ESTIMATION OF PREVALENCE, EFFECT AND COST OF MASTITIS ON SIMMENTAL DAIRY FARMS OF DIFFERENT SIZES

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ABSTRACT

Mastitis, a production disease highly prevalent in dairy farming, poses a significant challenge to farmers. It is responsible for decreased milk production, reduced milk quality, and increased treatment costs. Thus, early detection and prompt treatment are essential to prevent the infection and minimize the mastitis impact. This study aimed to determine how farm size affects the prevalence, effect, and cost of mastitis. Therefore, a total of 4,922,751 test-day records for dairy Simmental cows collected in the period 2005-2022 were analysed. Results showed that mastitis was most prevalent among small farms, which also exhibited a lower total increase in milk production. In contrast, the highest prevalence of healthy cows was observed at large farms, with the highest total increase in milk production.

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These findings suggest that mastitis prevalence and recovery potential in cows are highly variable and significantly impacted by the farm size. Larger farms exhibit better management practices related to microclimate conditions, feeding, and higher genetic potential of animals. These conditions ensure a lower frequency of mastitis-related problems and higher chances of animal recovery and restoration of production, in line with the genetic potential of animals.

Introduction

Production diseases are a class of diseases that are primarily caused by management practices, such as metabolic disorders. Among dairy cows, production diseases are pre-dominantly related to inadequate feeding or handling practices. The term has been expanded to include a range of other disorders, such as infertility, mastitis, and laminitis, which may involve infectious agents but are largely exacerbated by nutritional or management factors (Nir, 2003). While infectious diseases can result in significant economic losses during outbreaks and receive greater public attention, production diseases continue to be of paramount economic importance for the overall efficiency of animal production. According to Hogeveen et al. (2019), the economic impact of production diseases is several times greater than that of epidemic infectious diseases. Furthermore, it is vital to acknowledge the significance of production diseases which are a critical factor in animal production, particularly in the dairy industry. By addressing the underlying causes of production diseases, such as poor feeding or handling practices, we can enhance the overall health and well-being of the animals while simultaneously improving the eco-nomic efficiency of animal production.

Mastitis is the most widespread production disease that affects dairy cattle (Seegers et al., 2003). It is the inflammation of the parenchyma, or functional tissue, of the mammary gland. This inflammation can be caused by various factors, but intramammary infection (IMI) is the most common cause, usually resulting from the presence of infectious pathogens such as bacteria in the udder. Mastitis is a complex disease that results in physical, chemical, and usually bacteriological changes in milk and pathological changes in the gland tissue. The inflammation can be in an acute or chronic stage, and depending on the signs of inflammation, mastitis in dairy cows is divided into clinical and subclinical categories. Clinical mastitis is characterized by visible changes in milk, mammary gland, or even at the level of the entire organism. These changes can include clots, discoloration, and a decrease in the milk production. The affected cow may also have a fever, decreased appetite, and show signs of pain and discomfort. Subclinical mastitis, on the other hand, is not visible and does not show any physical symptoms. It is usually diagnosed by the somatic cell count (SCC) testing of milk, which measures the number of white blood cells in milk. Elevated SCCs indicate the presence of an immune response to an intramammary infection, even in the absence of visible signs of inflammation. Adkins and Middleton (2018) have classified clinical mastitis based on its severity as mild, moderate, and severe. In mild cases, changes in milk are evident, such as clots, scales, and alterations in colour and consistency of milk secretion. In moderate cases, changes are observed in both milk and the mammary gland. Inflammation in the tissue results in redness, heat, pain, and swelling. In severe cases, changes are evident in milk, mammary gland, and symptoms of systemic disease such as changes in body temperature, rumination rate, appetite, hydration status, and behaviour. Narváez-Semanate et al. (2022) have reported that the incidence of mild cases of clinical mastitis is the highest, followed by moderate cases. On the other hand, severe cases are relatively less common. Overall, mastitis is a significant concern for dairy farmers as it can result in the decreased milk production, decreased milk quality, and increased treatment costs. Therefore, early detection and prompt treatment are necessary in order to prevent the spread of infection and to minimize the impact of mastitis on dairy production.

The mastitis diagnosis is typically predicated on clinical observations or measurements of the inflammatory response to infection. Conversely, identifying the causative agent of infection is essential for diagnosing IMI. Detecting subclinical mastitis in dairy cattle is a challenging task due to its potential to cause more harm than clinical mastitis and the significant risk it poses. Even minor productivity changes can lead to prolonged losses in production. Hence, it is imperative to monitor and detect mastitis early to minimize the negative impact on dairy production. Regrettably, preventative measures against mastitis in cows are only implemented after their milk yield has significantly declined. Subclinical mastitis is more frequent than clinical mastitis and can account for up to 80% of milk production losses. Moreover, affected udder quarters can completely dry out, which can lead to death or culling from the herd. Halasa et al. (2007) assert that mastitis, regardless of the type, can have unfavourable consequences for the dairy industry, including the decreased milk production and quality. Furthermore, Özkan Gülzari et al. (2018) illuminated that mastitis's prevalence can contribute adversely to greenhouse gas emissions. Farmers can minimize milk losses, optimize culling rates, and reduce variable costs by preventing and managing subclinical mastitis. This can reduce the amount of emissions per kilogram of milk produced, ultimately increasing profits. Argaw (2016) stated that the early diagnosis of mastitis is crucial since changes in the udder tissue occur before they become visible. Early detection enables early treatment that minimizes or eliminates the need for antibiotics and maintains production continuity. This benefits the sick cow by decreasing the duration of the infection, leading to less damage to the udder. However, if the duration of mastitis infection, especially contagious mastitis, is prolonged, the possibility of infection spreading to other cows in the herd increases. Kamal et al. (2014) emphasized that the early diagnosis of mastitis also has economic implications, as it allows for the reduction of milk production losses and the increased chances of recovery.

Keeping track of somatic cell count (SCC) as a crucial piece of information from milk recording as it can indicate intramammary infections and help monitor milk quality at individual, herd, and population levels (Schukken et al., 2003). By tracking SCC for each animal in the herd, farmers can gain insights into the health of their udders. Elevated SCC usually signifies a more severe infection, making this metric a valuable tool for evaluating udder health. The number of somatic cells (SCC) is associated with inflammatory processes, making it a useful diagnostic method for assessing udder health (Ivanov et al., 2016). The invasion of the mammary gland tissue by pathogens promotes the trafficking of various immune cells to the inflammation site, leading to an increase in the number of somatic cells in the secreted milk (Alhussien and Dang, 2018). Notably, an increase in SCC during successive lactations was associated only with an increase in the number of polymorphonuclear leukocytes (PMN). However, an increase in SCC during any lactation was associated with an increase in both PMN and other milk somatic cells (Blackburn, 1966). When testing milk, an udder is considered healthy if the count of somatic cells is less than 100,000 cells/ml milk (Smith et al., 2001). Mikó et al. (2016) stated that the healthy milk should contain from 20,000 to 100,000 SCC/ml. However, an increase in somatic cells can result in a loss of milk production, leading to economic losses for dairy farmers (Hadrich et al., 2018). The total milk losses in the herd depend on the distribution of SCC at the cow level and parity within the herd (Chen et al., 2021). According to Mikó et al. (2016), a decrease in milk yield has been observed in cows with elevated somatic cell counts (SCC). The extent of the decline in milk production was directly associated with the degree of SCC, with cows having SCC levels from 50,000 to 100,000 cells/ml exhibiting a loss greater than 8%, while those with average SCC levels from 100,000 to 250,000 cells/ml displaying a decrease in milk production by more than 15%, and even up to 18% (Pfützner and Ózsvári, 2016). Furthermore, the impact of heat stress on somatic cell count (SCC) in Holstein cows has been the subject of study by Gantner et al. (2011, 2017). The study has identified variations in SCC depending on the temperature-humidity index value, daily production level, breed, and parity.

The increasing significance of preventing disorders and diseases in dairy cattle has led to research aimed at determining the prevalence of mastitis and its consequent impact and costs in the population of dairy Simmental cows in Croatia, while considering farm size.

Materials and methods

The statistical analysis was conducted using the milk recording database of cows that are being selected in Croatia. The data was obtained from the Croatian Agency for Agriculture and Food (HAPIH). In Croatia, milk recording is carried out following the AT4/BT4 method, which involves measuring the amount of milk and sampling milk from each lactating cow during morning/evening milking every four weeks. The collected milk samples are analysed in the Central Laboratory for Milk Quality Control (SLKM) of HAPIH. The International Committee for Animal Recording (ICAR, 2017) has defined the procedure for taking milk samples during milk recording, as well as laboratory testing of samples. Milk samples undergo chemical composition testing to determine the content of milk fat, protein, lactose, dry matter, dry matter without fat, urea, and freezing point. Additionally, the content of casein, free fatty acids, pH value, and ketone bodies are tested. The accredited laboratory uses infrared spectrophotometry to analyse the proportion of milk fat, proteins, lactose, and urea. The fluoro-opto-electronic method is used to count somatic cells. The chemical quality of milk is determined by MilkoScan analyzers, while Fossomatic analyzers are used for somatic cell count.

As part of the logical data control process, test-day records that had individual traits falling outside of the following ranges were deleted from the database: daily milk yield less than 3 kg or greater than 100 kg, daily milk fat content less than 1.5% or greater than 9%, daily protein content less than 1% or greater than 7%, and daily lactose content less than 3% or greater than 6%. Additionally, test-day records with missing or illogical values for lactation stage (less than 5 days or greater than 400 days), parity (less than 1 or greater than 10), age at first calving (less than 21 or greater than 36 months), calving date, milk recording date, and herd code were also deleted from the database. After the logical data control process, the database contained a total of 4,922,751 test-day records for dairy Simmental cows, covering the milk recording period from January 1st, 2005 to December 31st, 2022.

The cows were divided into four different classes based on their parity: 1, 2, 3, and 4 or more. Depending on the size of the herd, five classes were formed ranging from less than 5 cows to 200 - 500 cows. The test-day records were also grouped into four seasons based on the month of milk recording: winter (December, January, and February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November). To evaluate the prevalence of mastitis, the daily somatic cell count (SCC) of the cows was analysed. Cows with an SCC below 200,000/ml were considered healthy, while cows with an SCC ranging from 200,000/ml to 400,000/ml were considered at risk of mastitis. An SCC exceeding 400,000/ml was indicative of the presence of mastitis in cows.

The prevalence of mastitis among Simmental cows refers to the percentage of cows in a specific mastitis class, based on the number of somatic cells produced per day, out of the total number of animals. Additionally, the prevalence rate was calculated separately for each herd size class. To analyse the impact of mastitis prevalence on production indicators, only cows with a confirmed mastitis (SCC > 400,000/ml) were included in the study. The reference point for daily milk yield was set to the date of mastitis prevalence determination. The mastitis index was determined based on the number of days after the mastitis diagnosis, with D-0 being the test-day record on the day of diagnosis, A-1 within 35 days, A-2 between 36 and 70 days, A-3 between 71 and 105 days, and A-4 more than 105 days. The effect of the mastitis index on daily milk production (milk, fat, and protein yield) was analysed separately by herd size class. This was done using a specific statistical model:

$$y_{ijklmn} = \mu + b_1(d_i/305) + b_2(d_i/305)^2 + b_3\,ln(305/d_i) + b_4\,ln^2(305/d_i) + A_j + P_k + S_l + M_m + e_{ijklmn} \quad (1)$$

The given equation estimates the daily milk, fat, and protein yield of a cow. The variables used in the equation are as follows: y_{ijklm} represents the estimated milk production trait, μ is the intercept, b_1, b_2, b_3, b_4 are regression coefficients, and d_i is the stage of lactation (i ranging from 6 to 400 days). A_j represents the fixed effect of age at first calving (j ranging from 21 to 36 months) but is only applicable for the first parity, while P_k represents the fixed effect of parity (k ranging from 1, 2, 3, to ≥4). S_l represents the fixed effect of recording season (l ranging from spring to winter) and M_m represents the fixed effect of mastitis index (m ranging from D-0, A-1, A-2, A-3, to A-4). Finally, e_{ijklm} represents the residual. The statistical significance of differences between estimated LsMeans was evaluated by means of Scheffe's method of multiple comparisons, implemented via the MIXED procedure of the SAS software package (SAS Institute Inc., 2019). The estimated differences in daily yields of milk, fat, and protein for each of the analysed milk recordings, namely D-0, A-1, A-2, A-3, and A-4, were presented separately based on herd size.

After the diagnosis of mastitis, the total difference in milk yield for four successive milk recordings (from D-0 to A-4) was calculated using the equation below:

$$Y = D_{A1-D0} * I_{D0-A1} + D_{A2-A1} * I_{A1-A2} + D_{A3-A2} * I_{A2-A3} + D_{A4-A3} * I_{A3-A4} \quad (2)$$

where:

Y = estimated milk yield (kg);

$D_{A1\text{-}D0}$ – the difference between the estimated daily milk yield at the first successive milk recording and the daily milk yield determined at the reference milk recording;

$I_{D0\text{-}A1}$ – the interval between the reference recording and the first successive milk recording;

$D_{A2\text{-}A1}$ – the difference between the estimated daily milk yield at the second and first successive milk recordings;

$I_{A1\text{-}A2}$ – the interval between the first and second successive milk recordings;

$D_{A3\text{-}A2}$ – the difference between the estimated daily milk yield at the third and second successive milk recordings;

$I_{A2\text{-}A3}$ – the interval between the second and third successive milk recordings;

$D_{A4\text{-}A3}$ – the difference between the estimated daily milk yield at the fourth and third successive milk recordings;

$I_{A3\text{-}A4}$ – the interval between the third and fourth successive milk recordings.

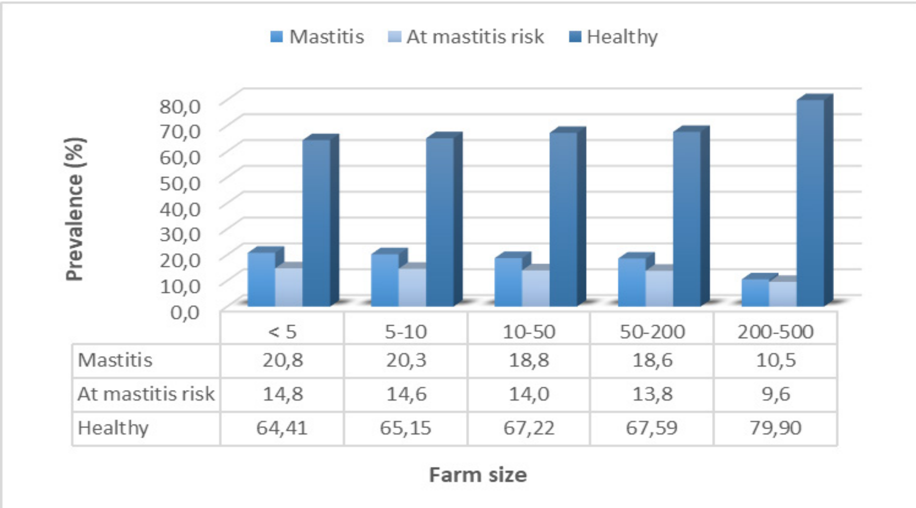
The total difference in milk production in quantity (kg) and value (euro, (Jurinić Kojić et al., 2023)) was presented separately for herd size class.

Results

The present study aimed to examine the prevalence of healthy cows, cows at mastitis risk, and cows with mastitis in response to the number of animals in lactation (farm size). The analysis revealed that there was a significant variation in the prevalence of mastitis, ranging between 10.5% and 20.8% (Figure 1). Similarly, the prevalence of cows at mastitis risk varied from 9.6% to 14.8%. The percentage of healthy cows varied between 64.41% and 79.90%. The observed differences in animal health status were largely attributable to the milk recording season. Notably, the highest prevalence of mastitis was identified in small-scale farms with less than 5 cows, which accounted for 20.0% of the total population. Conversely, the lowest mastitis prevalence was observed in large-scale farms with 200-500 cows, which registered a prevalence rate of 10.5%. Additionally, the percentage of healthy cows was highest in the largest farms (79.90%).

This study underscores the need for careful and regular monitoring of cow health status, with particular attention to the prevalence of mastitis in small-scale farms. Such monitoring can help to reduce the incidence of animal disease, optimize milk production, and promote animal welfare.

Figure 1. The prevalence of healthy, cows at mastitis risk, and cows with mastitis regarding the herd size class.



Source: Authors' calculations

The results of the statistical analysis indicated that all independent variables, including lactation stage, age at first calving, parity, recording season, and breeding region, as well as mastitis index (D-0, A-1, A-2, A-3, A-4), had a statistically significant effect (p < 0.001) on daily milk yield in both breeds and across all farms, regardless of size.

The mastitis index (D-0, A-1, A-2, A-3, A-4) has a significant effect on daily milk, fat, and protein yield, as confirmed by statistical analysis. This effect is present across all farm sizes, suggesting that mastitis has a similar impact on milk production regardless of the size of the farm. The data in Table 1 shows that LsMeans of daily milk yield varied from 13.924 kg/day at D-0 to 14.404 kg/day at A-4 at the smallest farms; from 14.078 kg/day at D-0 to 14.836 kg/day at A-3 at farms with 50 - 10 cows; from 14.932 kg/day at D-0 to 15.923 kg/day at A-2 at farms with 10 - 50 cows; from 16.896 kg/day at D-0 to 17.768 kg/day at A-3 at medium farms with 50 - 200 cows; and from 16.422 kg/day at D-0 to 19.094 kg/day at A-3 at the largest farms with 200 - 500 cows. The lowest daily milk yield was deter-mined at D-0, which is the test-day record when the mastitis prevalence was determined. This finding is consistent across all farm sizes. In contrast, an increase in daily milk yield was observed at successive milk recordings. However, the degree of increase varied de-pending on the farm size, with the largest farms showing the most significant increase in daily milk yield.

The variability in daily fat yield showed a different pattern with the highest values determined at D-0 (0.630 kg/day at the smallest farms; and 0.811 kg/day at the largest farms) followed by a drop at successive milk recordings. This pattern was also observed across all farm sizes. The LsMeans for daily protein yield showed similar variability to daily milk yield, with the lowest values determined at D-0 milk recording (from 0.495 kg/day at farms with less than 5 cows to 0.619 kg/day at farms with more than 200 cows) followed by an increase in value at successive milk recordings. This detailed analysis suggests that the mastitis index has a significant impact on milk production, regardless of the size of the farm. The data also highlights the importance of regular milk recordings in detecting changes in milk yield caused by mastitis.

Table 1. LsMeans of daily yields (milk, fat, and protein) at analysed milk recordings (D-0, A-1, A-2, A-3, A-4) regarding the herd size class

Herd size	MR	Daily milk yield (kg)			Daily fat yield (kg)			Daily protein yield (kg)		
		Estim	StdEr	P	Estim	StdEr	P	Estim	StdEr	P
< 5 cowS	D-0	13.924	0.055	< 0.0001	0.630	0.003	< 0.0001	0.495	0.002	< 0.0001
	A-1	14.385	0.060	< 0.0001	0.592	0.003	< 0.0001	0.498	0.002	< 0.0001
	A-2	14.394	0.061	< 0.0001	0.597	0.003	< 0.0001	0.498	0.002	< 0.0001
	A-3	14.338	0.064	< 0.0001	0.591	0.003	< 0.0001	0.497	0.002	< 0.0001
	A-4	14.404	0.053	< 0.0001	0.597	0.003	< 0.0001	0.498	0.002	< 0.0001
5 – 10 cows	D-0	14.078	0.082	< 0.0001	0.623	0.004	< 0.0001	0.504	0.003	< 0.0001
	A-1	14.736	0.087	< 0.0001	0.603	0.004	< 0.0001	0.515	0.003	< 0.0001
	A-2	14.684	0.087	< 0.0001	0.601	0.004	< 0.0001	0.511	0.003	< 0.0001
	A-3	14.836	0.090	< 0.0001	0.607	0.005	< 0.0001	0.517	0.003	< 0.0001
	A-4	14.824	0.080	< 0.0001	0.608	0.004	< 0.0001	0.516	0.003	< 0.0001
10 – 50 cows	D-0	14.932	0.107	< 0.0001	0.652	0.005	< 0.0001	0.542	0.004	< 0.0001
	A-1	15.923	0.112	< 0.0001	0.641	0.006	< 0.0001	0.564	0.004	< 0.0001
	A-2	15.823	0.113	< 0.0001	0.643	0.006	< 0.0001	0.560	0.004	< 0.0001
	A-3	15.834	0.115	< 0.0001	0.642	0.006	< 0.0001	0.560	0.004	< 0.0001
	A-4	15.913	0.104	< 0.0001	0.646	0.005	< 0.0001	0.562	0.004	< 0.0001
50 – 200 cows	D-0	16.896	0.556	< 0.0001	0.725	0.028	< 0.0001	0.618	0.020	< 0.0001
	A-1	17.635	0.561	< 0.0001	0.708	0.029	< 0.0001	0.630	0.021	< 0.0001
	A-2	17.626	0.560	< 0.0001	0.715	0.029	< 0.0001	0.629	0.021	< 0.0001
	A-3	17.768	0.564	< 0.0001	0.716	0.029	< 0.0001	0.633	0.021	< 0.0001
	A-4	17.524	0.555	< 0.0001	0.710	0.028	< 0.0001	0.624	0.020	< 0.0001

Herd size	MR	Daily milk yield (kg)			Daily fat yield (kg)			Daily protein yield (kg)		
		Estim	StdEr	P	Estim	StdEr	P	Estim	StdEr	P
200 – 500 cows	D-0	16.422	1.394	< 0.0001	0.811	0.067	< 0.0001	0.619	0.050	< 0.0001
	A-1	17.928	1.374	< 0.0001	0.793	0.066	< 0.0001	0.656	0.050	< 0.0001
	A-2	19.094	1.334	< 0.0001	0.804	0.064	< 0.0001	0.681	0.048	< 0.0001
	A-3	18.809	1.528	< 0.0001	0.766	0.073	< 0.0001	0.680	0.055	< 0.0001
	A-4	19.047	1.039	< 0.0001	0.775	0.050	< 0.0001	0.680	0.038	< 0.0001

*MR – milk recording; D-0 – milk recording when the mastitis prevalence was determined; A-1, A-2, A-3, A-4 – successive milk recordings; Estim – estimate; StdEr – standard error of estimate. *Source*: Authors' calculations

The estimated variations in daily milk production between the D-0 and A-1 milk recordings were found to differ based on the size of the farm. The highest increase was observed in the largest farms, reaching up to 1.51 kg/day (equivalent to 45.20 kg/month), while the lowest increase was seen in the smallest farms with less than 5 cows, where it was limited to 0.46 kg/day (equivalent to 13.86 kg/month). A range of differences, from a decrease of 0.01 kg/day to an increase of 1.17 kg/day, were observed in the other analysed milk recordings (A-1&A-2, A-2&A-3, and A-3&A-4), and these variations were dependent on the number of milk recordings and the size of the farm.

The daily fat yield decreased between the D-0 and A-1 milk recordings, ranging from -3.81 kg*10-2/day (for farms with less than 5 cows) to -1.06 kg*10-2/day (for farms with 10 - 50 cows). On the other hand, the daily protein yield increased from 0.33 kg*10-2/day (for farms with less than 5 cows) to 3.68 kg*10-2/day (for farms with 200 - 500 cows). The variations in daily fat and protein yield between the other analysed milk recordings (A-1&A-2, A-2&A-3, and A-3&A-4) ranged from 0.09 kg*10-2/day to 3.82 kg*10-2/day for fat and from 0.02 kg*10-2/day to 2.56 kg*10-2/day for protein, and they were found to be dependent on the number of milk recordings and the size of the farm.

Table 2. Estimated differences in daily milk, fat, and protein yield between the analysed milk recordings (D-0, A-1, A-2, A-3, A-4) regarding the herd size class

Herd size (N cows)	I. MR	II. MR	Daily milk yield (kg)				Daily fat yield (kg*10^{-2})				Daily protein yield (kg*10^{-2})			
			Est	SE	P	Mdif	Est	SE	P	Mdif	Est	SE	P	Mdif
< 5	D-0	A-1	0,46	0,05	***	13,86	-3,81	0,30	***	-114,36	0,33	0,20	n.s.	10,04
	A-1	A-2	0,01	-0,06	n.s.	0,25	0,52	-0,33	n.s.	15,61	-0,02	-0,22	n.s.	-0,58
	A-2	A-3	-0,06	-0,06	n.s.	-1,69	-0,64	-0,35	n.s.	-19,15	-0,13	-0,23	n.s.	-4,04
	A-3	A-4	0,07	-0,06	n.s.	2,00	0,61	-0,31	n.s.	18,28	0,17	-0,21	n.s.	5,21
5 – 10	D-0	A-1	0,66	0,07	***	19,76	-1,98	0,34	***	-59,46	1,07	-0,25	***	32,02
	A-1	A-2	-0,05	-0,07	n.s.	-1,56	-0,18	-0,37	n.s.	-5,36	-0,39	0,27	n.s.	-11,80
	A-2	A-3	0,15	-0,08	n.s.	4,56	0,59	-0,39	n.s.	17,82	0,65	-0,29	n.s.	19,57
	A-3	A-4	-0,01	-0,07	n.s.	-0,36	0,11	-0,35	n.s.	3,22	-0,11	-0,25	n.s.	-3,38

Herd size (N cows)	I. MR	II. MR	Daily milk yield (kg)				Daily fat yield (kg*10^{-2})				Daily protein yield (kg*10^{-2})			
			Est	SE	P	Mdif	Est	SE	P	Mdif	Est	SE	P	Mdif
10 – 50	D-0	A-1	0,99	0,08	***	29,75	-1,06	0,39	n.s.	-31,85	2,15	0,28	***	64,55
	A-1	A-2	-0,10	-0,09	n.s.	-3,00	0,21	-0,43	n.s.	6,22	-0,40	-0,31	n.s.	-11,88
	A-2	A-3	0,01	-0,09	n.s.	0,32	-0,14	-0,45	n.s.	-4,31	0,00	-0,33	n.s.	-0,10
	A-3	A-4	0,08	-0,08	n.s.	2,38	0,45	-0,40	n.s.	13,55	0,26	-0,29	n.s.	7,79
50 – 200	D-0	A-1	0,74	0,17	***	22,18	-1,72	0,85	n.s.	-51,71	1,24	0,61	n.s.	37,23
	A-1	A-2	-0,01	-0,18	n.s.	-0,28	0,74	-0,93	n.s.	22,17	-0,14	-0,67	n.s.	-4,21
	A-2	A-3	0,14	-0,19	n.s.	4,25	0,09	-0,98	n.s.	2,66	0,45	-0,70	n.s.	13,51
	A-3	A-4	-0,24	-0,17	n.s.	-7,31	-0,64	-0,86	n.s.	-19,14	-0,93	-0,62	n.s.	-27,84
200 – 500	D-0	A-1	1,51	1,45	n.s.	45,20	-1,77	6,95	n.s.	-53,00	3,68	5,23	n.s.	110,47
	A-1	A-2	1,17	-1,43	n.s.	34,97	1,06	-6,87	n.s.	31,71	2,56	-5,16	n.s.	76,77
	A-2	A-3	-0,29	-1,58	n.s.	-8,56	-3,82	-7,61	n.s.	-114,54	-0,10	-5,72	n.s.	-3,04
	A-3	A-4	0,24	-1,46	n.s.	7,15	0,93	-6,99	n.s.	27,77	-0,02	-5,26	n.s.	-0,58

* D-0 – milk recording when the mastitis prevalence was determined; A-1, A-2, A-3, A-4 – successive milk recordings; Est – estimated difference, Mdif – estimated monthly difference (Est*interval between the successive milk recordings). *Source*: Authors' calculations

Table 3 presents the differences in milk production in both quantity (kg) and value (euro) during the analysed period from D-0 to A-4 milk recording, with respect to farm size. Cows raised on the smallest farms with fewer than 5 lactating animals showed the lowest increase in daily milk production during the first milk recording (A-1), amounting to 13.857 kg/month (7.21 euro/month), and the lowest total increase of 14.422 kg (7.50 euro)/month. In contrast, the farms with more than 200 cows showed the highest increase in milk production during the first milk recording and the entire analysed period, with 45.195 kg (23.50 euro)/month and 78.757 kg (40.95 euro)/month, respectively.

Table 3. Estimated differences in daily milk, fat, and protein yield between the analysed milk recordings (D-0, A-1, A-2, A-3, A-4) regarding the herd size class

Herd size (N cows)	A-1		A-2		A-3		A-4		Total difference	
	kg	**euro**	**kg**	**euro**	**kg**	**euro**	**kg**	**euro**	**kg**	**euro**
< 5	13.857	7.21	0.251	0.13	-1.685	-0.88	1.999	1.04	14.422	7.50
5 – 10	19.760	10.28	-1.560	-0.81	4.559	2.37	-0.359	-0.19	22.400	11.65
10 – 50	29.749	15.47	-3.003	-1.56	0.319	0.17	2.377	1.24	29.442	15.31
50 – 200	22.181	11.53	-0.280	-0.15	4.255	2.21	-7.314	-3.80	18.842	9.80
200 – 500	45.195	23.50	34.969	18.18	-8.556	-4.45	7.149	3.72	78.757	40.95

Source: Authors' calculations

These results demonstrate that the potential for an animal's recovery and restoration of production is largely variable and significantly influenced by farm management and genetic potential. The animal's genetic potential offers the highest possibility of recovery and restoration of production at the largest farms with better management strategies.

Discussions

This study analysed the prevalence of mastitis, cows at risk of mastitis, and healthy cows based on farm size. Mastitis prevalence varied between 10.5% and 20.8%, while healthy cow proportion ranged from 64.41% to 79.90%. Small-scale farms had the highest mastitis prevalence (20.0%), and large-scale farms had the lowest (10.5%) with the highest percentage of healthy cows (79.90%).

Mastitis is a common infectious disease that affects dairy cows and has a significant impact on milk production and quality. Several factors can influence the occurrence and incidence rate of clinical mastitis cases in dairy herds, as reported by Tomazi et al. (2018). These factors include the season, production system, cow's production level, herd size, and somatic cells in milk. High temperatures and humidity during the summer period create a favourable environment for heat stress in dairy cows, increasing the risk of intra-mammary infections, especially those caused by environmental pathogens. According to Gantner et al. (2011), changes in environmental conditions during the summer period can significantly affect the quantity and quality of milk, somatic cell counts, and mastitis prevalence. Nobrega and Langoni (2011) found that the level of lactose in cows during the dry season was higher, indicating a higher prevalence of mastitis during that period. Similarly, Sharma et al. (2018) reported that mastitis cases are most common during the early autumn or winter, and there is an increased risk of mastitis during winter calving. The authors explain that free and open housing on farms increases the risk of infectious agents in the cows' bedding, which contributes to mastitis-related problems. Weber et al. (2020), in a study on the Holstein breed in Brazil, found that the season significantly affected the composition and quality of milk. Milk was of higher quality during the winter and spring seasons, while in the hotter months of summer and autumn, the quality and availability of forage, and the frequency of mastitis (increased somatic cell counts) negatively affected milk quality. According to Haygert-Velho et al. (2018), heat stress affects lactating cows in summer and autumn, leading to variation in monthly milk production and quality. Antanaitis et al. (2021) state that summer is the most crucial time for the appearance of the causative agent of subclinical mastitis in milk. However, mastitis can also be related to management systems, nutrition, and housing in different seasons. During the outdoor season, milk is more likely to contain higher proportions of environmental bacteria. Furthermore, the micro(climate) of a farm and its management practices can significantly impact animal performance, particularly in relation to mastitis. Notably, larger farms tend to exhibit better management practices and environmental conditions, leading to a lower incidence of mastitis. This conclusion is supported by a study conducted by Fesseha et al. (2021), which found that herd size is strongly correlated ($p < 0.05$) with mastitis prevalence. Specifically, the study reported that farms with fewer than 10 cows had the highest prevalence of mastitis (over 77%), while the lowest prevalence was observed at the largest farms. According to a study conducted by Shuiyun et al. in 2023, the prevalence of clinical mastitis in Chinese dairy cows varied depending on the region. The study also identified parity, age, season, and lactation as the potential risk factors for mastitis. The authors recommended that practitioners improve management strategies to develop appropriate prevention and control programmes for the disease.

This research showed that the mastitis index (D-0 to A-4) significantly affected daily milk, fat, and protein yield, regardless of farm size. The lowest daily milk yield was recorded at D-0 across all farm sizes. Successive milk recordings showed an increase in daily milk yield, with the largest farms showing the most significant increase. Furthermore, daily fat yield varied across all farm sizes with the highest values recorded on the first day, followed by a decline in subsequent milk recordings. On the other hand, daily protein yield showed similar variability like daily milk yield.

Furthermore, the milk production differences between D-0 and A-1 varied based on the farm size. Largest farms saw a 1.51 kg/day increase, while the smallest had only a 0.46 kg/day increase. Other recordings showed a range of differences, from a decrease of 0.01 kg/day to an increase of 1.17 kg/day, dependent on the number of recordings and farm size. During the period between the first and second milk recordings (D-0 and A-1), the daily fat yield decreased for all farms. The decrease ranged from -3.81 kg*10-2/day for farms with less than 5 cows to -1.06 kg*10-2/day for farms with 10 - 50 cows. Conversely, the daily protein yield increased during this period. It ranged from 0.33 kg*10-2/day for farms with less than 5 cows to 3.68 kg*10-2/day for farms with 200 - 500 cows. The changes in daily fat and protein yield between subsequent milk recordings (A-1&A-2, A-2&A-3, and A-3&A-4) varied depending on the number of milk recordings and the size of the farm. The variations ranged from 0.09 kg*10-2/day to 3.82 kg*10-2/day for fat, and from 0.02 kg*10-2/day to 2.56 kg*10-2/day for protein.

The differences observed in this research regarding the increase of daily milk yield after the diagnosis of mastitis on different farms can be attributed to variations in feeding and microclimatic conditions within the production facilities. Simmental cows appear to recover more efficiently in farms with better management practices, including superior feeding options, microclimatic conditions, and animals with greater genetic potential, as indicated by the highest increase in daily milk yield on the largest farms. Research by Antanaitis et al. (2021) suggested that these differences in milk yield are linked to differences in management systems, feeding practices, and seasonal conditions. Wani et al. (2022) found that the highest milk loss during mastitis occurred in spring, followed by summer and autumn. Additionally, Yang et al. (2013) discovered that milk yield, composition, and related measures were influenced by parity and season. Chen et al. (2023) noted that the impact of season on mastitis occurrence varied across regions, likely due to diverse cli-mate conditions. Furthermore, Harjanti and Sambodho (2020) reported a statistically significant negative correlation ($P < 0.0001$) between mammary inflammation and milk pro-duction ($r = -0.59$), milk protein ($r = -0.55$), lactose ($r = -0.51$), and fat content ($r = -0.46$). They concluded that an increase in mammary infection in cows leads to a decrease in milk production and milk components.

The analysis of the differences in milk production (quantity in kg and value in euros) during the analysed period from D-0 to A-4 milk recording reveals that farm size plays an important role. Cows bred on farms with fewer than 5 lactating animals had the lowest increase in daily milk production during the first milk recording (A-1), which amounted to 13.857 kg/month (7.21 euro/month), and the lowest total increase of 14.422 kg (7.50 euro)/month. On the other hand, farms with more than 200 cows showed the highest in-crease in milk production during both the first milk recording and the entire analysed period, with 45.195 kg (23.50 euro)/month and 78.757 kg (40.95 euro)/month, respectively. These results demonstrate that the potential for an animal's recovery and restoration of production is largely variable and significantly influenced by farm management and genetic potential. The animal's genetic potential offers the highest possibility of recovery and restoration of production at the largest farms with better management strategies. According to Huijps et al. (2008), the economic losses of a clinical case of mastitis in a default scenario was found to be €210 on average, ranging from €164 to €235, depending on the month of lactation. The total economic losses of mastitis, including subclinical and clinical cases, per cow present in a default scenario varied between €65 and €182 per year, de-pending on the bulk tank somatic cell count. The study also found that over 7% of farmers expected their economic losses to be lower, averaging €78 per cow per year, but there was a large variation in this estimate ranging from €17 to €198 per cow per year. Same authors concluded that underestimating the economic losses of mastitis could be a general problem in the dairy sector, which can result in inadequate investment in prevention and control measures. Therefore, it is crucial to accurately estimate the financial impact of mastitis to encourage farmers to adopt effective measures to reduce the incidence of the disease. The findings of this research highlight the importance of effective management practices and suitable environmental conditions in mitigating mastitis prevalence on farms as well as the necessity of developing adequate strategies to control and prevent the disease in dairy herds. Furthermore, in small farms, where technological advancements are limited, and cattle with lower genetic potential are present, the prevention of mastitis becomes even more crucial. Due to the lack of knowledge and optimal management practices, small farms often face significant challenges in reducing mastitis infections. This results in lower milk production and lower profitability. Therefore, it is imperative to provide education and training to all farmers, particularly the ones with smaller farms. With proper education and training, farmers can learn how to prevent mastitis infections and implement best practices to increase milk production and profitability. By reducing mastitis infections, farmers can achieve higher milk quality, lower treatment costs, and increased sales revenue. This, in turn, will lead to higher profitability of small farms.

Conclusions

The study aimed to determine how different farm management practices related to the farm size affected the prevalence, the impact and the cost of mastitis. The results showed that mastitis was most prevalent at the smallest farms, with a lower total increase in milk production. Conversely, the highest prevalence of healthy cows was observed at the largest farms, with the highest total increase in milk production after the mastitis occurrence. These findings indicate that mastitis prevalence and recovery potential in cows are highly variable and significantly impacted by the farm size. Larger farms imply better management practices related to microclimate conditions, feeding as well as higher genetic potential of animals. These conditions ensure a lower frequency of problems and a higher chance of animal recovery as well as the restoration of production, in line with the genetic potential of animals, and finally lower total direct costs.

In conclusion, preventing and managing subclinical/clinical mastitis is essential for the dairy industry. The early diagnosis of mastitis is crucial since it allows for early treatment, which minimizes the need for antibiotics and maintains production continuity. This not only benefits the sick cow by reducing the duration of the infection, but it also re-duces the possibility of infection spreading to other cows in the herd. Early diagnosis of mastitis has economic implications, as it allows for the reduction of milk production losses and increased chances of recovery. By minimizing milk losses, optimizing culling rates, and reducing variable costs, farmers can reduce the amount of emissions per kilo-gram of milk produced, ultimately increasing profits and decreasing environmental foot-print.

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Conflict of interests

The authors declare no conflict of interest.

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