The influence of stallions on the properties of the udder of daughters

E D Chirgin¹, V G Semenov²*, V G Tyurin³, D A Nikitin² and K N Biryukov⁴

¹Department of Livestock Production Technology, Mari State University, 1 Lenin Square, 424000, Yoshkar-Ola, Russian Federation
²Department of Morphology, Obstetrics and Therapy, Chuvash State Agricultural Academy, 29 K Marx Street, 428003, Cheboksary, Russian Federation
³Laboratory of Zoo Hygiene and Environmental Protection, All-Russian Research Institute of Veterinary Sanitation, Hygiene and Ecology – Branch of Federal Scientific Center – All-Russian Research Institute of Experimental Veterinary Medicine of the Russian Academy of Sciences, 5 Zvenigorodskoye Highway, 123022, Moscow, Russian Federation
⁴Department of Animal Hygiene and Poultry Breeding named after A.K. Danilova, Moscow State Academy of Veterinary Medicine and Biotechnology – MVA by K.I. Skryabin, 23 Academician Scriabin Street, 109472, Moscow, Russian Federation

*E-mail: semenov_vg@edu.academy21.ru, https://orcid.org/0000-0002-0349-5825

Abstract. The presented work is the result of studies of the influence of the linearity of mares of the Russian heavy draft breed on milk productivity, morphological characteristics of the udder and adaptability to machine milking. We examined mares belonging to four lines of stallions: Day laborer, Casket, Svist and Karaul. The calculated milk yield on average per lactation was the highest in mares of the Svist line, and the lowest in the Larchik line. Lifetime milk yield of mares of the Svist line exceeded the same indicator of mares of the Podennik line by 12.13%, of the Karaul line – by 18.51% and the Larchik line – by 47.77%. Studies have shown that Whistle stallions not only contribute to the high milk production of their daughters, but also impart good adaptability to machine milking. Mares of the Larchik line in this population of horses of the Russian heavy draft breed are the least productive and the least adapted to machine milking.

1. Introduction

Productive horse breeding is a promising area of agriculture. It is subdivided into two branches - meat herd and dairy. In Russia, productive horse breeding began to develop in the 50s of the XX century, when the increasing level of mechanization of agricultural production freed a significant part of horses from work.

Nowadays, productive horse breeding has become important. It has reserves for increasing meat and dairy productivity to meet the needs of the population for food. The greatest development received in Bashkiria, Yakutia, in the southeast of Siberia, the Middle Volga region and in other regions of the country [1], as well as in the Czech Republic, Slovenia, Great Britain, Spain, Portugal, France [2].

Mare’s milk is a hypoallergenic product, therefore it can be used as a substitute for human milk [3]. It should be noted that fermentation of mare's milk into kumis produces many useful functional
compounds which are useful for human nutrition [4]. The quality and formation of bioactive components in fermented kumis are based on the complex metabolism of the microbial community [5]. The traditional method of obtaining kumis by the seed method has disadvantages in terms of microbiological diversity and nutritional properties, therefore, a two-stage fermentation method has been developed to increase the production of kumis powder [6]. In addition to kumis, a low-alcohol fermented milk drink, airag, is made from mare’s milk [7].

Mare’s milk is obtained not only from dairy breeds of mares, but also from heavy draft mares [8]. The most numerous of them in Russia is the Russian heavy draft breed. Mares are distinguished by long-term milk production. In New Kyrgyz, Kyrgyz mares and their crosses, an increase in milk productivity is observed up to 15 years of age. The highest milk yield in Buryat mares was observed at the age of 7 to 14 years, and in Kazakh mares – from 7 to 15 years [1].

Progress in the production of mare’s milk can be achieved more quickly in small groups of animals, for example, with linear breeding. The belonging of animals to certain lines and families affects milk productivity and morphological characteristics of the udder of mares [9]. A line should be understood as a group of animals of related origin, usually descended from some outstanding ancestor and characterized by similar features of conformation, performance and heredity. Very often it can be observed that direct descendants very sharply deviated towards the lateral ancestors and are in no way typical of their direct ancestor. The line must be drawn up not only taking into account the origin, but also the nature of the entire pedigree, hereditary qualities.

Linear breeding in industrial horse breeding is used to improve the hereditary qualities of stallions in daughters, in particular, milk production is closely related to the morphological properties of the udder of mares [10]. The main technological features that characterize the suitability of mares for machine milking include: the shape, size of the udder and teats, the uniformity of development of the udder lobes (symmetry or asymmetry of the udder of mares).

The aim of the work was to study the influence of the linearity of heavy draft mares on their milk productivity, morphological characteristics of the udder and adaptability to machine milking.

2. Materials and methods

The study involved mares of the Russian heavy draft breed. All of them were randomly selected from a large herd (Closed Joint Stock Company Plemzavod ‘Semenovsky’, Republic of Mari El, Russia). The mares that participated in the experiment had from 1 to 22 lactations. The conditions of keeping and feeding the animals were the same all the time. Their average live weight was 630 kg. Mares were kept in large groups of 12-14 heads on the grounds near the stables, and at night they were kept in a stable with a deep litter. The animals had constant free access to water and food. In the light time of the day – 16 hours – the mares were without foals. Milking was carried out every 2 hours, in total mares were milked 8 times a day. In the dark, the mares were together with the foals (8 hours) and the foals had the opportunity to suck the udders of their mothers.

Mares were milked on the milking platform, in the dual mode milking machine (DDU-2, FSBSI ‘FCAC VIM’, Russia) milking machine. Machine milking of mares was performed by milking after stimulation of the udder by the foal to activate the milk ejection reflex. For this purpose, the milking machine provides a corral for the foal. The foal is allowed to approach one nipple, the second nipple is controlled by the milkmaid at this time. As soon as the active release of milk begins, the foal is removed from the udder, the udder is disinfected and a milking machine is put on. For milking, the dual mode milking machine (DDA-2, FSBSI ‘FCAC VIM’, Russia), adapted to the mare's udder, is used. The average vacuum level is 45 kPa, the pulsation frequency is 120-140 cycles per minute. Milk yield was recorded using graduated measuring cylinders. Control milking was performed every 10 days.

The daily calculated milk yield of mares was determined by the formula (1) of I A Saigin [11]:

\[ M_d = M_t / t \cdot 24 \]  

(1)
where, \( M_d \) – estimated amount of milk in 24 hours, kg; \( M_t \) – the actual amount of milk received, ‘24’ – hours per day.

The calculated milk yield was also determined by the months of lactation, for full lactation, for the highest lactation, on average for all lactation, and the lifetime milk yield of mares was calculated. The duration of economic use of mares was calculated from the beginning of the first lactation to the culling from the milking herd.

The most accurate dairy productivity of mares is determined by conducting round-the-clock control milking. At the same time, alternating milking of the left and right half of the udder is combined with suckling of the foal.

For example, mares were milked daily from 9 to 21 hours after 2 hours; during this time (12 hours) they received an average of 9.8 kg of milk, and for the remaining 12 hours it was sucked by a foal. Hence, the daily dairy productivity of a mare is \((9.8 \times 24)/12=19.6\) kg. The milk production of mares that are not milked can be approximately determined by the increase in the live weight of foals (for 1 kg of increase in the first month of life, they use 10 kg of milk). First, according to the difference in the weight of monthly and newborn foals, the increase is multiplied by 10. For example, a newborn foal weighs 39 kg, and a monthly foal weighs 76 kg. The average daily increase is \((87-39)/30=1.6\) kg. Consequently, during the first month of lactation, the mare released an average of 16 kg of milk per day.

In all mares, the morphological features of the udder were determined, including the adaptability to machine milking. The shape of the udder and teats in mares was determined in accordance with the original method developed by E D Chirgin. The following udder measurements were measured: the width and length of the udder were measured with a measuring compass; the height and girth of the udder, the length, width, thickness and circumference of the nipples, the distance between the nipples – using a measuring tape; the shape of the udder, the type of the udder output system, the size of the udder, the development of milk veins, the shape of the nipples, the orientation of the nipples, the shape of the tips of the nipples were determined by visual inspection and using calculations; the decline of the udder was determined by probing. The attachment density of the mares' udders was determined by measuring the angle between the cranial wall of the udder and the abdominal wall. The udder symmetry index was defined as the difference between the width of the right and left halves of the udder of mares along a line passing at an angle of 180° to the white line of the abdomen at the level of the anterior edge of the base of the nipples. The study of the morphological features of the udder was carried out by somatometric and photographic methods (figure 1).

![Figure 1. Udder of high – milk mares.](image_url)
the base of the nipple to its tip, the width of the nipple from the front to the rear edge of the base of the
nipple. The distance between the nipples was determined between the tips of the nipples. The density
of attachment of the udder of mares was determined by the size of the angle formed by the anterior
edge of the udder and the abdominal wall.

All procedures were conducted according to the guide-lines for the ethical use of animals in applied
animal behavior research on the protection of animals used for experimental and other scientific
purposes.

The results obtained were processed by conventional methods of variation statistics using the
Microsoft Office software using Excel.

3. Results and discussion

The udder of the mare differs from the udder of the queens of other farm animals: it is small, compact,
covered with smooth elastic skin. Consists of two separate halves (milky hills) – right and left, each
with one nipple. Each half of the udder has two lobes – anterior and posterior with independent
alveoli, milk passages, excretory ducts, cisterns, teat canals and holes, of which there are two in each
teat. Although the udder of a mare is small in size, due to its well-developed glandular tissue, it is
capable of producing as much milk as the udder of a cow produces, several times larger than the size
of the udder of mares.

As milk production in mares is intense and the udder capacity is small, mares are milked more
often than cows. Milk production in mares occurs in two phases, separated by a pause. In the first
phase, milk is released in thin streams of 80-120 grams per second. After 15-20 seconds, the secretion
stops, the nipples become empty, although the amount of milk received does not exceed 10% of a
single milk yield. In the second phase, after 45-50 seconds, the nipples are again filled with milk and
its rapid release with thicker streams begins – from 50 to 60 grams per second, or 1.5-2 liters of milk
or more, depending on the capacity of the udder (figure 2).

![Figure 2](image1.png)

Figure 2. Milking mares at the DDA-2 milking unit.

![Figure 3](image2.png)

Figure 3. Feed table in the stable, in the section.

The success of milking mares lies in the speed of milking, otherwise the milk yield and milk fat
content decrease. The sooner the milk flow occurs, the earlier the mare develops a milking reflex. In
some mares, milk flow is inhibited, which is often associated with noise, pain, and so on. These
unpleasant sensations in mares are removed by bringing in their own foal, changing the environment
and creating a favorable external environment in the milking areas.

The morphological features of the udder of mares of heavy draft horse breeds have not yet been
studied enough. All this creates certain problems when milking heavy draft mares on kumis farms,
animals are discarded earlier from the milking herd due to problems with machine milking and, as a
result, lower milk productivity [12].

In researches by E D Chirgin et al. it was shown that mares of the Russian heavy draft breed can be
used for milk production up to 21 lactation inclusive and produce up to 88,138 kg of milk during this
time. According to the results of the research of these scientists, mares of the Russian heavy draft breed were used for an average of 6.50 years, during this period, 4.10 lactation was obtained from them [5]. Average lifetime milk yield of mares of the Russian heavy draft breed in the studies of Chirgin E D et al. it was 21,200.08 kg of milk from one mare [9].

In the Closed Joint Stock Company Plemzavod ‘Semenovsky’, all mares of the Russian heavy draft breed belonged to four lines: Podenshik, Larchik, Svist and Karaul (figure 3). Calculated milk yield on average per lactation was highest in mares of the Svist line, and lowest in animals of the Larchik line (27.24% less than in mares of the Svist line) (table 1).

| Linear affiliation | n, heads | M±m | Lim: min-max | σ     | Cv, % |
|--------------------|---------|-----|--------------|-------|-------|
| Larchik            | 12      | 2715.62±373.42** | 1014-4856 | 1293.55 | 47.63 |
| Svist              | 15      | 3455.29±214.43    | 1647-5375 | 830.49  | 24.04 |
| Podenshik          | 6       | 3359.35±309.59    | 2170-4470 | 758.33  | 22.57 |
| Karaul             | 23      | 3320.88±170.08    | 2102-4648 | 721.60  | 21.73 |

*P<0.05; **P<0.01; n – number; M±m – Max±min; Lim – limited; σ – standard deviation; Cv – coefficient of variation

The second place in the average milk yield per lactation was occupied by mares of the Podenshik line, the third – by the Karaul. In mares of the Larchik line, the variability of this indicator was twice higher than in animals of the other two lines, which allows the use of individual mares of this line with high milk productivity in the breeding process.

In dairy horse breeding, for horses, as for late-maturing animals, the duration of the economic use of animals is of paramount importance. We decided to find out how the mares belonging to a particular line affects the duration of economic use (table 2).

| Linear affiliation | n, heads | M±m | Lim: min-max | σ     | Cv, % |
|--------------------|---------|-----|--------------|-------|-------|
| Larchik            | 12      | 6.33±1.65                     | 4-16  | 5.42  | 85.52 |
| Svist              | 15      | 9.80±1.49                     | 1-20  | 5.77  | 58.90 |
| Podenshik          | 6       | 9.67±1.65                     | 1-14  | 4.03  | 41.72 |
| Karaul             | 23      | 8.44±1.37                     | 1.19  | 5.81  | 68.84 |

*P<0.05; **P<0.01; n – number; M±m – Max±min; Lim – limited; σ – standard deviation; Cv – coefficient of variation

The longest productive life was observed in mares of the Svist line – 9.80 years. According to this indicator, they outperformed the animals of the Podenshik line by 1.34%, the Karaul line by 16.11% and the Larchik line by 54.82%.

In terms of the lifetime milk yield, the places among the four lines of horses of the Russian heavy draft breed were distributed in the same way as in the first two tables (table 3).

| Linear affiliation | n, heads | M±m | Lim: min-max | σ     | Cv, % |
|--------------------|---------|-----|--------------|-------|-------|
| Larchik            | 12      | 19,187.58±6735.97             | 1750-72,840 | 42,334.09 | 121.60 |
| Svist              | 15      | 28,354.27±4538.52             | 1647-63,020 | 17,577.63 | 61.99 |
| Podenshik          | 6       | 25,287.83±4284.34             | 8680-37,668 | 10,494.46 | 41.50 |
| Karaul             | 23      | 23,925.11±4041.20             | 2178-56,838 | 17,145.36 | 71.66 |

n – number; M±m – Max±min; Lim – limited; σ – standard deviation; Cv – coefficient of variation
The first place in the lifetime milk yield was occupied by mares of the Svist line. Their lifetime milk yield exceeded that of the mares of the Podenshik line by 12.13%, the Karaul line by 18.51%, and the Larchik line by 47.77%. The duration of economic use of mares and their lifetime milk yield is influenced by various factors, including the belonging of animals to different lines. The influence of the lines on the studied traits is quite significant: up to 54.82% for the duration of productive life and up to 47.77% for lifetime milk yield. Therefore, taking into account the linear affiliation can help in the selection of mares with the longest period of economic use and with the highest lifetime milk yield. Udder measurements of the studied mares also differed depending on their linear affiliation (table 4).

In terms of the length of the mare's udder, the Svist lines outstripped the Karaul line by 6.64%, and the Larchik line by 10.22%. The width and girth of the udder were approximately the same for all mares. The girth of the udder was slightly larger in the mares of the Svist line, and the width of the udder was the smallest. Our studies have shown that when milk productivity increases, the udder depth increases more than other measurements. In mares of the Svist line, the udder depth was significantly greater and 20.11% higher in mares of the Karaul line, and 24.98% higher than the udder depth in mares of the Larchik line. It is natural that mares with higher milk productivity had significantly more udder measurements.

### Table 4. Measurements of the udder of mares.

| Linear affiliation | n, heads | Measurements of the udder of mares, cm |
|--------------------|---------|---------------------------------------|
|                    |         | length | width | depth | girth |
| line Larchik       | 12      | 26.89±0.95* | 20.50±0.91 | 11.85±0.73** | 92.50±2.16 |
| line Svist          | 15      | 29.54±0.78** | 20.31±0.71 | 14.81±0.92** | 95.62±2.20** |
| line Podenshik      | 6       | 27.70±0.34* | 21.00±0.68 | 12.33±0.81 | 92.65±1.37 |
| line Karaul         | 23      | 27.80±0.92* | 20.70±0.54 | 12.64±0.70 | 93.64±2.12 |

*P<0.05; **P<0.01.

Nipple measurements were not so clearly distributed in mares of different lines (table 5).

If the length of the nipples and the distance between the nipples did not differ much in all mares, then the width of the nipples and the girth of the nipples were the greatest in mares of the Larchik line. These differences were not accidental. We believe that they reflect the adaptability of the udder to machine milking. One of the features of the udder of mares is that in each nipple there are two milk ducts from two mammary glands. On average, 5-7% of mares show polymastia, then there are not two, but three or four milk ducts in the nipple. Then the nipple becomes wider. If the length of the nipple is greater than the width or the width is greater than the length by 20-30%, then such a nipple is normally captured and given out by the device, since it has a conical shape. If the nipple is wide and short or it has a cylindrical shape, then the extreme milk ducts are squeezed completely or partially by the rubber of the milking cup. At the same time, part of the milk is not given out, but remains in the udder. All indicators of the udder's adaptability to machine milking are presented in table 6.

### Table 5. Nipple measurements in mares.

| Linear affiliation | n, heads | Nipple measurements in mares, cm |
|--------------------|---------|---------------------------------|
|                    |         | length | width | girth | distance between the nipples |
| line Larchik       | 12      | 3.10±0.16* | 5.40±0.26** | 14.35±0.61** | 7.40±0.82 |
| line Svist          | 15      | 3.73±0.21** | 4.54±0.31 | 12.77±0.89* | 7.81±0.53* |
| line Podenshik      | 6       | 3.54±0.12* | 4.32±0.22 | 13.00±0.55 | 7.42±0.34 |
| line Karaul         | 23      | 3.33±0.21* | 4.48±0.26 | 12.30±0.71 | 7.09±0.66 |

*P<0.05; **P<0.01.
Table 6. Indicators of the adaptability of the udder of mares to machine milking.

| Linear affiliation | Udder shape   | Nipple shape   | Direction of the nipples downwards, % | Excess of the nipples over the valley, % | Distance between the nipples, lim: min-max |
|--------------------|---------------|----------------|--------------------------------------|----------------------------------------|------------------------------------------|
| line Larchik       | in the form of a bath 90% | in the form of a cone in 90% | 80%                                  | 74.19%                                  | 4.0-12.0                                  |
| line Svist         | in the form of a bath 100% | in the form of a cone in 100% | 88.89%                               | 21.72%                                  | 4.0-10.0                                  |
| line Podenshik     | in the form of a bath 78.26% | in the form of a cone in 100% | 68.75%                               | 34.53%                                  | 3.0-12.0                                  |
| line Karaul        | in the form of a bath 78.26% | in the form of a cone in 100% | 68.75%                               | 34.53%                                  | 3.0-12.0                                  |

In mares of the Larchik line, all indicators of fitness for machine milking more than in other lines, deviated from the norm.

The distance between the nipples in all mares is on average 7 cm, possible deviations of ±3 cm are allowed. Thus, the extreme normal options are from 4 to 10 cm.

And another indicator is not included in the table 6 this is the length of the nipples. On the nipples, which are shorter than three centimeters, the milking cups are held weakly. In mares, the Svist lines have the shortest nipples, 3 cm long. In mares, the Larchik line have 2.5 cm, and the Karaul line have 2 cm.

Stallions of the Svist line not only contribute to the high milk productivity of their daughters, but also give them a good adaptation to machine milking. Mares of the Karaul line have lower milk productivity and more deviations from the optimal indicators of fitness for machine milking. The Larchik mares in this population of horses of the Russian heavy draft breed are the least productive and the worst adapted to machine milking.

4. Conclusion
As a result of our research, a significant difference was revealed between mares of the Russian heavy draft breed of different lines in terms of the calculated milk yield per lactation and life-long milk yield. It was found that the highest milk yield per lactation was observed in mares of the Svist line and amounted to 3455.29±214.43 kg, and the lowest in animals of the Larchik line (2715.62±373.42 kg).

We have noted the influence of the linearity of mares on the duration of their economic use. The longest productive life was observed in mares of the Swist line – 9.80 years. According to this indicator, they surpassed the animals of the Dayman line by 1.34%, the Karaul line by 16.11% and the Larchik line by 54.82%.

The adaptability of the udder of mares to machine milking was carried out according to the following parameters: the shape of the udder, the shape of the teats, the direction of the teats downward, the excess of the width of the teats over the length, the distance between the teats. Stallions of the Whistle line, along with an increase in milk productivity, improved the shape of the udder (100% bath-like) and teats (100% conical) in their daughters, and also contributed to better adaptability of the daughters' udders to machine milking. The mares of the Larchik line turned out to be the least dairy and the least adapted to machine milking. An intermediate position in terms of milk yield and morphological properties of the udder was occupied by the animal lines of the Guard.

Thus, we conclude that in the production of mare's milk, mares belonging to the lines of the Whistle and the Day laborer should have an advantage.
References

[1] Chirgin E D, Onegov A V, Rozhentsov A L, Holodova L V, Novoselova C S, Mikhalev E V and S Yu Smolentsev 2016 The Russian heavy draft milk type mares characteristics. RJPBCS 7(2) 1930

[2] Markiewicz-Keszycka M, Czyzak-Runowska G, Wojtowski J, Jozwik A, Pankiewicz R, Leska B, Krzyzewski J, Strzałkowska N, Marchewka J and Bagnicka E 2015 Influence of stage of lactation and year season on composition of mares’ colostrum and milk and method and time of storage on vitamin C content in mares' milk. J. Sci. Food Agr. 95(11) 2279 doi.org/10.1002/jsfa.6947

[3] Fiocchi A et al. 2010 World Allergy organization (WAO) diagnosis and rationale for action against cow’s milk allergy (DRACMA) guidelines. World Allergy Organ J. 3(4) 57 doi: 10.1097/WOX.0b013e3181defeb9

[4] Xia Y, Yu J, Miao W and Shuang Q 2020 A UPLC-Q-TOF-MS-based metabolomics approach for the evaluation of fermented mare’s milk to koumiss. Food. Chem. 320 126619 doi.org/10.1016/j.foodchem.2020.126619

[5] Xia Y, Oyunsuren E, Yang Y and Shuang Q 2021 Comparative metabolomics and microbial communities associated network analysis of black and white horse-sourced koumiss. Food. Chem. 370 130996 doi: org/10.1016/j.foodchem.2021.130996

[6] Li H, Wang Y, Zhang T, Li J, Zhou Y, Li H and Yu J 2020 Comparison of backslopping and two-stage fermentation methods for koumiss powder production based on chemical composition and nutritional properties. J. Sci. Food Agr. 100(4) 1822 doi.org/10.1002/jsfa.10220

[7] Tsuchiya R, Kawai T, Bat-Oyun T, Shinoda M and Morinaga Y 2020 Electrical conductivity, pH, minerals, and sensory evaluation of airag (fermented mare’s milk). Foods 9(3) 333 doi.org/10.3390/foods9030333

[8] Centoducati P, Maggiolino A, De Palo P and Tateo A 2012 Application of Wood’s model to lactation curve of Italian heavy draft horse mares. J. Dairy 95(10) 5770 doi.org/10.3168/jds.2012-5513

[9] Yu X, Fang C, Liu L, Zhao X, Liu W, Cao H and Lv S 2021 Transcriptome study underling difference of milk yield during peak lactation of Kazakh horse. J. Equine. Vet. Sci. 102(s1) 103424 doi.org/10.1016/j.jevs.2021.103424

[10] Chirgin E D, Semenov V G, Baimukanov D A, Iskhan K Zh, Rzabayev T S and Zhikishev Ye K 2019 The relation of productive longevity of lithuanian heavy draft mares with the udder capacity. Bulletin of National Academy of Sciences of the Republic of Kazakhstan 5(381) 23 doi.org/10.32014/2019.2518-1467.119

[11] Saigin I A 1973 Kumys farms of Bashkiria. Horse Breeding and Equestrian Sports 6 10 [In Russian]

[12] Chirgin E D, Onegov A V, Strelnikov A I, Holodova L V and Novoselova K S 2019 Changes in milk yield, fat and protein mass fractions in mares’ milk within 24 hours. IOP Conf. Ser.: Earth Environ. Sci. 315(423) 042046 doi: 10.1088/1755-1315/315/4/042046