumps) and colour (shade, homogenity).

Hardness and adhesive properties of the fermented samples were evaluated using Brookfield CT3 Texture Analyzer (Brookfield Engineering Laboratories, Middleborough, Massachusetts, USA) according to the method described by KYCIA et al. [9].

Syneresis was determined by calculating the percentage of water that separates from the beverage during centrifugation under standard conditions as described by ZIARNO et al. [8].

These analyses were performed in triplicate.

### Statistical analysis

The results obtained were statistically analysed by the analysis of variance (ANOVA) to determine significant differences in the mean values of the evaluated parameters between fermented coconut beverages prior to and after storage in the refrigerator. Statgraphics 18 Centurion (Statgraphics Technologies, The Plains, Virginia, USA) was used to perform the statistical analysis. Tukey's comparison test was used to compare mean values obtained and differences between them were taken as statistically significant at $p < 0.05$.

## RESULTS AND DISCUSSION

### Fatty acids and sterols

Initially, we analysed the fatty acid profile of coconut oil that was used as a fat level regulator in coconut beverages subjected to the fermentation process. Coconut oil is a source of saturated fatty acids, mainly lauric and myristic acids [10], as confirmed by this study (Tab. 1). In addition, SIVAKANTHAN et al. [11] demonstrated that the most abundant fatty acids in the coconut oil were lauric and myristic acids and the fatty acid profile indicated their percentage to be 52.2 % and 21.2 %, respectively. Moreover, they reported the presence of palmitic (8.8 %), oleic (8.5 %), capric (3.6 %), caprylic (2.7 %), linoleic (2.3 %) and stearic (0.8 %) acids [11]. Lauric and myristic acids are saturated medium-chain fatty acids, which exhibit health-promoting properties, unlike the saturated long-chain fatty acids [1–3].

**Tab. 1.** Profile of fatty acids and sterols of raw “organic” coconut oil.

| Fatty acid | Percentage [%] |
|---|---|
| **Saturated fatty acids** | **92.9** |
| Caproic acid C6:0 | 0.2 ± 0.0 |
| Caprylic acid C8:0 | 9.2 ± 0.4 |
| Capric acid C10:0 | 6.7 ± 0.2 |
| Lauric acid C12:0 | 51.3 ± 0.7 |
| Myristic acid C14:0 | 15.6 ± 0.1 |
| Palmitic acid C16:0 | 6.9 ± 0.3 |
| Stearic acid C18:0 | 2.9 ± 0.2 |
| Arachidic acid C20:0 | 0.1 ± 0.0 |
| **Unsaturated fatty acids** | **7.2** |
| **Monounsaturated fatty acid** | **6.0** |
| Palmitoleic acid C16:1 | 0.1 ± 0.0 |
| Oleic acid C18:1 *cis* 9 | 5.9 ± 0.5 |
| *Cis* isomers of oleic acid | 0.0 ± 0.0 |
| **Polyunsaturated fatty acid** | **1.1** |
| Linoleic acid C18:2, *cis* 9, *cis* 12 | 0.9 ± 0.1 |
| Linolenic acid C18:3 *cis* 6, *cis* 9, *cis* 12 | 0.1 ± 0.1 |
| *Cis* isomers of linolenic acid | 0.0 ± 0.0 |
| Docosadienoic acid C22:2 | 0.0 ± 0.0 |
| Docosapentaenoic acidC 22:5 | 0.1 ± 0.0 |

| **Raw coconut oil** | Content [mg·kg$^{-1}$] |
|---|---|
| Campesterol | 40.5 ± 3.9 |
| Stigmasterol | 89.9 ± 4.9 |
| β-Sitosterol | 274.2 ± 16.5 |
| Δ5-Avenasterol | 159.8 ± 12.0 |
| Total content of the sterols | 564.3 ± 32.0 |

Values represent mean ± standard deviation ($n$ = 6).

Regarding sterols, the oil used in the experiment contained β-sitosterol, $\Delta^5$-avenasterol, stigmasterol and campesterol. About 40 different types of plant sterols are currently identified, and the most well-known and widespread among them are β-sitosterol, campesterol and stigmasterol. In all edible oils, β-sitosterol is dominant, which was also demonstrated by our analyses. The average total sterol percentage in the coconut oil was much below 0.1 %. A higher percentage of sterols (approximately 0.1 %) was reported by Marina et al. [1, 2] in "virgin" coconut oil. Those authors also mentioned that refined coconut oil may contain a lower percentage of total sterols, much below 0.1 % [1]. Previous studies demonstrated that coconut oil may contain up to 70–80 mg of phytosterols per 100 g, and that this proportion depends on the type of oil and on environmental conditions of coconuts ripening [12, 13].

**Starter bacteria**

The counts of *S. thermophilus* in the coconut beverage samples fermented using the YO-MIX 205 starter culture reached only 8.7 log CFU·ml$^{-1}$ immediately after the completion of the fermentation process (Tab. 2), regardless of the fat content ($p$ = 0.0577), while the decrease in the cells counts noted during refrigerated storage was not statistically significant ($p$ = 0.3745).

In the case of lactobacilli, the bacterial cell population was approximately by an order of magnitude lower than that determined for lactic streptococci and was also independent of the fat content ($p$ = 0.0284). However, during the refrigerated storage, the reduction in cell counts was statistically significant ($p$ = 0.0001). The statistical analysis showed no variability in the population of *Lb. acidophilus*, which was independent of the fat content ($p$ = 0.5343) during the refrigerated storage of fermented coconut beverage ($p$ = 0.0904).

Regarding bifidobacteria (Tab. 2), cell counts immediately after fermentation were, on average, 6.7 log CFU·ml$^{-1}$ irrespective of the fat content ($p$ = 0.4710). However, a successive but statistically significant reduction in counts of these bacteria was noted during 28 days of refrigerated storage, usually at the end of the experiment ($p$ = 0.0050).

According to the declaration of culture producer, the YO-MIX 205 starter is a blend of selected strains for direct inoculation of food matrix specially developed to provide a minimum of 1 million of *Lb. acidophilus* and *B. lactis* cells per one millilitre of fermented product. However, according to the Codex Alimentarius guidelines [14], the counts of starter bacterial cells in yogurts should be at a concentration of at least $10^7$ CFU·ml$^{-1}$ throughout their shelf life period. The Codex Alimentarius Standard recommends the addition of other microflora to yogurt, besides the yogurt bacteria [14]. Usually, this additional microflora includes strains of *Lactobacillus, Bifidobacterium* or *Propionibacterium* genera, and most often these are potentially probiotic strains (beneficial for the consumer's body) or strains exhibiting bioprotective properties (beneficial for the quality and stability of the product) [15]. As Zaręba and Ziarno [16] proved, viability of lactobacilli and streptococci was dependent on the type of plant beverage and the starter culture used, as well as on whether the beverage was fermented or not. As it is known, the basic factor that determines the viability of microbial cells is their ability to adapt to the conditions of their environment. The factors that determine the levels and viability of bacterial cells in yogurt include the technological process of

**Tab. 2.** Starter microflora population in fermented coconut milk beverages stored under refrigeration.

| Storage time [d] | Colony count [log CFU·ml$^{-1}$] | |
|---|---|---|
| | Full-fat beverage | Low-fat beverages |
| *Streptococcus thermophilus* | | |
| 0 | 8.7 ± 0.1$^{a}$ | 8.6 ± 0.2$^{a}$ |
| 7 | 8.7 ± 0.2$^{a}$ | 8.5 ± 0.2$^{a}$ |
| 14 | 8.7 ± 0.1$^{a}$ | 8.3 ± 0.1$^{a}$ |
| 21 | 8.4 ± 0.2$^{a}$ | 8.4 ± 0.3$^{a}$ |
| 28 | 8.4 ± 0.3$^{a}$ | 8.4 ± 0.2$^{a}$ |
| *Lactobacillus delbrueckii* subsp. *bulgaricus* | | |
| 0 | 7.6 ± 0.2$^{a}$ | 7.5 ± 0.3$^{a}$ |
| 7 | 7.4 ± 0.2$^{a}$ | 7.4 ± 0.2$^{a}$ |
| 14 | 7.3 ± 0.2$^{a}$ | 7.0 ± 0.3$^{ab}$ |
| 21 | 7.1 ± 0.2$^{a}$ | 6.8 ± 0.2$^{b}$ |
| 28 | 6.8 ± 0.2$^{b}$ | 6.7 ± 0.1$^{b}$ |
| *Lactobacillus acidophilus* | | |
| 0 | 6.7 ± 0.1$^{a}$ | 6.8 ± 0.1$^{a}$ |
| 7 | 6.4 ± 0.2$^{a}$ | 6.6 ± 0.2$^{a}$ |
| 14 | 6.4 ± 0.3$^{a}$ | 6.6 ± 0.1$^{a}$ |
| 21 | 6.6 ± 0.2$^{a}$ | 6.5 ± 0.2$^{a}$ |
| 28 | 6.5 ± 0.4$^{a}$ | 6.2 ± 0.4$^{a}$ |
| *Bifidobacterium lactis* | | |
| 0 | 6.8 ± 0.2$^{a}$ | 6.9 ± 0.2$^{a}$ |
| 7 | 6.8 ± 0.4$^{a}$ | 6.7 ± 0.1$^{a}$ |
| 14 | 6.6 ± 0.4$^{a}$ | 6.4 ± 0.3$^{ab}$ |
| 21 | 6.4 ± 0.3$^{ab}$ | 6.2 ± 0.4$^{ab}$ |
| 28 | 5.8 ± 0.2$^{b}$ | 5.6 ± 0.3$^{b}$ |

Values represent mean ± standard deviation ($n$ = 6). Different superscripts for the results of a specific parameter show significant difference at the $p$-value of 0.05.

their production, refrigeration conditions used for their storage and storage time of the final product. The high nutritional and health-promoting value of yogurts containing additional microflora, especially the potential probiotic strains, depends on the presence of a sufficient number of viable cells of this particular microflora. Our research showed that both samples of fermented coconut beverages (low-fat and full-fat) fulfilled this criterion, which makes the fermented coconut beverage beneficial for human consumption. As mentioned earlier, the viability and activity of yogurt bacterial cells are closely related to the stability of both the strains and the yogurt [17]. Particular attention should be paid to the population and activity of *Lb. delbrueckii* subsp. *bulgaricus*. These bacteria produce, among others, threonine aldolase, an enzyme that converts threonine to acetaldehyde, the excess of which can be perceived in the product as a result of fermentation [18]. Therefore, it is necessary to use appropriately selected starter cultures with a balanced ratio of lactobacilli and streptococci. The current trend is to use starter cultures containing non-traditional lactobacilli in order to modulate the fermentation process. It is also necessary to optimize the fermentation temperature [19].

**pH values**

Lactic acid bacteria used for the fermentation of coconut beverages are heterofermentative in nature, and are characterized by the production of not only lactic acid but also other metabolites, which contribute to sample pH changes and attractive appearance. The data presented in Tab. 3 prove that the pH value of the fermented coconut beverages did not depend on the fat content ($p = 0.1159$), but was influenced by the storage time during refrigeration ($p = 0.7871$). According to the declaration of culture producer, the YO-MIX 205 LYO starter quickly acidifies the cows' milk to pH 4.70–4.80 and then slow acidification takes place to reach lower pH. This characteristic allows good pH control during the processing time and the shelf life. Zaręba and Ziarno [16] observed a reduction of pH during the refrigerated storage of the coconut beverage and this phenomenon depended on the starter culture used.

It is known that, besides fructose, coconut milk naturally contains very little amounts of other carbohydrates. In our study, we added extra glucose (30 $g \cdot kg^{-1}$) so that the increased amount of the substrate would stimulate fermentation process, which probably stimulated further pH changes during the refrigerated storage of samples. Changes in the pH value during refrigerated storage of such fermented beverages as milk yogurts or fermented vegetable drinks are widely observed regardless of the matrix or starter culture used, thus our results are consistent with those reported by other authors [8, 17, 20, 21].

**Texture and syneresis**

The full-fat beverages were initially characterized visually by uniform appearance (without delamination and lumps), dense consistency and pure white colour, which is typical of the coconut milk [3]. The low-fat beverages were characterized by a uniform appearance (without delamination and lumps), slightly ductile and compact consistency, and by white colour.

It is noteworthy that the beverages showed significant changes in consistency during storage, becoming thinner visually than immediately after production. However, the changes in appearance and consistency observed during the storage pe-

Tab. 3. pH and textural parameters of fermented coconut milk beverages stored under refrigeration.

| Storage time [d] | Full-fat beverage | Low-fat beverage |
|---|---|---|
| **pH value** | | |
| 0 | $4.38 \pm 0.42^{a}$ | $4.41 \pm 0.40^{a}$ |
| 7 | $4.17 \pm 0.24^{a}$ | $4.46 \pm 0.32^{a}$ |
| 14 | $4.21 \pm 0.21^{a}$ | $4.41 \pm 0.36^{a}$ |
| 21 | $4.18 \pm 0.27^{a}$ | $4.50 \pm 0.46^{a}$ |
| 28 | $4.10 \pm 0.28^{a}$ | $4.23 \pm 0.16^{a}$ |
| **Hardness** [mJ] | | |
| 0 | $36.82 \pm 2.39^{a}$ | $107.82 \pm 4.98^{b}$ |
| 7 | $40.92 \pm 3.45^{a}$ | $104.21 \pm 6.96^{b}$ |
| 14 | $43.49 \pm 3.26^{a}$ | $98.51 \pm 1.63^{b}$ |
| 21 | $44.10 \pm 3.86^{a}$ | $109.18 \pm 8.73^{b}$ |
| 28 | $42.73 \pm 6.14^{a}$ | $112.70 \pm 6.00^{b}$ |
| **Adhesiveness** [mJ] | | |
| 0 | $10.41 \pm 0.60^{a}$ | $12.30 \pm 1.75^{b}$ |
| 7 | $10.84 \pm 0.75^{a}$ | $12.98 \pm 1.71^{b}$ |
| 14 | $12.61 \pm 2.58^{a}$ | $13.86 \pm 1.67^{b}$ |
| 21 | $11.95 \pm 2.32^{a}$ | $14.59 \pm 2.27^{b}$ |
| 28 | $11.11 \pm 1.85^{a}$ | $14.49 \pm 1.70^{b}$ |
| **Syneresis** [%] | | |
| 0 | $9.8 \pm 0.5^{a}$ | $14.6 \pm 0.5^{c}$ |
| 7 | $11.1 \pm 0.7^{b}$ | $14.7 \pm 0.8^{c}$ |
| 14 | $12.1 \pm 0.4^{b}$ | $14.7 \pm 0.3^{c}$ |
| 21 | $11.6 \pm 0.4^{b}$ | $14.7 \pm 0.4^{c}$ |
| 28 | $11.5 \pm 0.2^{b}$ | $14.0 \pm 0.9^{c}$ |

Values represent mean ± standard deviation ($n = 6$). Different superscripts for the results of a specific parameter show significant difference at the $p$-value of 0.05.

riod were not reflected by changes in syneresis of stored beverages.

The data presented in Tab. 3 prove that the hardness value of the fermented coconut beverage samples was statistically dependent only on the fat content ($p = 0.0000$) and not on the storage time ($p = 0.1442$). Interestingly, the hardness value was found to be higher in the low-fat fermented coconut beverages when compared to the full-fat ones. We can conclude that, regardless of the composition of coconut fatty acids, the content of non-fat solid mass had a greater impact on the hardness of the sample, as in case of milk yogurt.

The non-fat solid mass content determines the physical properties of the final yogurt product. In case of milk yogurt, an increase of the milk protein content increases the amount of bound water and firmness of the resulting gel. In our studies, the content of non-fat solid mass was higher in low-fat than full-fat fermented coconut beverages samples. In addition, we used the addition of native wheat starch and agar, which stabilized the resulting gel of non-fat solid mass in fermented coconut beverages samples.

Adhesion is defined as the work that is necessary to overcome the forces of attraction that act between the surface of the sample and another body with which it comes in contact with (e.g. tongue, teeth, palate). The data presented in Tab. 3 prove that the adhesion value of fermented coconut beverage samples was statistically dependent only on the fat content ($p = 0.0028$), but not on the storage time ($p = 0.3017$).

The value of adhesiveness was demonstrated to be higher in the low-fat fermented coconut beverage than in the full-fat one. This finding is in contrast to the results published by Simuang et al. [22], who showed that fat content had significant effect on the rheological property of coconut "milk". The rheological properties of coconut "milk" with different fat contents (15–30 %) were studied by Simuang et al. [22] at a range of temperatures of 70–90 °C. As we know, coconut "milk" is an oil-in-water emulsion rich in fat, which contains a lot of saturated medium-chain fatty acids [1–3]. The saturated fatty acids from 12:0 to 24:0 have a waxy consistency at room temperature and this explains why the composition of saturated medium-chain fatty acids in the tested coconut beverage samples could determine the structural features, as it results from the data presented in Tab. 1. Therefore, we can conclude that the different analytical methods used could explain the differences in our and cited results. As another possible source of discrepancies, it can be mentioned that Simuang et al. [22] studied unfermented coconut "milk", and our samples were fermented coconut milk beverages.

It has been established that the texture of fermented beverages may depend on the metabolic activity of the lactic acid bacteria in the fermentation process [23, 24]. Yogurt bacteria that produce extracellular polysaccharides (EPS) are commonly used in the dairy industry to improve yogurt texture by enhancing viscosity, independent of the fat content. Exopolysaccharides produced by lactic acid bacteria may contribute to the texture, flavour, and viscosity of the fermented matrix [23–25]. This can explain the differences between our results and literature data, since our beverages were fermented using an industrial yogurt culture, which produced a dense consistency and a pure yogurt flavour. The YO-MIX 205 LYO starter used in our experiments is a mildly acidifying culture with high polysaccharide production that produces a "mild" yogurt with medium thickness and with "clean" yogurt flavour. It is obvious that the low-fat samples contain more fermentable substrate and starter bacteria have a greater impact on the non-fatty components contained than in the full-fat fermented coconut beverages. In addition, starter bacteria selected for the production of yogurts with a thick consistency are characterized by the ability to produce exopolysaccharides, which modify their properties during storage. Some data in this regard are available in literature on fermented plant beverages and milk yogurts [8, 21, 26] but no information is available in this respect on fermented coconut beverages.

The data presented in Tab. 3 prove that the syneresis value of the fermented coconut beverages depended on both the fat content ($p = 0.0000$) and the storage time ($p = 0.0459$). A higher syneresis value was observed in the low-fat fermented coconut beverages compared to the full-fat ones. It is worth noting, however, that in the case of the full-fat beverage, the value of this parameter changed significantly during the refrigerated storage, while the low-fat beverage was characterized by a stable syneresis value throughout the storage period. Some data in this regard are available in literature on fermented beverages derived from vegetable or dairy sources [27–30] but no information is available in this respect on fermented coconut beverages stored under refrigeration.

## CONCLUSIONS

An increase in the fat content, from 20 $g \cdot kg^{-1}$ to 150 $g \cdot kg^{-1}$, of the fermented coconut milk beverage samples achieved by the addition of raw „organic"

coconut oil (rich in saturated fatty acids, mainly lauric and myristic acids) led to changes in selected qualitative properties. In addition, some of the studied qualitative properties changed during refrigerated storage of the fermented coconut milk beverages samples.

The pH values of the fermented coconut milk beverages did not depend on the fat content and on the duration of storage at 6 °C during 28 days.

The textural changes measured instrumentally were not reflected in the appearance and consistency of the samples when analysed visually. The full-fat beverages were initially characterized visually by uniform appearance, dense consistency, and pure white colour, which is typical of the coconut “milk”. The low-fat beverages were characterized by a uniform appearance, slightly ductile and compact consistency, and white colour. The textural properties and syneresis of the fermented coconut “milk” beverage samples, instrumentally examined, were statistically dependent on the fat content and/or storage time. The hardness and adhesiveness of the low-fat fermented coconut “milk” beverages were found higher compared to the full-fat ones, but did not depend on the storage time. A higher syneresis value was observed in the low-fat fermented coconut milk beverages compared to the full-fat ones, but only in the case of full-fat fermented coconut milk beverages this value changed significantly during the refrigerated storage.

The population of *S. thermophilus*, *Lactobacillus* spp. and bifidobacteria in the fermented coconut “milk” beverages did not depend on the fat content. Only the storage time of samples had a significant impact on the population of lactobacilli and bifidobacteria. The population of *S. thermophilus* proved to be resistant to the conditions of refrigerated storage of fermented coconut “milk” beverages samples for 28 days. Increasing the fat content of the fermented coconut beverages by adding raw “organic” coconut oil resulted in the increase in the content of sterols originating in the coconut oil (β-sitosterol, $\Delta^5$-avenasterol, stigmasterol and campesterol).

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## REFERENCES

1. Marina, A. M. – Che Man, Y. B. – Amin, I.: Virgin coconut oil: emerging functional food oil. Trends in Food Science and Technology, *20*, 2009, pp. 481–487. DOI: 10.1016/j.tifs.2009.06.003.
2. Marina, A. M. – Che Man, Y. B. – Nazimah, S. A. H. – Amin, I.: Chemical properties of virgin coconut oil. Journal of the American Oil Chemists’ Society, *86*, 2009, pp. 301–307. DOI: 10.1007/s11746-009-1351-1.
3. Liu, S.-Q. (Ed.): Coconut handbook. Singapore : Tetra Pak International, 2016. ISBN: 978-981-09-7362-9.
4. Santana, I. A. – Ribeiro, E. P. – Iguti, A. M.: Evaluation of green coconut (*Cocos nucifera* L.) pulp for use as milk, fat and emulsifier replacer in ice cream. Procedia Food Science, *1*, 2011, pp. 1447–1453. DOI: 10.1016/j.profoo.2011.09.214.
5. Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives. Official Journal of the European Union, *51*, 2008, L354, pp. 16–33. ISSN: 1725-2555. <http://data.europa.eu/eli/reg/2008/1333/oj>
6. Derewiaka, D. – Sosińska, E. – Obiedziński, M. – Krogulec, A. – Czaplicki, S.: Determination of the adulteration of butter. European Journal of Lipid Science and Technology, *113*, 2011, pp. 1005–1011. DOI: 10.1002/ejlt.201100006.
7. Derewiaka, D. – Obiedziński, M. – Wołosiak, R. – Antoniuk, A.: Contents of phytosterols and oxyphytosterols in soybean oil with different addition of sea buckthorn seed oil after thermal processing. Polish Journal of Food and Nutrition Sciences, *60*, 2010, pp. 323–327. ISSN: 1230-0322.
8. Ziarno, M. – Zaręba, D. – Maciejak, M. – Veber, A. L.: The impact of dairy starter cultures on selected qualitative properties of functional fermented beverage prepared from germinated white kidney beans. Journal of Food and Nutrition Research, *2*, 2019, pp. 167–176. ISSN: 1338-4260 (print), 1338-4260 (online). <http://www.vup.sk/en/download.php?bulID=2022>
9. Kycia, K. – Chlebowska-Smigiel, A. – Gniewosz, M. – Sokol, E.: Effect of pullulan on the physicochemical properties of yoghurt. International Journal of Dairy Technology, *71*, 2018, pp. 64–70. DOI: 10.1111/1471-0307.12401.
10. Appaiah, P. – Sunil, L. – Prasanth Kumar, P. K. – Gopala Krishna, A. G.: Composition of coconut testa, coconut kernel and its oil. Journal of the American Oil Chemists’ Society, *91*, 2014, pp. 917–924. DOI: 10.1007/s11746-014-2447-9.
11. Sivakanthan, S. – Jayasooriya, A. P. – Madhujith, T.: Optimization of the production of structured lipid by enzymatic interesterification from coconut (*Cocos nucifera*) oil and sesame (*Sesamum indicum*) oil using response surface methodology. LWT - Food Science and Technology, *101*, 2019, pp. 723–730. DOI: 10.1016/j.lwt.2018.11.085.
12. Dayrit, F. M. – Buenafe, O. E. M. – Chainani, E. T. – de Vera, I. M. S.: Analysis of monoglycerides, diglycerides, sterols, and free fatty acids in coconut (*Cocos nucifera* L.) oil by $^{31}$P NMR spectroscopy. Journal of Agricultural and Food Chemistry, *56*, 2008, pp. 5765–5769. DOI: 10.1021/jf8005432.
13. Daksha, A. – Jaywant, P. – Bhagyashree, C. – Subodh, P.: Estimation of sterols content in edi-

ble oil and ghee samples. International Journal of Pharmaceutical Sciences Review and Research, *5*, 2010, pp. 021. ISSN: 0976–044X.
14. Codex Stan 243-2003. Codex standard for fermented milks. Adopted in 2003. Revision 2008, 2010. Rome : Food and Agriculture Organization, 2011. <www.fao.org/input/download/standards/400/CXS_243e.pdf>
15. Saxelin, M. – Tynkkynen, S. – Mattila-Sandholm, T. – de Vos, W. M.: Probiotic and other functional microbes: from markets to mechanisms. Current Opinion in Biotechnology, *16*, 2005, pp. 204–211. DOI: 10.1016/j.copbio.2005.02.003.
16. Zaręba, D. – Ziarno, M.: The viability of yogurt bacteria in selected plant beverages. Advances of Agricultural Sciences Problem, *591*, 2017, pp. 87–96. DOI: 10.22630/ZPPNR.2017.591.46.
17. Mani-López, E. – Palou, E. – López-Malo, A.: Probiotic viability and storage stability of yogurts and fermented milks prepared with several mixtures of lactic acid bacteria. Journal of Dairy Sciences, *97*, 2014, pp. 2578–2590. DOI: 10.3168/jds.2013-7551.
18. Hickey, M. W. – Roginski, H. – Broome, M. C.: Growth and acid production of Group N streptococci in ultrafiltered milk. Australian Journal of Dairy Technology, *12*, 1983, pp. 138–143. ISSN: 0004-9433.
19. Shihata, A. – Shah, N. P.: Proteolytic profile of yoghurt and probiotic bacteria. International Dairy Journal, *10*, 2000, pp. 401–408. DOI: https://doi.org/10.1016/S0958-6946(00)00072-8.
20. Mituniewicz-Małek, A. – Ziarno, M. – Dmytrów, I. – Tuma, P. – Witczak, A. – Vovk, S.: Properties of drinking yogurt obtained from cow's and goat's organic milk fermented by traditional yogurt cultures. Infrastructure and Ecology of Rural Areas, *4*, 2017, pp. 1755–1771. DOI: 10.14597/infraeco.2017.4.3.132.
21. Ziarno, M. – Zaręba, D. – Henn, E. – Margas, E. – Nowak, M.: Properties of non-dairy gluten-free millet-based fermented beverages developed with yoghurt cultures. Journal of Food and Nutrition Research, *58*, 2019, pp. 21–30. ISSN: 1338-4260 (print), 1338-4260 (online). <http://www.vup.sk/download.php?bulID=2006>
22. Simuang, J. – Chiewchan, N. – Tansakul, A.: Effects of fat content and temperature on the apparent viscosity of coconut milk. Journal of Food Engineering, *64*, 2004, pp. 193–197. DOI: 10.1016/j.jfoodeng.2003.09.032.
23. Folkenberg, D. M. – Dejmek, P. – Skriver, A. – Ipsen, R.: Interactions between EPS-producing *Streptococcus thermophilus* strains in mixed yoghurt cultures. Journal of Dairy Research, *73*, 2006, pp. 385–393. DOI: 10.1017/S0022029906001920.
24. Nwodo, U. U. – Green, E. – Okoh, A. I.: Bacterial exopolysaccharides: functionality and prospects. International Journal of Molecular Sciences, *13*, 2012, pp. 14002–14015. DOI: 10.3390/ijms131114002.
25. Welman, A. D. – Maddox, I. S.: Exopolysaccharides from lactic acid bacteria: perspectives and challenges. Trends in Biotechnology, *21*, 2003, pp. 269–274. DOI: 10.1016/S0167-7799(03)00107-0.
26. Mituniewicz-Małek, A. – Zielińska, D. – Ziarno, M.: Probiotic monocultures in fermented goat milk beverages – sensory quality of final product. International Journal of Dairy Technology, *72*, 2019, pp. 240–247. DOI: 10.1111/1471-0307.12576.
27. Fox, P. F. – McSweeney, P. – Cogan, T. M. – Guinee, T. P.: Fundamentals of Cheese Science. New York : Springer, 2000. ISBN: 10:0834212609.
28. Panesar, P. S. – Shinde, C.: Effect of storage on syneresis, pH, *Lactobacillus acidophilus* count, *Bifidobacterium bifidum* count of *Aloe vera* fortified probiotic yoghurt. Current Research in Dairy Sciences, *4*, 2012, pp. 17–23. DOI: 10.3923/crds.2012.17.23.
29. Baú, T. R. – Garcia, S. – Ida, E. I.: Evaluation of a functional soy product with addition of soy fiber and fermented with probiotic kefir culture. Brazilian Archives of Biology and Technology, *57*, 2014, pp. 402–409. DOI: 10.1590/S1516-89132014005000005.
30. Shahbandari, J. – Golkar, A. – Taghavi, S. M. – Amiri, A.: Effect of storage period on physicochemical, textural, microbial and sensory characteristics of stirred soy yogurt. International Journal of Farming and Allied Sciences, *5*, 2016, pp. 476–484. ISSN: 2322-4134.

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