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POSSIBLE PHYSIOLOGICAL AND ENVIRONMENTAL FACTORS AFFECTING MILK PRODUCTION AND UDDER HEALTH OF DAIRY COWS: A REVIEW

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ABSTRACT

The milk production efficiency is affected by many factors, where the quantity and quality are the most important. An important role in the overall milk production economy is not only the current purchase price and the associated costs. The costs of rearing heifers and pregnant animals in relation to future milk production and udder health are very important too. During the rearing of the calf heifers and during the drying off period of the pregnant animals, many factors directly influence the effectiveness of milk production and udder health. Among them, the breeding environment (temperature, ventilation, nutrition etc.), the physiological state (stage and order of lactation, growth intensity of heifers early after birth, duration of drying, the age at first conception or season of calving etc.) and the udder health (the level of somatic cell count at time of dry off and calving) are discussed in the paper.

Key words: cows; physiological and environmental factors; milk production; udder; health

INTRODUCTION

Milk production and milk composition, hygienic safety and technological qualities (udder health – mastitis pathogens) are crucial factors affecting the economy of dairy farms. However, from the point of view of farm economy, the most important factor is the quantity of milk production. Milk quality and hygienic safety are considered important economic factors only when these parameters are decreased, and dairy processor is not willing to pay fixed price. In that case, the income from milk production is, thus, directly related to the milk composition and the udder health. Therefore, for effective economy of dairy farms, the complex husbandry factors affecting milk performance have to be considered. Especially at present, there are big data available about animals and housing systems (regular milk recording, electronic identification of different behavioural activities or milk performances, microclimatic conditions, etc.), which should be used to improve management of dairy farms in a term of precision farming. As it is described in a literature review, many factors influence milk performance during the period of cows' life, but these factors were studied mainly separately under experimental conditions. Therefore, on the base of scientific knowledge related to the factors significantly involved in milk performance, it would be very important for dairy practice to evaluate the effects of most important factors and their economic importance in milk performances more complexly, under certain practical conditions in Slovak dairy farms.

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Thus, the aim of this review was to collect data from literature to summarise the physiological and environmental factors affecting the milk production and udder health of dairy cows with the emphasis on relationships between rearing conditions during prenatal and early postnatal period of heifer calves and their adult production.

The rearing of heifer calves

Heifer calves represent the future of each dairy farm. Thought less evidence probably future metabolic, milking and reproductive functions of the cow nowadays is not only a result of genetics, but also the consequence of the metabolic environment during foetal development and postnatal nutrition and management (Bach, 2012). Moreover, the season of birth, but not calving, had a significant influence on milk yield, with winter-born heifers producing less than heifers born in any other season (van Eetvelde *et al*., 2017). Last mentioned authors also pointed out that the lower yielding winter-born heifers had higher insulin concentrations at birth, whereas glucose concentrations were similar. They concluded that heifers born during the hotter months are born with higher peripheral insulin sensitivity, finally leading to a higher first-lactation milk yield. Therefore, during early postnatal period good system of heifer rearing gives an important basis for future milk production and health. The information or data available on farm making optimal management decisions to rear dairy heifers properly. However, the costs of heifer rearing are too high to wait until we have found out that something went wrong during her growing phase (Bach and Ahedo, 2008). The high cost of rearing during this period is associated strongly with the age at breeding and age at conception (Boulton *et al*., 2015). They pointed out that during the period from weaning to conception the good rearing and breeding practice should by well managed to ensure that recommended daily live weight gains are maintained consistently and that high conception rates are achieved.

During the whole period from birth to parturition the development of heifers is influenced by many factors that more or less affect their milk production at the first and probably other lactations. Therefore, any data about animal response to housing are useful for proper rearing of heifers to other farmers. One of the most important data indicating optimal growth rate is body weight. As heifer rearing is a costly investment, dairy farmers have been stimulated to maximize early growth of their calves, mainly by enhanced liquid feeding (van Eetvelde *et al*., 2017). The effects of enhanced liquid milk feeding were intensively investigated on milk performance, especially during the first lactation (Moallem *et al*., 2010; Shamay *et al*., 2015). However, as it was pointed out by van Eetvelde and Opsomer (2017), a little is known about the long-term effects of this "accelerated feeding" on fertility, metabolic health and lifespan of dairy cows. In our dairy practice there are limited data (if any), related to body weight during milk nutrition, prepubertal and postpubertal period or body weight at first mating. There are many results from different studies that high growth rate during first 2-3 week of age of heifers significantly increase their milk production during lactation (Drackley, 2005). Even well fed calves (native milk *ad libitum*) were 5 cm taller, reached puberty onset 23 day earlier, calved 30 d earlier, and produced 453 kg more milk at the first lactation than calves fed milk replacer in restricted amounts (Bar-Peled *et al*., 1997; Shamay *et al*., 2005). In another work, the milk yield was even 1100 kg higher in well fed calves before weaning during their first lactation (Pollard *et al*., 2003). Intensive growth of calves before weening was also related to the shorter age of first calving and tendency of higher milk production (Rincker *et al*., 2011). Also, Ettema *et al*. (2004) found out that higher growth rate during the first 6 months of life has been shown to decrease the age at first calving, reducing rearing costs and shortening the non-productive life of the heifer. Hence, optimization of rearing strategies is necessary, as early body weight accretion is most efficient (Bach *et al*., 2008). At present, at the nutrition of young dairy heifers is a widespread problem, which should be addressed by improved monitoring of growth at regular intervals on both beef and dairy units would aid farmers to optimise their heifer management (Wathes *et al*., 2014). Researchers found that 22 % of the variation in first lactation milk yield was explained by pre-weaning growth, and this effect was three to five times greater than that of genetic merit (Van Amburgh *et al*., 2011). On the other hand, opposite effect is observed during prepubertal period where the negative effect of excessive rate of weight gain impairs the development udder resulting in lower milk production during future lactation (Sejrsen and Purub, 1997). We also demonstrated positive effect of growth rate of calves during period before weaning and negative ones during prepubertal period on milk yield of Holstein cows in our experimental farm (Uhrinčať *et al.*, 2007). In addition, rearing systems of calf heifers also affect their behaviour in response to environmental factors in adults. For example, under stress impact the higher residual milk volume after milking indicates that heifers reared under own nursing cows express higher sensitivity to stressors during whole production life (Mačuhová *et al.*, 2009).

Growth intensity of calves during milk nutrition period depends mainly on milk powder composition or amount of feed consumed by calves. However, if environmental conditions are very aggressive (temperature, humidity, airflow etc.) the nutrients are needed for thermogenesis, that reduces the amount of nutrients for body weight gain and in dairy practice it is often possible to notice even body weight loss. For example, a 45 kg calf consuming 500 $g.d^{-1}$ of a typical milk replacer powder will lose body weight when the effective environmental temperature is below 5 °C (National Research Council, 2001). Therefore, the effects of environmental conditions and level of nutrition shortly after birth (colostrum intake), during period of first weeks of calf's life and the prepubertal period on milk performance and their health at adult deserve detail study at the farm level because of significant economic impact. Also weaning is considered as a stressful factor (Weary and Jasper, 2008), which may compromise the immune response of calves for at least 2 weeks after weaning (Hulbert *et al.*, 2011), and caused health problems may negatively influence growth of calves (Berge *et al.*, 2009)

The heat stress

Another very important factor in the calf prenatal development is the effect of environmental temperature on pregnant heifers or cows especially in the last trimester of pregnancy. Calves from cooled cows had greater body weight than calves from stressed cows by heat at birth (42.5 vs. 36.5 kg) (Tao *et al.*, 2012). Mentioned differences in body weights between cooled and heat stressed animals were observed also in their calves at weaning time (78.5 vs. 65.9 kg). The differences in the body weight between calves calved to cooled or heat stressed cows could be also related to the development of digestive tracts and other regulatory mechanisms of the body. It was significantly proved that calves from cooled cows had higher total protein, total serum immunoglobulins G and apparently efficient absorption than the calves from heat-stressed cows (Tao *et al.*, 2012). Moreover, recent research suggests that heat stress during the last 6 wk of gestation negatively affects fertility and milk production up to and through the first lactation of offspring. A possible explanation for this difference could be the direct effect of the body weight on fertility, as heavier heifers seem to become fertile earlier, or by differences in mammary gland development and altered metabolic efficiency (Monteiro *et al.*, 2016). During the dry period, heat stress results in impaired mammary growth, leading to reduced milk yield in the subsequent lactation. Nevertheless, the effects of heat stress on milk composition and quality are inconclusive (Tao *et al.*, 2018).

Heat stress affects also gestation length, which was at average 4 d shorter for heat-stressed cows compared with cooled cows. Cooled cows had greater milk production (28.9 vs. 33.9 $kg.d^{-1}$), lower milk protein concentration (3.01 vs. 2.87 %), and tended to have lower somatic cell score (3.35 vs. 2.94) through 280 days in milk (Tao *et al.*, 2011). Under practical farming the effect of month of calving on gestation length was also confirmed (Tomasek *et al.*, 2017). Maternal heat stress also desensitizes a calf's stress response and alters the foetal development by reducing the hormonal profiles (Guo *et al.*, 2016). Recently it was also shown that *in utero* heat stress during late gestation had immediate and prolonged effects on passive immunity, growth and activity patterns in dairy calves (Laporta *et al.*, 2017). In pregnant cows the heat stress during the dry period decreased mammary cell proliferation rate (1.0 vs. 3.3 %) at −20 d relative to calving compared with cooled cows (Tao *et al.*, 2011). Even cooling cows during the dry period alter immune functions and neutrophil response in the udder to mastitis at early lactation (Thompson *et al.*, 2014). The importance of microclimatic conditions during the dry-off period was also pointed out in the study of Thompson and Dahl (2012). They found out increased incidence of postpartum disorders (retained placenta and mastitis) associated with the exposure of cows to high temperatures during above-mentioned critical period. Thus, this heat stress of the dam during the dry period (and possible effect of a season of calving) compromises the foetal growth, immune and endocrine functions of offspring from birth to weaning, as well as the immune system of the udder. In dairy practice, there are different conditions of housing of pregnant animals, therefore, more detail view on this impact could contribute to the optimal development of offspring during the dry-off period. Based on our practical experiences, there is limited effort of farmers to prevent the effect of heat stress on pregnant animals. The response of animals to heat stress could be evaluated in relation to certain breeds. It seems that Jersey cows appeared to be more heat tolerant than Holstein cows (West *et al*., 2003; Smith *et al*., 2013). Therefore, a breed should be taken into account when the effect of heat stress is evaluated.

The management of dry-off period

Very important part for next milk performance after previous lactation is the management of dry-off period. It represents ideal conditions for mammary gland recovery from many aspects – physiological, morphological and immunological (Pezeshki *et al*., 2010). Though there many scientific articles were published that recommend the optimal management of dry period for milk performance there is a need to re-evaluate the influence of the management of dry period due to changes or clear increase in milk production of dairy cows throughout last decades (Annen *et al*., 2004; Grummer and Rastani, 2004). As it was mentioned in last reviews or new results of Chen *et al*. (2015) and Van Hoeij *et al*. (2016), the duration of dry period is important not only for milk yield, but also for metabolic status of cows after parturition and udder health following lactation. The lengths of dry period have some effect on udder health (Sawa *et al*., 2015), but crucial role is played also by the manner of drying of dairy cows – with or without antibiotic injection into the udder (Scherpenzeel *et al*., 2014; Golder *et al*., 2016) and abrupt or gradual cessation (reduced frequency of milking) (Gott *et al*., 2016). Some studies demonstrated that a dry period less than 40 d reduces milk yield in the subsequent lactation, and an 8-wk dry period is optimal (Funk *et al*., 1987; Sørensen and Enevoldsen, 1991). Most of the studies that led to the recommendation of a 60 days pospartum were completed before 1990. Others have shown no production losses following a 30 days dry period (Bachman, 2002; Gulay *et al*., 2003). The effect of dry-off lengths still deserves detail study under practical conditions. Furthermore, short-day length during the dry period also increases milk yield post-partum. Season of the year affects both yield and composition of milk. Seasonal variables known to impact milk yield and composition are photoperiod and thermal environmental variables, such as temperature, wind speed, solar infrared load and humidity (Collier *et al*., 2017).

The impact of mastitis during the dry-off period

Mastitis is considered to be the most important and challenging dairy cattle disease, with huge financial impacts. The economic consequences of clinical or subclinical mastitis include loss of milk production, loss of milk sales, lower price for high somatic cell count (SCC) in milk, increased culling rates and cost for veterinary treatments (Petrovski *et al*., 2006; Halasa *et al*., 2007; Huijps *et al*., 2008). Despite this, disease--recording systems compiling data from a large number of farms are still not widely implemented in dairy practice; thus, selection for mastitis resistance, which would improve resistance against other diseases and enhance both fertility and longevity, is often based on genetically correlated indicator traits, such as somatic cell count, udder depth and fore udder attachment (Martin *et al*., 2018).

The very important part of the review is to point out the research in the biological and economic impact of the prevention and treatment of mastitis, caused by a variety of contagious and environmental pathogens in dairy practice. Mastitis occurred during lactation but more frequently the udder health status is negatively connected shortly after the dry-off time and also new intramammary infections acquired at the end of dry period (shortly before parturition) are affecting udder health after parturition and during following lactation. Therefore, mastitis should be seriously considered in dry-off management (Vangroenweghe *et al*., 2005). Greater last SCC before the conventional drying-off day (no antibiotics) was associated with a two-time greater risk of at least one case of clinical mastitis in the subsequent lactation (van Hoeij *et al*., 2017). Recently, Bradley *et al*. (2015) found out that dynamics of intramammary infections acquired during the dry period on European dairy farms was not influenced by a cow and quarter factors measured in their study suggest that the herd and management factors may be more influential. A relatively high proportion of dairy cows also have subclinical mastitis (Heringstad *et al*., 2000). Subclinical mastitis might be caused by extended dry period (143 to 250 d), which increases the occurrence of subclinical mastitis during early lactation, has a negative association with reproductive performance (Pinedo *et al*., 2011) and affects milk production and quality, which is characterized by the presence of inflammatory components in the milk (Heringstad *et al*., 2000).

Due to the legislative and consumer pressure on the reduction of antibiotics used in dairy practice, it seems that selective using of antibiotics at drying period could be a useful tool, but only at quarters or udders with low somatic cells without presence of pathogens (Scherpenzeel *et al*., 2014), or alternative methods for infected quarters could be used, such as natural casein hydrolase (Leitner *et al*., 2017). Last mentioned authors pointed out that the decrease in the antibiotic use by drying off quarters without antibiotics significantly increases clinical mastitis (CM) and somatic cell count in milk after parturition, but such increase was not compensated by an increase in antibiotic use for treating CM. Total antibiotic use related to mastitis was thus reduced by 85 % in these quarters. Despite proven efficacy and widespread use of antibiotics before the dry-off status, the use of antibiotics has limitation due to several reasons. Over time the antibiotics reduce the efficacy at the end of dry period (Oliver *et al*., 1990; Pinedo *et al*., 2012). At parturition there are many environmental bacteria (gram-negative) that are not so sensitive against antibiotics. It was found that environmental bacteria are now the most common causes of new mastitis during the dry period (Bradley and Green, 2004). In our previous work with the milk samples from cows suspicious for mastitis, we revealed that many milk samples were microbiologically positive mainly for environmental bacteria (Idriss *et al*., 2013a). On the base of microbiological cultivation, the management can implement effective mastitis control program (Idriss *et al*., 2013b) already used in Nordic countries (Osteras and Solverod, 2009), which is based on treating the cows that are most likely to have intra-mammary infection (Kiesner *et al*., 2016) i.e. the cows with high SCC last day before the dry-off period (Vanhoudt *et al*., 2018). However, in present situation dairy practitioners in Slovakia are not willing to finance the microbiological cultivation, so there is a limited information about mastitis pathogens in dairy practice. One of the reasons of this status is that the most of the samples are bacteriologically negative (Idriss *et al*., 2013b). Therefore, there is necessary to focus on further research to explain the high percentage of microbiologically negative samples of milk from the mastitis cows and to define possible factors involved. Without regular cultivation of milk samples from suspicious cows there is very low chance to reduce mastitis occurrence in the herd.

Another challenge of effective dry-off is high milk yield at the time of drying, which increases a risk of milk accumulation in the udder and possible negative effect on welfare (pressure in the udder) and the udder health (milk leakage) (Ollier *et al*., 2015). The increased yield at drying-off has been associated with an increased risk of new mastitis in the dry period and calving, mainly because of increased risk of leaking milk and intra-mammary pressure (Bradley and Green, 2004; Rajala-Schultz *et al*., 2005). On the other hand, gradually reducing milking frequency of high-producing cows resulted in reduced time spent to anticipating milking and reduced milk leakage after dry-off (Zobel *et al*., 2013). It is possible to conclude that implementation of different management schemes near dry-off for different status of animals may significantly improve milk performance and mammary health within a herd and, thus, the economic efficiency and price competition of dairy farms.

CONCLUSIONS

As we described above, there are many environmental and animal factors influencing milk performance during the period of cows' life. Therefore, on the base of scientific knowledge related to factors significantly involved in milk performance, it would be very important for dairy practice to evaluate the effects of most important environmental factors and their economic importance in milk performances more complexly under current practical conditions.

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