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# Microstructure of goat milk

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As a raw material for dairy products, goat milk must be safe for human consumption. Bacterial contamination and somatic cell count are the main indicators of milk safety. Somatic cell count is used as an indicator of milk quality and udder health in dairy goats, although its interpretation is complicated by non-infectious factors, including seasonality, parity, farm-specific conditions and physiological factors. Compared with the threshold level for cows, the somatic cell count in goat milk is higher. The aim of the study was to identify morphological features of goat milk components (including somatic cells) using scanning electron microscopy. Sample analysis was performed on a scanning electron microscope equipped with a low vacuum chamber and an X-ray microanalysis system in the electron microscopy laboratory of Sumy National Agrarian University. Somatic cells, fat globules, protein micelles, fat-protein agglomerates, calcium salts, and foreign impurities were detected in goat milk samples during observation using a scanning electron microscope. A detailed analysis revealed that somatic cells have a dense consistency and clearly defined boundaries. The characteristics of typical morphological structures of goat milk are summarized, the morphological features of somatic cells of goat milk in scanning electron microscopy images are described. Milk secretion in goats occurs according to the apocrine type, as a result of which milk contains mainly fragments of the apical cytoplasm of secretory cells, rather than whole epithelial cells.

*Keywords*: goat milk; somatic cells; fat; casein; scanning electron microscopy.

## Introduction

Goat milk production has been the fastest growing sector of U.S. agriculture for the past 20 years. However, there is very little information on the quality management of goat milk. Despite the global importance of goat farming, there is a critical shortage of drugs specifically approved for the treatment of diseases in goats. The limited availability of species-specific veterinary pharmaceuticals has led to the widespread use of cattle drugs outside of approved indications, raising concerns about their efficacy, safety, and appropriate withdrawal periods in goats, and there are species-specific physiological differences, such as higher somatic cell counts and susceptibility to deep infections in goats (Zazharskyi et al., 2023; Gorden, 2025; Lima et al., 2025). As a raw material for dairy products, goat milk must be safe for human consumption. The number of mesophilic microorganisms, somatic cells and individual mastitis pathogens should be limited. A prerequisite for the production of milk of high hygienic quality is a healthy mammary gland (Kolchyk et al., 2024; Gancárová, et al., 2025).

Mastitis is a costly disease that affects dairy ruminants worldwide (Zigo et al., 2019; Sklyarov et al., 2020; Melnychuk et al., 2024). Somatic cell count is the most common tool for monitoring udder health, but in goats it is significantly influenced by non-infectious factors (Kurban et al., 2022; Smistad et al., 2025). Somatic cell count and the California mastitis test are common diagnostic tests for detecting subclinical mastitis, but their reliability is questionable due to the wider spectrum of somatic cells in goat milk (Zahumenská et al., 2024; Fonseca et al., 2025; Tibebu et al., 2025). Changes in somatic cell count in goat milk have been investigated at the gene expression level during the early mammary response of goats to experimental *S. aureus* infection (Cremonesi et al., 2012). Some scientists are trying to use mineral, vitamin, marine fat and plant essential oil supplements, as well as some by-products of the agricultural industry, to reduce the number of somatic cells in the milk of goats (Nudda et al., 2023).

Somatic cell count is used as an indicator of milk quality and udder health in dairy goats, although its interpretation is complicated by non-infectious factors, including seasonality, farm-specific conditions and physiological factors. Results of a study of 868 milk samples from 9 Norwegian dairy goat farms showed that somatic cell count peaked during the grazing period and then decreased, but remained elevated towards the end of lactation. Bacterial counts in individual milk samples showed a positive correlation with higher somatic cell counts, although this correlation varied considerably between farms and time periods. The presence of intra-mammary infection only partially explains the different correlations between somatic cell count and bacterial contamination. This indicates that the relationship between somatic cell count and bacterial contamination is influenced not only by infections, but also by management practices, environmental conditions and other factors on the farm (Desidera et al., 2025). The influence of different farm conditions and lactation stages on somatic cell counts has been reported by other scientists (Lianou et al., 2021; Zazharsky et al., 2024; Ali et al., 2025). Ogorevc et al. (2019) propose a validated genotyping analysis and confirm its relationship with somatic cell counts in goat milk.

Goats have an apocrine secretory system, which results in a high content of cytoplasmic cell particles and a large number of cell fragments in milk, which leads to exceeding the physiological limit of somatic cell counts (Paape et al., 2007; Fotina et al., 2018; Kasai et al., 2022). The aim of the work was to identify the features of typical morphological structures of goat milk in scanning electron microscopy images.

## Materials and methods

Analysis of goat milk by scanning electron microscopy (Karcz et al., 2011; Woodward & Wepf, 2019) was performed using a scanning electron microscope REM-106I ("Selmi", Ukraine) equipped with a low vacuum chamber and a X-ray microanalysis system in the electron microscopy laboratory of Sumy National Academy of Sciences.

Milk from healthy goats and animals with subclinical mastitis was centrifuged at 3000 rpm for 5–7 minutes to obtain a concentrated somatic cell pellet. The supernatant was removed, after which a fixative – glutaraldehyde in phosphate buffer was added to the pellet. Then the samples were resuspended and centrifuged again. This procedure was performed three times to increase the purity of the cellular material. The resulting somatic cell precipitate was washed with phosphate buffer to remove fixative residues, after which a dehydration step was performed in a gradient series of ethyl alcohol solutions (30%, 50%, 75%, 95%, 100% – 15 minutes each, then 100% alcohol – 1 hour). After dehydration of the samples in absolute alcohol and subsequent centrifugation, the test samples were applied to the surface of a carbon tape and dried in air. To ensure electrical conductivity, a thin layer of silver was applied to the surface of the samples by sputtering in a VVP-5 installation at a vacuum of about $10^{-5}$ mm Hg. The prepared samples (Fig. 1) were placed in the chamber of a scanning electron microscope and morphological analysis of the cells was performed (Walther et al., 2012; White, 2014).

**Results**

The following marks are located at the bottom of the scanning electron microscopy image (Fig. 2):

– WD = 13.9 mm – Working Distance – the working distance between the object and the lower edge of the objective lens of the electron microscope. The distance affects the depth of field and resolution;

– 20.00 kV – the accelerating voltage of the electron beam – 20 kilovolts. The higher the voltage, the greater the electron penetration and the better the signal from the internal structures;

– × 3.00 k – magnification – 3000 times;

– the scale mark and its length (20 µm) are shown on the right.

In the scanning electron microscopy image of goat milk (Fig. 2), you can see heterogeneous morphological structures.

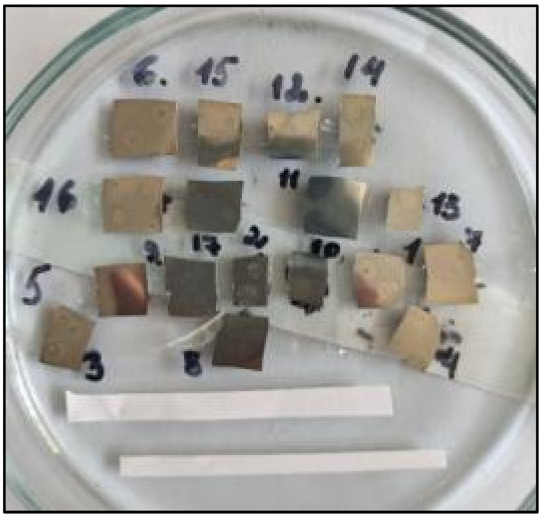


**Fig. 1.** Prepared samples

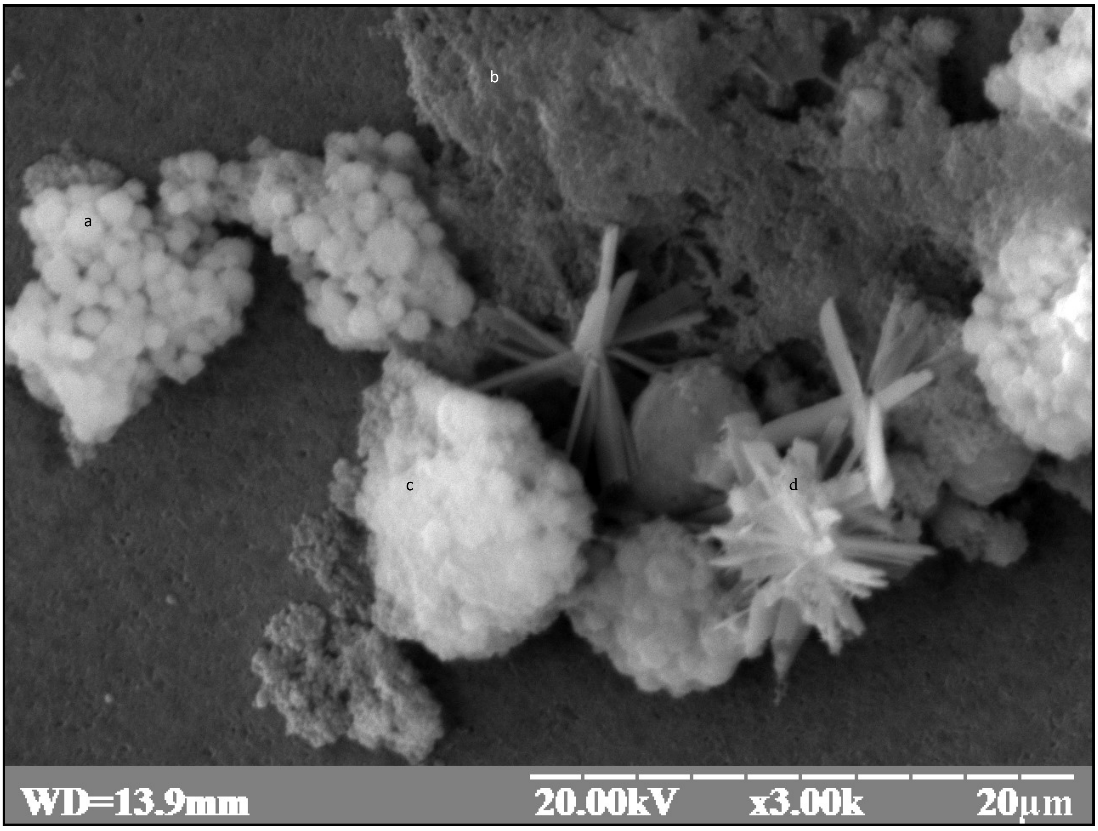


**Fig. 2.** Goat milk (scanning electron microscope): *a* – fat globules, *b* – casein micelles, *c* – fat-protein agglomerate, *d* – calcium salts

Fat globules in milk are rounded, light convex structures with a smooth surface of different diameters, some of them are slightly deformed or stuck together (Fig. 2a). They often form conglomerates (Fig. 2c) due to membrane destruction during sample preparation for scanning electron microscopy. Fat globules are the main characteristic structure in goat milk. Under a scanning electron microscope, fat globules have typical features: a smooth or slightly wavy surface (without clear cellular structures), a regular, almost perfectly round shape, size – 1–5 µm in goat milk. Fat globule membranes may be partially destroyed during preparation of the sample for scanning electron microscopy, which is why the surface appears uneven.

Casein aggregates or denatured protein complexes in scanning electron microscopy images often clump together after drying the sample and appear as amorphous and fine-grained formations (Fig. 2b). Calcium salts (calcium lactate) are formed during the drying of milk or its mineralization and in the images have the appearance of needle-like or star-shaped crystalline structures (Fig. 2d).

During the preparation of the sample for scanning electron microscopy (during drying, vacuum treatment, metal sputtering), the fat globule shell may be damaged. The fat phase comes out, leaving a cavity, so a ring-shaped structure or a "donut" appearance may be visible under the microscope (Fig. 3a).

Scanning electron microscopy images sometimes show foreign impurities that accidentally got in during sample selection or preparation. Textile fibers (from laboratory clothes, napkins, filter paper) have a characteristic appearance: an elongated shape, resembling a ribbon; a surface with grooves or microcracks; the fiber thickness is much greater than that of the protein or fat structures of milk. In the photo, the "ribbon" has a smooth, long and continuous shape (Fig. 3b), therefore it is identified as a foreign impurity (fabric fiber).

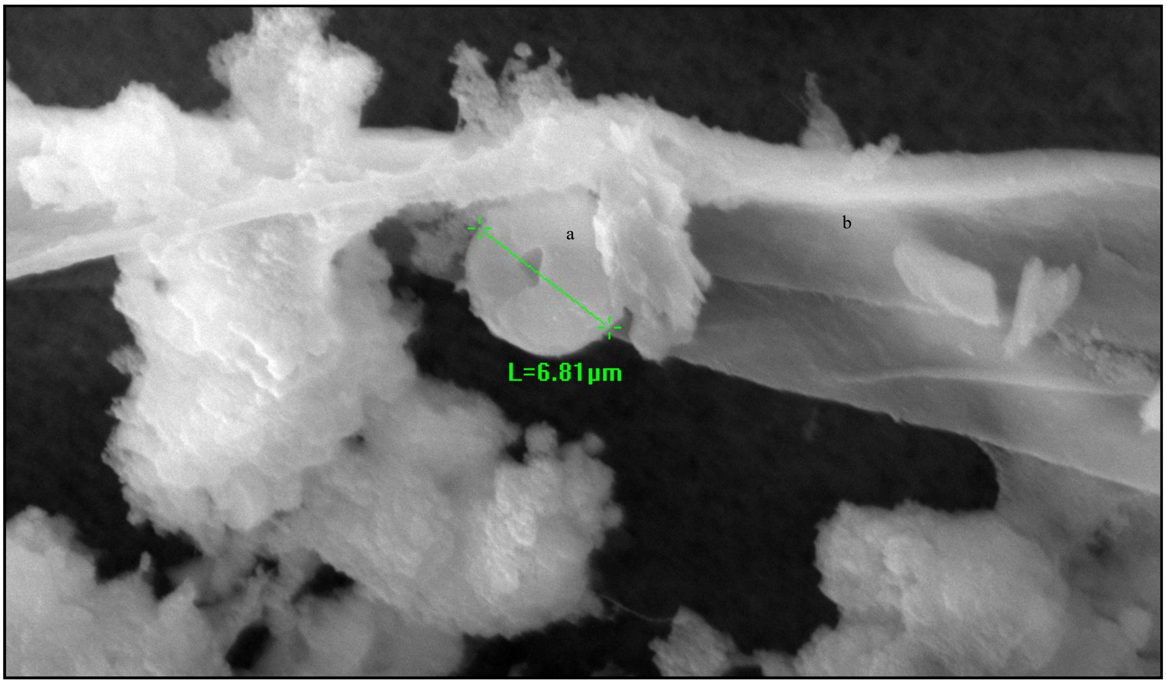


**Fig. 3.** Goat milk (scanning electron microscope): *a* – destroyed large fat globule, *b* – textile fiber (foreign impurity)

A picture of milk from a goat with subclinical mastitis is presented in Figure 4. Milk from animals with subclinical mastitis is characterized by a large number of somatic cells. In scanning electron microscopy images, somatic cells (epithelial cells or leukocytes) have an irregular shape, a flatter or elongated surface, sometimes with a "graininess" or structured relief (Fig. 4a).

In Figure 5, the background has a microrelief typical of dried protein or lipid aggregates. Numerous light (white) rounded structures are visible on the surface, located singly or in clusters. Spherical structures with uniform electron density and clear boundaries are characteristic of cell nuclei or whole cells (Fig. 5a). Darker areas and aggregates are casein granules or protein clots (Fig. 5b), which form a matrix in which other structures are "embedded". The dark areas between the structures are the space that in the liquid state was filled by the aqueous phase of the milk; after drying, this space looks like a cavity.

Scanning microscopy involves the use of an internal "electron caliper" of the microscope, which is used to determine the linear dimensions of objects. Figure 5 shows the measured diameters of somatic cells (3.60–5.32 µm) with a relative error of 4%. These cells have a spherical shape with clearly defined contours. The surface of the leukocytes is covered with smooth, randomly arranged outgrowths of irregular shape. The presence of these spines significantly increases the contact area between the nucleus and the cytoplasm, contributing to its stable position inside the cell. In rare cases, this may also indicate membrane residues remaining after the cytoplasm dries out under the influence of the electron beam.

Fat globules (milk fat globules – Fig. 6c) have the appearance of rounded or hemispherical structures with a smooth surface. The surface smoothness of the fat globules indicates the preserved MFGM (milk fat globule membrane), which is characteristic of fresh, unprocessed milk. Sometimes minor damage or flattening is visible (Fig. 6d) – a consequence of dehydration during sample preparation. Smaller granular or amorphous structures surrounding large globules are casein micelles or protein aggregates (Fig. 6b). Their surface is rough, they often stick together in clusters. Single larger formations with a relief surface, with microcavities or "folds", are somatic cells (Fig. 6a).

Somatic cells in Fig. 7 have typical features: the surface is granular, uneven, with microvilli or folds. The shape may be imperfectly round, sometimes irregular. The size is usually larger (4.88 and 4.78 µm) than that of fat globules. Often, depressions, membrane fragments or even signs of the nucleus are visible (in the case of partial destruction of the cell). The surface of somatic cells is not smooth, but granular, with microprotrusions – typical of living cells that have undergone dehydration before scanning. This appearance is characteristic of polymorphonuclear neutrophils – the main somatic cells in goat milk (Fig. 7a).

A round cell with a relatively smooth but not shiny surface, with minor microvilli, is identified as a lymphocyte (Fig. 7b). Lymphocytes are not very common among somatic cells of goat milk. The fine-grained background in the image is a protein matrix (casein or whey proteins – Fig. 7c), which forms a meshwork that holds fat globules in suspension.

At such a high magnification (×5000), various surfaces of cells and fat globules are visible. However, when studying with a scanning electron microscope REM-106I, it is impossible to visualize the cytoplasm and organelles of the cell, which is due to the peculiarities of the method – work in a vacuum chamber and the influence of a high-energy electron beam.

In the images of scanning electron microscopy at high magnification (×6000), the structure and shape of the cell are clearly visible, which allows us to determine the size of the nucleus and attribute the cell to a certain type (Fig. 8). The uneven, with pronounced relief (knobs, folds) surface of the cells is typical for somatic cells (especially leukocytes), while fat globules have a smooth spherical surface. The pronounced cellular contour, a volumetric, convex shape is visible, which distinguishes cells from protein or fat aggregates. The size of the cells is much larger (7.89 and 8.49 µm) than typical fat globules characteristic of goat milk. Large round or oval cells with a folded surface, with numerous protrusions, pseudopodia – this is how macrophages look in scanning electron microscopy images (Fig. 8).

A rounded structure, often with a granular or folded surface (Fig. 9a), with a diameter of 6–10 µm in scanning electron microscopy corresponds to somatic cells of milk. It is the "soft", uneven surface with micro-cavities or protrusions that determines that this is the cytoplasm or cell membrane, and not the surface of a fat globule. During sample preparation (fixation, drying), fat globules and protein aggregates can stick together, forming agglomerates of a protein-fat nature (Fig. 9c). The surface of such structures is usually heterogeneous: partly smooth, partly granular. Elongated, ribbon-like formations can be foreign impurities (for example, fabric or filter fibers) that accidentally got into the sample during preparation (Fig. 9d).

The image shows the normal microstructure of goat milk, characteristic of a natural sample (Fig. 10). Rounded structures with a diameter of approximately 1–4 µm are typical fat globules (Fig. 10c). They have a smooth or slightly flattened surface, sometimes with traces of partial sticking. Between them are small granular formations of 0.1–0.3 µm, which correspond to casein micelles (Fig. 10b) or protein-fat aggregates. They form the background and can bind fat globules together. A somatic cell with a diameter of more than 6 µm, a matte surface, with micropits or "wrinkles" protrudes above a field of smaller, smooth globules (Fig. 10a). It can be identified as a macrophage, since they are larger than other leukocytes and often retain a rounded but "crumpled" shape after dehydration.

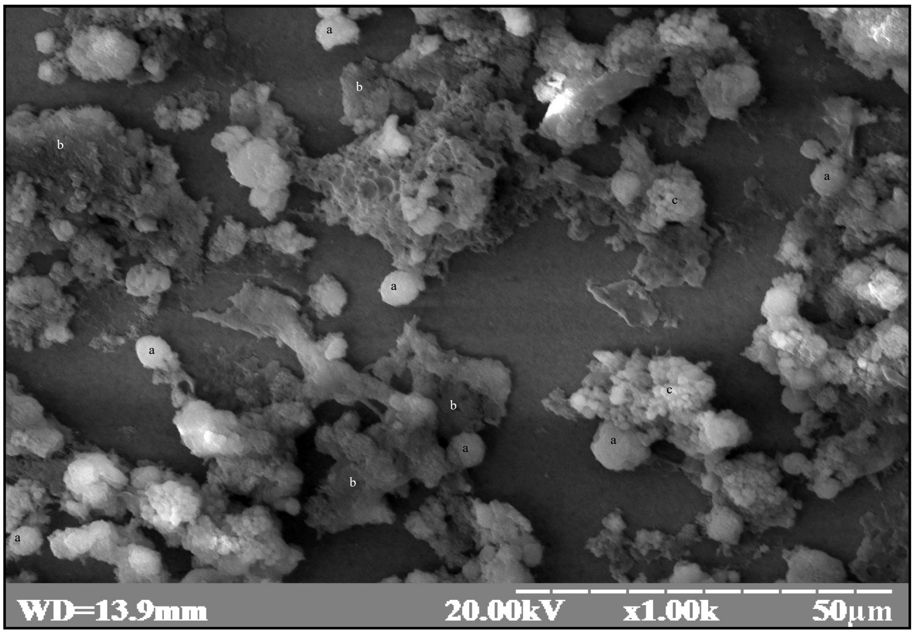


**Fig. 4.** Goat milk with subclinical mastitis (scanning electron microscope): *a* – somatic cell, *b* – casein micelles, *c* – fat globules

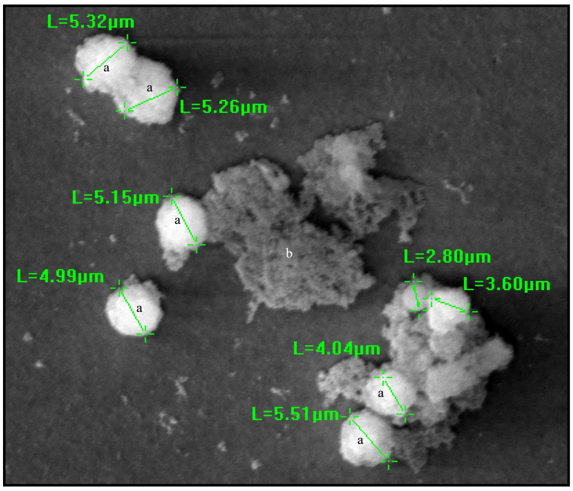


**Fig. 5.** Somatic cells in goat milk (scanning electron microscope): *a* – somatic cell, *b* – casein micelles

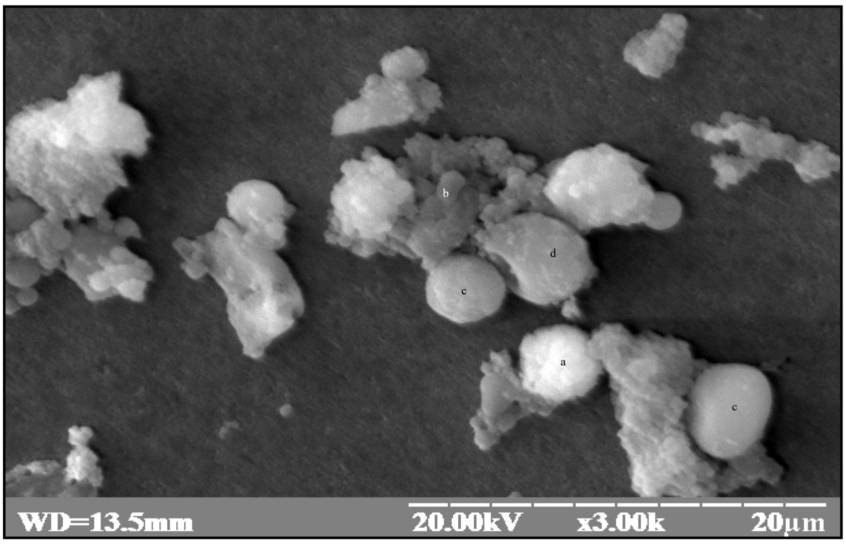


**Fig. 6.** Goat milk (scanning electron microscope): *a* – somatic cell, *b* – casein micelles, *c* – large fat globule, *d* – destroyed large fat globule

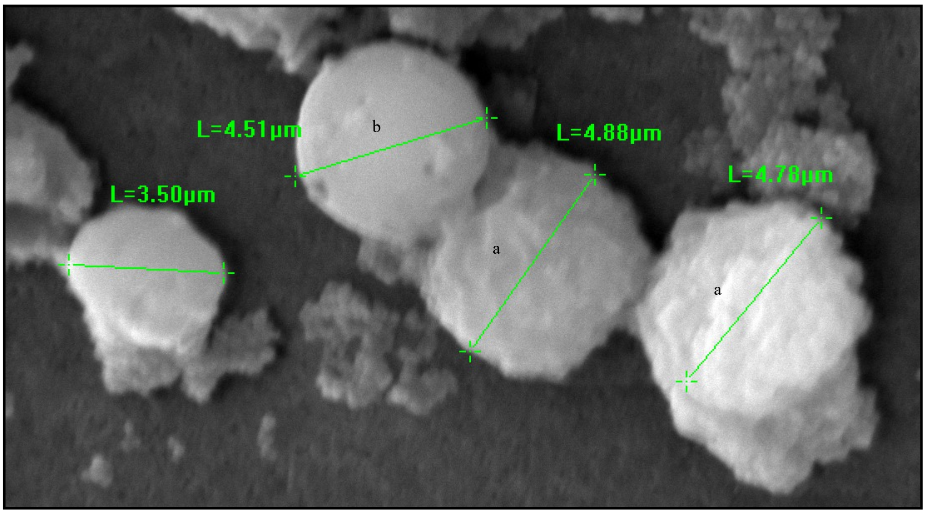


**Fig. 7.** Goat milk (scanning electron microscope): *a* – somatic cell (neutrophil), *b* – somatic cell (lymphocyte), *c* – casein micelles

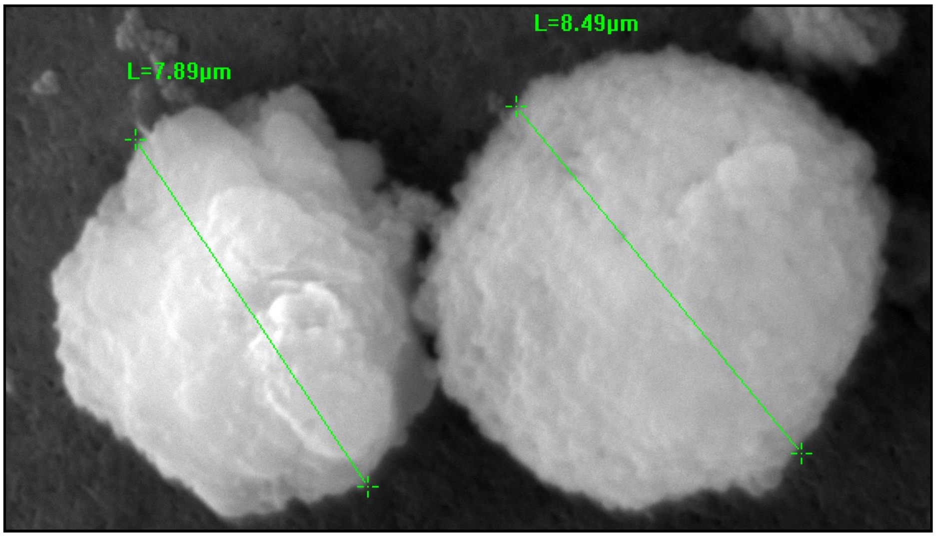


**Fig. 8.** Somatic cells in goat milk (scanning electron microscope)

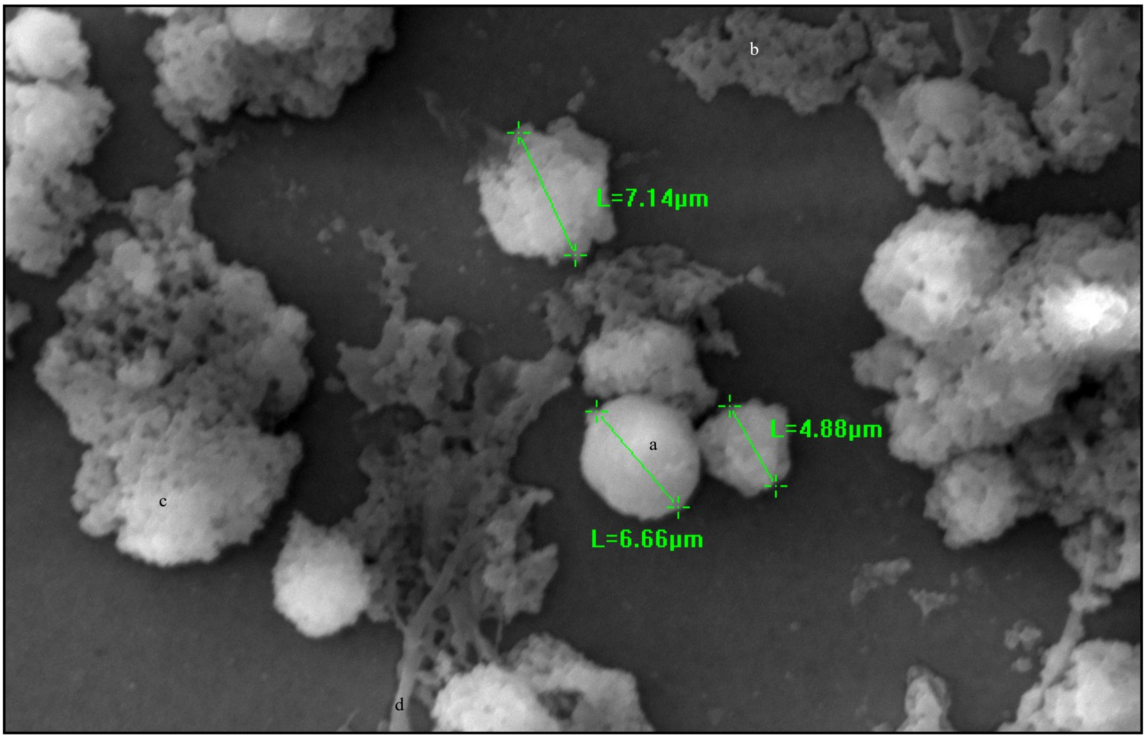


**Fig. 9.** Goat milk (scanning electron microscope): *a* – somatic cell, *b* – casein micelles, *c* – fat-protein agglomerate, *d* – foreign impurity

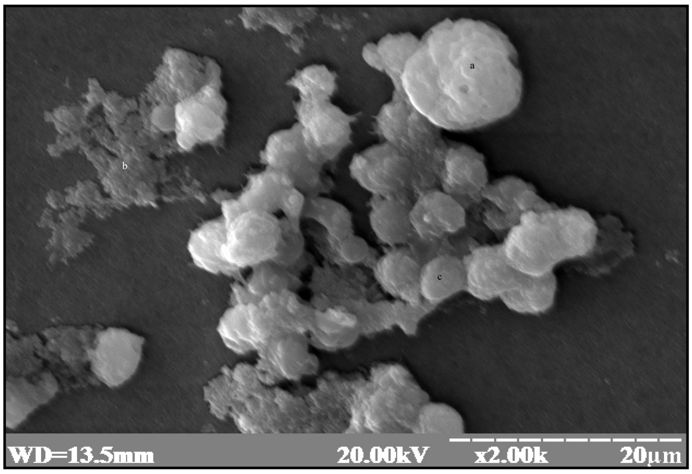


**Fig. 10.** Goat milk (scanning electron microscope): *a* – somatic cell, *b* – casein micelles, *c* – fat globule

**Discussion**

Somatic cells are an important component naturally present in milk and are commonly used as an indicator of milk quality and udder health in ruminants. Unlike other types of secretion, in the apocrine type of milk secretion in goats, individual components are not simply separated from the cells, but a significant part of the cytoplasm with a peripheral membrane is detached. This process leads to the release of rounded milk particles ranging in size from 5 to 30 µm into the lumen of the alveoli, which then enter the milk ducts.

The number of somatic cells is considered an indirect indicator of the hygienic quality of milk. An increase in the somatic cells count indicates inflammation of the mammary gland (Zazharska, 2024). This does not apply to goat milk (apocrine type of secretion), which naturally contains a higher number of epithelial cells and their fragments, resulting from epithelial desquamation and physiological regeneration of the mammary alveoli (Jiménez-Granado et al., 2014). For this reason, raw goat milk usually has a higher somatic cell count compared to cow milk.

European regulations set specific limits for somatic cell count for cow milk (Zazharska et al., 2024), as it is a well-established indicator of udder health, but do not have such criteria for goat or sheep milk. A positive correlation has been found between somatic cell count and total bacterial count with lactation number, indicating disruption of the udder epithelial tissue, as well as a greater susceptibility to bacterial infections in older goats (Salomone-Caballero et al., 2024).

There are currently no established thresholds for somatic cell count in goat milk at the legislative level (Zazharska et al., 2021). The US has set a maximum limit of $1000 \times 10^3$ cells/mL for goat milk. Kaskous et al. (2022) consider this threshold to be too high and, based on their own research, propose $750 \times 10^3$ cells/mL for goat milk. The scientists note that this proposed high threshold for the number of somatic cells in goat milk is due to the high concentration of cytoplasmic particles (Kaskous et al., 2022). Some authors (Silanikove et al., 2014) believe that grade A goat milk should contain up to $840 \times 10^3$ cells/mL, and goat milk with a content of more than $3{,}500 \times 10^3$ cells/mL should not be accepted for sale (Leitner et al., 2008). A high number of somatic cells significantly affects the technological parameters of goat milk. The most striking differences were found in milk with a somatic cell count above $1000 \times 10^3$ cells/mL, which was expressed in a decrease in thermostability, an increase in the level of protein, casein, chlorides and non-fat dry matter (Podhorecká et al., 2021; Zazharska, 2025).

Compared to cow's milk, somatic cell count in goats is higher and more dependent on physiological factors such as parity, stage of lactation and season. Therefore, somatic cell count is considered to be a less accurate indicator of intramammary infections in dairy goats than in cows, and there is no consensus on the threshold values for this indicator to recognize goats as infected. Smistad et al. (2021) found significant variability in somatic cell count associated with physiological factors, indicating that the threshold for detecting infected goats should be a dynamic threshold adjusted for number of lactations, stage of lactation and season (Smistad et al., 2021).

According to our own results, scanning electron microscopy allows the clear identification of goat milk components, including somatic cells. Scanning electrochemical microscopy was used by Kasai et al. (2022) to create a chip for somatic cells in cow's milk. This allowed them to distinguish between milk from healthy cows and those with mastitis (Kasai et al., 2022). The relationship between the increased number of somatic cells in raw cow's milk and the size of casein micelles was investigated using transmission electron microscopy. The results showed that an increase in the number of somatic cells leads to a decrease in the size of casein micelles with an increase in their aggregation. This study confirmed that increased proteolytic activity, different mineral composition of milk from animals with mastitis, can affect the properties of casein micelles (Moslehishad & Ezzatpanah, 2010).

Scanning electron microscopy images of goat milk show the microstructure of goat milk, which allows one to determine its composition. Fat globules in milk from different animals range in size from ~0.1 to ~15 µm (Bagga et al., 2024). Other sources indicate that globules in milk of small ruminants are generally smaller than in cow milk, i.e. large globules (>5 µm) are less common. According to Attaie & Richter (2000), in goat milk the average globule diameter is around 2.76 µm. Milk from French Alpine goats and Holstein cows was obtained from a tank immediately before analysis. The size of the fat globules was determined using laser particle size analysis. Individual fat globules in goat milk ranged from 0.73 to 8.58 µm in diameter. The average particle diameter, based on the volume to surface area ratio, was 2.76 µm, which was smaller than the average value of 3.51 µm for cow's milk, in which fat globules ranged from 0.92 to 15.75 µm in diameter. Ninety percent of the total particles found in goat's milk were less than 5.21 µm in diameter, while 90% of the total particles in cow's milk were less than 6.42 µm in diameter (Attaie & Richter, 2000). According to Fox (2022), the average diameter of fat globules in cow's milk is 3–4 µm. Fat globules appear as rounded, light or dark "balls" of varying diameters under scanning electron microscopy. They are the main characteristic structure in goat's milk. During dehydration, fat globules may change shape or coalesce, increasing their apparent diameter (Fox et al., 2017; Ji et al., 2019). Therefore, if the image shows rounded structures > 5 µm with a smooth surface and no evidence of cellular architecture, these are large or fused fat globules.

Many scanning electron microscopy images show a finely dispersed granular mass, which is the remnants of the protein matrix (casein or whey fraction) that holds the fat globules and somatic cells of the milk (Fox & McSweeney, 2017). During scanning electron microscopy, proteins in fresh goat milk appear as spherical, smooth, small particles (Li et al., 2020).

If the object has signs of a cellular nature (relief surface, uneven contours, possibly signs of membrane destruction), it may be a somatic cell. Somatic cells (epithelial cells or leukocytes) in scanning electron microscopy images have an irregular shape, a flatter or elongated surface, sometimes with a "graininess" or structured relief.

Small foreign inclusions may also be present - remnants of protein aggregates, microparticles or accidental contamination (for example, tissue fibers during sample preparation), which is reflected in Figures 3 and 9.

Based on our own research results and generalization of literature sources (Gallier et al., 2020; Sun et al., 2020; Fox, 2022), a table of characteristics of typical morphological structures of goat milk in scanning electron microscopy images (Table 1) has been compiled.

**Table 1**
Characterization of components of goat milk under a scanning electron microscope

| Sign | Fat globule | Casein micelle | Somatic cells |
|---|---|---|---|
| Size | 1–10 µm (more often 1–5 µm) | 0.05–0.3 µm, but can aggregate to 2–3 µm | 5–12 µm (depending on cell type) |
| Shape | almost perfectly round | very small granules clumped together | round, irregular-oval or amorphous, with protrusions or wrinkles |
| Surface | smooth, shiny, even, without protrusions | uneven, granular, amorphous, rough | uneven, with folds or granules, granular or folded, often with "wrinkles" or microgrowths |
| Structure | homogeneous, without inclusions | uneven surface, grainy structure, like "sand" between larger structures | may have partial tears, "stuck" with small protein particles |
| Number | many in the field of view | many in the field of view | cells in the field of view |
| Arrangement | evenly dispersed in a protein matrix, individual light "globules", with clear boundaries; often of different sizes, may clump together | form a matrix in which fat globules and somatic cells are located | may be solitary, sometimes adherent to fat globules or protein aggregates; often adherent to the protein matrix, "embedded" in it |

Somatic cell count and morphology are important diagnostic markers of mammary gland status. Somatic cells are a natural component of milk and consist of epithelial cells and leukocytes (Alhussien & Dang, 2018). Unlike cows (which have a merocrine type of secretion), goats secrete milk in an apocrine manner. This means that during milk secretion, part of the apical cytoplasm of the secretory cells of the alveoli is separated. Therefore, along with fat globules and secretion, membrane fragments, vesicles, cytoplasmic debris, but not necessarily whole cells, enter the milk.

Milk contains many types of leukocytes, such as macrophages, lymphocytes, and neutrophils, the ratio of which varies depending on the animal species. Neutrophils are the main type of leukocyte found in the milk of healthy goats (Paape et al., 2001; Bagnicka et al., 2011) compared to cow and sheep milk, which mainly contain macrophages (Alhussien & Dang, 2018). In mastitis, neutrophils are increased in cow and sheep milk, but not in goat milk, in which they still represent the dominant type (Paape et al., 2001; Bagnicka et al., 2011). This is consistent with other data: among the somatic cells of milk, the following cells can be distinguished: neutrophils, macrophages, lymphocytes, mammary epithelial cells, cell fragments and cytoplasmic particles. Polymorphonuclear neutrophils (40–80%) represent the main cell type in the milk of healthy, uninfected goats (Kaskous et al., 2022). In healthy goats, even without infection, a relatively high proportion of neutrophils is observed; this is not always a sign of inflammation (Smistad et al., 2024).

The morphological features of somatic cells in goat milk under a scanning electron microscope are presented in Table 2 based on our own observations and a generalization of literature sources (Bagnicka et al., 2011; Kaskous et al., 2022; Smistad et al., 2024). Intact epithelial cells (with a nucleus and an intact membrane) are rare in goat milk. They appear mainly: in cases of trauma or inflammation (mastitis); in cases of high epithelial cell turnover; or as random cells that have detached completely.

Cytoplasmic fragments are most often observed in goat milk – they appear on scanning electron microscopy images as irregular, loose formations, sometimes with membrane fragments and bubbles. Such fragments often have a rough or spongy surface – this is the result of the detachment of the apical part of the cell. These structures are not considered somatic cells in the strict sense, but they participate in the composition of the cell sediment and can affect the total number of somatic cells measured by instruments (Kaskous et al., 2022).

**Table 2**
Morphological features of somatic cells in goat milk under a scanning electron microscope

| Sign | Macrophages | Lymphocytes | Neutrophils |
|---|---|---|---|
| Fraction | 10–45 % | 5–10 % | most common somatic cells in goat milk 40–80% |
| Size | 8–12 µm | 5–8 µm | 6–10 µm |
| Shape | round or amoeba-shaped | almost perfectly rounded | rounded |
| Surface | uneven, folded, granular, with numerous protrusions, pseudopodia and depressions | relatively smooth but not shiny, may have slight microvilli | granular, with small bumps and porous areas; sometimes traces of degradation are visible |
| Appearance features | may look like "wrinkled balls" | round, compact, sometimes have slight membrane folds | surface is bumpy, often with visible granules or membrane deformations; may appear as "grainy balls" |

Thus, in goat milk, somatic cells are mainly leukocytes (neutrophils, macrophages, lymphocytes). Epithelial cells are rare and more often present as cytoplasmic fragments (apocrine particles). Intact epithelial cells may be present in mastitis, but are very rare in milk from healthy goats (Lianou et al., 2021).

## Conclusion

In goat milk samples, during observation using a scanning electron microscope, somatic cells, fat globules, protein micelles, fat-protein agglomerates, calcium salts, and foreign impurities were detected. A detailed analysis revealed that somatic cells have a dense consistency and clearly defined boundaries. A generalized characteristic of typical morphological structures of goat milk is presented, and morphological features of somatic cells of goat milk in scanning electron microscopy images are described. Milk secretion in goats occurs according to the apocrine type, as a result of which milk contains mainly fragments of the apical cytoplasm of secretory cells, rather than whole epithelial cells.

The authors declare they have no conflict of interest.

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