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The Quality of Dairy Cow Bedding and the Occurrence of Environmental Mastitis: Review

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Abstract

An excessive incidence of inflammation of the mammary glands of dairy cows has been observed in many dairy farms in the past, which has been demonstrably correlated with an increased incidence of microbial pathogens in livestock environments. The causes of mastitis can be infectious or non-infectious in nature, one of the main sources of this disease is litter material in the lager. The issue of mastitis has a significant impact on the economic value of dairy cows and therefore it is necessary to create effective measures that eliminate the appearance of pathogenic microorganisms. In this respect, litter material obtained by physical separation and thermal treatment of slurry may represent a suitable alternative ensuring inhibition of the development of dangerous bacteria while maintaining the comfort of dairy cows. Current evidence on the safety and benefits of such material is limited and data on effects on clinical and/or subclinical mastitis are insufficient. In this review, therefore, we would like to shed light on the onset of mastitis in dairy cows and point out possible procedures for treating slurry in practice.

1. Introduction

With the rapid development of the cow breeding industry, intensive, large-scale farming has gradually increased. Although the development of intensive dairy farms provides high-quality milk for the market, manure and sewage from dairy cow farms are causing increasingly serious pollution to the environment, which hinders sustainable development in the dairy industry **(Li *et al.*, 2018)**. The population perceives in particular the risk of air pollution or drinking water sources, and increased accumulation, concentration of nitrogen and phosphorus in rivers or lakes, which can lead to eutrophication, is also becoming a growing social problem. The increase in air pollution rates is in turn attributed to emissions of ammonia and greenhouse gases such as carbon dioxide and methane respectively **(Bolan *et al.*, 2010; Liu *et al.*, 2019)**. Hogan and **Smith (2012)** state, that the most livestock manure is used as a solid/liquid stimulant for the growth of agricultural crops due to its high content of macro- and micro- nutrients. On the other hand, livestock manure can contain high concentrations of various pathogenic microorganisms. Where such products are used as agricultural fertilisers, this may pose a serious risk in terms of contamination of soils and agricultural crops. Contaminated crops can further negatively affect the health of consumers, ending the cycle of pathogen dispersion (Figure 1). On the other hand, after technological treatment and transformation, livestock manure can be used as an energy source (biogas). Since 2018, the European Union has been working towards its policy goal of reducing greenhouse gas emissions by 40% and improving installed renewable energy capacity by 32% in 2030 **(European Commission, 2018)**. Since anaerobic digestion (AD) of livestock manure can guarantee the parallel disposal of waste and the formation of biogas through a series of bioprocesses. At the same time, the output product AD can be used as a fertiliser with improved properties and low greenhouse gas emission potential. In view of the above, the identification of further measures for the treatment and use of cow manure is a highly pressing topic **(Lecler and Laurent, 2017)**.

For decades, mastitis has been considered the most economically significant and frequently occurring disease in dairy cattle, and its incidence has continuously contributed to reducing the profits of dairy farms around the world. In addition to its economic impact, this disease in dairy cows has a negative impact on milk production and processing, on the nutritional value of milk and on the overall composition of milk. Most often, there is a decrease in the concentration of minerals such as phosphorus, sodium or calcium, and a decrease in fat or protein components has also been confirmed. Several possible sources of this inflammatory disease are currently being identified, with the lying area – dairy litter – appearing to have a decisive influence **(Gong, 2007; Hogeveen *et al.*, 2011)**. Dairy cows spend 40 to 65% of their time lying down, and during these periods their udders may come into direct contact with bacteria found in the **litter (Tucker and Weary, 2004; Cook *et al.*, 2005; Hogan and Smith, 2012)**. The incidence of clinical mastitis has been shown to be related to bacterial populations at udder ends in correlation with bacterial populations found in litter **(Zdanowicz *et al.*, 2004)**.

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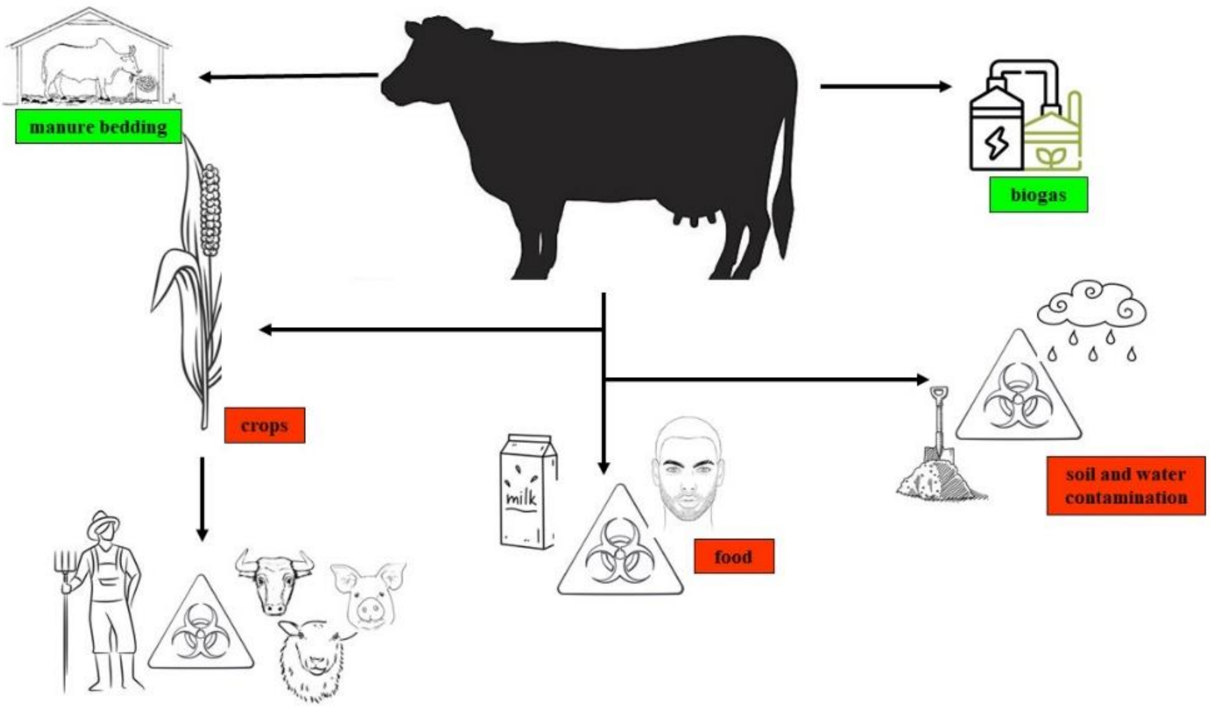

Figure 1. Schematic overview of manure applications

2. Mastitis in dairy cows

Bovine mastitis is a condition typified by the persistent and inflammatory reaction of the udder tissue due to either physical trauma or infections caused by microorganisms. Thus, I can say that inflammation of the mammary gland can be infectious or non-infectious in nature. The non-infectious nature of mastitis can be caused by physical injury to the mammary region, poor hygiene and/or trauma, also cause this condition **(Loccatelli *et al.*, 2008)**. Several types of microorganisms are involved in the development of infectious mastitis. In the vast majority (almost 90%), these are bacterial infections, in a smaller number of cases they are infections by other organisms (viruses, fungi, yeast, parasites and others). The total number of known bacterial agents of dairy mastitis is large and apparently not yet complete **(Zehner *et al.*, 1986)**. According to **Sharif *et al.* (2009)**, the main bacterial pathogenic causing mastitis include *Staphylococcus aureus, Streptococcus agalactiae, and Streptococcus uberis*. Of the environmental pathogens, *Streptococcus disagalactiae, Escherichia coli and Klebsiela* are most often found. Other environmental pathogens commonly found on mammary gland skin include negative staphylococcus, particularly *Staphylococcus chromogenes, S. simulans, S. xylosus, S. haemolyticus, S. warneri, and S. epidermidis* (**Pyörälä and Taponen, 2009)**. With few exceptions, mastitis occurs when microbes enter the teat via the teat canal. Almost any microbe can opportunistically invade the teat canal and cause mastitis. If we look at it in detail, the main cause of udder inflammation is the penetration of the pathogen from the external environment into the teat canal and subsequently the cistern, outlet ducts and udder tissue itself **(Vasil *et al.*, 2016)**. With the penetration of microorganisms through the tee duct into the inside of the cistern, infection of the mammary gland begins. Therefore, the tee duct is considered the first defence system of penetration of microorganisms into the mammary gland. Microorganisms located on the surface of the tee tip penetrate into the udder during milking through the tee duct. After milking, the teat canal is opened within one to two hours, both when damaged and throughout the entire period between milkings. This condition promotes the penetration of pathogenic microorganisms, the sources of which may be litter or poor hygienic quality during milking. After penetration of microorganisms into the mammary gland, the latter attack and populate the tissues. Part of the microorganisms penetrates into the higher glandular tissues of the mammary gland by the movement of the dairy cow, when the milk is mixed in the milk tanker. These microorganisms are responded to by white blood cells found in milk in low concentration, which form the so-called second defence system. These processes provoke an even more intense passage of additional white blood cells from the blood to milk. If white blood cells are not able to destroy microorganisms, they multiply and damage the intralobular ducts and the alveoli themselves. By damaging the epithelial cells of the alveoli, capillary permeability increases. At the same time, white blood cells increase in infected tissues, and minerals and clotting factors penetrate from the blood. Precipitated milk can close the ducts, resulting in the retention and production of additional milk. The activity of secretory cells is suppressed, the alveoli are reduced in size, the destruction of alveolar cells occurs, which are replaced by connective tissue. The destruction of secretory cells is the third defence mechanism that dampens infection. Another defence mechanism is the production of antibodies in the blood IgG, IgA and IgM. These antibodies have the task of opsonizing microorganisms, thereby promoting their phagocytosis. In addition, they prevent the adherence of microorganisms to epithelial cells, reduce the number of microorganisms, neutralize their toxins and cause agglutination of bacteria. Other substances such as lactoperoxidase, lysozyme, cytokines and lactoferrin are also involved in the defence mechanism **(Sharif *et al.*, 2009; Zadoks *et al.*, 2011; Vršková *et al.*, 2015)**.

3. Mastitis induced by pathogenic microorganisms

The bedding used to house cattle is the primary source of environmental pathogens. **Zdanowic *et al.* (2004)** confirmed that bacterial populations in poor quality materials used as bedding in suckler cow stables were demonstrably correlated with an increased incidence of mastitis Although bacterial populations vary significantly in backfill materials, basic parameters such as pH, particle size, and dry matter content of litter play a decisive role. Dairy cattle breeding uses several types of bedding material such as fresh or recycled sand, straw, manure products and other organic and inorganic alternatives. Straw is most commonly used, but its durability and hygienic effect are often insufficient, and they become a source of dangerous pathogens. From inorganic materials, sand, limestone, or zeolite are most often used, but after their soaking in urine and feces in the winter months, the litter often freezes and udders of dairy cows are injured **(Hillerton and Berry, 2003; Hogan and Smith, 2012)**. Another source of infectious pathogens is the udders of sick dairy cows. Transmission of infection in the herd is possible with poor hygiene in the milking parlor, when several dairy cows may come into contact with infected milking parlor's equipment, milkmaids' hands or contaminated materials. With the use of disposable wipes, disinfection before and after milking, as well as effective hygiene of milking equipment, it is possible to prevent the transmission of pathogens from a dairy cow to a dairy cow. Other sources of infection can be infected supernumerary of dairy cows, festering wounds on the skin of milkmaids' hands, or inflammation of the genital apparatus and hooves of dairy cows. A significant carrier of infection is also stinging insects, especially flies **(Schreiner and Ruegg, 2003; DeVier *et al.,* 2012)**. In the context of the above, it is obvious that the use of some bedding materials can be a source of pathogenic microorganisms and thus initiate the onset of mastitis. Management practices that attempt to reduce exposure to bacteria are often logistically challenging and require additional funding to provide disinfectants. One of the ways to achieve the desired litter quality in the long term and ensure its optimal height and hygienic effect is the procedure of thermal treatment of slurry **(Rowbotham and Reugg, 2016)**.

4. Livestock manure processing options

The concept of reusing livestock manure as a cost-effective bedding material for cattle appeared back in the 70s in the USA. The growing number of farms and herds of cattle increased the amount of livestock manure produced, and intensive consideration began to be given to its reuse **(Keys *et al.,* 1976)**. Gradually, methods of separating the solid fraction of slurry from cow manure began to emerge and intensive research was launched into its use as a bedding material, which is tested on many dairy farms around the world. Manure consists of a liquid and solid fraction, which is mainly made up of undigested fibre. Due to concerns about possible bacterial burden, further processing steps from composting to anaerobic digestion have been implemented to eliminate possible risks and eliminate negative impacts on animal and human health. Thus, composting the solid fraction of sludge could be advantageous because it involves thermophilic microorganisms. At temperatures between 40°C and 65°C, this process causes maximum destruction of intestinal pathogens and microbial stabilization occurs **(House, 2016; Bonifacio *et al.,* 2017)**. The composting process can take place in static piles for 3 to 10 days, in rows turned over every 4 days for 2 weeks or using mechanical drum composting for 18 to 72 hours. Individual procedures have their advantages and disadvantages. Static piles are less labor-intensive than rotational composting. On the other hand, rotation is a convenient way to increase the oxygen content in the inner cups of sludge, which leads to a decrease in the number of intestinal microorganisms **(Timms, 2008; Husfeldt *et al.,* 2012)**. In-container composting would typically entail higher acquisition and operating costs than static and swivel methods but allows for faster composting and consistent quality of bedding separation **(Heinonen-Tansaki *et al.*, 2006)**. The process of composting livestock manure is an important part of manure treatment, as many studies have shown that the total number of pathogenic microorganisms was demonstrably higher when using fresh slurry separation compared to composted solid parts of livestock manure. However, the sterilization process remains an integral part **(Husfeldt *et al.*, 2012; Cole, 2015)**. Anaerobic digestion is a process in which livestock manure is broken down by bacteria in an oxygen-free environment at a temperature of 35°C for 20 days or more. In addition, bacteria produce biogas, mainly composed of methane and carbon dioxide. The remaining mass is referred to as digestate. This slurry processing process has several advantages, such as destroying pathogenic microorganisms, reducing smell while maintaining the value of fertilizer from livestock manure. Digestate can then be used as litter material in cattle beds **(House, 2015)**. Mechanical separation aims to separate solid and liquid fractions of the slurry and can consist of different technologies, typically involving a screw press, a centrifuge, or a screen. Separators are efficient in producing a solid fraction with high dry matter content on a relatively cost-effective basis base. Mechanical separation can reduce the volume of the liquid fraction by up to 40% as compared to the volume of raw slurry **(Feiken and Laarhoven, 2012)**.

5. Conclusion

Methods of separating the solid fraction from cow manure and the use of such material for bedding are gaining popularity and its use is increasingly appearing on many dairy farms. It is clear that the use of separated and thermally treated digestate can present many other advantages in addition to availability and economic acceptability. Not only has a reduced incidence of pathogenic microorganisms been demonstrated, but at the same time sufficient stability and protection against the onset of mastitis in dairy cows has been confirmed. It is therefore appropriate to continue research into the use of livestock manure as a hygienically sound source of litter material in dairy cow lairs.

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Declaration of interest
The authors report no conflicts of interest.

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