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RESEARCH ARTICLE

The characteristic of functional fermented caprine milk

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ABSTRACT

The aim of this study was to characterize functional fermented caprine milk. Functional properties of fermented milks was an effect of increasing the level of whey proteins, MUFA and PUFA content in final product Milk used for experiments was obtained from experimental station belonging to Poznań University of Life Sciences. Feeding strategy was included modification by adding 12% of *Camelina sativa* cake. The fermentation process was done by using *Lactobacillus acidophilus, Lactobacillus* spp., and kefir grain microflora. The quality properties which were considered was metabolic activity, monosaccharide, disaccharide, lactic acid and ethanol content, aroma and fat profile. It was noted that increasing the content of functional components in processed milk caused changes in lactose, MUFA, PUFA and volatile acids content in final product.

Keywords: Caprine milk, Fermentation, Functional components

INTRODUCTION

In dairy production, the level of biologically high-value compounds can be increased by supplementing animal diets under controlled conditions (mainly by changing the composition of fatty acids) and through the use of membrane separation to change the composition of milk protein (Danków and Pikul, 2011; Ahmed et al., 2015; Nongonierma and FitzGerald, 2015).

Feed composition has a significant effect on shaping the biologically active components in small ruminant milk (Yao et al., 2016). A common method for increasing the level of unsaturated fatty acids in milk is to add oil seeds, algae or fish oil to the feed (Cais-Sokolińska et. al.,2011). There are various feeding strategies that affecting the quality and quantity of lipids in ruminant milk. These should include intensifying the naturally occurring processes that create optimal conditions for the development of microflora in the rumen (Szumacher-Sztrabel, 2011). The main sources of the biologically active compounds in the ruminant milk are unsaturated fatty acids, which are substrates for the biohydrogenation process and the *de novo* synthesis of fatty acid in the mammary gland. The biohydrogenation process can be further stimulated by oil seeds, vegetable oils, algae, and fish oils (Cieślak et al., 2009). The inclusion to feed components such as flax seed, rape seed, soybean and canola or flax oil can catalyze the reduction of lauric, myristic and palmitic acids. The ratio in milk of n-6 to n-3 polyunsaturated fatty acids can be reduced by adding to fodder saturated short-chain fatty acids, as these are capable to inhibiting the conversion of n-6 acids and thus favorably influencing this ratio. Traditional summer pasture and fodder enriched in sunflower oil, flax seed oil or corn contribute to the conjugated linoleic acid (CLA) content of milk (Mel'uchová et al., 2008; Castro et al., 2009; Szumacher-Strabel et al., 2011; Ciołkowska et al., 2012).

The other way to increase the concentration of functional components in milk is using membrane techniques. Membrane techniques allow the effective normalization of milk components without adding additional substances (Saboya and Maubois, 2000; Biadała and Konieczny, 2018). The greatest advantage of using membrane techniques

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for standardizing and removing microorganisms from milk is that there is no need for either high temperature treatment or chemicals or biological agents that could contribute to the degradation of valuable functional ingredients (Tziboula et al., 1998; Debon et al., 2010). The membrane techniques was used by Heino et al., 2008 to reduce lactose, whey protein and ash content in milk for Emmental cheese production. The other possibilities for using membrane techniques is utilization of microfiltration for reducing the number of total bacteria, spores and coliforms in skim milk which was done by Elwell and Barbano, 2006.

The functional properties of fermented milk beverages may also be improved by using probiotic bacteria in the production process. Fermented milk drinks made with probiotic microflora are considered functional foods due to properties such as their abilities to alleviate lactose intolerance, inhibit the growth of pathogenic bacteria, normalize intestinal motility disorders and inhibit bacterial nitroreductase, which catalyzes the synthesis of nitrosamines (Lacroix and Yildirim, 2007; Reid, 2008; Thirabunyanon et al., 2009; Aureli et al., 2011).

The aim of the study was to examine the impact of:
- increased content of MUFA and PUFA
- increased ratio of whey proteins to caseins from 1:4 to 1:1on quality of probiotic fermented caprine beverage.

MATERIAL AND METHODS

Preparation of experimental caprine milk

The milk was obtained from goats of the Polish White Improved breed with an average body weight of 52 kg. The animals were aged 3–4 years (second and third lactation). Milking was carried out mechanically during the fourth and fifth months of lactation. Each day's total milk yield was obtained by combining the same quantity of milk from morning and evening milkings.

The nutritional experiment was conducted at the Złotniki experimental station belonging to Poznań University of Life Sciences. The goats were divided into two groups: a control group without any addition to the feed and an experimental group with a 12% addition of *Camelina sativa* cake, which partially replaced the mealy part of rapeseed in the mix. In both groups, the total mixed ration (TMR) method of feeding was used and included components of roughage: 50% corn silage, 20% grass haymill, 30% feeds content. In addition, TMR enriched fodder components included triticale, barley, post-extraction rapeseed meal, soybean meal and mineral compounds. The animals in both groups received 4.2 kg TMR per day. Thirty-three animals were randomly assigned to each of two groups (Szumacher-Strabel et al., 2011).

In order to increase the ratio of whey protein to casein (1: 1) in experimental milk, a membrane separation process was used, preceded by centrifugation. As a result of this processing, cream and skim milk were obtained. The cream was pasteurized at 98°C for 5 min, and the skim milk was microfiltered at 20°C using an Isoflux double membrane system with a modified filter layer with cut-offs of 1.4 μm and 0.2 μm. The initial pressure was 6.08 bar, and during the process was reduced to 2.03 bar. The transmembrane pressure was 0.41 bar and the flow rate through the membrane was 2 m/s. The milk used for further experiments was combined with a suitable proportion of raw milk, cream, and double filtrate (containing a reduced number of microorganisms and only whey proteins). The fat content was standardized to 3%. This milk was then subjected to homogenization (152 bar), pasteurization at 80°C for 15 seconds and finally cooled to 4–6°C. Four experimental milk samples resulted from these processes:

- FM-1: milk from control group animals with the natural ratio of whey proteins to casein (1:4);
- FM-2: milk from control group animals with an increased ratio of whey proteins to casein (1:1);
- FM-3: milk from experimental group animals with the natural ratio of whey proteins to casein (1:4),
- FM-4: milk from experimental group animals with an increased ratio of whey proteins to casein (1:1).

The milk sample with both natural and increased ratio of whey proteins to casein were used to produce fermented beverages. For this purpose, the milk was heated to the processing temperature of 30°C and inoculated with a commercially used starter culture, which included *Lactobacillus acidophilus, Lactobacillus* spp., and kefir grain microflora (0.2 g/L^3). Incubation was carried out at 30°C, until the active acidity reached pH 4.6. After the incubation process, the fermented milk was subjected to two-stage cooling to 4–6 °C. The final product was obtained after cooling for 24 h.

Methods

Estimating the metabolic activity of bacteria and yeasts

An analysis of the metabolic activity of bacteria and yeast was performed by measuring changes in the electrical impedance in the medium (Flint and Brookes, 2001; Gomez et al., 2002). A BacTrac 4100 automatic analyzer of microbial growth was employed.

Rating metabolic activity of bacteria and yeast

The metabolic activity of bacteria and yeast was evaluating using direct and indirect method based on measuring

impedance changes in cultured medium or in KOH solution (Lasik and Pikul, 2012; Lasik et al., 2016).

Determination of monosaccharide and disaccharide, organic acid and ethanol contents

Determining the monosaccharide, disaccharide, organic acid and ethanol content of experimental and fermented milk using high-performance liquid chromatography requires protein precipitation (Mullin and Emmons, 1997; Álvarez-Martin et al., 2008; Pescuma et al., 2008). To do this 0.013N H_2SO_4 (milk samples), or 0.01N H_2SO_4 (fermented milk samples) was used. After stirring and centrifuged the supernatant was filtered through an LCR Millex low-protein binding hydrophilic LRCPTFE 0.45 nm filter (Millipore). For analysis HPX 87H, BioRad column with RI detector was used (Lasik and Pikul, 2012; Lasik et al., 2016).

Extraction of volatile compounds

The extraction of volatile compounds was performed by HS-SPME at 50°C for 40 min using carboxen polydimethylsiloxane (PDMS) 85µm fiber (Cais-Sokolińska et al., 2011).

Determination of volatile compounds

The concentration of volatile compounds in the experimental milk and the final fermented product were determined by 2D GC-MS. Separation was carried out in two columns (ZB-5 and Supelcowax 10). The mass scan range was 38–388 m/z and the scan rate 150 spectra/s. The temperature source was 220°C (Cais-Sokolińska et al., 2011; Lasik et al., 2016).

Fat extraction

The extraction of the fat from the experimental milk and fermented product was carried out using the Rose–Gottlieb method (Cichoń, 2001).

Fatty acid profiling

The fatty acid profile was determined following the method described by Cieślak et al. (2009), using a gas chromatograph (Varian Star CP 3800) coupled with an ionization detector with a capillary column of diameter 0.25 mm and length 100 m, covered with 0.2 µm CP-Sil 88 (Chrompack, Varian). Nonadecanoic acid (Sigma Chemical Co., St. Louis, MO, USA) was used as the internal standard. Chromatographs were analyzed for retention times compared with standard fatty acid methyl esters (37 FAMEMix, Supelco, Poole, UK; Conjugated Linoleic Acid - CLA; Supelco). CLA was identified by comparing the retention times of the standard (methyl ester of conjugated linoleic acid, a mixture of methyl esters of cis- and trans-9, 11, -10, 12-octadecanoic acid, Sigma), according to the methodology described by Collomb et al. (2006) using Varian workstation (Version 5.31).

Statistical analysis

Each experiment was conducted in triplicate and results was analyzed by the Student t - test using STATISTICA 10 software (StatSoft, Cracow, Poland). The differences were considered statistically significant at the P value of < 0.05.

Statistical analysis of the results obtained to assess the metabolic activity of microorganisms constituting the starter culture was carried out using the Curve Export Professional 2.0 program. The experimental curves were described using the Gompertz mathematical model. Based on the Gompertz model, parameters characterizing the dynamics of the course changes of the electrical impedance of the medium were set (Lasik et al., 2016)

I_{max} – The maximum rate of change of electric impedance

$I_{max} = (a*c)/e$

$e = 2,7183$

x_I – time to reach I_{max} (h)

Z_b – potential metabolic activity.

RESULTS AND DISCUSSION

Impedance and metabolite content changes in milk during fermentation

Analysis of the detection time for 5% impedance changes in caprine milk showed the shortest time for the FM-2 sample (the control group with the increased ratio of whey protein to casein), and the longest time for the FM-4 sample (the experimental group on a diet supplemented with 12% addition of *Camelina sativa* cake and with increased ratio of whey protein to casein) (Fig. 1).

The changes in electrical impedance in milk inoculated with a starter culture expressed in percent relative to the initial values are presented graphically in Fig. 2 and 3. The shape of the curves is similar for both the change in the impedance caused by the activity of lactic acid bacteria as well as yeast.

To allow for comparative assessment of experimental data, a mathematical model was employed. For this purpose, the experimental curves of the impedance changes, showing the dynamics of the microbial metabolism, was described by the Gompertz model. The correlation coefficients between the experimental and theoretical data showed a very high degree of matching for caprine milk $0.94 < r < 0.99$ (Tab. 1). The curves are described by the following parameters: the maximum rate of change in impedance (I_{max}), the time to reach I_{max} (x_I) and the potential ability to metabolize components of the growth medium (Z_b). The graphical interpretation of the parameter Z_b is the area under the curve of change in impedance (Lasik and Nowak, 2010; Lasik et al., 2016).

The highest value of I_{max} was observed in FM-1 and FM-2 what indicate that there is significant impact of the type of feed on the rate of change in impedance.

The mathematical description of changes in electrical conductivity of the substrate was applied by Paquet et al., 2000 in assessing the activity of starter cultures in cheese production. The dynamics of microbial metabolic parameters are described by the maximum rate of change in conductivity of the environment and the time taken to reach that maximum. The velocity of change in conductivity of the cultured medium correlated with the acidity changes of the environment. Paquet et al., 2000 suggested using dynamic parameters to monitor the activity of starter cultures as an alternative method to measure the changes in the acidity of the environment.

Table 1: Mathematical parameters of the Gompertz model characterizing the dynamics of electrical impedance changes in caprine milk

Sample	Gompertz model coefficient				Parameters of dynamic changes in impedance		
	a	b	c	R	I_{max} (ac/e)	x_l (b/c)	Z_b $\int f(x)\,dx$
FM-1	44.12	5.10	0.48	0.99	$7.79^{C*)}$	10.63^{B}	10.06^{C}
FM-2	31.51	7.38	0.66	0.94	7.65^{C}	11.18^{C}	7.02^{A}
FM-3	38.15	4.25	0.37	0.97	5.19^{B}	11.49^{C}	8.10^{B}
FM-4	45.10	2.36	0.27	0.98	4.48^{A}	8.74^{A}	10.64^{C}

*) various capitals with average values in the columns indicate statistically significant differences at the level of p=0.05
I_{max}–The maximum rate of change of electric impedance
x_l–time to reach I_{max} (h)
Z_b–potential metabolic activity

A statistically significant effect of the feeding strategy was observed on the lactose content in final product (Tab. 2). No consistent effect of increasing the ratio of whey proteins to casein on the lactose content of the produced fermented beverage was observed. A similar trend was seen in the analysis of changes in the galactose content of the tested samples. Manzi et al., 2007 studied the proportion of individual monosaccharides in functional dairy drinks and showed that the galactose content of products fell in the range from 0.01–1.01 g/100 g.

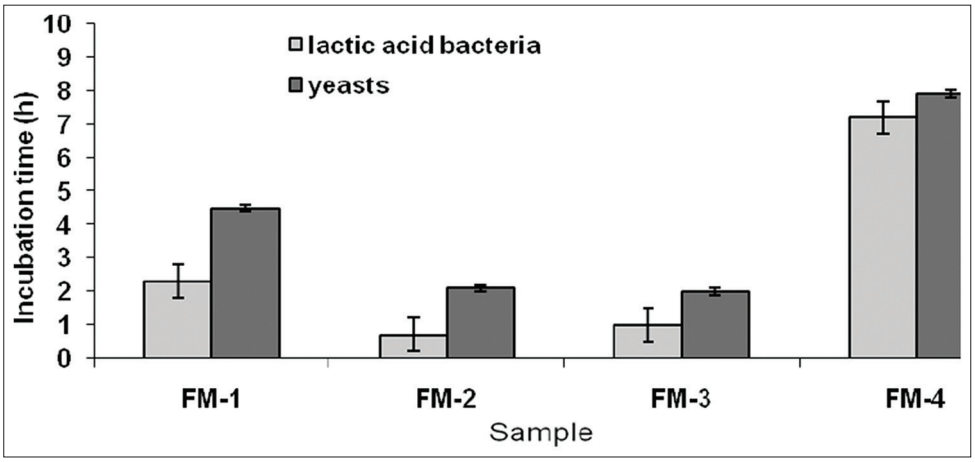

Fig 1. Detection time of 5% impedance changes in caprine milk caused by the growth of lactic acid bacteria and yeast. FM-1: milk from control group animals with the natural ratio of whey proteins to casein (1:4); FM-2: milk from control group animals with an increased ratio of whey proteins to casein (1:1); FM-3: milk from experimental group animals with the natural ratio of whey proteins to casein (1:4), FM-4: milk from experimental group animals with an increased ratio of whey proteins to casein (1:1).

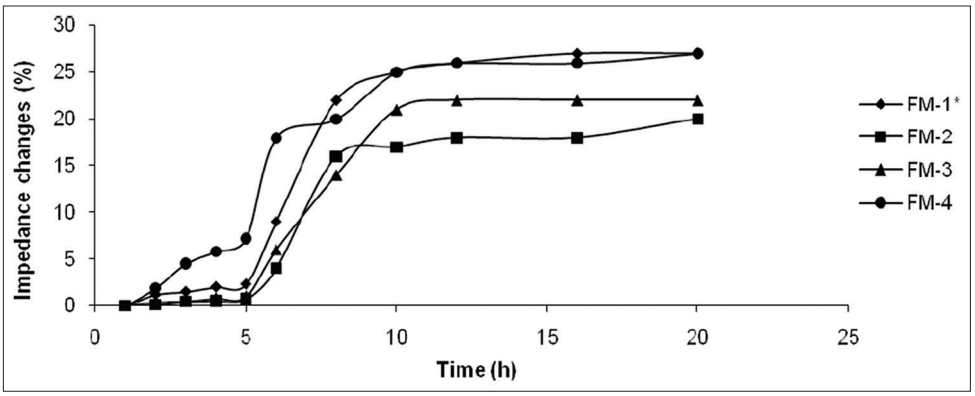

Fig 2. Impedance changes in caprine milk caused by activity of lactic acid bacteria

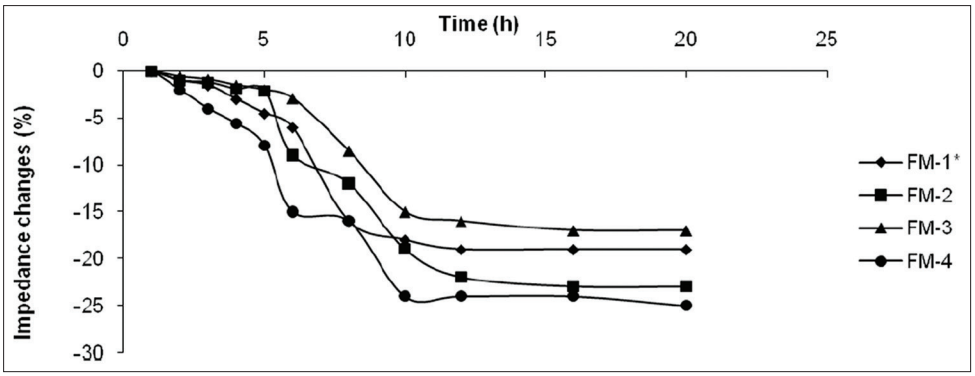

Fig 3. Impedance changes in caprine milk caused by activity of yeast

Table 2: Lactose, galactose, lactic acid and ethanol content in experimental and fermented caprine milk

Sample	Lactose (g/L)	Galactose (g/L)	Lactic acid (g/L)	Ethanol (µg/g)
FM-1				
Experimental milk	47.82$^{C*)}$	Nd$^{**)}$	Nd	Nd
Fermented milk	33.84^{B}	0.37^{A}	3.24^{A}	2.31^{B}
FM-2				
Experimental milk	47.26^{C}	Nd	Nd	Nd
Fermented milk	34.19^{B}	0.39^{A}	3.73^{B}	1.94^{A}
FM-3				
Experimental milk	48.39^{D}	Nd	Nd	Nd
Fermented milk	31.26^{A}	0.43^{B}	3.17^{A}	2.21^{B}
FM-4				
Experimental milk	49.34^{D}	Nd	Nd	Nd
Fermented milk	30.57^{A}	0.45^{B}	3.82^{B}	1.72^{A}

*)various capitals with average values in the columns indicate statistically significant differences at the level of p=0.05
Nd-not detected

Changes in fatty acids profile

Analysis of the fatty acid profile showed a statistically significant reduction in the proportion of saturated fatty acids (SFA) and an increase in the share of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) in milk collected from a group of animals fed with feed supplemented with a 12% addition of *Camelina sativa* cake (Tab. 3). These changes resulted from the statistically significant decrease in the proportion of $C_{16:0}$ and an increase in the share of $C_{18:1}$ trans-$C_{18:3}$ and CLA in milk from goats in the experimental group. Increasing the ratio of whey protein to casein in the processed milk did not affect the fatty acid profile.

Enriching the feed with flax seeds, canola or soy helps to reduce the levels of $C_{12:0}$, $C_{14:0}$ and $C_{16:0}$ and increase the CLA content in milk (Kuczyńska et al., 2009; Maciołek and Gieszcz, 2009). The levels of monounsaturated and polyunsaturated fatty acids in milk can be increase not only by adding oil seeds to the feed, but also by supplementing with seaweed or fish oil (Albenzio et al., 2016). Renna et al., 2011 evaluated the effects of increasing the proportion of hay and green grass in the feed on the fatty acid profile of goat's milk and found significant deterioration in this profile as a result of the increase in saturated fatty acids and the reduction in monounsaturated and polyunsaturated fatty acids. Strzałkowska et al., 2009 examined the effect of lactation on the level of polyunsaturated fatty acids in goat's milk and found a statistically significant increase in the share of PUFA with each successive lactation.

The fermentation process did not have a statistically significant effect on the changes in the fatty acid profile of the final product. There was a trend towards a greater concentration of CLA in fermented milk than in the processed milk. On the basis of the results, there was a significant increase in the share of $C_{18:1}$- trans, $C_{18:3}$ and CLA and a decrease in the share of acid $C_{16:0}$ in fermented beverages make from the milk of goats in the experimental group.

Changes in aroma profile

During fermentation, lactic acid bacteria produce many of the compounds that impact the aroma of fermented foods. The catabolic activity of probiotic strains is different from the activity which characterizes traditional microflora. Acetic acid, acetaldehyde, diacetyl, ethanol, propanone and 2-butanone are the major aroma compounds typical of fermented milk beverages (Beshkova et al., 2003). Ketones make up the largest proportion of the identified volatile compounds. The contribution of volatile fatty acids is significantly less in the processed milk with the increased ratio of whey protein to casein. Supplementation of feed with 12% *Camelina sativa* cake contributed to a statistically significant reduction in the proportion of volatile aldehydes in the processed milk.

Cais-Sokolińska et al., 2011 and Cais - Sokolińska et al., 2015 investigated the effect of supplementing goat feed with 10% and 20% additions of *Camelina sativa* cake. They found significant changes in the flavor of the milk resulting from a decrease in the share of volatile aldehydes

Table 3: Fatty acids profile of processed and fermented caprine milk

Fatty acids	FM–1*)		FM-2		FM-3		FM-4	
	Experimental milk	Fermented milk	Experimental milk	Fermented milk	Experimental milk	Fermented milk	Experimental milk	Fermented milk
$C_{4:0}$	2.77	2.59	2.74	2.86	2.46	2.79	2.61	2.97
$C_{6:0}$	1.37	1.58	1.38	1.55	1.69	1.61	1.34	1.56
$C_{8:0}$	1.68	1.69	1.78	1.82	1.50	1.51	1.66	1.39
$C_{10:0}$	9.27	8.78	9.53	8.87	9.56	9.21	9.79	9.59
$C_{12:0}$	5.34	5.04	5.27	4.67	4.76	4.51	5.32	4.84
$C_{14:0}$	10.34	10.17	10.15	10.29	9.99	10.12	9.80	9.56
$C_{16:0}$	$27.17^{b*)}$	27.38^{b}	27.29^{b}	27.27^{b}	23.06^{a}	23.31^{a}	23.27^{a}	23.66^{a}
$C_{16:1}$	2.46	2.35	2.49	2.23	2.70	2.44	2.76	2.51
$C_{18:0}$	7.60	7.76	7.42	7.84	6.54	6.60	6.21	6.47
$C_{18:1}$	25.18	26.67	26.29	27.18	24.96	25.67	24.57	25.19
$C_{18:1\ trans}$	2.29^{a}	2.17^{a}	2.28^{a}	2.17^{a}	7.24^{b}	6.81^{b}	6.98b	6.97^{b}
$C_{18:2}$	2.27	2.29	2.20	2.03	2.58	2.58	2.46	2.39
CLA	1.03^{a}	1.05^{a}	0.99^{a}	1.06a	2.47b	2.56^{b}	2.43^{b}	2.72^{b}
$C_{18:3}$	0.20^{a}	0.23^{a}	0.15^{a}	0.22^{a}	0.61^{b}	0.63^{b}	0.73^{b}	0.73^{b}
SFA	65.52^{b}	65.33^{b}	65.15^{b}	65.15^{b}	59.70^{a}	59.54^{a}	59.98^{a}	60.12^{a}
MUFA	30.86^{a}	31.01^{a}	31.47^{a}	31.59^{a}	34.70^{b}	34.93^{b}	34.48^{b}	34.59^{b}
MUFA *cis*	28.6^{5}	29.07	28.95	29.51	27.55	28.19	27.54	27.70
MUFA *trans*	2.22^{a}	2.05^{a}	2.25^{a}	2.12^{a}	7.13^{b}	6.79^{b}	6.95^{b}	6.88^{b}
PUFA	3.49^{a}	3.59^{a}	3.28^{a}	3.27^{a}	5.59^{b}	5.80^{b}	5.53^{b}	5.64^{b}

*various small letters at the average values in rows within the type of fatty acids means the statistically significant difference at p=0.05

Table 4: The percentage of individual groups of volatile compounds affecting the aroma of experimental and fermented caprine milk

Sample	Acids	Alcohols	Aldehydes	Ketones	Esters
FM-1					
Experimental milk	$10.52^{B*)}$	0.57^{A}	4.54^{B}	80.86^{C}	2.76^{A}
Fermented milk	52.24^{C}	13.04^{D}	5.84^{C}	26.48^{B}	3.38^{B}
FM-2					
Experimental milk	6.34^{A}	1.52^{B}	3.64^{B}	82.69^{C}	5.81^{D}
Fermented milk	67.68^{D}	9.49^{C}	5.89^{C}	8.71^{A}	8.21^{E}
FM-3					
Experimental milk	12.36^{B}	1.23^{B}	1.84^{A}	80.38^{C}	4.19^{C}
Fermented milk	55.71^{C}	8.12^{C}	4.40^{C}	22.03^{B}	9.14^{E}
FM-4					
Experimental milk	8.36^{A}	1.57^{B}	0.97^{A}	84.13^{C}	4.97^{C}
Fermented milk	76.15^{D}	10.13^{C}	4.11^{B}	5.13^{A}	4.48^{C}

*)various capitals with average values in the columns indicate statistically significant differences at the level of p=0.05

Table 5: The percentage of volatile fatty acids which can influence on aroma of experimental and fermented caprine milk

Sample	Fatty acids				
	Acetic acid	Butyric acid	Caproic acid	Caprylic acid	Capric acid
FM-1					
Experimental milk	$30.21^{A*)}$	1.34A	30.98^{B}	17.36^{C}	19.65^{B}
Fermented milk	67.24^{B}	6.31^{B}	16.08^{A}	5.06^{A}	4.29^{A}
FM-2					
Experimental milk	34.28^{A}	1.98^{A}	28.34^{B}	20.17^{C}	15.23^{B}
Fermented milk	64.04^{B}	1.15^{A}	16.69^{A}	10.96^{B}	6.87^{A}
FM-3					
Experimental milk	30.55^{A}	1.24^{A}	31.06^{B}	21.97^{C}	15.18^{B}
Fermented milk	68.26^{B}	5.89^{B}	15.25^{A}	5.12^{A}	5.48^{A}
FM-4					
Experimental milk	35.68^{A}	2.59^{A}	$20.39A^{B}$	21.87^{C}	19.47^{B}
Fermented milk	63.28^{B}	2.01^{A}	15.21^{A}	11.06^{B}	8.44^{A}

*)various capitals with average values in the columns indicate statistically significant differences at the level of p=0.05

in the processed milk prepared from animals fed the 20% *Camelina sativa* diet, as compared to milk from the animals fed the diet with 10% supplementation.

During fermentation, the proportion of volatile acids, alcohols and esters significantly increased in all the fermented beverages under consideration (Tab. 4). The

fermented milk with the increased ratio of whey proteins to casein had a significantly greater share of volatile acids than the samples with the natural protein composition.

Table 5 shows the percentage of individual volatile organic acids that affect the flavor of goat's milk and fermented beverages made from it. There were no statistically significant differences in the proportions of volatile acids. Acetic acid was the most common volatile organic acid in all the fermented products. Increasing the ratio of whey protein to casein in the processed milk resulted in a significant reduction of butyric acid.

CONCLUSION

Increasing the content of functional ingredients in experimental caprine milk significantly affects certain qualities of the final product. The most significant and positive influence was observed in the fat profile. Supplementation of the animal's feed with 12% *Camelina sativa* cake and increasing the ratio of whey to casein proteins from 1:4 to 1:1, may thus be an interesting solution to manufacturers who wish to offer high quality products without the need to use additives in production.

Autor contributions

Agata Biadała – main researcher, originator of experiment
Jan Pikul – consultant during experiment design
Magdalena Rudzińska– consultant and helper in fatty acids analysis
Małgorzata Majcher - consultant and helper in aroma compounds analysis
Małgorzata Lasik – Kurdyś - consultant and helper in estimated the metabolic activity of microorganisms and determination of mono- disaccharides and ethanol
Tomasz Szablewski, Renata Cegielska-Radziejewska-results analysis

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