PROBLEMS CAUSED BY MASTITIS AND THEIR ASSESSMENT FOR COW HERDS: THE CASE OF LATVIA

Aleksejs Nipers, **Irina Pilvere**, **Anda Valdovska**
Latvia University of Agriculture
Aleksejs.Nipers@llu.lv; Irina.Pilvere@llu.lv; Anda.Valdovska@llu.lv

Abstract
The European Union livestock sector is a major player of the agricultural economy and its land use, and livestock is one of the fastest-growing sectors in agriculture, potentially presenting opportunities for economic growth and poverty reduction in rural areas. In Latvia, the year 2014 was quite difficult for the dairy industry both due to Russia's embargo on dairy product import and low milk purchase prices and due to concerns that milk quotas had been exceeded. It is therefore important that cows are healthy and no additional losses are suffered from mastitis. Mastitis is a complex disease involving many factors, which is mainly caused by bacteria and there is no simple model that encompasses different possible aspects. Therefore, the **research aim** is to assess the effects of mastitis in cow herds for farms in Latvia. The research study proceeds in two stages or phases: firstly, to review the scientific literature on mastitis problems and solutions to the problems in other countries, secondly, to survey dairy farms of various sizes in the regions of Latvia in order to examine the real situation concerning mastitis and its effects on the economy of farms. A survey results of 74 farms in Latvia revealed that 90.5% of the farms had problems with mastitis. Consequently, if sick cattle are timely culled, it is possible to keep the herd milk yield without a significant drop. In case of cows with mastitis, farms suffer losses from smaller quantities of milk produced depending on farming intensity and due to cows culled with mastitis.
Key words: cows, mastitis, milk yield, culling, evaluation.

Introduction

The Food and Agriculture Organization of the United Nations (FAO) estimates that the population will grow to 9.1 billion in 2050. Livestock is one of the fastest-growing sectors in agriculture, potentially presenting opportunities for economic growth and poverty reduction in rural areas, though unless carefully managed the main social effects may be negative – if the livestock-dependent poor are squeezed out of markets and are presented with few viable livelihood alternatives (FAO, 2011). FAO (2014) emphasises that livestock production makes an important contribution to economic development, rural livelihoods, poverty alleviation and meeting the fast growing demand for proteins of animal origin.

Throughout the EU the livestock sector is a major player of the agricultural economy and its land use. The relative importance of different subsectors varies enormously among the EU member states, influenced at the same time by cultural values and bio-physical conditions (pork in Spain and beef in Ireland), while economic conditions also interfere (small ruminants are often playing a larger role in more subsistence production oriented economies). Even though a trend has been seen in the last decades to increasing intensification and larger farm units in all member states of the European Union, diversity of farming systems remains large (Leip *et al*., 2010). In the EU-28 there were 88.4 million heads of bovine animals in 2014. The largest livestock populations were reported in France (19.3 million), Germany (12.7 million), United Kingdom (9.7 million), while the smallest were in Malta (0.01 million), Cyprus (0.06 million) and Luxembourg (0.20 million) (Eurostat, 2015).

Since 2000, the number of cattle has increased by 15% (from 367 to 422 thousand in 2014) in Latvia. However, the number of cows in this period decreased by 19% (from 204 to 166 thousand in 2014) (Central Statistical Bureau, 2015), which indicated the different economic processes in livestock farming. The year 2014 was quite difficult for the dairy industry both due to Russia's embargo on dairy products and low milk purchase prices, and due to concerns that milk quotas had been exceeded. Despite the problems, the total output of milk rose by 6.2% in 2014 compared with 2013. In Latvia, dairy farmers increasingly prefer black and white Holstein cows, and their number increases from year to year (Ministry of Agriculture, 2015).

Under the current circumstances, farmers seek to achieve high milk yields and as low production costs as possible. However, the more productive the cow is, the greater burden is put on the key milk producer – the udder. Cursory care and insufficient knowledge lead to health problems for livestock. Mastitis is an inflammation of the mammary gland (udder), usually caused by infection. Mastitis, inflammation of the mammary gland, can be in clinical or subclinical form and can be caused by various agents, however, the majority of cases are infectious and usually caused by bacteria (Markey *et al*., 2013). FAO (2014) concludes that mastitis is the most prevalent production disease in dairy herds and it is well documented as disease with a heavy burden in developed countries, while very limited information is available for developing countries. Mastitis is one of the most prevalent production diseases affecting the dairy cattle industry worldwide. Its occurrence is associated with direct and indirect losses and expenditures (Petrovski, Trajcev, & Buneski, 2006). In both clinical and subclinical mastitis there is a substantial loss in milk production (Halasa *et al*., 2007). This opinion is shared by J.K. Holland and co-authors (2015), revealing that reduced milk yield due to mastitis has been estimated. When milk production per cow is decreased by mastitis, less milk will be delivered to the factory and the net return of the farm will decrease. There might also be an association between mastitis and other cattle diseases (Halasa *et al*., 2007).

The economic impact of mastitis is usually due to increased milk somatic cell count, decreased milk production and selling, increased costs of veterinary treatment, and premature culling of infected animals. Dairy cattle usually catch mastitis from lying in dirty conditions or from poorly clean milking equipment. Cows can be treated using antibiotics. During treatment the milk is withdrawn from human food chain and is either thrown away or given to calves. There are big penalties against farmers that allow treated milk into the bulk tank. For dairy producers worldwide, somatic cell count is not only a measure of herd udder health performance, it is also a determinant of the marketability of their milk (Vavrova, Palik, & Sladek, 2015)

Mastitis is a common disease of dairy cattle causing significant economic loss, which has been estimated to cost the New Zealand dairy industry USD 180 million annually (Ullaha *et al*., 2013). The dairy producer incurs the cost of these negative outcomes through reduced quality and quantity of milk, as well as increased production costs (Rollina, Dhuyvetterb, & Overtona, 2015). Dairy farmers seek to strike an optimal balance between investments into disease management and economic losses due to mastitis. The research studies are mainly popular-scientific and practical, less scientific. Milk quality is mainly researched with regard to factors affecting it (Zagorska, Ciprovica, 2008; Konosonoka, 2005; Cimermanis, 1999), mastitis as a disease of domestic animals is less examined (Gulbe & Valdovska, 2012; Jemeljanovs *et al*., 2008) and almost no research studies are available on economic effects of mastitis. For these reasons, the **research aim** is to assess the effect of mastitis in cow herds for farms in Latvia. To achieve the aim, two specific **research tasks** were set: 1) to examine the scientific literature on the economic effects of mastitis in cow herds; 2) to analyse the effect of mastitis on milk yield and calculate losses due to lower milk yields and cow culling for farms in Latvia.

The **object of the research** is problems caused by mastitis in dairy cow herds.

Materials and Methods

This research study is part of a broader research study aiming at identifying opportunities for the use of grassland by livestock industries in Latvia (Latvia University of Agriculture, 2015). The research study proceeds in two stages or phases: firstly, to review the scientific literature on mastitis problems and solutions to the problems in other countries, as a few such research studies are available in Latvia; secondly, to survey dairy farms of various sizes in the regions of Latvia in order to examine the real situation concerning mastitis and its effects on the economy of farms.

In 2014, a survey of dairy farms was conducted in Latvia, acquiring information on 74 dairy farms of various sizes in various regions of Latvia, including 10 farms with less than 20 dairy cows (inclusive), 13 farms with a cow herd ranging from 20 (exclusive) to 50 (inclusive), 17 farms having a herd ranging from 50 (exclusive) to 100 (inclusive), 20 farms with a herd ranging from 100 (exclusive) to 300 (inclusive) and 14 farms having more than 300 dairy cows (Farmer interviews, 2014). Compared with the entire target group of dairy livestock farms in Latvia, the present sample group is mostly represented by large farms and, accordingly, small farms are proportionally less represented.

Various sources of materials and data have been used: the scientific literature, legislation, reports and recommendations, as well as websites, the Internet. Appropriate research methods have been used in the research study, mainly qualitative and also quantitative: monographic; analysis and synthesis, data grouping, abstract analysis, logical construction, etc.

Research limitations: an analysis of the scientific literature on mastitis problems and their economic effects was performed in the broadest aspect; yet, the situation in Latvia was analysed from only two aspects owing to limited availability of information: a) the effect of mastitis on milk yield per cow and losses caused by mastitis; b) losses due to livestock culling.

Results and Discussion

1. Literature review on the economic effects of mastitis on milk production

Literature on mastitis management is quite abundant, but less research has been published regarding the economics of mastitis and mastitis management (Halasa *et al*., 2007). H.Seegers, C.Fourichon and F.Beaudeau (2003) have made an extensive summary on the economic effects of mastitis finding that the effects of mastitis take the forms of additional costs (extra investment in resources) and losses (revenue decrease). Estimates of the economic effects of mastitis are mainly based on two approaches: analyses based on farm livestock productivity data as well as examinations that add simulation results to the data by means of such methods as partial budgeting and dynamic simulation.

The economic consequences of mastitis (clinical or subclinical) are due to treatment, production losses, culling, changes in product quality and the risk of other diseases. A summary of a number of research studies (Halasa *et al*., 2007; FAO, 2014; Seegers, Fourichon, & Beaudeau, 2003; Vavrova, Palik, & Sladek, 2015) leads to a conclusion that the majority of the authors, when simulating the economic effects of mastitis, consider that the associated costs can be divided among the following factors: 1) milk production losses; 2) discarded milk; 3) product quality decrease; 4) produced and unsold milk; 5) extra treatment costs; 6) extra drug costs; 7) veterinary services; 8) additional labour costs; 9) additional materials and investments; 10) extra diagnostics costs; 11) lethality and occurrence of other diseases; 12) premature culling and replacement; 13) fines; 14) decrease in feed consumption. There are large variations between studies in the calculations of the economic damage of mastitis and the benefits of mastitis management (Halasa *et al*., 2007; FAO, 2014; Seegers, Fourichon, & Beaudeau, 2003; Vavrova, Palik, & Sladek, 2015).

Some authors take into account such negative aspects as lower milk prices, poorer sales of meat (euthanized livestock, live weight decreases and lower sale prices) and extra costs to purchase calves for replacing culled livestock. Therefore, the results acquired by various authors differ depending on the methods and the number of indicators employed in their research. Lower milk output is considered to be the key reason of economic losses; yet, depending on the method employed and the research period examined, the results acquired are significantly different. Estimates of average lactational loss due to a clinical case ranged from nonsignificant or very low values to values higher than 700 kg of milk in others. To summarise, a reasonable (and probably underestimated) average cumulated loss of 375 kg (about 5%) can be proposed for a so-called average clinical case, occurring in the second month of lactation in a Holstein cow. However the losses are very variable. To take this variability into account, it can be proposed that out of 10 cases, 4 lead to a quite negligible loss, 5 to an average loss, and 1 case to a very high loss (about 1000 kg) (Seegers, Fourichon, & Beaudeau, 2003).

In her research, Christel Nielsen (2009) estimated economic losses caused by clinical and subclinical mastitis and found that the greatest deal of the losses was incurred by lower milk yield. The research results by various authors in the theoretical discussion of the paper identify the key risk factors of mastitis. Older cows, productive cows as well as cows that had mastitis or other diseases face a greater risk of mastitis. Cows face a greater risk of clinical mastitis (CM) at the beginning of lactation, whereas the risk of subclinical mastitis (SCM) is faced at the end of lactation; some effect is also made by the season, as a greater number of cases of mastitis are observed in winter months. A cow breed too determines a higher or lower predisposition to pathogens causing mastitis. The development of mastitis is also influenced by the cow farming conditions, pattern of milking, milking equipment, cow diets, feed quality, and cow cleanliness and prevention measures.

To estimate a decrease in milk output caused by mastitis, C. Nielsen (2009) in her doctoral dissertation, employed weekly observation data on cow productivity in a herd of 150 dairy cows (Swedish Red and Holstein cows) on a training and research farm of the Swedish University of Agricultural Sciences. Her research discovered causal relationships between decrease in milk output and the lactation phase; besides, different results were acquired for primiparous cows and groups of other cows. Reduced milk production constitutes the major cost component of the total economic loss caused by mastitis. The magnitude of yield loss is determined by the stage of lactation in which the cow develops mastitis: milk yield is most severely affected when CM occurs in early and when SCM occurs in late lactation. The lactation yield loss associated with CM varies between 0 and 705 kg in primiparous cows and between 0 and 902 kg in multiparous cows, depending on lactation week at clinical onset. Most cases of CM develop in the first week of lactation and results in a yield loss of 578 and 782 kg milk in primiparous and multiparous cows, respectively. The particular research revealed that the average economic loss per case of clinical mastitis and subclinical mastitis were EUR 275 and EUR 60.

E. Cha and co-authors (2011) in their research aimed to estimate the cost of three different types of clinical mastitis (caused by gram-positive bacteria, gram-negative bacteria and other microorganisms) at the individual cow level and thereby identify the economically optimal management decision for each type of mastitis. The average costs per case (USD) of gram-positive, gram-negative and other clinical mastitis causing agents were USD 133.73, USD 211.03 and USD 95.31, respectively. The main contributor to the total cost per case was treatment cost for gram-positive clinical mastitis (51.5% of the total cost per case), milk loss for gram-negative clinical mastitis (72.4%) and treatment cost for other clinical mastitis (49.2%). The model can provide farmers with economically optimal guidelines specific to their individual cows suffering from different types of clinical mastitis.

D. Bar and co-authors (2008) found that the average cost of clinical mastitis per cow and year in these herds was USD 71. The average cost of a clinical mastitis case was USD 179. It was composed of USD

115 because of milk yield losses, USD 14 because of increased mortality and USD 50 because of treatment-associated costs. The estimated cost of clinical mastitis was highly dependent on cow traits: it was highest (USD 403) in cows with high expected future net returns (e.g., young, high-milk-yielding cows), and lowest (USD 3) in cows that were recommended to be culled for reasons other than mastitis.

T. Gröhn and co-authors (2004) aimed to estimate the effects of the first occurrence of pathogen-specific clinical mastitis on milk yield in 3071 dairy cows in 2 New York State farms. The results indicate that milk loss in mastitis cows did indeed vary depending on the pathogen responsible for the mastitis. Among parity 1 cows, *Staph. aureus, E. coli*, and *Klebsiella spp*. caused the greatest declines in milk yield. Milk yield also dropped in clinically mastitis cows for whom no pathogen was isolated. Among mastitis parity 2+ cows, *Streptococcus spp., Staph. aureus, E. coli, Klebsiella spp.,* and *A. pyogenes* were responsible for the largest milk losses. In general, in both groups of cows, the milk yield often began to drop several weeks before diagnosis of clinical mastitis.

E.Rollina, K.C. Dhuyvetterb and M.W. Overtona (2015) examined the cost of clinical mastitis during the first 30 days in milk by using recent estimates of its effects and described current market conditions and management practices in the United States. The average case of clinical mastitis resulted in a total economic cost of USD 444, including USD 128 in direct costs and USD 316 in indirect costs. Direct costs included diagnostics (USD 10), therapeutics (USD 36), non-saleable milk (USD 25), veterinary service (USD 4), labour (USD 21) and death loss (USD 32). Indirect costs included future milk production loss (USD 125), premature culling and replacement loss (USD 182) and future reproductive loss (USD 9). As discussed in numerous studies, to be able to consider the real cost of mastitis, the prevalence and incidence should first be established. Then estimation of all relevant costs and expenditures should be made.

2. Problems caused by mastitis and their assessment for cow herds in Latvia

The fact that there were problems with mastitis was admitted by 67 of the 74 surveyed farms, which culled their livestock or bought medicines to treat the disease. However, the scale of this disease on each farm was different, as well as each farm's action to cope with this disease differed.

The analysis of average milk yields for the farms with mastitis problems and no such problems revealed that it was not possible to conclude whether the farms with mastitis problems had lower milk yields (Table 1). A justification for the fact that the data did not allow us to make such a conclusion may be acquired in the following way – a farm with minimum mastitis problems was shifted to a group of farms having no mastitis problems. In this case, the average milk yield for the cow group with "no mastitis problems" increased to 7543 kg, while that for the cow group with "mastitis problems" decreased to 7219 kg. In this case too standard deviations and standard errors were relatively large.

Of the 67 farms having large or small problems with mastitis, 36 performed cow culling operations. The average culling rate was 7.4% a year; yet, the rates differ among the farms – from 1% to 34%.

It has to be noted that in general farms that culled their livestock had higher milk yields. It is interesting that such farms even had higher milk yields than those with no mastitis problems (Table 1). It may be associated with the fact that mastitis problems are specific to intensive farms (yet, the large standard error for the average milk yield on the farms with no mastitis problems does not allow making unambiguous conclusions).

Also, no explicit effects of mastitis on the average number of somatic cells in milk were identified. This may be related to two key factors: the fact that the quantity of milk of sick cows is not significant in the total quantity of milk and the fact that sometimes there are a number of other factors influencing the number of somatic cells in milk (for example, several bacterial

Table 1

Milk yields on the surveyed farms depending on their situation with mastitis in Latvia

Situation on the farm	Number of observations (farms)	Average number of cows on farms	Milk yield per cow (kg year^{-1})		
			Average	Standard error	Standard deviation
There are problems with mastitis	67	152	7261	± 200	± 1634
incl. cows are culled because of mastitis	36	156	7615	± 295	± 1769
incl. cows are not culled because of mastitis	31	147	6849	± 247	± 1378
No problems with mastitis	7	179	7191	± 590	± 1562

Source: farmer interviews, 2014; Latvia University of Agriculture, 2015.

Table 2

Losses from lower milk yields due to mastitis problems for the surveyed farms in Latvia

Decrease in milk yield	Decrease in milk yield per cow, kg	Milk price, EUR kg^{-1}	Decrease in revenue, EUR	Decrease in cost, EUR	Losses per cow per year, EUR
Decrease in milk yield (medium intensive farms)	342	0.3	103	45	58
Decrease in milk yield (intensive farms)	766	0.3	230	101	129

Source: farmer interviews, 2014; Latvia University of Agriculture, 2015.

agents). That is why, the number of somatic cells in milk does not exceed a critical value if cows sick with mastitis do not prevail in the herd.

An analysis of the extent to which grazing contributes to mastitis problems revealed that of 42 farms that grazed their cows, 39 had mastitis problems. At the same time, of 32 farms that did not graze their cows, 28 had mastitis problems. This allows assuming that grazing or no grazing is not a factor promoting mastitis.

A similar situation was observed for cows farmed under tied and loose housing systems. Of 43 farms practising tied housing, 40 had mastitis problems. However, of 32 farms under the loose housing system, 27 had problems with mastitis.

No positive or negative effects of some particular milking technology on mastitis problems were identified empirically.

Losses from mastitis were estimated from the perspectives of lower milk yield and cow culling. Within the present research, the data do not allow us to unambiguously estimate the extent to which mastitis influences milk yield. However, some indicative assessments have been made. Two scenarios were considered: medium intensive farming and intensive farming. In case of medium intensive farming, the effect of mastitis was estimated by comparing the milk yields on farms having no mastitis problems with those on farms having mastitis problems and culling their livestock.

In case of intensive farming, the effects of mastitis were estimated by comparing milk yields on farms that tackled their mastitis problems through culling livestock (due to which actually or potentially milk yields were lower) with those on farms having mastitis problems and not culling their livestock.

The calculations estimated a decrease in revenue due to milk unsold (because of lower milk yields) and a decrease in costs (sick cows consume less feed).

It was found that in case of medium intensive farming, the losses from unproduced milk were equal to EUR 58 per cow per year. However, in case of intensive farming, the losses from unproduced milk totalled EUR 129 per cow per year (Table 2).

As regards farm losses from culling sick cows, the situation was analysed for the farms culling their sick livestock. Three scenarios were assessed based on the real situation on the analysed farms: medium (at the cow culling rate of 7.4%), minimum (at the cow culling rate of 1%) and maximum (at the cow culling rate of 34%).

It was concluded that at the average cow culling rate (7.4% of the herd a year), the average losses per dairy cow per farm amounted to EUR 74 a year. In case of minimum problems (at a 1% cow culling rate), the average losses per dairy cow per farm totalled EUR 10 a year. In case of maximum problems (at a 34% cow culling rate), the average losses per dairy cow per farm reached EUR 340 a year (Table 3).

Therefore, the knowledge and awareness of risk factors and characteristics of mastitis caused by pathogens involved are essential to control the wide spread of the disease at farm level (FAO, 2014).

Table 3

Losses from culling livestock due to mastitis problems for the surveyed farms in Latvia

Cow culling	Culling rate	Price of a healthy cow, EUR	Price of a culled cow, EUR	Average losses per cow, EUR
Medium	7.4%	1500	500	74
Minimum	1.0%	1500	500	10
Maximum	34.0%	1500	500	340

Source: farmer interviews, 2014; Latvia University of Agriculture, 2015.

Conclusions

1. Mastitis is a complex disease involving many factors, which is mainly caused by bacteria and there is no simple model that encompasses different possible aspects. The scientific literature deals with various factors determining economic effects of mastitis: 1) milk production losses; 2) discarded milk; 3) product quality decrease; 4) produced but unsold milk; 5) extra treatment costs; 6) extra drug costs; 7) veterinary services; 8) additional labour costs; 9) additional materials and investments; 10) extra diagnostics costs; 11) lethality and occurrence of other diseases; 12) premature culling and replacement; 13) fines; 14) decrease in feed consumption.
2. The scientific literature has identified the key risk factors of mastitis: cow age, cow productivity, other cow diseases, lactation period, season, cow breed, cow farming conditions, milking pattern, milking equipment, cow diets, feed quality, cow cleanliness and prevention measures.
3. The survey of dairy farms conducted in Latvia revealed that:
   - 90.5% of the farms had problems with mastitis. Slightly more than half of the farms having mastitis problems performed cow culling operations; in the result, if sick cattle are timely culled, it is possible to keep the herd milk yield without a significant drop;
   - no association was identified between cases of mastitis and grazing or no grazing and tied or loose housing, as well as no positive or negative effects on mastitis problems caused by some particular milking technology were identified;
   - losses from lower milk output ranged from EUR 58 per cow per year in case of medium intensive farming to EUR 129 in case of intensive farming;
   - losses from culling cows due to mastitis differed depending on the cow culling rate: from EUR 10 per dairy cow per year at a minimum rate (1% a year) to EUR 340 at a maximum culling rate (34%).

Acknowledgements

This research paper is prepared with the support of the Ministry of Agriculture and refers to the research carried out within project No 2013/86 ‘Competitive and Efficient Production of Milk and Meat’, subproject ‘Development of Efficient Farming Models’.

References

1. Bar, D., Tauer, L.W., Bennett, G., González, R.N., Hertl, J.A., Schukken, Y.H., Schulte, H.F., Welcome, F.L., & Gröhn, Y.T. (2008). The Cost of Generic Clinical Mastitis in Dairy Cows as Estimated by Using Dynamic Programming. *Journal of Dairy Science*, Volume 91, Issue 6, June 2008, pp. 2205-2214.
2. Central Statistical Bureau (2015). LLG022. Lauksaimniecības dzīvnieku skaits gada beigās (tūkstošos) (Number of Livestock at the end of Year (in thousands)) Retrieved December 16, 2015, from http://data.csb.gov.lv/pxweb/lv/lauks/lauks__ikgad__05Lopk/LL0220.px/?rxid=cdcb978c-22b0-416a-aacc-aa650d3e2ce0. (in Latvian).
3. Cha, E., Bar, D., Hertl, J.A., Tauer, L.W., Bennett, G., González, R.N., Schukken, Y.H., Welcome, F.L., & Gröhn, Y.T. (2011). Production Effects Related to Mastitis and Mastitis Economics in Dairy Cattle Herds. *Journal of Dairy Science*, Vol. 94(9), pp. 4476-4487.
4. Cimermanis, M. (1999). Activity of the Service of Dairy Quality in Latvia; Problems and Solutions. Proceedings of an International Workshop in conjunction with the East-West-Forum of the Federal Ministry for Food, Agriculture and Forestry and the ’Window of German Animal Breeding’ at the International Green Week 24 – 25 January, ICC, Berlin, Germany.
5. Eurostat (2015). Agricultural Production – Animals. Data extracted in October 2015. Retrieved December 16, 2015, from http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_production_-_animals#Livestock_numbers.
6. Farmer Interviews (2014).
7. Food and Agriculture Organization of the United Nations (FAO) (2011). *Mapping Supply and Demand for Animal-source Foods to 2030*, by T.P. Robinson, & F. Pozzi. Animal Production and Health Working Paper. No. 2. Rome. 154 p.
8. Food and Agriculture Organization of the United Nations (FAO) (2014). *Impact of Mastitis in Small Scale Dairy Production Systems*. Rome, November 2014. 44 p.
9. Gröhn, Y.T., Wilson, D.J., González, R.N., Hertl, J.A., Schulte, H., Bennett, G., & Schukken, Y.H. (2004). Effect of Pathogen-Specific Clinical Mastitis on Milk Yield in Dairy Cows, Journal of Dairy Science, Vol. 87(10), pp. 3358-3374.

10. Gulbe, G., & Valdovska, A. (2012). Microbiological Quality of Cows' Milk in Organic Farming (PRELIMINARY REPORT). Research for Rural Development 2012, Annual 18th International Scientific Conference Proceedings, Jelgava, Volume No. 1, pp. 196-202.
11. Halasa, T., Huijps, K., Osteras, O., & Hogeveen, H. (2007). Economic Effects of Bovine Mastitis and Mastitis Management: A Review. Veterinary Quarterly, 29:1, pp. 18-31.
12. Holland, J.K., Hadrich, J.C., Wolf, C.A., Lombard, J. (2015). Economics of Measuring Costs Due to Mastitis-Related Milk Loss. Presentation at the 2015 AAEA& WAEA Joint Annual Meeting, San Francisco, California, 26 – 28 July 2015, 18 p.
13. Jemeljanovs, A., Konosonoka, I.H., Bluzmanis, J., & Ikauniece, D. (2008). Changes of Mastitis Pathogen Spectrum in Dairy Herds of Latvia. Mastitis control – From Science to Practice. International conference, Wageningen Academic Publishers, Hague, Netherlands, pp. 83.
14. Konosonoka, I.H. (2005). *Microbial Contamination of Cow's Milk and Isolated Associations of Microorganisms*. Summary of promotion work for acquiring The Doctor's degree of Engineering Sciences in the Food Sciences, Sigulda, 27 p.
15. Latvia University of Agriculture (LLU) (2015). Gala atskaite par apakšprojektu 'Efektīvas saimniekošanas modeļu izstrāde' (Report of the Subproject 'Development of Efficient Farming Models'. Jelgava, 117 lpp. (in Latvian).
16. Leip, A., Weiss, F., Wassenaar, T., Perez, I., Fellmann, T., Loudjani, P., Tubiello, F., Grandgirard, D., Monni, S., & Biala, K. (2010). *Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (GGELS) – Final Report*. European Commission, Joint Research Centre, 323 p.
17. Markey, B., Leonard, F., Archambault, M., Cullinane, A., & Maguire, D. (2013). *Clinical Veterinary Microbiology*. 2nd ed., Mosby-Elsevier, 915 p.
18. Ministry of Agriculture (2015). *Latvijas lauksaimniecība 2015 (Agriculture of Latvia 2015)* Riga, 156. lpp. (in Latvian).
19. Nielsen, C. (2009). *Economic Impact of Mastitis in Dairy Cows*. Swedish University of Agricultural Sciences. Doctoral Thesis. Swedish University of Agricultural Sciences, Uppsala, Acta Universitatis agriculturae Sueciae, 2009:29; 81 p.
20. Petrovski, K., Trajcev, M., & Buneski, G. (2006). A Review of the Factors Affecting the Costs of Bovine Mastitis. Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North, New Zealand. Journal of the South African Veterinary Association, Vol. 77 (2), pp. 52-60.
21. Rollina, E., Dhuyvetterb, K.C., & Overtona, M.W. (2015). The Cost of Clinical Mastitis in the First 30 days of Lactation: An Economic Modeling tool. Preventive Veterinary Medicine, Volume 122, Issue 3, 1 December 2015, pp. 257-264.
22. Seegers, H., Fourichon, C., & Beaudeau, F. (2003). Production Effects Related to Mastitis and Mastitis Economics in Dairy Cattle Herds. Veterinary Research, BioMed Central, 2003, 34 (5), pp. 475-491.
23. Ullaha, Z., Margerisona, J.K., Simcockb, D.C., Thatcherc, A., & Villalobosc, N.L. (2013). BRIEF COMMUNICATION: Mastitis Pathogens Isolated from Dairy Cattle that Were Managed on Conventionally or Organically Maintained Matched Farmlets. Proceedings of the New Zealand Society of Animal Production, Vol 73, pp. 183-185.
24. Vavrova, E., Palik, J., & Sladek, Z. (2015). Evaluation of Clinical Mastitis Occurrence, Treatment Protocols and Pathogen Prevalence in a Dairy Herd During 12 Months. MendelNet *2015*, pp. 178-181.
25. Zagorska, J., & Ciprovica, I. (2008). The Chemical Composition of Organic and Conventional Milk in Latvia. Proc. 3rd Baltic Conference on Food Science and Technology. (FOODBALT-2008). Latvia University of Agriculture Faculty of Food Technology. 10-14.