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FUNCTIONAL PROPERTIES OF THE UDDERS OF SWISS BREED COWS IN OPEN-AIR EXERCISE YARD CONDITIONS

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The article presents the results of a study on the functional characteristics of the udder in Brown Swiss cows, analyzed in relation to age and udder shape. The study was conducted at the private enterprise "Agro-Novoselivka 2009" (Kharkiv District, Kharkiv Region) during 2024–2025, where the animals were kept year-round in open-air exercise yards.

It was established that, under a three-times-daily milking regimen, both milk yield and the rate of milk flow increased with the age of the animals. Specifically, from the first to the second lactation, individual milking yields showed a statistically significant increase, ranging from 1.1% to 8.9% ($P < 0.001$), with the exception of the evening milking. Similarly, the rate of milk flow increased by 8.7%–14.4% ($P < 0.05 – P < 0.001$).

The study determined that, throughout the day, as the yield per milking increased, the duration of the milking process increased proportionally. Calculations revealed a positive correlation between the yield per milking and the rate of milk flow; for both the first and second lactations, the correlation coefficient was positive, ranging from 0.163 to 0.644 ($P < 0.001$).

Furthermore, the calculations established an inverse correlation between the duration of the milking process and the rate of milk flow. During the first lactation, the correlation coefficient was moderately negative, ranging from -0.415 to -0.665 ($P<0.001$); during the second lactation, it ranged from -0.321 to -0.825. In all cases, only a trend of dependency was observed ($P<0.1$).

The study established that 68% of the examined Brown Swiss cows had a bowl-shaped udder, while 32% had a cup-shaped udder. It was determined that cows with a bowl-shaped udder outperformed those with a cup-shaped udder in terms of single-milking yield (by 1.3–3.4%) and milk flow rate (by 4.1–7.9%) during both the first and second lactations. However, the differences were not statistically significant in any of the cases. For animals with both udder shapes, a positive correlation (ranging from 0.166 to 0.938) was found between single-milking yield and the intensity of milk flow.

It has been demonstrated that Brown Swiss cows, when kept in open-air exercise yards within the Forest-Steppe zone of Ukraine, exhibited adaptive traits to the management system and the moderately continental climate; this contributed to favorable functional characteristics of their udders.

Keywords: Brown Swiss breed, cows, functional characteristics, udder, single-milking yield, milk flow intensity, udder shape, bowl-shaped, cup-shaped, open-air exercise yards

ФУНКЦІОНАЛЬНІ ВЛАСТИВОСТІ ВИМ'Я КОРІВ ШВІЦЬКОЇ ПОРОДИ В УМОВАХ ВІДКРИТИХ ВИГУЛЬНИХ МАЙДАНЧИКІВ

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В статті наведено результати досліджень по вивченню функціональних властивостей вим'я корів швіцької породи в залежності від віку та різних форм вим'я в умовах цілорічного утримання на відкритих вигульних майданчиках у ПП «Агро-Новоселівка 2009» Харківського району, Харківської області у 2024-2025 роках.

Встановлено, що за умов триразового доїння продуктивність і інтенсивність молоковіддачі тварин з віком збільшувалися. Так, від першої до другої лактації разові надої на протязі доби вірогідно збільшилися в межах від 1,1 до 8,9 % (P<0,001), за винятком вечірнього доїння. Аналогічно підвищилася і швидкість молоковиведення на 8,7-14,4 % (P < 0,05 - P<0,001).

Визначено, що впродовж доби із зростанням разового надою час доїння пропорційно збільшувався. Розрахунками визначено додатну кореляційну залежність між разовим надоєм та інтенсивністю молоковіддачі. Як в першу так і в другу лактацію коефіцієнт кореляції був додатним 0,163-0,644 (P < 0,001).

Розрахунками встановлено обернену кореляційну залежність між тривалістю доїння та інтенсивністю молоковіддачі. В першу лактацію коефіцієнт кореляції був середній від'ємний і дорівнював від -0,415 до -0,665 (P<0,001, у другу лактацію дорівнював -0,321…-0,825, в усіх випадках визначена тільки тенденція залежності (P<0,1).

Дослідженнями встановлено, що 68 % дослідного поголів'я корів швіцької породи мали ванноподібну форму вимені, 32 % – чашоподібну. Визначено, що

корови з ванноподібною формою вимені перевершували аналогів з чашоподібною формою за разовими надоями на 1,3-3,4 % і швидкістю молоковіддачі на 4,1-7,9 %, як в першу так і в другу лактації. Проте різниця у всіх випадках була не вірогідною. У тварин з обома формами вимені визначено додатну кореляцію між разовими надоями та інтесивністю молоковіддачі на рівні 0,166-0,938.

Доведено, що корови швіцької породи за утримання на відкритих вигульних майданчиках в умовах Лісостепу України проявили адаптивні властивості до умов технологічного утримання та помірно континентального клімату, що обумовило їх добрі функціональні властивості вим'я.

Ключові слова: швіцька порода, корови, функціональні властивості, вим'я, разовий удій, інтенсивність молоковіддачі, форма вим'я, ванноподібна форма, чашоподібна форма, відкриті вигульні майданчики.

Introduction. The development of modern dairy farming is inextricably linked to enhancing the genetic potential for livestock productivity and realizing this potential within specific production environments (Ladyka, 2024). Achieving these goals requires the implementation of modern housing technologies and the creation of conditions that allow for the optimal expression of the animals' biological traits, while ensuring that the resources invested in dairy production yield a return (Hladii, M. V., 2021; Pishchan, S. H., 2017).

Within the milk production process, the milking of cows is the most complex, labor-intensive, and critical stage. Its primary objective is to ensure the timely removal of milk from the mammary gland while fostering favorable conditions for continued milk secretion (Lutsenko, M. M., 2025).

For a long time, the global dairy industry has focused on the issue of ensuring cow comfort. Modern farms are transitioning to loose housing systems, intelligent climate control, and soft resting stalls. These measures reduce animal stress and improve milk quality. Providing comfortable housing conditions for the animals is a key priority. In the Netherlands, over 96% of cows are kept in loose housing systems; in the USA, the figure is approximately 80%, and in Germany, it exceeds 70% (Moloko i Ferma, 2025).

According to reports by Voitenko, S. L., et al. (2022) The increase in milk yield and milk fat content in Ukrainian Red-and-White dairy cattle by 2.5–3.4% and 2.1–4.8%, respectively, is attributed to the natural-climatic zone of operation, while an increase of 7.7–9.3% in yield and 4.4–6.3% in fat content is attributed to the influence of Holstein genetics. This factor must be taken into account when developing a high-yielding herd within a specific natural-climatic zone of Ukraine. Ruban S. et al. (2024) note that Ukraine's predominantly flat landscape features a temperate continental climate, divided into five agricultural-climatic zones. They suggest that loose housing in compost-bedded barns during the winter is a promising approach, as it aligns with animal welfare standards.

In their study on housing systems for Ukrainian Black-and-White dairy cattle, Krupelnytskyi T. V. and Sokoliuk V. M. (2023) determined that tie-stall housing limits the implementation of innovative organizational and technological solutions, highly efficient mechanization, and modern milking equipment. The research findings indicate that, under tie-stall conditions, the average annual milk yield per cow was 4.4% higher (7,902 kg) than under loose housing; however, the milk fat content was 0.2% lower (3.7%), resulting in a total milk fat yield that was 132 kg (0.3%) lower.

Under conditions of intensive exploitation, the functional properties of a cow's udder are influenced by a complex set of factors: genetic factors (breed, parentage and progeny, and the level of inbreeding); technological factors (management conditions, the

level and type of feeding, and age at first calving); and the animal's phenotypic characteristics (level of milk production, body and udder conformation, and disease resistance) (Pishchan, I.S., 2021).

In breeding programs for dairy cattle, special attention is paid to the development of the mammary gland (Iliashenko, H.D., 2014; Ponko, L.P., 2014). The udder is one of the most important conformation traits in dairy cattle. Furthermore, the morphological characteristics and shape of the udder are closely linked to a cow's level of milk production (Vedmedenko, O.V., 2019; Kohut, M.I., 2018; Kuziv, M.I., 2021). The milk-ejection reflex is a complex physiological process that involves changes in muscular tone, the contraction of the myoepithelial cells surrounding the alveoli, and the relaxation of the teat sphincter. In conventional milking systems, a well-established protocol for preparing cows for milking is employed, which ensures the effective activation of the milk-ejection reflex (Lutsenko, M., 2021).

According to the technological requirements for milking cows, the preparatory and preventive procedures consist of immersing each teat in a cup containing a cleaning solution, wiping it dry with a towel, stripping the first streams of milk, and attaching the teat cups. These actions are intended to trigger a full milk-ejection reflex – a process that begins with the stimulation of the udder’s receptors and concludes with the movement of milk from the alveolar region into the udder cisterns (Pishchan I.S., 2016a).

The comparative analysis of the functional properties of the udder during machine milking (Pishchan I.S., 2016c) has shown that a cow’s readiness for milk ejection is established during the interval between milkings. It is determined by the degree to which the udder is filled with milk, as well as by a combination of conditioned and unconditioned stimuli that form a specific operational routine. Some researchers consider readiness for milking to be a behavioral act involving the preparation of the entire organism for milk ejection.

It is well established that the entire organism participates in the process of milk production; however, the mammary gland is the specific organ responsible for its synthesis. In the context of modern intensive livestock farming, the value of a breed is assessed not only by its productive traits but also by the animals' adaptability to industrial production technologies. Therefore, the morphological traits and functional properties of the cow’s udder are becoming key criteria for selection, facilitating the development of high-yielding animals adapted to the requirements of modern production systems (Kosior L.T., 2012; Stavetska R.V., 2016; Kuziv M.I., 2021).

Consequently, in countries with well-developed dairy industries, the selection process, alongside primary productivity traits, places significant emphasis on the morphological and functional characteristics of the udder, as well as the animal’s suitability for machine milking (Gašparík M., 2019; Carlström C., 2016).

The animal serves as the primary biological component of the production system; therefore, all technological solutions must align with its physiological needs. In this context, it has become necessary to investigate the functional properties of the udder in Brown Swiss cows, specifically as an indicator of their comfort and adaptability to being kept in open-air exercise areas.

The purpose of the article was to investigate the functional udder traits of Brown Swiss cows in relation to age and various udder shapes, under conditions of year-round open-air exercise yards.

Materials and methods. The study was conducted in 2024–2025 at the agricultural enterprise PE "Agro-Novoselivka 2009," located in the Kharkiv district of the Kharkiv oblast. The subjects were 25 Brown Swiss cows in their first and second lactations.

All animals were kept year-round in open-air exercise yards with a permanent (deep) straw bedding, situated in the southern part of the Forest-Steppe zone. The daily allowance of bedding material is 3 kg of straw per head, increasing to 5–7 kg during periods of severe frost. The yards are divided into sections and equipped with feed troughs, heated waterers, and a sheltered resting area. The cows were fed twice daily using a specialized feed distributor to deliver a complete mixed ration. Milking was performed three times a day at 7-hour intervals in a milking parlor, utilizing an AID-10 milking system.

The functional udder traits were evaluated based on milk productivity, which was determined by measuring the yield per milking session. This was assessed via control milking conducted over the course of a single day (morning, midday, and evening sessions) during the 2nd to 3rd month of lactation. During the control milking, the amount of milk yielded (kg) was recorded, and the total milking time for each animal (min, s) was determined. The average rate of milk flow (kg/min) was calculated.

Statistical analysis of the research results was performed using methods of mathematical statistics and biometry, with the aid of MS Excel (2010) software. Standard parametric statistical methods were applied, assuming a normal distribution of the data; calculations included the arithmetic mean (M), the standard error of the mean (m), the coefficient of variation (Cv), the correlation coefficient (r), and the statistical significance (P).

Research results. According to observational data (Table 1), the preparatory operations were performed quite professionally and met the general requirements. Specifically, immersing each teat of the cow's udder into a cup containing a cleaning solution took 3.8 ± 0.03 seconds. This immersion likely exerted a stimulating effect on the udder's thermoreceptors, and, to some extent, its mechanoreceptors similar to the natural stimulation of the milk-ejection reflex that occurs when a calf suckles, involving the warmth and moisture of its mouth. Following this, the operators proceeded to wipe the base of the udder and then the teats using a dry towel. During this process, the mechanoreceptors of the teats and the baroreceptors within the teat cisterns received the appropriate unconditioned-reflex stimulation; this stimulation was brief, lasting no more than 23 seconds.

Table 1

Pre-milking stimulation of the milk-ejection reflex in Brown Swiss cows, s

Indicator	M±m	Cv, %	Limit
Cleaning teats with a washing solution	3.8±0.03	9.2	3.1-4.0
Wiping the udder base and teats with a towel	22.8±0.68	35.7	9.0-29.0
Stripping the first streams of milk	3.5±0.12	20.1	2.0-3.0
Attaching teat cups to the teats	7.4±0.08	3.0	6.5-7.2
Total duration of tactile (physical) stimulation	37.5±0.66	20.2	22.6-42.0

Upon completion of the sanitary-preparatory procedures, the operators performed the manual stripping of the first streams of milk from each teat. This operation was very rapid, lasting an average of 3.5 ± 0.12 seconds – a duration that did not significantly

exceed the standard. While this was likely a simulation of stripping, the passage of milk through the teat sphincter canal serves as a signal to trigger a full milk-ejection reflex in the cows, which is crucial for the effectiveness of the process. The reflex stimulation of the udder's receptor system prior to milking was relatively brief, lasting 37.5 ± 0.66 seconds.

Once all preparatory procedures were finished, the operator attached the milking units to the teats. The cow's neurohumoral system promptly transmitted impulses to the udder; the glandular tissue responded rapidly to oxytocin (the milk-ejection hormone), and the milk-removal process began. Studies indicated that, following brief unconditioned-reflex stimulation of the udder's receptor system, the cows in the study demonstrated good adaptability to the milking process and yielded a relatively high volume of milk per milking (Table 2).

Table 2

Functional characteristics of the cows' udders

Indicator	First lactation		Second lactation	
	M±m	Cv, %	M±m	Cv, %
Average daily milk yield, kg:	32.4±0.28	4.38	34.1±0.27*	4.16
Morning	15.5±0.66	4.27	16.4±0.63*	3.86
Midday	7.9±0.11	7.07	8.6±0.12*	7.31
Evening	9.0±0.12	6.62	9.1±0.16	8.73
Duration of milking, min: daily	15.6±0.18	5.77	14.9±0.19	6.30
Morning	6.3±0.11	9.0	6.12±0.11	9.14
Midday	4.5±0.09	9.88	4.44±0.09	10.64
Evening	4.9±0.12	12.39	4.33±0.08	9.79
Milk flow rate, kg/min: daily average	2.08±0.03	8.43	2.29±0.04*	9.85
Morning	2.51±0.07	13.28	2.73±0.07***	12.72
Midday	1.77±0.05	15.36	1.94±0.06***	16.65
Evening	1.87±0.04	12.34	2.14±0.07**	16.12

*Note: * – P < 0.001, ** – P < 0.01, *** – P < 0.05 (the second lactation compared to the first).*

Studies have shown that with three-times-daily milking, the daily milk yield was distributed unevenly. It was observed that nearly half of the total daily milk yield was obtained during the morning milking. Specifically, during the first lactation, 47.8% of the daily yield was obtained in the morning, 24.4% at midday, and 27.8% in the evening. The similar trend was observed during the second lactation: 48.1%, 25.2%, and 26.7%, respectively. The average daily milk yield per cow during the second lactation was significantly higher, by 5.2% ($P < 0.001$), than that of the first lactation. The similar pattern was noted regarding the milk yield obtained during individual daily milkings: yields were 5.8% higher in the morning ($P < 0.001$) and 8.9% higher at midday ($P < 0.001$), while the evening yield showed a non-significant difference of 1.1%. The coefficient of variation remained relatively low, ranging from 4.27% to 6.62% during the first lactation and from 3.86% to 8.73% during the second one, indicating limited variation in productivity among individual animals within the group.

Milking duration is an important factor in the adaptation of cows to industrial management systems and the actual milking process using mechanized milking equipment. Throughout the day, milking duration decreased in proportion to the reduction

in milk yield per milking. Specifically, during the first lactation, the duration at the midday milking was 40.1% shorter (P<0.001) than at the morning milking, and 28.6% shorter (P<0.001) at the evening milking; during the second lactation, the corresponding reductions were 37.8% and 41.3% (P<0.001). The coefficient of variation was relatively low, ranging from 9.0% to 12.39% for the first lactation and from 9.14% to 10.64% for the second one, which is a significant factor when milking cows using mechanical milking systems. The duration of individual milkings during the second lactation showed a non-significant decrease compared to the first, by 2.9%, 1.3%, and 13.1%, respectively.

It was established that the rate of milk flow increases with the age of the animals (Table 2). Specifically, the average daily rate of milk flow during the second lactation increased by 10.1% (P<0.001). This included an increase of 8.7% (P<0.05) during the morning milking and 9.6% (P<0.05) during the midday milking; for the evening milking, despite a slight increase in the yield per milking, the rate also rose by 14.4% (P<0.01). The coefficient of variation for the rate of milk flow ranged from 12.34% to 13.28% for cows in their first lactation, and from 12.72% to 16.65% for those in their second lactation. Calculations revealed a positive correlation between the yield per milking and the rate of milk flow. Specifically, during the first lactation, the mean positive correlation coefficient between the daily yield and the milk flow rate was 0.553 for the morning milking, 0.644 for the midday milking, and 0.163 (a low positive correlation) for the evening milking (P < 0.001). During the second lactation, the correlation remained moderately positive, with values of 0.435, 0.539, and 0.571, respectively (P < 0.001).

It should be mentioned that the study established an inverse correlation between the duration of milking and the rate of milk flow. During the first lactation, the mean negative correlation coefficient between the duration of a single milking and the milk flow rate was -0.665 for the morning milking, -0.415 for the midday milking, and -0.509 for the evening milking (P < 0.001). During the second lactation, the correlation was classified as strongly negative for the morning and midday milkings (-0.825 and -0.770, respectively), while it was moderately negative (-0.321) for the evening milking. Furthermore, across both lactations and all milking sessions, only a trend toward a relationship was observed between these two indicators (P < 0.1).

Most researchers assert that a cow's milk yield depends on the shape of its udder, with the bowl-shaped and cup-shaped forms being the most productive. Some point to functional advantages associated with the bowl-shaped udder. Consequently, the bowl-shaped and cup-shaped forms are considered the most desirable for lactating animals, as they are the most productive and best suited for efficient milking management.

Visual assessment revealed that 68% of the study population possessed a bowl-shaped udder. This type fits tightly against the abdomen and has an elongated shape, forming either a very slight angle, or no angle at all, where it meets the abdominal line. The remaining 32% of the animals had a cup-shaped udder characterized by a regular cylindrical or slightly conical form, where the length and width of the attachment base are nearly equal (differing by only 5–10%). This type is moderately deep, well-developed both vertically and laterally, and adheres closely to the abdominal wall without abrupt transitions – a trait also highly desirable in dairy-type animals. The functional characteristics of the udders in the study cows, categorized by udder shape, are presented in Table 3.

During the third month of the first lactation, the daily milk yield of cows with a bowl-shaped udder was 1.9% higher than that of cows with a cup-shaped udder; however, this difference was not statistically significant. Thus, the coefficient of variation was low – 3.66% for the first group and 5.73% for the second, indicating that the average deviation from the mean within the group is quite insignificant. Single-milking yields from cows

with a bowl-shaped udder were also higher (though not statistically significantly so) than those of their counterparts: by 1.9% in the morning, 1.3% at midday, and 2.2% in the evening. The coefficients of variation ranged from 4.45% to 6.11% and from 3.91% to 9.29%, indicating a low degree of variation among the animals within the groups.

Table 3

Functional udder traits of cows according to udder shape

Indicators	Udder shape			
	Bowl-shaped (n=17)		Cup-shaped (n=8)	
	M±m	Cv, %	M±m	Cv, %
	1st lactation			
Average daily milk yield, kg:	32.6±0.29	3.66	32.0±0.65	5.73
Morning	15.6±0.17	4.45	15.37±0.21	3.91
Midday	7.9±0.11	6.11	7.8±0.25	9.29
Evening	9.1±0.11	5.22	8.9±0.28	9.11
Milk flow rate, kg/min: daily average	2.09±0.05	8.97	2.07±0.06	8.07
Morning	2.57±0.08	13.25	2.42±0.10	12.04
Midday	1.77±0.06	14.29	1.78±0.08	18.44
Evening	1.85±0.06	12.78	1.92±0.08	11.78
	2nd lactation			
Average daily milk yield, kg:	34.3±0.29	3.48	33.7±0.65	5.53
Morning	16.6±0.15	3.86	16.3±0.21	3.78
Midday	8.5±0.14	7.04	8.5±0.25	8.36
Evening	9.2±0.16	6.94	8.9±0.38	12.20
Milk flow rate, kg/min: daily average	2.33±0.06	10.21	2.24±0.06	7.71
Morning	2.77±0.08	12.59	2.64±0.10	10.84
Midday	1.92±0.08	17.10	1.97±0.11	16.21
Evening	2.18±0.07	13.39	2.02±0.16	12.75

*Note: * – P < 0.001, ** – P < 0.01, *** – P < 0.05*

In the third month of the first lactation, the daily milk yield of the experimental cows with a bowl-shaped udder was 1.9% higher than that of cows with a cup-shaped udder; however, this difference was not statistically significant. The coefficient of variation was low – 3.66% for the first group and 5.73% for the second, indicating that the deviation from the group mean is quite minor. Single-milking yields for cows with a bowl-shaped udder were also higher than those of the comparison group (though not statistically significantly so): by 1.9% in the morning, 1.3% at midday, and 2.2% in the evening. The coefficients of variation ranged from 4.45% to 6.11% and from 3.91% to 9.29%, indicating low variability among the animals within the groups.

The rate of milk flow is of particular importance regarding the animals' adaptability to technological factors. Observations revealed that the milk flow rate in cows with a bowl-shaped udder was higher than in the comparison group: by an average of 4.1% per day, by 4.9% during the morning milking, and by 7.3% during the evening milking, while at the midday milking, the rates were comparable. However, the observed difference was not statistically significant, despite relatively low coefficients of variation: 10.2–17.1% for the first group and 7.71–16.21% for the second.

The similar trend was observed during the second lactation. Specifically, the daily milk yield of the experimental cows with bowl-shaped udders was 1.8% higher than that of cows with cup-shaped udders; the morning yield was 1.8% higher, the midday yield was comparable, and the evening yield was 3.4% higher, though these differences were not statistically significant. The coefficients of variation ranged from 3.48–7.04% and 3.78–12.20%, respectively. The rate of milk ejection in cows with bowl-shaped udders was also higher: by 4.0% on a daily basis, 4.9% during the morning milking, and 7.9% during the evening milking; conversely, it was 2.6% lower during the midday milking, though this difference was not statistically significant. The coefficients of variation ranged from 10.21–17.10% and 7.71–16.21%.

The study demonstrated that, for all experimental animals, both individual milking yields and the rate of milk ejection increased with age. In cows with a bowl-shaped udder, average daily milk yields increased by 11.0% ($P<0.001$) during the second lactation compared to the first. Single-milking yields increased by 6.4% ($P<0.001$) in the morning, 7.6% ($P<0.01$) at midday, and 1.2% in the evening (not statistically significant). The rate of milk flow increased by 11.5% ($P<0.01$), 7.8% ($P<0.05$), 8.5% (not statistically significant), and 17.8% ($P<0.001$), respectively. The coefficient of variation ranged from 8.97%–14.29% to 10.21%–17.10%, reflecting greater variability for this indicator within the group of animals. During the first lactation, the correlation coefficient between single-milking yield and the rate of milk flow was positive and moderate: 0.646 for the daily average, 0.515 for the morning milking, 0.606 for the midday milking, and 0.166 (low) for the evening milking ($P<0.001$). During the second lactation, these values were 0.750, 0.565, 0.564, and 0.461, respectively ($P<0.001$).

Cows with a cup-shaped udder exhibited an identical trend: single-milking yields increased with age. During the second lactation, compared to the first, average daily milk yields increased by 5.3% ($P<0.1$ – a trend); morning yields increased by 6.5% ($P<0.01$), midday yields by 8.9% ($P<0.1$ – a trend), while evening yields remained unchanged. Milk flow intensity increased by 8.2% ($P<0.1$ – a trend), 9.1% ($P<0.05$), 10.7% (not statistically significant), and 5.2% (not statistically significant), respectively. The coefficient of variation ranged from 8.07–18.44% and 7.71–16.21%, which resulted in a relatively low level of statistical significance. In the first lactation, the correlation coefficient between the yield per milking and milk flow intensity was high and positive for the daily average (0.936), moderate for the morning (0.622) and midday (0.731) milkings, and low for the evening milking (0.262) ($P<0.001$). In the second lactation, the corresponding correlation coefficients were 0.938, 0.190, 0.603, and 0.641 ($P<0.001$).

Discussion. The studies conducted have demonstrated that cows of the Brown Swiss breed have adapted well both to the climatic conditions of the Forest-Steppe zone of Ukraine and to the management system involving year-round housing in open-air exercise yards, with milking performed three times a day in a milking parlor.

Based on the findings, it can be concluded that, thanks to their high adaptive capacity, Brown Swiss cows adjust well to being kept in open-air exercise yards within the Forest-Steppe zone of Ukraine, while exhibiting quite satisfactory functional udder characteristics and a high rate of milk flow.

Observations indicated that the preparation of the cows' udders prior to milking was carried out in a highly professional manner, meeting standard requirements, with an average duration of 37.5 seconds. In a study by Pishchan I.S. (2016a), which examined the activation of the milk-ejection reflex in Brown Swiss cows during milking in a "Parallel" type milking parlor, similar preparatory procedures were performed; these lasted 30.9 seconds, which is 6.6 seconds faster.

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Our research has shown that, during both the first and second lactations, cows with a bowl-shaped udder exhibited higher single-milking yields (by 1.3–3.4%) and a higher rate of milk flow (by 4.1–7.9%) compared to their age-matched counterparts with a cup-shaped udder. However, the observed differences were not statistically significant in any of the cases, indicating a high adaptive capacity of Brown Swiss cattle to the technological conditions of housing and milking, regardless of udder shape.

Similar results were recorded in studies by Kuziv M.I. et al. (2021). Specifically, among Dutch-bred Black-and-White cattle, 66% of cows had a cup-shaped udder, 22% a bowl-shaped udder, and 12% a rounded udder; for West German-bred cattle, the figures were 66%, 23%, and 11%, respectively; for East German-bred cattle, 71%, 22%, and 7%; and for Ukrainian-bred cattle, 50%, 24%, and 26%. It was established that udder shape influences the milk productivity of cows. Animals with bowl-shaped udders exhibited the highest milk yields and milk fat output.

Research by R. Stavetska and N. Klopenko (2016) [20] on Ukrainian Black-and-White dairy cattle also found that the majority of cows possess bowl-shaped or cup-shaped udders.

In a study by Petrova Yu.V. (2016) on Ukrainian Red dairy cows at the "Askaniiske" State Enterprise Experimental Farm (a breeding herd), the proportion of animals with bowl-shaped udders was 50.0%, with cup-shaped udders 33.3%, and with rounded udders 16.7%. It has been established that udder shape is closely linked to the rate of milk let-down, milk yield, and overall milk productivity. Specifically, first-lactation cows with a bowl-shaped udder outperformed those with a cup-shaped udder by 265 kg (6%) and those with a rounded udder by 380 kg (8.8%) in terms of milk yield.

The study by Bello et al. (2023) in Nigeria examined the relationship between milk yield and udder morphological traits in a herd of 58 White Fulani (Bunaji) cows at the onset of their second, third, and fourth lactations. The findings indicated that phenotypic correlations between udder length (an indicator of a bowl-shaped udder) and daily milk yield were the strongest across the different parities.

Consequently, udder morphological traits serve as promising indicators of milk yield in dairy cattle. Bhuiyan et al. (2004) noted that udder size and shape are significant conformation traits; they play a vital role in assessing a dairy animal's suitability for commercial milk production and should be taken into account during the selection process. According to Tilki (2005) and Shitu et al. (2023), udder traits are of great importance in dairy cattle, as the morphological characteristics of the udder directly influence milk yield.

Our research established that with three-times-daily milking, the daily milk yield was distributed unevenly: the largest portion was obtained in the morning (48%), followed by 25% at midday, and 27% in the evening. It was found that the rate of milk flow increases with the age of the animals. Specifically, the average daily milk flow rate during the second lactation was 2.29 kg/min – an increase of 10.1% ($P<0.001$) compared to the first lactation. Broken down by milking session, this represents an increase of 8.7% ($P<0.05$) for the morning milking, 9.6% ($P<0.05$) for the midday milking, and 14.4% ($P<0.01$) for the evening milking.

Supporting our findings, Lutsenko M. and Popkov V. (2023) report that the milk flow rate in cows across different lactations depends on their productivity and the stage of lactation, and that it increases with the animal's age. For instance, among Holstein cows managed under a robotic milking system at TDV "Terezyne" (Bila Tserkva district, Kyiv oblast), the average milk yield per milking session was 11.0 kg for cows in their first lactation, 13.6 kg for the second, 14.1 kg for the third, and 15.8 kg for the fourth; the corresponding average milk flow rates during the milking process were 2.0 kg/min and

2.55 kg/min, respectively. 2.71 and 2.92 kg/min, which represents an increase of 21.6% in the second lactation, 5.9% in the third, and 7.2% in the fourth.

In studies by Kosior (2012) on Ukrainian Black-and-White dairy and Holstein breeds, no trend toward increased milk flow intensity with the animals' age was observed. In fact, during the third lactation, a decrease in the rate of milk flow was noted for both breeds, dropping to 1.50 and 1.57 kg/min, respectively.

Research by Kuziv M.I. et al. (2021) on Black-and-White cows found that the milk flow intensity for first-lactation cows of foreign origin ranged from 1.71 to 1.75 kg/min, while for those of Ukrainian origin, it was 1.58 kg/min. The correlation coefficient between daily milk yield and milk flow intensity was negative and statistically significant for cows of foreign origin, ranging from -0.145 ($P<0.05$) to -0.238 ($P<0.001$); for animals of domestic origin, it was slightly positive, at 0.174. The strong, significant relationship was established between daily milk yield and milking duration across all studied groups of animals (+0.603 to +0.899, with $P<0.001$ in all cases).

Studies by Pishchan I.S. (2016a) in the Dnipropetrovsk oblast, conducted on Brown Swiss cows in the 2nd–3rd month of lactation using a "Parallel" type milking system, yielded results based on a nearly identical single-milking yield of 11.4–11.5 kg. The average milk flow rate in animals of Group II (the control group) was 2.7 kg/min, whereas in cows of Group I, it was 18.2% higher ($P<0.01$), amounting to 3.3 kg/min. Similar results were obtained in subsequent studies by Pishchan I.S. (2016b) involving Brown Swiss cows at 2–3 months of lactation, where single-milking yields of 10.9, 11.7, and 11.8 kg were recorded. In these cases, the milk flow rates were 2.4, 2.8, and 2.5 kg/min, respectively.

It should be emphasized that in the aforementioned studies, Brown Swiss cows—milked using a "Parallel" type milking system, exhibited higher milk flow rates (by 14–34%, or even by 1.21 kg/min, an increase of 58%) compared to our own experimental data, despite having single-milking yields that were 35–43% lower.

Research conducted by Batyr R.Yu. (2013) revealed a trend: the milk flow rate increases in direct proportion to the single-milking yield, both throughout the daily yield cycle and across the entire lactation period. Specifically, during the first 100 days of lactation, the milk flow rate was 2.29 kg/min; during the second 100 days, it was 2.15 kg/min; and during the final 100 days, it was 1.90 kg/min.

It should be outlined that other researchers have experimentally obtained lower values for the functional properties of the udder under conditions of intensive milk production technologies. For instance, in a study on the breeding value of Holstein, Ukrainian Black-and-White Dairy, and Ukrainian Red-and-White Dairy cows, Ivanov I.A. and Didkivskyi A.M. (2018) determined that with single-milking yields of 10.9, 11.0, 11.7, and 11.2 kg, the rate of milk flow was 1.9, 1.9, 1.8, and 1.9 kg/min, respectively.

In studies on the milk productivity of Jersey, Ukrainian Red-and-White Dairy, and Ukrainian Black-and-White Dairy cows, Holubenko T.L. et al. (2023) established that the rate of milk flow in these cows ranges from 1.62 to 1.95 kg/min, compared to the standard of 1.92 kg/min. Among first-calf heifers, the udder shape was predominantly cup-shaped (75–78%).

Consequently, some researchers have focused their studies on the lactation performance of cows in relation to their type of higher nervous activity. According to Pryshedko V.M. (2017), cows with medium to low stress resistance exhibited longer milking durations and lower completeness of milking.

In the research of Pishchan I.S. (2016 d) on Brown Swiss cows during the 2nd–3rd month of lactation, animals exhibiting an inhibited milk-ejection reflex – with a

single-milking yield of 9.9 kg – showed a milk-flow rate of 2.0 L/min; in contrast, those with an active milk-ejection reflex, yielding 10.1 kg, showed a rate of 2.4 L/min.

Thus, the completeness of milking and the rate of milk flow in a milking system are cumulative effects determined, on the one hand, by the quality of the stimulating cues and, on the other, by the state of the animal receiving them (genotype, phenotype, stage of lactation, physiological status, and conditions of housing and feeding) (Pishchan I.S., 2016 d).

It should be noted that Brown Swiss cows, kept year-round in an open-air exercise yard, demonstrated good adaptability to the specific management conditions and machine milking. Furthermore, they exhibited high levels of productivity and milk-flow rates, both of which showed a statistically significant increase with age, characterized by a positive correlation.

Conclusions. Based on research conducted to determine the functional properties of the udder in Brown Swiss cowsanalyzed in relation to age and various udder shapes, with the animals kept in open-air exercise yards within the Forest-Steppe zone of Ukraine the following conclusions can be drawn:

1. The studies established that keeping Brown Swiss cows in open-air exercise yards does not negatively affect the physiological processes within the animals' bodies; they exhibit the standard patterns of milk synthesis and milk ejection characteristic of cattle. It was demonstrated that, under a three-times-daily milking regimen, both productivity and the intensity of milk ejection increased with the animals' age. The average daily milk yield per cow during the second lactation was significantly higher than that of the first lactation by 5.2% ($P < 0.001$). Specifically, the yield increased by 5.8% ($P < 0.001$) during the morning milking and by 8.9% ($P < 0.001$) during the midday milking, while the increase during the evening milking was 1.1% (not statistically significant). The average daily rate of milk ejection increased by 10.1% ($P < 0.001$) during the second lactation, specifically by 8.7% ($P < 0.05$) in the morning, 9.6% ($P < 0.05$) at midday, and 14.4% ($P < 0.01$) in the evening.

2. It has been established that when kept in open-air exercise yards, cows of the Brown Swiss breed demonstrated adaptability to the management conditions; the impact on the functional characteristics of the udder was comparable to that observed under other housing systems. The positive correlation was identified between the yield per milking and the rate of milk flow. During the first lactation, the average positive correlation coefficient between daily yield and milk flow rate was 0.553 for the morning milking, 0.644 for the midday milking, and 0.163 (a low positive correlation) for the evening milking ($P < 0.001$). During the second lactation, the correlation remained moderately positive, with values of 0.435, 0.539, and 0.571, respectively ($P < 0.001$).

3. Calculations revealed an inverse correlation between the duration of milking and the rate of milk flow. During the first lactation, the correlation coefficient between the time taken for a single milking and the milk flow rate was moderately negative: -0.665 for the morning milking, -0.415 for the midday milking, and -0.509 for the evening milking ($P < 0.001$). During the second lactation, the correlation was classified as strongly negative for the morning (-0.825) and midday (-0.770) milkings, while it was moderately negative (-0.321) for the evening milking. In all instances, only a trend toward such a relationship was observed ($P < 0.1$).

4. The adaptability of Brown Swiss cattle to the technological conditions of housing and milking has been demonstrated, regardless of udder shape. It was determined that cows with a bowl-shaped udder outperformed those with a cup-shaped udder, though not to a statistically significant degree, by 1.3–3.4% in single-milking yield and by 4.1–7.9% in milk flow rate, during both the first and second lactations. For both udder shapes,

a positive correlation was identified between single-milking yield and milk flow intensity, ranging from 0.166 to 0.938.

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