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Correlation between mammary gland morphology and gland cistern size to lactation milk yield in goat

Związek pomiędzy cechami morfologicznymi wymienia i wielkością zatok
mlecznych a wydajnością laktacyjną kóz

Summary. The studies involved 18 goats of White Improved and Saanen breed managed under the same breeding conditions. The measurements were taken once from an immobilized animal in the 4th lactation month, 2 hr before milking. The goats from breed groups were of the same age (third and fourth lactations). The following udder zoometric measurements were performed: udder floor length, width, depth, vertical semi-circumference, horizontal circumference, distance from the ground (milking stall), teat length, diameter, distance between teats. Besides, US measurements of gland cisterns were made. Correlation coefficients were calculated between the performed udder zoometric measurements and ultrasonographical ones of milk cisterns and daily milk production on the measurement day and throughout the lactation period. The studies showed that Saanen goat udders had greater depth, vertical semi-circumference, horizontal circumference as well as longer, wider teats placed at lower distance to the ground. The gland cisterns area in Saanen goat udders averaged 56.6 cm² and was higher by 21% as compared to White Improved breed goat group. Vertical semi-circumference, horizontal circumference and diameter of teats exhibit a strict correlation to daily milk yield (correlation coefficients were $r = 0.65$, $r = 0.57$, $r = 0.48$, respectively). The relationship between gland cisterns area and udder measurements showed positive, highly statistically significant correlations to depth, vertical semi-circumference and horizontal circumference, while a negative high significant dependence was noted between the cistern size and udder distance to the ground. The correlation of both cisterns size to lactation milk yield was $r = 0.46$.

Keywords: goat, udder measurement, USG gland cistern

INTRODUCTION

The growing interest in goats observed in Poland since 1980s resulted in development of goat raising and breeding. As for goat population number and milk efficiency Poland is found among the top ten European countries, thus being competitive with dynamically developing goat breeding and caprine milk processing in the neighbouring countries.

The goat milk production in Poland is estimated at roughly 3.8 t annually and this milk is recommended mainly for allergy sufferers. Another aspect of demand for goat milk is consumer knowledge on its nutritional and health benefits as caprine milk products are a natural source of vitamins and minerals. The available literature extensively discusses some of the factors influencing goat milk performance, especially nutrition, breed and female goat age, bodyweight or milking techniques. However, caprine mammary gland has received little attention in the research studies, in particular udder size and correlations between traits of the udder and milk cisterns and lactation milk production.

The objective of the present research was performance of the zoometric measurements of goat udder as well as ultrasound measurements of milk sinuses followed by analyses on the correlations between the obtained results and milk efficiency.

MATERIAL AND METHODS

The studies were carried out in the Didactic-Research Experimental Station in Bezek, a part of the University of Life Sciences in Lublin. The investigations included goats of two breeds: White Improved and Saanen (9 units each breed) at third and fourth lactation. The goats in the genetic groups were at the same age. A goat flock under study was provided with milk yield control based on a traditional method. The measurements were taken in the fourth lactation month once on an immobilized animal in a standing position, 2 hr prior to planned milking. The following measurements were taken: udder floor length (cm) – horizontal distance between the fore and rear udder attachment (by a zoometric compass); udder width (cm) – horizontal distance between udder external walls (by a zoometric compass); udder depth (cm) – vertical distance between the lateral point of udder attachment and the base of teat (by a zoometric compass); vertical semi-circumference (cm) – in the vertical plane the circumference not completely closed from the previous udder attachment, through its floor to the rear attachment (by a zoometric tape); horizontal circumference (cm) – the widest horizontal udder circumference across the udder (by a zoometric tape); udder-ground (milking stall) distance (cm) – vertical distance between the right teat base and the ground (by a zoometric tape measure); teat length – distance from the base of teat to its distal end (by a ruler); teat diameter – measured at the mid-point of the right teat length (by a caliper); distance between teats (cm) – distance between external sides of teats measured in half of their length (by ruler).

Besides, there was performed ultrasound measurement of the gland cisterns using the USG EchoBlaster 128 with a sector probe C3.5/40/128Z of 3 MHz frequency. The probe was applied to the middle of the caudal part so that it could penetrate the area of udder cistern opening into teat canal. The obtained images were stored in the computer's memory in the form of the disc files (a bit map). The measurements of udder cisterns cross-section area were made using the computer program MultiScan ver. 808.

The results were analyzed statistically by one-factor variance analysis (SAS 9.1.3). There were calculated correlation coefficients between the zoometric measurements of udder and ultrasonographic of gland cisterns and daily milk yield on the measurement day and during the lactation period.

RESULTS AND DISCUSSION

Mean values of udder morphological traits are summarized in Table 1. The research results indicated that the udder of Saanen breed goat compared to the mammary gland of White Improved goat was deeper, of higher vertical semi-circumference and horizontal circumference. However, the differences that reached ca 10% appeared to be statistically insignificant. Whereas, there was stated a significant correlation between the breeds in terms of the udder – ground distance and teat length. Longer teats and smaller udder-ground distance were recorded for the Saanen breed goats. These does were characterized by a greater teat diameter as well (by 0.8 cm), but the difference was not significant statistically. Similar results of morphological traits of the udder and teats were reported by Pawlina *et al.* [2005]. Horak and Gerża [quoted after Pawlina *et al.* 2005] observed progressive enlargement of the udder with advancing age of goats.

Table 1. Morphological traits of udder (cm) of studied goat breeds
Tabela 1. Cechy morfologiczne wymion (cm) badanych ras kóz

Udder measurements Wymiary wymienia	Saanen Saaneńska		White Improved Biała uszlachetniona	
	mean średnia	SD	mean średnia	SD
Floor length Długość podstawy	14.7	4.6	14.3	3.9
Width Szerokość	14.5	2.3	15.2	2.6
Depth Głębokość	21.1	4.1	19.1	4.1
Vertical semi-circumference Półobwód pionowy	52.5	7.4	47.3	2.0
Horizontal circumference Obwód poziomy	54.2	6.8	50.0	7.6
Distance to the ground Odległość od podłoża	29.3*	1.0	33.2*	3.6
Teat length Długość strzyka	6.8*	1.9	5.2*	0.9
Teat diameter Średnica strzyka	3.5	1.0	2.7	0.7
Distance between teats Rozstaw strzyków	14.0	3.8	15.4	2.7

*P ≤ 0.05

According to the studies of Bosek *et al.* [2003b], measuring udder volume is a challenge. However, the authors found that this udder trait is best described by the following characteristics: horizontal circumference, vertical semi-circumference, depth and width; the correlations established between udder volume and the aforementioned traits reached high values ranging within the 0.70–0.86 interval.

A critical element of goat udder estimation proves to be appropriate conformation of the mammary gland. The doe's udder should be long and wide, show ample capacity with symmetrical, evenly balanced udder halves, the texture should be pliable and elastic. Fully functional, uniform size teats of cylindrical shape are desirable. While a low hanging, pendulous udder with unsymmetrical halves contributes to low milk efficiency.

Appropriate conformation of the udder and teats facilitates efficient milking and makes them more resistant to traumas associated with a machine milking system.

Ultrasound technique is widely applied in the zootechnical studies to examine morphology of the ruminant mammary gland. The results of US technique used by Strzetelski *et al.* [2004] indicated some significant interdependences between a percentage of udder secretory tissue and milk performance in cows.

Table 2. Gland cistern size in studied goats (cm²)
Tabela 2. Wielkość zatok mlecznych wymion badanych kóz (cm²)

Breed Rasa	Left cistern Zatoka lewa		Right cistern Zatoka prawa		Total gland cistern Cała zatoka mleczna	
	mean średnia	SD	mean średnia	SD	mean średnia	SD
Saanen Saaneńska	29.98	12.9	26.50	9.3	56.48	17.6
White Improved Biała uszlachetniona	23.00	10.7	23.40	8.3	46.4	18.6

Table 2 presents descriptive statistics of the size of the udder cisterns in the investigated goats of Saanen and White Improved breed. The Saanen does had mammary glands with milk cisterns varying in size. The left gland cistern appeared to be greater by 13% compared to the right one; a difference of ca 3.5 cm² was statistically insignificant. Mammary cisterns in White Improved goats were of the same area. The overall estimation of the investigated trait showed that the gland cisterns area in the Saanen goats was 56.5cm², being greater by 21% as against the White Improved goats.

Inequality in udder cistern area, as determined in the present researches, implies that total area of both cisterns should be taken into consideration while performing estimation

Table 3 presents correlation coefficients between udder measurements and daily milk yield. Strong correlations were established between the udder width and its depth, vertical semi-circumference and horizontal circumference. The coefficients value was found within the $r = 0.52$ up to $r = 0.64$ interval.

Similar high dependences were noted between udder horizontal circumference and its length ($r = 0.52$), width ($r = 0.64$) and depth ($r = 0.65$) and vertical semi-circumference ($r = 0.91$). In each analyzed case, the coefficients values proved to be positive and highly statistically significant.

Correlation with udder length and width was negative for distance to the ground ($r = -0.31$), alike with udder depth ($r = -0.66$), vertical semi-circumference ($r = -0.70$) and horizontal circumference ($r = -0.74$) for distance to the ground. Importantly, this relationship was highly statistically significant. Similar research results were reported by Bosek and Pawlina [2003] and Bosek *et al.* 2003a, 2003b].

Strong, positive and statistically significant dependences were also established between the udder measurements (depth, vertical semi-circumference, horizontal circumference) and teat measures (length, diameter and spacing).

Table 3. Correlation coefficients (r) between udder measurements and daily milk efficiency in goats
Tabela 3. Współczynniki korelacji (r) pomiędzy wymiarami wymienia i wydajnością dzienną kóz

Udder measurements Wymiary wymienia	Width – Szerokość	Depth – Głębokość	Vertical semi-circumference Półobwód pionowy	Horizontal circumference Obwód poziomy	Distance to the ground Odległość od podłoża	Teat length Długość strzyka	Teat diameter Średnica strzyka	Distance between teats Rozstaw strzyków	Daily milk production Dzienna wydajność mleka
Floor length Długość podstawy	0.34	0.21	0.43	0.52*	-0.33	0.31	0.45	0.36	0.45
Width Szerokość		0.55*	0.52*	0.64**	-0.31	0.42	0.31	0.56**	0.29
Depth Głębokość			0.68	0.65**	-0.66**	0.51**	0.47*	0.33	0.23
Vertical semicircumference Półobwód pionowy				0.91**	-0.70**	0.70**	0.59**	0.60**	0.65**
Horizontal circumference Obwód poziomy					-0.74**	0.63**	0.55**	0.59**	0.57**
Distance to the ground Odległość od podłoża						-0.41	-0.41	-0.12	-0.60**
Teat length Długość strzyka							0.77**	0.51*	0.42
Teat diameter Średnica strzyka								0.38	0.48*
Distance between teats Rozstaw strzyków									0.29

** $P \leq 0.01$ * $P \leq 0.05$

The studies of Mavrogenis *et al.* [quoted after Bosek *et al.* 2003] implied that the udder measurements: circumference and depth may be considered as descriptive of udder volume. The authors state that heritability estimates for these traits are high, thus could be proposed as a selection objective to effectively improve milk production.

The relationships between daily milk efficiency and udder measures in goats were also of great interest. Correlation value between daily milk production and vertical semi-circumference, horizontal circumference and teat diameter proved to be highly statistically significant and amounted to $r = 0.65$; $r = 0.57$; and $r = 0.48$, respectively. According to expectations, negative correlation was noted only to distance to the ground (stall) ($r = -0.60$).

Table 4. Correlation coefficients between udder traits and lactation milk yield and gland cistern size
Tabela 4. Współczynniki korelacji pomiędzy cechami wymienia i wydajnością laktacyjną a wielkością zatoki mlecznej

	Floor length Długość podstawy	Width – Szerokość	Depth – Głębokość	Vertical semi-circumference Półobwód pionowy	Horizontal circumference Obwód poziomy	Distance to the ground Odległość od podłoża	Teat length Długość strzyka	Teat diameter Średnica strzyka	Distance between teats Rozstaw strzyków	Lactation milk production Wydajność laktacyjna
Gland cistern Zatoka mleczna	0.14	0.33	0.87**	0.69**	0.60**	-0.72**	0.51*	0.47	0.35	0.46*

** $P \leq 0.01$ * $P \leq 0.05$

Table 4 presents correlation coefficients between milk cistern size and morphological traits of the udder. The highest, positive and highly statistically significant correlation values were determined between gland cisterns size and depth ($r = 0.87$), vertical semi-circumference ($r = 0.69$) and horizontal circumference ($r = 0.60$), while a negative correlation ($r = -0.72$) to distance to the ground.

Positive and statistically significant correlation was stated between milk cisternal area and lactation milk yield which averaged $r = 0.46$.

Similar research results were reported by Junkuszew *et al.* [2005]. The authors found that correlation between udder cistern area and milk efficiency was 0.4 (the left cistern), 0.7 (the right cistern) and 0.55 (total area of both cisterns). Repeatability of the measurement ranged between 0.7–0.8. The studies of Wójtowski *et al.* [2002] established a slightly lower level of this correlation value 0,359. Importantly, the measurements were taken 4hr after goat milking, which in their opinion, was likely to affect the calculated correlation values.

The available Polish literature tends to give scant attention to the feasibility of ultrasonic imaging application for small ruminants mammary gland monitoring. Bearing in mind the importance of the problem, the research studies should be continued, techniques and skills at ultrasound image read-out further upgraded so that the obtained results could have practical implications for breeding programs involving improvement of udder morphological traits.

CONCLUSIONS

1. Differentiation in the udder morphological traits in respect to goat breed was found. Mammary glands of Saanen goats were characterized by greater depth, vertical semi-circumference, horizontal circumference as well as longer, wider teats placed at smaller distance to the ground.

2. There was shown a positive, high significant correlation between daily milk yield and horizontal circumference, vertical semi-circumference, whereas a negative correlation to distance to the ground. The most important udder measurements for dairy goat evaluation prove to be horizontal circumference, vertical semi-circumference and teat diameter. Gland cisternal area of Saanen goats was greater by 21% compared to White Improved breed goats.

3. Estimation of correlations between milk cistern size and udder measurements indicated positive, highly statistically significant relationships with depth, vertical semi-circumference and horizontal circumference, while negative highly significant dependence with gland cistern size and distance to the ground. Correlation between both cisterns size and lactation milk yield was $r = 0.46$.

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Streszczenie. Badania przeprowadzono na 18 kozach rasy białej uszlachetnionej i saaneńskiej utrzymywanych w jednakowych warunkach środowiska hodowlanego. Pomiary wykonano jednorazowo w czwartym miesiącu laktacji na stojącym unieruchomionym zwierzęciu, 2 godziny przed planowanym udojem. Kozy w grupach rasowych były w jednakowym wieku (trzecia i czwarta laktacja). Wykonano następujące pomiary zoometryczne wymienia: długość podstawy wymienia, szerokość wymienia, głębokość wymienia, półobwód pionowy, obwód poziomy, odległość wy-

mienia od stanowiska, długość strzyka, średnica strzyka, rozstaw strzyków. Ponadto wykonano również pomiary ultrasonograficzne zatok mlecznych aparatem USG. Uzyskane wyniki opracowano statystycznie za pomocą jednoczynnikowej analizy wariancji (SAS 9.1.3). Obliczono wskaźniki korelacji pomiędzy wykonanymi pomiarami zoometrycznymi wymienia i ultrasonograficznymi zatok mlecznych a dobową wydajnością mleka w dniu pomiarów i w okresie całej laktacji. Badania wykazały, że wymiona kóz saaneńskich charakteryzowały się większą głębokością, półobwodem pionowym, obwodem poziomym oraz że strzyki były dłuższe, szersze i usytuowane w mniejszej odległości od stanowiska udojowego. Powierzchnia zatok mlecznych w wymionach kóz saaneńskich wynosiła 56,5 cm² i była większa o 21% niż w wymionach rówieśnic rasy białej uszlachetnionej. Półobwód pionowy, obwód poziomy i średnica strzyków wykazują ścisłą zależność z wydajnością dobową mleka (współczynniki korelacji przyjęły wartość odpowiednio $r = 0,65$; $r = 0,57$; $r = 0,48$). Związek pomiędzy powierzchnią zatok mlecznych a pomiarami wymienia wykazał dodatnie, wysoko istotne statystycznie zależności z głębokością, półobwodem pionowym i obwodem poziomym, natomiast ujemną wysoko istotną zależność odnotowano między wielkością zatoki a odległością wymienia od stanowiska. Korelacja pomiędzy wielkością powierzchni obu zatok a wydajnością laktacyjną wyniosła $r = 0,46$.

Słowa kluczowe: kozy, pomiary wymienia, USG zatok mlecznych