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MILK YIELD AND COMPOSITION, TECHNOLOGICAL PROPERTIES AND HOMEOSTASIS INDICES AT DIFFERENT LACTATION STAGES AND PARITIES OF TWO POLISH DAIRY GOAT BREEDS

– Research paper –

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Abstract: The purpose of the research was to determine the effect of breed, lactation number, and lactation stage on milk efficiency and goat milk ingredients, these being indicators of milk technological parameters and homeostasis disturbances. Goat breed and number of lactation affected energy-corrected milk, value-corrected milk yield, fat corrected milk, protein, casein, lactose contents and free fatty acids. Additionally, differences in non-fat solids and urea contents were found between two Polish common dairy breeds White Improved (PWI) and Fawn Improved (PFI) goats. Moreover, parity affected milk yield, its acidity and somatic cell count (SCC). Milk yield and milk components were found to vary according to lactation stage. At the beginning of lactation, milk is richer in ingredients which have effect on cheese and yoghurt production. All the goats undergo similar changes related to the lactation stage that is at the same time and this can affect the yield and quality of the curd. In production focused on liquid milk, the age structure of the herd should be properly managed, as the goats in their third lactation or above have higher milk yields, regardless of breed. For cheese production, the PWI breed would be more suitable than PFI as the PWI goat milk contains less SCC and more components essential for milk processing, including caseins.

Key words: goat, parity, stage of lactation, milk yield

INTRODUCTION

Milk provides all the necessary energy and food ingredients for newborn mammals, ensuring appropriate growth and development. Hence, it is no surprise that breast milk is the ideal form of nutrition for human newborns (Lawrence, 1994). However, for older children, particularly in the one- to three-year-old age group, cow and goat milk are excellent sources of many nutrients and functional substances, especially fat, protein and calcium, and are superior to most drinks selected by some parents as an alternative to livestock milk (Agostoni and Turck, 2011; Lad et al., 2017; Collard and McCormick, 2021). The livestock milk consumption and dairy products is also regarded as an important part of a healthy and balanced diet in adults (FAO, 2013; Pereira, 2014).

Goat products contain more nutrients and less cholesterol compared to cow milk. They are recommended for the elderly, sick, convalescing and disabled. The milk and its products have a growing market share in developing countries, where they are basic food products, and high-quality cheeses are produced in the industrial world (Haenlain, 2004; Pereira, 2014; Bao et al., 2016). The world goat population currently is about one billion heads: 1,111,283,638 (FAO, 2021). In Poland, the vast majority are dairy goats population comprises dairy goats, whose population is estimated to be about 54 225 heads in 9 503 herds (ARiMR, 2020). It is estimated that around 90% of goat milk is processed by farm owners or agritourist

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farms, and into products delivered mostly to healthy or organic stores. Most Polish goats are White Improved (PWI) and Fawn Improved (PFI) breeds; they have been mated with Saanen and Alpine bucks, or their frozen semen imported from France, according to the coat color to improve productivity traits. Therefore, their productivity should be comparable with that of high-yielding breeds rather than local ones (Kaba and Bagnicka, 2009; Bagnicka et al., 2015).

At the beginning of lactation, goats experience an increased demand for nutrients. This condition is defined as metabolic load, defined as the burden imposed by the increasing milk synthesis and secretion (Sundrum, 2015). Goats demonstrate a similar net efficiency of metabolic energy for maintenance of life processes and milk production to cows and sheep, i.e. approximately 70% (Larson, 1978). As the low freezing point depression (FPD) value may mean a metabolic processes worsening in the udder, and somatic cell count (SCC) is a significant indicator of mastitis, both can serve as indices of homeostasis of the udder (Górecka-Bruzda et al., 2019; Le Maréchal et al., 2011).

Milk proteins are synthesized by similar mechanisms to most other proteins, and their main precursors are amino acids. Milk also contains varying amounts of fat, whose synthesis requires glucose, acetate, beta-hydroxybutyrate, triglycerides, chylomicrons and low density lipoproteins. In addition, two other key components of milk are water and lactose. Milk production is strongly dependent on lactose concentration: it has osmotic properties which increase the water content, and hence production (Summer et al., 2019; Widodo et al., 2021). The precursor of this main milk sugar is glucose, which undergoes numerous changes during production (Gorewit, 1988). On the other hand, while high lactose content increases water precipitation from blood to the udder, it thus dilutes the curd component content resulting in poorer yield (Garzón et al., 2023).

While goat and cow milks have similar overall compositions, they differ in protein, fatty acid, mineral and vitamin profile/content (Rubio-Martin et al, 2017). Production characteristics and efficiency of milk in cows, ovine and caprine animals are influenced by many factors including genotype, age (lactation number), stage and length of lactation, as well as production conditions (Zobel et al., 2015; Mattiello, 2016; El-Tarabany et al., 2018). Feeding and diet supplementation also can affect the productivity in goats; for example, the milk, fat, and protein production is influenced by organic selenium supplementation (Reczyńska et al., 2019). However, lipid supplementation resulted in increased content of fat in goat's milk but not in cow's (Chilliard et al., 2003).

The milk suitability for processing depends on its technological properties such as acidity, solid not fat (SNF), free fatty acid (FFA), protein and fat content. These factors affect the milk flavor and final dairy products such as yoghurt or cheese (Raynal-Ljutovac et al., 2005); for example, unsuitable acidity inhibits cheese production (Summer et al., 2019).

We hypothesized that breed, parity, and stage of lactation influence not only milk yield and its contents as it was shown in many studies but also milk technological properties and the homeostasis of dairy goat's udder.

The study aims to analyzed the effect of breed, parity and lactation stage on milk yield and its contents, as well as its technological properties, and the homeostasis indices of dairy goats' udders.

MATERIAL AND METHODS

The animal material was group of 24 dairy goats, kept in pens with unlimited access to water and salt licks. The nutrient requirements were established according to the system developed in IZ-BIP based on INRA recommendations (Brzóska, 2014) and were under the constant care of veterinarian. Goats were milked twice daily using a DeLaval milking system (Stockholm, Sweden). Two analogous groups were formed regarding breed (PWI and PFI) and parity: goats in second lactation, i.e. animals still under somatic development but not as intensive as in the first lactation, and goats in their third or higher lactation as animals with finished somatic development. The goats were kept in the same environmental conditions.

Milk samples were taken five times during lactations for two consecutive years: on day 7 (perinatal period), 30 (lactation beginning), 60 (lactation peak), 140 (mid lactation) and 200 (late lactation=preparing to dry off period). A total of 240 samples were collected. During morning milking, the yield of milk of each goat was recorded, and representative samples of whole udder milk were taken to determine their composition, *viz.* milk fat, total protein, casein, lactose, dry solids (TS), SNF, FFA, urea, citric acid contents, FPD, and milk acidity in Turner degrees, using the MilkoScan FT2

apparatus (Foss, Hillerød, Denmark). SCC was tested using a Bactoccount IBC_M (Bentley Instruments Inc., Chaska, MN, USA).

Before each milking, we also collected foremilk samples in a sterile manner, and the microbiological analysis was performed as described previously (Urbańska et al., 2021).

In the present study, the non-invasive procedures, in view of European directive 2010/63/EU and Polish laws related to ethics in animal experimentation, were used.

Statistical analysis

The analysis investigated the effect of breed (PWI, PFI), lactation number (2 or 3 or higher) and lactation stage on morning milk yield, fat corrected milk (FCM), value-corrected milk yield (VCM), energy-corrected milk (ECM), and milk components. The procedure MIXED of SAS (SAS/STAT, 2002-2010) was performed to study the variation with the Tukey-Kramer post-hoc test to compare the means. As the initial analysis did not indicate that the presence of bacteria in milk or year of sampling had any influence on goat milk parameters, these were not included in the final model.

The model used for yield traits was as follow:

$$y_{ijklmn} = \mu + a_i + B_j + SL_k + NrL_l + RB_m + e_{ijklmn} \quad (1)$$

y_{ijklmn} – trait value (milk yield in the morning milking, FCM, VCM, ECM); μ – overall mean; a_i – animal as random; B_j –breed effect as fixed (j=1, 2); SL_k –lactation stage effect as fixed (k=1,... 5); P_l – lactation effect as fixed (l=2, ≥4); RB_m – year of sampling effect as fixed (m=1,2); e_{ijklmn} – random error.

Milk yield adjusted to 4% fat content, fat and protein content and standardized energy content was calculated as follows:

$$FCM=0.4 * (Mkg) *15 * Fatkg \quad (2)$$

where: FCM – fat-corrected milk yield; Mkg – daily milk yield in kg; Fatkg – daily fat yield in kg;

$$VCM=-0.05*(Mkg)+8.66+Fatkg+25.98*Protkg \quad (3)$$

where: VCM –value-corrected milk yield; Mkg – daily milk yield in kg; Fatkg – daily fat yield in kg; Protkg – daily protein yield in kg;

$$ECM=M * [38.3 * Fat+24.2 * Protein +15.65 * Lactose +20.7] 3140 \quad (4)$$

where: ECM – energy-corrected milk in kg per day; M –daily milk yield in kg; Fat – daily fat yield in g per kg;Protein – daily protein yield in g per kg; Lactose – daily lactose yield in g per kg.

In addition to the effects shown in the statistical model above, the model for milk content analysis included milk yield in morning milking as fixed regression. SCC was subjected to natural logarithm transformation before analysis.

RESULTS

Microbiological analysis

Microbiological analysis revealed the presence of only environmental bacteria in 71% of samples. The most frequent bacteria were *S. xylosus* (in 15 samples), *S. gallinarum* (in 11 samples) and *S. caprae* (in 11 samples) (Figure 1).

Breeds

The mean milk yield in the morning milking obtained throughout the whole lactation was 1.51 kg (SD=0.47). Differences in ECM, FCM ($p \leq 0.01$) and VCM ($p \leq 0.05$) in morning milking were found between breeds but not for absolute milk yields. The PWI goats demonstrated higher milk yield than the PFI goats (Figure 2).

Milk composition differed between breeds (Figures 3, 4 and 5). The PFI goats demonstrated higher lnSCC, urea ($p \leq 0.05$) and FFA ($p \leq 0.01$), and lower protein ($p \leq 0.05$), casein, lactose, SNF levels ($p \leq 0.01$) compared to PWI goats.

Parity

Higher milk yield ($p \leq 0.05$) and FCM, VCM, and ECM ($p \leq 0.01$) were observed in milk from lactations three and above than in the second lactation (Figure 6).

Higher lnSCC, protein, and casein contents ($p \leq 0.01$), as well as higher acidity, were noted in milk from lactations three and above compared to milk from the second lactation (Figures 7, 8 and 9). The fat content did not differ between. Higher lactose ($p \leq 0.05$) and FFA ($p \leq 0.01$) contents were observed in the milk of younger goats.

Stage of lactation

Stage of lactation influences both absolute and relative milk yield in morning milking with the highest yield at the beginning of lactation (Figure 10). The differences in the content of fat, protein, casein, FFA, SNF, TS, urea, TS, SNF, and acidity were found over the course of lactation with the highest levels being observed in the perinatal period (day 7) (Figures 11 and 12). The urea highest level was observed at the lactation end (on day 200) (Figure 7c). No changes were found in FPD density or citric acid during lactation (Figures 7a and 7b).

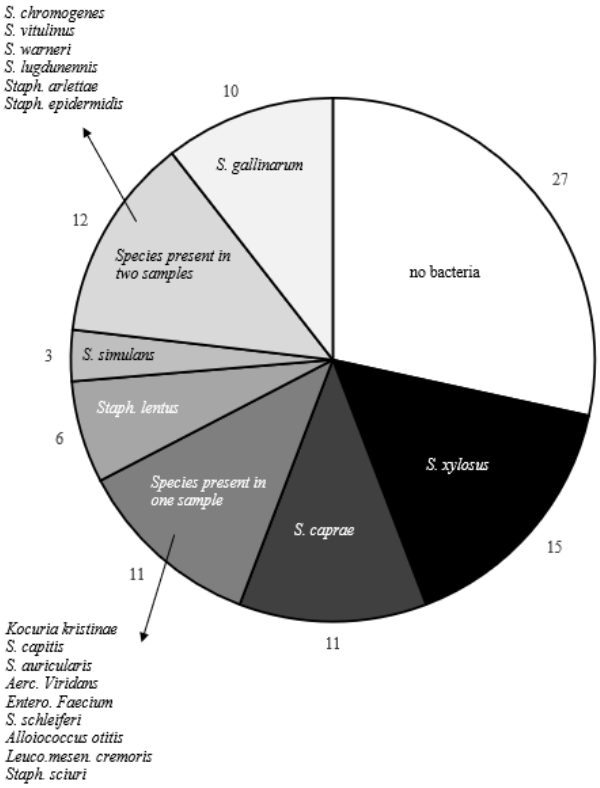


Figure 1. Bacteria prevalence in studied milk samples.

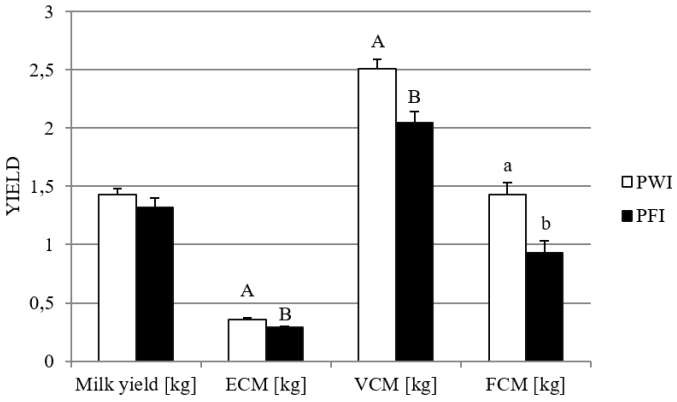


Figure 2. The mean least squares of milk yield, ECM, VCM and FCM, together with their standard errors (SE), in morning milking of PWI and PFI goats. A, B – differences at p≤0.01; a, b – differences at p≤0.05, no difference at p>0.05. ECM – energy-corrected milk yield; VCM – value-corrected milk yield; FCM – fat-corrected milk yield

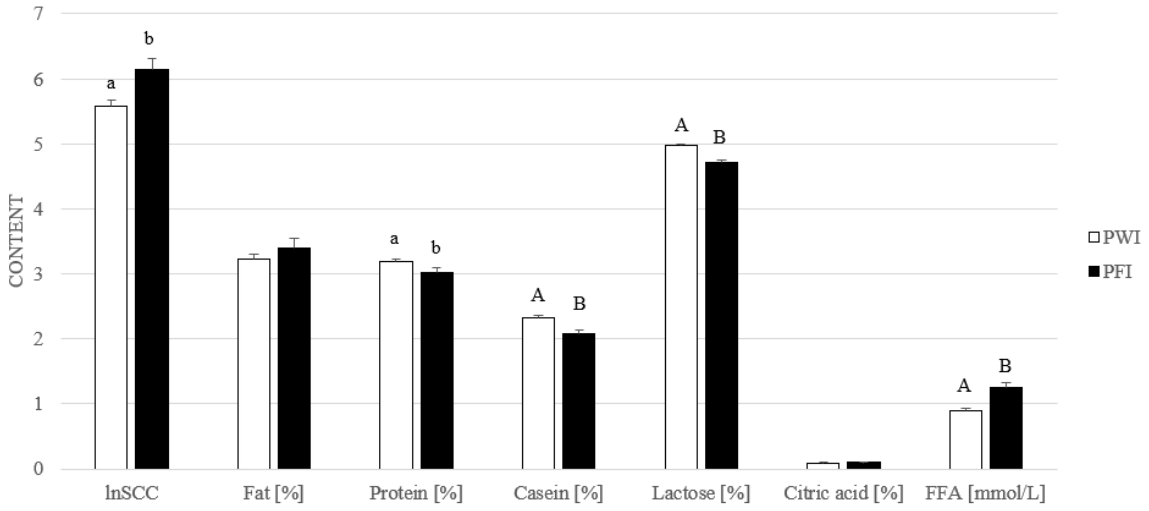


Figure 3. The mean least squares of lnSCC, fat, protein, casein, lactose, citric acid, FFA contents (along with their standard errors (SE)) in PWI and PFI goats' milk from morning milking. A, B – differences at p≤0.01; a, b – differences at p≤0.05; PWI – Polish White Improved; PFI – Polish Fawn Improved; lnSCC – the natural logarithm of the somatic cell count; FFA – free fatty acids

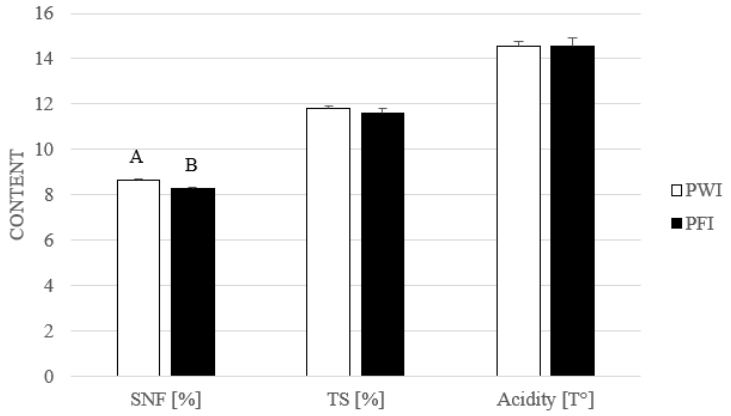


Figure 4. The mean least squares of SNF, TS content, acidity (along with standard errors (SE)) in PWI and PFI goats' milk from morning milking. A, B – differences at p≤0.01; PWI – Polish White Improved; PFI – Polish Fawn Improved; TS – total solid content; SNF – solid not fat content, T° - Turner's degree.

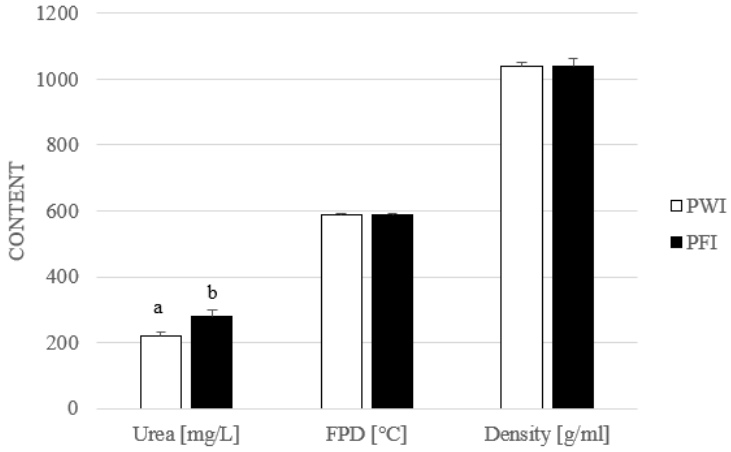


Figure 5. The mean least squares of urea, FPD, density (along with standard errors (SE)) in PWI and PFI goats' milk from morning milking. a, b – differences at p≤0.05; PWI – Polish White Improved; PFI – Polish Fawn Improved; FPD – freezing point depression

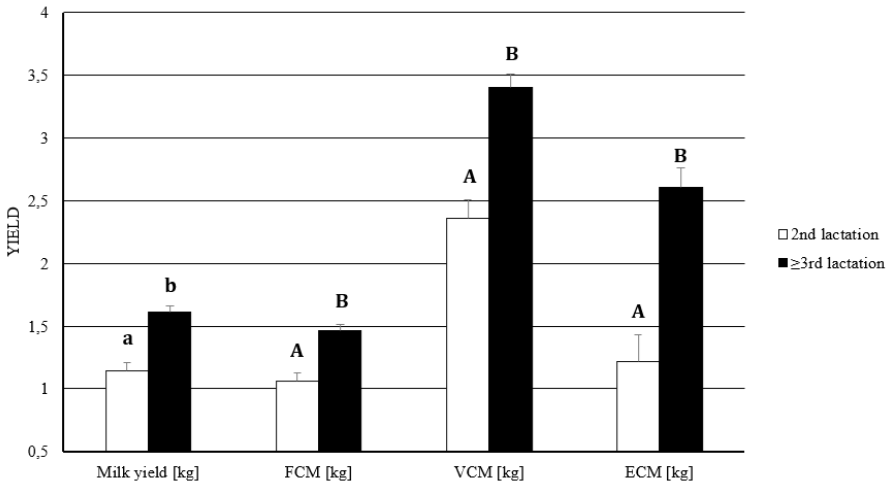


Figure 6. The mean least squares of milk yield in morning milking, ECM, VCM, ECM (along with standard errors (SE)) in morning milking in second lactation and ≥ third lactation. A, B - Mean values with different letters are significantly different at p≤0.01; a, b – Mean values with different letters are significantly different at p≤0.05; VCM – value-corrected milk yield; ECM – energy corrected milk yield; FCM – fat-corrected milk yield

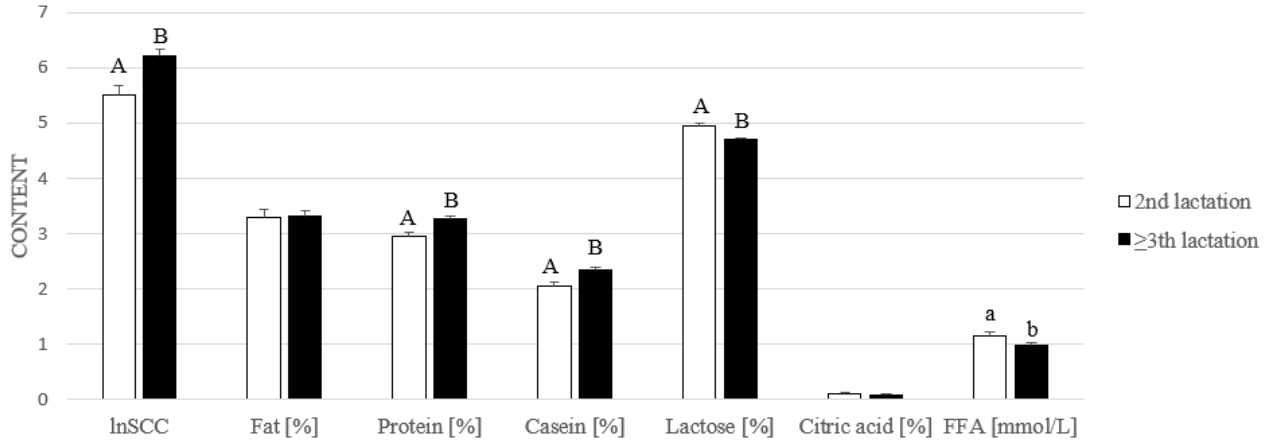


Figure 7. The mean least squares of lnSCC, fat, protein, casein, lactose, citric acid, FFA contents (along with standard errors [SE]) in morning milking in lactations 2 and ≥3. A, B – differences at p≤0.01; a, b – differences at p≤0.05; lnSCC – the natural logarithm of the somatic cell count; FFA – free fatty acids

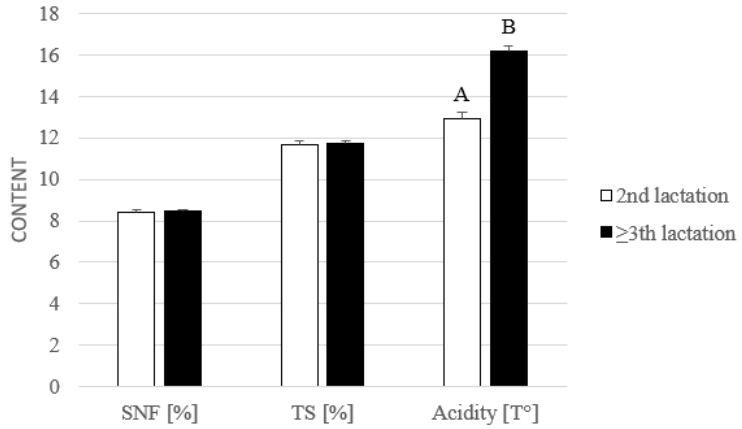


Figure 8. The mean least squares of SNF, TS contents, acidity (along with standard errors [SE]) in morning milking in lactations 2 and ≥3. A, B – differences at p≤0.01; TS – total solid; SNF – solid not fat, T° - Turner's degree

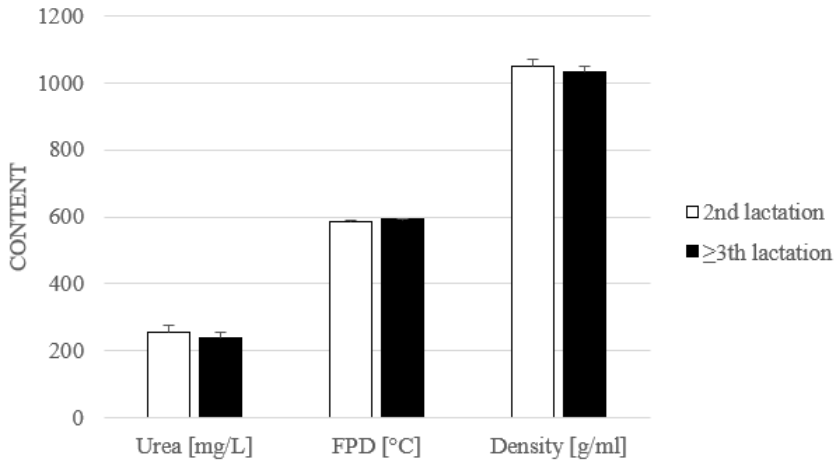


Figure 9. The mean least squares of urea, FPD, density (along with standard errors [SE]) in morning milking in lactations 2 and ≥3. FPD – freezing point depression

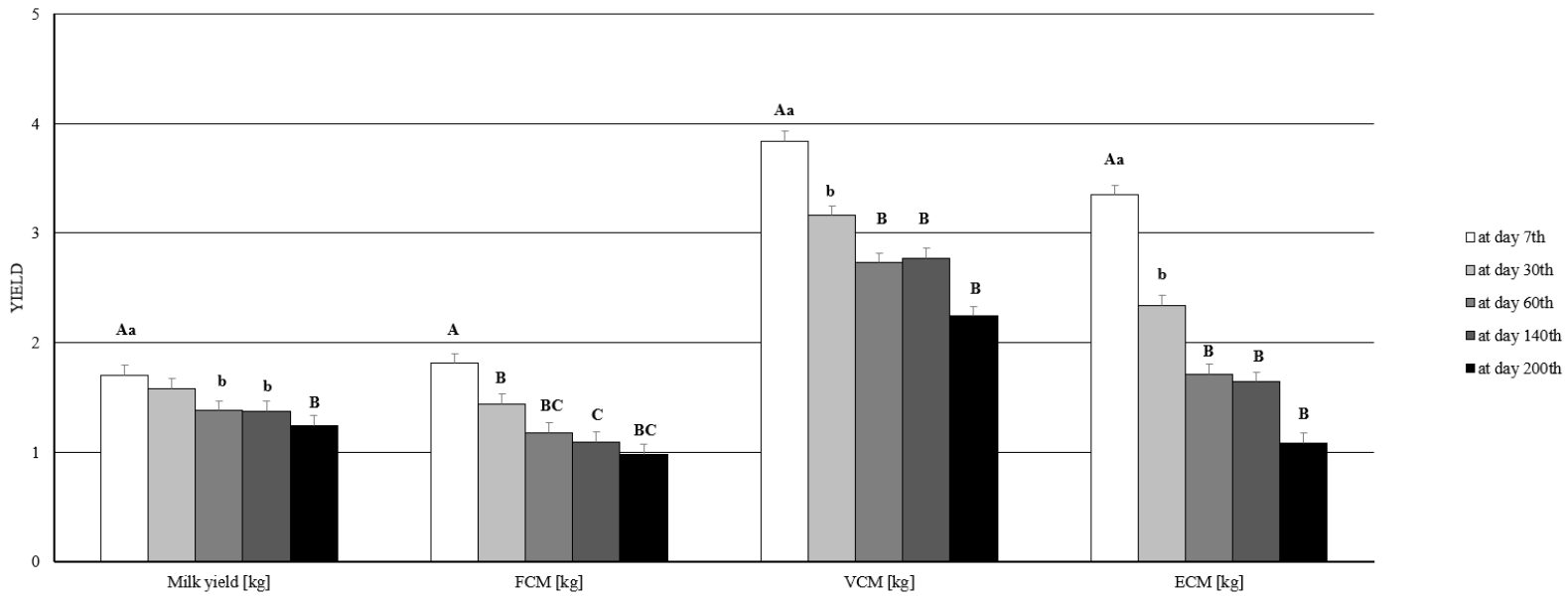


Figure 10. The mean least squares of ECM, VCM and FCM in morning milking during stage of lactation.
A, B - Mean values with different letters are significantly different at p≤0.01; a, b – Mean values with different letters are significantly different at p≤0.05; VCM – value-corrected milk yield' ECM – energy corrected milk yield; FCM – fat-corrected milk yield

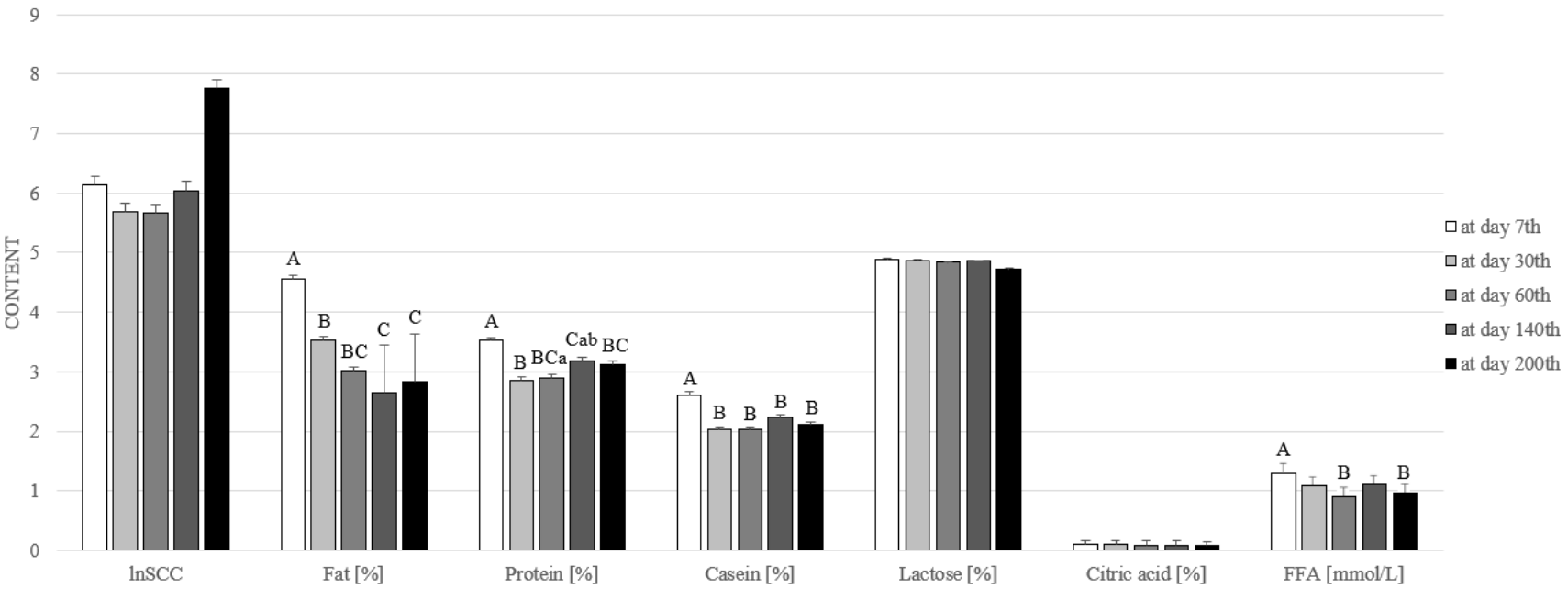


Figure 11. The mean least squares of lnSCC, fat, protein, casein, lactose, citric acid, FFA (along with standard errors (SE)) in morning milking according to stage of lactation.. A, B – differences at p≤0.01; a, b – differences at p≤0.05; lnSCC – the natural logarithm of the somatic cell count; FFA – free fatty acids

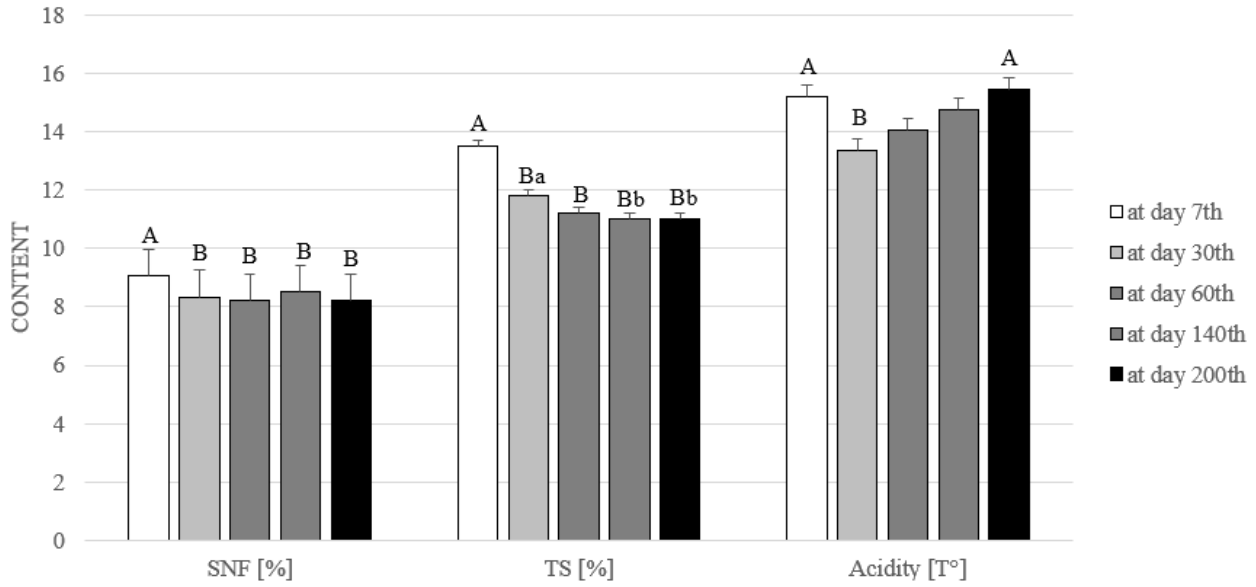


Figure 12. The mean least squares of SNF, TS, acidity (T° - Turner's degree) (along with standard errors (SE)) in morning milking according to stage of lactation. A, B – differences at p≤0.01; a, b – differences at p≤0.05; SNF – solid not fat; TS – total solid; FPD – freezing point depression, T° - Turner's degree.

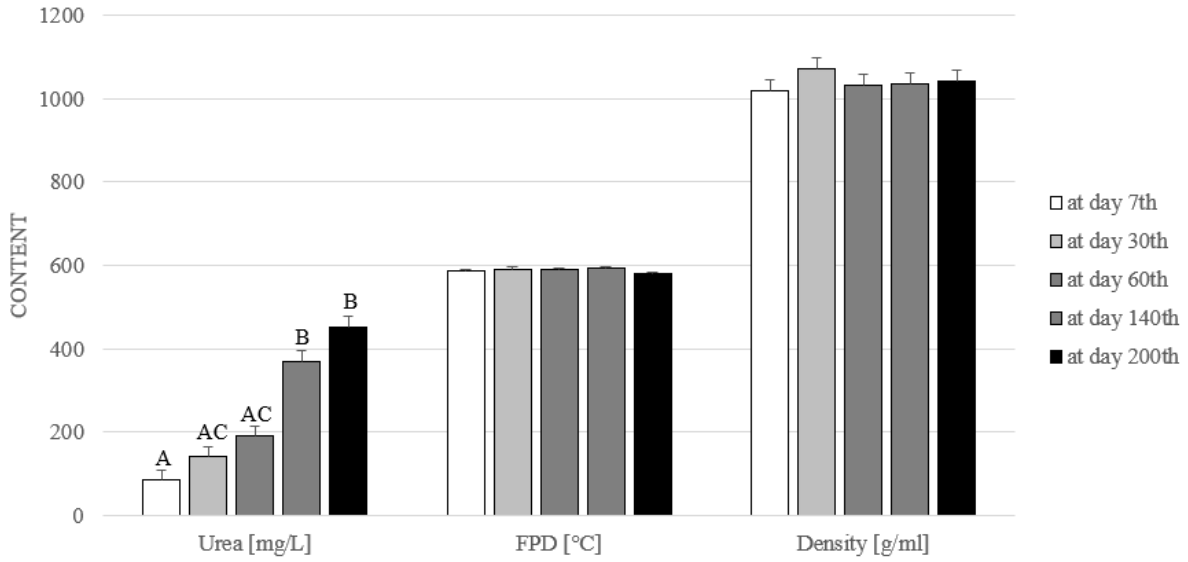


Figure 13. The mean least squares of urea, FPD, density (along with standard errors (SE)) in morning milking according to stage of lactation. A, B – differences at p≤0.01; FPD – freezing point depression

DISCUSSION

The bacteria which were found in milk samples were environmental strains but opportunists. These commonly colonize the mammary gland of goats (Urbańska et al., 2021) and in our case, their presence does not influence yield of milk or quality. Part of the studied parameters did not differ significantly between the two breeds. This lack of differences can be explained by their genetic similarity. A recent study explored the profiles of gene expression in somatic cells that were isolated from the milk, as well as from milk fat globules, or peripheral blood nuclear cells of goats at the peak of their third lactation using Bovine (V2) Gene Expression Microarray (4x44K) (Pławińska-Czarnak et al., 2019). The only observed differences concerned the expression of the agouti signalling protein that determines coat colour, which is conserved in many species. As noted in the

Introduction, the Polish breeds were improved using French Saanen or Alpine bucks, or their semen, which would influence the coat colour. However, higher content of protein and casein, while lower FAA in the milk of PWI goats indicate better suitability of their milk for processing.

Our results are consistent with those shown by Frattini et al. (2014), who did not identify any differences in absolute milk yield between Saanen and Alpine goats maintained in Italy. In the present study, differences in ECM, VCM and FCM were found between the studied Polish breeds, implying differences in the contents of some milk components what was confirmed in our study and is presented below.

Our findings indicate that lnSCC levels differed between the studied breeds. Similarly a previous study performed in the same herd but on milk collected from particular udder halves during three lactations as well as for 11 years found higher lnSCC in milk from PFI goats compared to PWI goats (Bagnicka et al. 2011; 2016). Currò et al. (2019) also report higher lnSCC in Saanen and Garganica goats than in other local breeds. In contrast, Zeng and Escobar (1996), do not note any differences in SCC between Alpine and Nubian goats. In the presented study, milk samples were taken from goats that were maintained in the same environment conditions; therefore, it is unlikely that SCC content was influenced by any external factors. High SCC level induces changes in the biochemical composition of milk; however, these probably does not influence the value of the milk for cheese-production (Raynal-Ljutovac et al., 2005; Giaccone et al. 2007)

Regarding lactose, our findings confirm that the milk from the PWI goats was richer in this sugar than that from the PFI goats. However, these results are inconsistent with those obtained in a previous study on this herd, in which no differences between breeds were recorded during three and 11-year observation periods (Bagnicka et al., 2011, Bagnicka et al., 2016). The higher lactose content was also accompanied by a lower lnSCC level, which is to be expected as the two are always negatively correlated (both are (sub)clinical mastitis indices); this suggests that the PWI goats appear to have healthier udders than the PFI goats, even though all animals were free from clinical mastitis. Similarly, Zeng and Escobar (1996) presented any differences between Alpine and Nubian goats maintained in Oklahoma and Arkansas (USA).

In the present study, it is possible that the higher lactose content observed in PWI goats may be due to individual animal preferences associated with social dominance, as PWI goats are larger than PFI goats and large size most likely favors dominance (Barroso et al., 2000). Such dominance would allow the PWI goats to approach the drinkers and licks more often than the smaller PFI goats. This phenomenon would be an interesting subject for a future behavioral study.

Cheese quality, its sensory value and fatty acid level, can also depend on goat breed (Olechnowicz and Sobek, 2008; Frattini et al., 2014). However, although the fatty acid profile was not analysed during this study, it can be seen that FFA concentration was lower in PWI than PFI goats. Whilst, Žan et al. (2006) report lower FFA levels in the Alpine goat's milk maintained in Slovakia compared to Saanen goats. FFA content not only is an indicator of a proper diet, it also highlights the presence of psychrotrophic bacteria and the quality of milk storage and handling. The FFA level in the pressed curd is associated with quality in some ripening cheeses as this increases significantly during storage (Weatherup at al., 1988).

Milk from Alpine and Nubian goats, two major dairy breeds in the United States, has been found to differ in SNF (Zeng and Escobar, 1996), casein, and TS contents (Soryal et al. 2005). However, no differences in TS and fat contents between breeds were found in the present study. This finding was confirmed by Bagnicka et al. (2015) regarding fat content. Frattini et al. (2014) also report the differences between Alpine and Saanen goats in fat content but not protein content. Hence, despite the genetic similarity between the two studied breeds and their identical environmental conditions, milk of PWI goats appears to have better curd yields.

The urea concentration in milk is affected by *inter alia* nutrition, breed, bodyweight, stage and lactation number, time of milking, season, production and milk composition and SCC in milk (Ljoljić et al., 2020). However, it depends mainly on the diet (Superchi et al., 2007). We were still found differences between breeds, even though the goats were maintained in the same conditions, fed the same diet, and maintained together in the same groups in the same pens. The higher level of urea observed in the milk of PFI goats may suggest a higher protein intake from forage due to eating much more hay which is better protein source than corn silage and concentrates. It could also be again connected with the dominance of PWI goats: PWI did not allow PFI to eat concentrate feed mixed with maize silage. However, again, this requires further behavioural study.

Milk acidity is connected mainly with the levels of its basic components. A lack of differences between breeds is probably connected with constant fat content (Strzałkowska et al., 2010a). As lower

titratable acidity is associated with a worse curd firming time and curd firmness, both breeds appear to produce milk of similar quality for cheese production regarding this parameter.

FPD indicates the freezing point of the milk and it is used in dairy production to confirm whether extra water has been added to the bulk milk. However, if individual milk samples are examined, FPD is influenced by access to licks and water (animals had *ad libitum* access), lactose content and chloride, Ca, K, Mg and phosphate levels; it can also be influenced by the number and stage of lactation, nutrition and udder health. As mentioned above, all animals were fed the same diet, they were in the same stage of lactation and were free from subclinical mastitis. Both groups were also analogous regarding parity. From these effects, only lactose content was higher, while lnSCC lower in PWI goat milk and they did not influence FPD.

Our results are in agreement with those of Rota et al. (1993), who also indicated higher milk yield among goats above third lactation. However, in a study of Polish dairy goat breeds, Bagnicka et al. (2015) report higher performance in the third, fourth and fifth and above lactations compared to the second one. Crepaldi et al. (1999) observed a similar effect in Alpine goats kept in Italy; they found milk yield to increase with subsequent lactation, with the highest yield recorded during the fifth lactation. Selvaggi et al. (2015) reported a higher performance in Italian Jonica goats in fourth lactation compared to goats in earlier lactations, Strzałkowska et al. (2010b) present similar results; they observed the highest productivity during the third and oldest animals compared to the first or second lactation.

Although goats reach reproductive maturity early, i.e. in around three months, their somatic development continues for another few years. In many cases, first lactation starts around the age of one year, while somatic development remains strong; therefore, during the first lactation, nutrients are needed for animal growth with the remainder used for milk synthesis (Kaba et al., 2009). Such competition for nutrients may limit the amount available for milk production. Radin et al., (2015) report lower performance of local breeds of dairy goats in the first lactation compared to older goats, but no dissimilarity in milk yield between the second and third lactations compared to older goats. This suggests that somatic development slows in goats older than two years and does not influence their productivity. As such, the productivity of dairy goats during their first lactation is treated as a separate trait to higher lactation yield (Bagnicka et al., 2015) and goats in the first lactation were excluded from this study. It has been proposed that milk yield increases with age because this is accompanied by increases in metabolic activity, number of secretory cells and the uptake of nutrients used in milk synthesis (Idowu and Adewumi, 2017). The milk lnSCC content was found to be highest in oldest goats, which is confirmed by Rota et al. (1993) and Bagnicka et al. (2011). Such changes in SCC level depend on the udder health. Older animals have undergone longer exposure to pathogens than the younger goats, and previous infections could result in higher SCC content (Jiménez-Granado et al., 2014).

The results regarding lactose content are consistent with those obtained by Rota et al. (1993) and Bagnicka et al. (2011), who also report higher lactose content in younger goats compared to those in third or higher lactation. Antunac et al. (2001) noted increasing lactation number to have a negative effect on milk yield, and on protein and fat level. Bagnicka et al. (2015) also noted differences in protein and fat content, which decrease with age of dairy goats. In contrast, Radin et al. (2015) did not report any differences in milk fat or protein content between subsequent lactations. Carnicella et al. (2008) report higher milk yield and lower protein, fat, and lactose content in the milk of Maltese goats in the fourth lactation compared to younger goats kept on farms in southern Italy. Moreover, Strzałkowska et al. (2010a) note higher protein, casein and FFA content in the first lactation in goats, and higher lactose content in the second lactation compared to older goats.

In the present experiment, the milk from younger goats demonstrated lower titratable acidity but higher FFA level. Bhosale et al. (2009) also noted an increase in acidity along with the lactation number. Titratable acidity affects the technological processing of milk, and high milk acidity caused by proliferation of acidic microflora may lead to quick coagulation.

Casein content is a more precise criterion for predicting and ensuring cheese yield than changes in protein percentage (Raynal-Ljutovac et al., 2005). The Polish breed goats in their third and higher lactation demonstrated higher casein contents than those in their second lactation, thus milk of older goats has better suitability for processing.

Many studies have shown a relationship between lactation stage and milk yield and its content (Zeng et al., 1997; Strzałkowska et al., 2009; Chartier et al., 2000; Strzałkowska et al., 2010a,b; Sánchez-Macias et al., 2014). Like Strzałkowska et al., (2010) our present studies noted the highest milk yield at the beginning of lactation. Previous studies have not provided any data regarding the effect of

lactation on FCM and VCM in goats; however, Jóźwik et al. (2012) study report lower FCM, VCM and ECM values at the end of lactation in Holstein-Friesian cows and Mba et al. (1975) found ECM to increase with lactation in goats.

In this study, fat, protein, casein, lactose, FFA, SNF, TS and urea levels were found to change with stage of lactation. While their levels were typically highest at the beginning of lactation, and then fell over its course, urea level rose systematically from the beginning of lactation to its end. Currò et al. (2019) found that the differences in contents of fat and protein in goat milk is related to lactation stage. Protein and fat lowest values were at the lactation peak, and highest at the end of lactation.

In goat milk, SCC is influenced not only by the presence of pathogenic bacteria but also by stage of lactation, changes in forage and supplementation (Jiménez-Granado et al., 2014; Reczyńska et al., 2019). Our present findings do not show any changes in lnSCC content during lactation. Similar results were obtained by Leitner et al. (2011), who showed no differences in SCC between the peak and the end of lactation. Sánchez-Macias et al. (2014) also observed a lack of changes in SCC during lactation in an Italian goat herd. The lack of any changes in SCC during lactation indicate that the studied goats were in good health and that udder homeostasis was preserved throughout lactation. Goat milk typically demonstrates SCC, with this tendency increasing as lactation progresses. An elevated SCC value, often caused by intra-mammary bacterial infection. The higher lnSCC alters the technological properties of milk (Podhorecká et al., 2021) and is inversely related to milk production. Moreover, SCC level is usually very high at the end of lactation, therefore it difficult to distinguish between healthy and diseased animals at this stage (Jiménez-Granado et al., 2014) but it was not our case.

Our data indicates higher levels of casein, fat and protein at the end of lactation, as previously noted by Leitner et al. (2011). In a study on the same goat herd but 10 years earlier, Strzałkowska et al. (2009) also showed no differences in lactose content over the course of lactation. Soryal et al. (2005) note higher fat, protein and casein contents during late lactations in Alpine and Nubian goats kept in the USA compared to the beginning and the lactation peak. In opposite, Zeng et al. (1997) indicate higher fat, protein and lactose content at the beginning of lactation compared to later stages in Alpine goats at the same location. A study of goats kept in Spain found the content of fat, protein and less lactose to be higher immediately after delivery compared to subsequent periods of lactation (Sánchez-Macias et al. (2014). These authors also report no change in milk acidity with the lactation stage, whereas Strzałkowska et al. (2010a,b) indicate milk acidity is higher at the lactation end than during earlier stages. We also observed changes in acidity in milk during lactation with the highest at the beginning and the end of lactation.

Milk taken at the end of lactation has a higher protein content, resulting in the milk curd being less firm, compared to early and middle lactation. Moreover, cheeses made from milk from early lactation are yellower than those from the others lactation stages and have a lower fat and dry matter content.

The highest levels of fat, protein, casein and FFA were observed at the beginning of lactation; it is likely that these differences are associated with metabolic changes. Fat content is one of the important milk technological properties due to it being a main component of cheese. Consequently, an increase in fat improves the yield of cheese. Fat content has also been found to be associated with the recovery of milk components such as protein, TS, water and energy in curd (Pazzola et al., 2019). The decrease in milk fat observed at the end of lactation is probably due to lipolysis, resulting from the action by either bacterial or endogenous enzymes in the udder (El-Tarabany et al., 2018).

TS content was also found to differ during lactation. This was confirmed by Strzałkowska et al. (2010a,b), who noted the highest content at the mid lactation, i.e. after 120 days, in milk of goats from the same herd but earlier generations. On the other hand, Zeng et al. (1997) observed higher SNF and TS content at the beginning of lactation in Alpine goats kept in the USA. Similarly, in goats kept in Spain, Sánchez-Macias et al. (2014) also found a higher SNF content just after delivery; in addition, urea content was lowest at the beginning of lactation, and increased over time. However, in contrast, Giaccone et al. (2007) found urea levels to fall between 30 and 60 days of lactation in Girgentana goats kept in Sicily, Italy. The urea content in milk also reflects the uptake of nitrogenous substances from feed (Khaled et al., 1999), and lower concentrations may be associated with a lack of metabolic burden (Osten Sacken, 1999). Both excessive and inadequate urea content indicates a poor protein to energy balance in the feed (Burroughs et al., 1975). Therefore, the observed low urea concentration in milk at the beginning of lactation can be explained by an insufficient amount of protein in the diet. In addition, goats may consume less forage just after delivery; urea will then increase with greater roughage intake in the later stages of lactation.

To summarize, in both breeds, lactose content peaked on day 7 after parturition, which is most likely related to metabolic changes and physiological load during parturition. The urea content of milk depends primarily on nutrition: the lower urea content noted at the beginning of lactation may be due to lower roughage intake in this perinatal period. Milk acidity is often associated with a change in TS, but this parameter did not differ between stages of lactation in this study. The cause for the increase in acidity could therefore be pasture feeding. Increases in ECM and VCM are higher values observed at the beginning of lactation, which both fell with the course of lactation.

Milk yield, FCM, VCM and ECM, and the levels of milk components (protein and casein) vary according to lactation number and breed. Among the studied animals, older goats and PWI goats have higher protein and casein levels. Milk taken at the beginning of lactation, as well as from older goats, is richer in milk components, which is important during the production of cheese and yoghurt.

Goats follow regular breeding seasons, and so lactation stage is closely related to the season of the year. Therefore, differences in milk yield and milk content over the course of lactation may depend on seasonally-available foods. The disadvantage is that unlike dairy cows, usually all the goats in a herd undergo similar changes related to the same lactation stage which more or less is simultaneously in all goats, which can strongly affect the curd quality and yield.

CONCLUSIONS

The technological parameters of goat milk strongly depend on breed, parity, and stage of lactation. Therefore, for the breeder, it is essential to select the proper breed and properly manage the herd depending on the desired aim of production. In production focused on liquid milk, the age structure of the herd should be properly managed, as the goats in their third lactation or above have higher milk yields, regardless of breed. For cheese production, the PWI breed would be more suitable than PFI as the PWI goat milk contains less SCC and more components essential for milk processing, including caseins.

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