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ON THE ISSUE OF COMPENSATION OF THE SECRETORY PROCESS BY THE LOBES OF THE COW'S MAMMARY GLAND

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Abstract

Diseases of the cattle mammary gland lobes and the reduction or loss of their secretory activity have long been a concern for livestock breeders. Mastitis, the inflammation of the mammary gland, has been studied in particular detail. Unfortunately, for some reason, everyone forgets that the mammary gland is a paired organ that is functionally characterized by compensatory reactions. Theoretically, these processes should compensate to some extent for the loss of secretion in the diseased lobe of the gland. In this regard, the aim of our study was to find and trace, if any, the possibilities of compensatory reactions of the secretory process by the lobes of the mammary gland in the conditions of reduced or stopped secretion in one of them. The study was carried out under conditions of motivated, 'voluntary' emptying of the mammary gland in Holstein cows with a yield of 4529–11603 kg of milk per lactation, using the automatic milking control system, which is mounted and operated in the VMS-2012 milking machine. To evaluate the nature of milk secretion by each lobe, we used the daily data from this system, namely the date and time of each milking and the weight of milk obtained from each lobe. These data were evaluated in experimental cows during one or two lactations. Our studies have shown that when secretory activity in one of the lobes of the cow's mammary gland decreases or stops, the remaining normally functioning lobes show a compensatory reaction. The possibility of restoring the secretory process in a lobe after its cessation in the previous lactation has also been proven, but this does not always happen. It has also been established that even if there is no resumption of secretion with the onset of a new lactation in one of the mammary gland lobes, other normally functioning lobes largely compensate for the milk secretion of the non-functioning lobe.

Keywords: Holstein breed, mammary lobes, secretion, compensation

Introduction

In virtually all countries with intensive dairy farming, mammary gland diseases are an economic and agricultural problem. Diseases of the mammary gland cause large losses to dairy cattle breeding. Thus, according to Demidova (1997), Popov and Petrov (1999), Dankvert and Zernaeva (2003), they cause: enormous milk losses due to a decrease in milk production of

cows; costs of feeding and housing that do not pay off; costs of treating sick animals; reduction of the period of economic use; and reduce the quality of milk and products made from it.

A significant increase in milk production is largely hampered by inflammation of the mammary gland, with mastitis being the dominant cause. Mastitis not only causes a decrease in milk yield and deterioration in milk quality (Damm et al., 2017; Madouasse et al., 2010), but also necessitates the use of antibiotics that get into dairy products from such milk (Bradley et al., 2018; Vangroenweghe et al., 2020). The average daily milk loss in cows with a somatic cell count of more than 500 thousand kg/ml exceeds 10% (Hagnestam-Nielsen et al., 2009). In Ukraine, according to Mutovin (1983), Nikitin and Podkuyko (1987), Ivashura (1991), Slobodianyk et al. (1999), Troshyn and Ilyinsky (2000), Turchenko and Popov (2002), Rubtsov (2006), Nikitin et al. (2007), Reshetka (2013), Chernyavska (2023), 12.1 to 18.9% of dairy cows suffer from mastitis during the year. In their opinion, inflammation of the mammary gland is most common in highly productive cows. According to their calculations, during the disease, milk losses per cow are on average 10–15% of the annual milk yield. Even after recovery, many animals do not fully recover their milk production due to irreversible changes in mammary tissue. Every year, up to 30% of cows with mastitis are culled. According to Stroyanovska and Suprovych (2021), mastitis was most common in cows in the third lactation, of which 11% had the disease re-occurrence. At the same time, 3% of animals were affected in the same quarter as the previous time. The analysis of the spread of mastitis by quarters showed that the most commonly affected quarters were the hind right udder quarters (33.6%). Also, it was these quarters that most often (37.5%) were affected repeatedly.

As we can see, most researchers agree that the cessation of milk secretion in one or more lobes of the mammary gland leads to significant productivity losses. According to Morris and Marsh (1985), most economic analyses of mastitis control programmes are based on the assumption that there is no milk supply in the infected quarter and that the neighbouring healthy quarters are unable to compensate for this loss of milk. Unfortunately, we found only a few studies in the available literature (Duraes et al., 1982; Woolford, 1985) that provide information on the functional possibility of compensatory processes in healthy mammary gland lobes that occur when secretion in one or more of them is reduced or stopped.

Therefore, the aim of our study was to find and trace, if any, possible compensatory reactions of the secretory process by the mammary lobes in the context of motivated ('voluntary') emptying of the mammary gland on a robotic milking machine in case of a decrease or cessation of secretion in one of them. In this case, we did not establish the reasons for such a decrease, but only tried to determine whether secretion compensation occurs and to what extent each lobe takes over the level of such compensation, if it actually occurs.

Material and methods

The study was carried out under conditions of 'voluntary' emptying of the mammary gland on a robotic milking machine in 6 Holstein cows with a milk yield of 4529–11603 kg of milk per lactation. Information on the level of daily milk yield of each animal was obtained using the automatic milking control system, which is mounted and operated in the VMS-2012 milking machine (DeLaval). The automated data storage system of the unit provides data on: identification of the animal's personal number, date and time of milking, weight of milk obtained for each milking from each lobe of the mammary gland, duration of milking and many other lactation and physiological parameters of each cow. To evaluate the nature of milk secretion by each lobe, we used the daily milk yield data accumulated in this system, namely the date and time of each milking and the weight of milk obtained from each lobe. These data were evaluated in experimental cows during one or two lactations. The data on the level of average daily milk yields during the assessment of compensatory reactions are presented in the tables. The cows

were housed in untethered boxed housing, fed the same type of year-round mixed ration according to the level of productivity.

Results

As practice shows, most cows have the most developed secretory lobes in the hind mammary gland, and they are often affected by secretory disorders. That is why we decided to start analysing possible compensatory reactions with the hind lobes. The data in Table 1 show that in the first month of lactation, the most common distribution of milk yields by mammary lobes is typical for a given cow. In the second half of the fourth month of lactation, there is a decrease in the secretory activity of the right hind mammary gland. The amount of milk yield from the right hind lobe in the total single milk yield decreases by 24.6%. At the same time, the left hind lobe increases its secretory activity by 13.8%. During the fifth month of lactation, all normally functioning lobes increase their secretory activity. For example, the left front lobe's milk yield increased by 0.31 kg compared to the first month, the right front lobe's by 0.36 kg, and the left posterior lobe's by 0.8 kg. During the sixth month of lactation, despite the overall decrease in productivity, we observe a further increase in the level of secretion. Thus, the milk yield in the right front lobe increased by 0.73 kg compared to the first month, and in the left hind lobe by 1.83 kg.

Table 1. Distribution of single milk yields by lobes of the mammary gland of cow no. 1694 in the second lactation (expected lactation yield – 9497 kg)

Indicator	Average daily milk yield per month, kg	Average single milk yield per milking session							
		left front		right front		left hind		right hind	
		kg	%	kg	%	kg	%	kg	%
1st month of lactation	42.1	2.24	18.8	1.61	13.6	3.61	30.1	4.49	37.7
4th month of lactation, before reduction	41.18	2.53	18.9	1.80	13.4	4.29	32.1	4.77	35.6
4th month of lactation, after reduction	25.05	2.25	24.8	1.64	18.1	3.98	43.9	1.19	13.1
4th month of lactation, average value	32.0	2.38	21.6	1.71	15.5	4.12	37.3	2.83	25.6
5th month of lactation	29.2	2.55	27.1	1.97	20.9	4.41	46.8	0.48	5.2
6th month of lactation	27.5	2.24	22.4	2.34	23.3	5.44	54.3	0	0

Analysing the possible compensatory reactions of the mammary gland lobes of cow no. 2662 (Table 2), we observe that in the tenth month of lactation, there is a decrease in secretory activity in the left hind lobe.

Table 2. Distribution of single milk yields by lobes of the mammary gland of cow no. 2662 in the second lactation (expected lactation yield – 4529 kg)

Indicator	Average daily milk yield per month, kg	Average single milk yield per milking session							
		left front		right front		left hind		right hind	
		kg	%	kg	%	kg	%	kg	%
9th month of lactation	32.89	1.89	17.24	2.04	18.61	3.57	32.57	3.46	31.57
10th month of lactation, before the decrease in secretion	31.08	2.05	18.10	2.04	18.05	3.76	33.27	3.45	30.53
10th month of lactation, after the decrease in secretion	21.04	1.66	22.55	1.65	22.42	1.16	15.76	2.89	39.27
11th month of lactation, before cessation of secretion	24.40	2.02	23.72	2.46	28.88	0.29	3.40	3.74	43.90
11th month of lactation after cessation of secretion	21.36	2.11	28.10	2.11	28.09	0	0	3.30	43.90
12th month of lactation	16.12	2.24	34.09	2.35	35.76	0	0	1.98	30.14

After a decrease in secretion in the left hind lobe (by 2.6 kg), there is a certain redistribution of milk yield across the normally functioning lobes. Thus, the percentage of milk yield in the left front lobe increases by 5.31% compared to the ninth month, in the right front lobe by 3.81%, and in the right hind lobe by 7.7%. The complete cessation of secretion in the left hind lobe occurs in the eleventh month of lactation. However, even before the complete cessation of secretion, we observe an increase in secretion in normally functioning lobes. For example, the weight in the left front lobe increases by 0.13 kg, in the right front lobe by 0.42 kg and in the right hind lobe by 0.29 kg. And even after the complete cessation of secretion in the left hind lobe, we observe an increase in secretion in the front lobes. Thus, the weight of the left anterior lobe increases by 0.22 kg compared to the ninth month of lactation, and the weight of the right front lobe increases by 0.07 kg. This is despite a general decrease in milk yield with the month of lactation. During the twelfth month of lactation, we observe the trends of the eleventh month. With an overall decrease in average daily milk yield, the front lobes continue to increase the secretory process. Thus, the milk yield in the left front lobe, compared to the ninth month, increases by 0.35 kg, and in the right front lobe –
by 0.31 kg.

It was also important to investigate whether compensatory reactions of normally functioning lobes are manifested in case of a decrease or cessation of secretory activity by several lobes of the mammary gland. The answer to this question can be found to some extent by analysing the data in Table 3.

Table 3. Distribution of single milk yields by lobes of the mammary gland of cow no. 2200 in the fourth lactation (expected lactation yield – 7062 kg)

Indicator	Average daily milk yield per month, kg	Average single milk yield per milking session							
		left front		right front		left hind		right hind	
		kg	%	kg	%	kg	%	kg	%
2nd month of lactation	36.50	3.12	26.22	3.21	26.97	2.97	24.96	2.60	21.85
10th month of lactation, decrease in secretion	8.38	0.209	6.76	0.672	21.74	2.11	68.28	0.102	3.30
11th month of lactation, cessation of secretion	7.09	0.009	0.32	0.568	20.58	2.12	76.81	0.057	2.06
1st month of new, fifth lactation	24.38	0	0	1.90	28.57	3.25	48.87	1.49	22.41

During the second month of lactation, the distribution of milk yields across the lobes of the mammary gland of a given cow was almost ‘perfect’, i.e. each lobe produced almost 25% of the single milk yield. At the tenth month of lactation, a sharp decrease in secretion occurred in three lobes. Thus, in the left front lobe, compared to the second month of lactation, milk yield decreased by 2.92 kg, in the right front lobe – by 2.54 kg, and in the right hind lobe – by 2.5 kg. Only the left hind lobe showed a decrease in milk yield, which, in our opinion, was due to a physiological decrease in milk yield over the months of lactation. By the end of the eleventh month of lactation, secretion in the left front and right hind lobes had almost stopped. In the right front lobe, it continued to decline, but in the left hind lobe, there was a tendency to a certain increase in the secretory process. This is confirmed by the results of the secretory activity of this mammary gland in the first month of the new, fifth lactation. Thus, while the secretion in the left front lobe did not recover, in the right front lobe it decreased by 1.31 kg compared to the second month of the previous lactation, and in the right hind lobe by 1.11 kg, while in the left hind lobe the secretion increased by 0.28 kg.

Equally interesting is the question of how fully, and whether at all, the secretory process is restored in the next lactation in the lobes that stopped secretion in the previous lactation.

Table 4. Distribution of single milk yields by lobes of the mammary gland of cow no. 7302 in the fourth lactation (expected lactation yield – 7112 kg)

Indicator	Average daily milk yield per month, kg	Average single milk yield per milking session							
		left front		right front		left hind		right hind	
		kg	%	kg	%	kg	%	kg	%
1st month of lactation	45.83	2.62	21.39	2.46	20.08	3.40	27.76	3.77	30.78
5th month of lactation	23.35	2.99	35.01	2.03	23.77	0.28	3.27	3.25	38.05
7th month of lactation	18.86	2.66	38.55	1.32	19.13	0	0	2.92	42.32
1st month of the new, fifth lactation	39.88	2.62	23.86	2.32	21.13	2.94	26.78	3.09	28.14

As shown in Table 4, in the first month of lactation, the distribution of milk yield by lobes of the mammary gland of this cow had a 'classical' appearance, i.e. the hind lobes were better developed than the front ones. In the fifth month of lactation, a significant (3.12 kg) reduction in the secretory process occurred in the left hind lobe compared to the first month of lactation. At the same time, while the right lobes also showed a slight decrease in secretion, which, in our opinion, was caused by a physiological decrease in secretion over the months of lactation, the left front lobe, on the contrary, showed an increase in secretion by 0.37 kilograms. At the seventh month of lactation, the secretory process in the left hind lobe stopped altogether, and in the right hind and front lobes, there was a significant reduction. Only in the left front lobe there is a tendency to a certain increase in the secretory process.

In the first month of the new lactation, the secretory process in the front lobes remained virtually at the level of the first month of the previous lactation. There was a recovery of secretion in the left posterior lobe, but in a slightly smaller volume (0.46 kg). The secretory process in the right hind lobe was also less intense (0.68 kg), which, in our opinion, is caused by a natural decrease in secretion with increasing age in lactation. That is, in this case, we observe a variant of the resumption of secretion after its cessation in the previous lactation. But this does not always happen, as can be seen in the following two examples. Thus, in cow no. 2122 in the ninth month of lactation (Table 5), there was a cessation of secretion in the left hind lobe. This animal was characterised by the fact that the 'lion's' share of milk was produced in the front lobes of the mammary gland. This trend was also observed in the tenth and fourteenth months of lactation with a gradual decrease in the secretory process towards the end of lactation.

Table 5. Distribution of single milk yields by lobes of the mammary gland of cow no. 2122 in the third lactation (expected lactation yield – 11603 kg)

Indicator	Average daily milk yield per month, kg	Average single milk yield per milking session							
		left front		right front		left hind		right hind	
		kg	%	kg	%	kg	%	kg	%
9th month of lactation	25.40	4.17	40.56	4.38	42.61	0	0	1.73	16.83
10th month of lactation	25.82	3.83	41.05	4.02	43.09	0	0	1.48	15.86
14th month of lactation	16.82	3.66	42.86	3.74	43.79	0	0	1.14	13.35
1st month of new, fourth lactation	21.34	2.65	32.30	2.92	35.61	0	0	2.64	32.19
2nd month of new, fourth lactation	27.50	3.74	34.89	3.73	34.79	0	0	3.24	30.22

In the first month of the new lactation, there was no recovery of secretion in the left hind lobe, but there was an increase in secretion in the other normally functioning lobes. At the same time, the distribution of milk yields by lobes was almost equalised. This is especially evident in the second month of lactation, when the milk yield in the left front lobe increased by 1.09 kg, in the right front lobe by 0.81 kg and in the right hind lobe by 0.6 kg compared to the first month. A similar pattern was observed in cow no. 3982 (Table 6).

Table 6. Distribution of single milk yields by lobes of the mammary gland of cow no. 3982 in the fourth lactation (expected lactation yield – 9376 kg)

Indicator	Average daily milk yield per month, kg	Average single milk yield per milking session							
		left front		right front		left hind		right hind	
		kg	%	kg	%	kg	%	kg	%
4th month of lactation	43.23	3.79	29.49	3.50	27.24	5.56	43.27	0	0
1st month of new, fifth lactation	30.29	3.21	31.10	2.85	27.62	4.26	41.28	0	0
2nd month of new, fifth lactation	32.34	3.18	29.07	2.99	27.33	4.77	43.60	0	0

In the first month of new lactation, there is no recovery of the secretory process in the right hind lobe. However, in this case, the front lobes of the mammary gland practically do not participate in compensating for the secretion of the right hind lobe. This function is almost entirely taken over by its functionally closest 'colleague' – the left hind lobe, which produces almost half of the daily milk yield.

Discussion

When assessing the nature of changes in the secretory process in the mammary gland of cows and the level of its compensation as a result of disorders in one or more lobes, it should be noted that this happens in different ways. Thus, in cow no. 1694, with a decrease in milk yield in the right hind lobe by 24.6%, the left hind lobe increases its secretory activity by 13.8%, i.e. there is a certain compensatory reaction to a decrease in milk secretion in the right hind lobe. And already in the fifth month of lactation, despite the overall decrease in milk yield during lactation, all other normally functioning lobes show a compensatory reaction. For example, the milk yield in the left front lobe increased by 8.3% compared to the first month, in the right front lobe by 7.3%, and in the left hind lobe, the highest increase was 16.7%. During the sixth month of lactation, we observed a further increase in compensatory reactions in the right front and left hind lobes. Thus, the right front lobe's expectation increased by 9.7% compared to the first month, and the left hind lobe's expectation increased by 24.2%. Thus, taking into account the results obtained, it can be argued that in case of a decrease or cessation of secretory activity in one of the lobes of the mammary gland, a compensatory reaction is usually manifested by all normally functioning lobes of such a gland.

Analysing the compensatory reactions of the mammary gland lobes of cow no. 2662 with impaired secretion in the left hind lobe, it can be stated that after a decrease in secretion in this lobe by 17.5%, there is a redistribution of milk yield to normally functioning lobes. Thus, the percentage of milk yield in the left front lobe increases by 5.31%, in the right front lobe – by 3.81%, and in the right hind lobe – by 7.7%. At the same time, even before the complete cessation of secretion in this lobe, we observe compensatory reactions of normally functioning lobes. Thus, the milk yield in the left front lobe increases by 6.9%, in the right front lobe by 20.6%, and in the right hind lobe by 8.1%. Even after the complete cessation of secretion in the left hind lobe, compensatory reactions are observed in the front lobes. Thus, the left front lobe's milk yield increased by 11.6%, and the right front lobe's milk yield increased by 3.4%. During the twelfth month of lactation, with a general decrease in average daily milk yield, the front lobes continue to compensate for the secretory process. At the same time, the milk yield in the left front lobe increased by 18.5%, and in the right front lobe – by 15.2%. Thus, in this case, we can state the fact that when secretory activity in one of the lobes of the mammary gland decreases or stops, the remaining normally functioning lobes show a compensatory reaction.

The answer to the question of whether compensatory reactions of normally functioning lobes are manifested in the event of a decrease or cessation of secretory activity by several lobes of the gland can be obtained by analysing the materials of secretory activity of the mammary gland of cow no. 2200. At the tenth month of lactation, three lobes, the left and right front and right hind lobes, showed a sharp (more than 2.5 kg) decrease in secretion. By the end of the eleventh month of lactation, in some lobes it had stopped or continued to decline, while in the left posterior lobe we observed a tendency to a certain compensation of the secretory process. This is confirmed by the results of the secretory activity of this mammary gland in the first month of the new, fifth lactation. Thus, while the secretion in the left front lobe did not recover, and in the right front and hind lobes it decreased by 59.2% and 57.3%, respectively, compared to the second month of the previous lactation, the secretion in the left hind lobe increased by 9.4%. That is, the tendency to compensate for the secretory process, which we observed in the previous lactation, was confirmed in the first month of the new one.

Answering the question of how complete, and whether it occurs at all, the restoration of the secretory process in the next lactation in the lobes that stopped secretion in the previous lactation, let us consider the results of the secretory activity of the mammary gland of cow no. 7302. Since in the fifth month of lactation in the left hind lobe, compared to the first month, there was a significant (3.12 kg) reduction in the secretory process, the left front lobe, on the contrary, increased the secretory process (by 14.1%), as a compensation for its decrease in the left hind lobe. This trend continued in the seventh month of lactation. In the first month of the new lactation, there was a restoration of secretion in the left hind lobe, but in a slightly smaller (13.5%) volume. The secretory process in the right hind lobe was also less intense (18.04%), which, in our opinion, is caused by a natural decrease in secretion with increasing age in lactation. Thus, in this case, we observe a variant of certain compensation and restoration of secretion after its cessation in the previous lactation.

However, this does not always happen, as can be seen in the following two examples. For example, in cow no. 2122, during the ninth month of lactation, secretion in the left hind lobe stopped. This animal is characterised by the fact that the majority of milk is secreted in the front lobes of the gland. This trend continues until the end of lactation, with a gradual decrease in the secretory process. In the first month of the new lactation, there was no recovery of secretion in the left hind lobe, but a compensatory secretion reaction in other normally functioning lobes was observed. At the same time, the distribution of milk yields by lobes is practically levelled. This is especially evident in the second month of lactation, when the yield in the left front lobe increased by 41.1% compared to the first month, in the right front lobe by 27.7% and in the right hind lobe by 22.7%. Thus, from the abovementioned information, it can be argued that even if there is no recovery of secretion with the onset of a new lactation in one of the lobes of the mammary gland, other normally functioning lobes largely compensate for the milk secretion of the non-functioning lobe.

Similar results were observed in cow no. 3982. In the first month of the new lactation, there is no recovery of the secretory process in the right posterior lobe. However, in this case, the front lobes of the mammary gland practically do not participate in compensating for the secretion of the right hind lobe. This function is almost entirely taken over by its functionally closest 'colleague' – the left hind lobe. In other words, in this case, we observe a compensatory reaction of the cow's mammary gland lobes.

Thus, to summarise our research, we can state that when milk secretion in one of the lobes of the cow's mammary gland decreases or stops, all normally functioning lobes of the mammary gland show a compensatory reaction. Under optimal conditions of cessation of secretion in one of the lobes of the mammary gland, in the next lactation, we observe a variant of its restoration almost to the previous level. In the absence of restoration of secretion in one of

the lobes of the mammary gland, with the onset of a new lactation, other normally functioning lobes largely compensate for the milk secretion of the non-functioning lobe.

To summarise our research, it should be noted that in order to confirm or refute the conclusions drawn in this paper, it is necessary to perform additional studies on a significantly larger number of animals.

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