Effect of heat stress on dairy farming at the period of global warming

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Abstract: Effect of heat stress on dairy farming at the period of global warming. The thermal environment is a major factor that can negatively affects milk production of dairy cows. Our objective was to provide a review of factors influencing heat stress (HS) in lactating dairy cows in time of global warming. Heat stress affects dairy cows in many regions of the world and leads to substantial economic losses through its detrimental effect on cow’s rumen health, metabolism, production and reproduction. Dairy breeds are typically more sensitive to HS than some other animals. It directly affects feed intake thereby, reduces growth rate, milk yield, reproductive performance, and even death in extreme cases. In future years, climate change will exacerbate these losses by making the climate warmer. More research is needed to identify improved comprehensive cow-side measurements and welfare that can indicate real-time responses to elevated ambient temperatures and that could be incorporated into heat abatement management decisions. Forecasted the severity of HS issue as an increasing problem in near future because of global warming progression. Hence, sustainable dairy farming remains a vast challenge in these changing conditions globally.

Key words: dairy cattle, climate change, heat stress

INTRODUCTION
Climate change will likely pose the most important challenge facing people this century (Intergovernmental... 2007). Global warming results in frequent periods of high temperatures, which occur in the temperate zone (Central Europe) and elsewhere. The problem of abnormally high temperatures (Schär et al. 2004) is well-known and it is gaining strength all over the world together with climate change. With the changing weather conditions considerable fluctuations in air temperatures inside production barns can be observed, i.e. in dairy cattle breeding (Renaudeau et al. 2012). This is especially clear during summer months, when temperatures can rise up to +35°C. With the growing intensity of global warming, the problem of heat stress in dairy cattle breeding is becoming a growing concern for breeders (Polsky et al. 2017). The air temperature and humidity levels form various combinations that might affect the thermoregulation of cows kept inside barns (i.e. their ability to adjust to certain
weather conditions). This is a problem that affects high yield cows, especially at peak lactation (Silanikove and Koluman 2015). Recent studies suggest that heat stress carries direct implications for feed intake, metabolism, milk yield capacity during lactation and, by extension, economic aspects of production (St-Pierre et al. 2003, Boonkum et al. 2011, von Keyserlingk and Hötzel, 2015, Gao et al. 2017, Polsky et al. 2017).

The aim of this paper is to evidence the growing problem associated with the unavoidable and progressing warming of our climate, which affects in particular animal production, namely the health of the animals, milk production and reproduction of dairy cattle.

HEAT STRESS

Heat stress includes high temperature, relative humidity, reduced air velocity and elevated solar radiation, which significantly obstruct the transfer of heat out of the bodies of animals (Kadzere at al. 2002). Thermal comfort zone varies depending on the breed, species as well as on the age, production state and yield capacity. All living organisms have a thermal comfort zone which is genetically predetermined and influenced by the environment in which they live. Comfort zone refers to conditions wherein a given organism feels most comfortable. The environment in which livestock are kept is characterised by one more anthropological factor, namely human beings. The maintenance of adequate zoo technical conditions on dairy farms is reflected by the right feed and water intake among animals (Polsky et al. 2017). Heat stress promotes oxidative stress, i.e. the accumulation of free radicals in the body (Sordillo 2013), especially during periods of elevated temperatures (Zheng et al. 2009). As a result, the immunity of animals becomes low triggering a series of health problems, which are especially pronounced during pregnancy, such as retained placenta, endometritis puerperalis or mastitis (Malinowski at el. 2003, Sordillo et al. 2007).

DAIRY CATTLE

Heat stress has negative effects on the health and biological functioning of dairy cows through depressed milk production and reduced reproductive performance. Cows, just like other animals, not necessarily those kept on farms, have a specific thermal comfort zone (from –7 to +18°C), with relative humidity of 60% to 80% (Berman 2005, Daniel 2008, Renaudeau et al. 2012). Observations suggest that dairy cows are more tolerant of low indoor temperatures. Adult cattle tolerate well temperatures below 0 provided that the air is dry and there is no draught inside the barn (Daniel 2008). Temperatures below –10°C increase feed intake and stimulate the growth of hair (Angrecka and Herbut 2012). Ambient temperatures exceeding +25°C reduce feed intake, weight gain and lower milk yield. (Lacetera et al. 1996). The susceptibility of dairy cattle to rising temperatures and high milk production increases the metabolic heat of animals (Sunil et al. 2011). The activity of dairy cows allows them to properly use nutrients, especially before and after calving (Collier et al. 1982, Lewis et al. 1984). According to reference literature, the greater the milk yield of an animal,
the greater the amount of heat that the animal emits. The response to heat stress depends on the physiological condition of the animal and it is much more pronounced during peak lactation (Bonkum et al. 2011). Milk production plus high ambient temperatures create a heavy strain on high yield cows, often resulting in overheating (De Rensis and Scaramuzzi 2003).

Researchers discovered that cows under heat stress experience a decline in fertility (Hansen and Aréchiga 1999), hormonal imbalances (Roth et al. 2000, West et al. 2003) and a decline in follicular survival and quality of ovarian follicles (Wolfenson et al. 2000, Włodarczyk et al. 2007). High ambient temperatures lead to embryo loss and death (De Rensis and Scaramuzzi 2003, Włodarczyk et al. 2007). Recent findings point to fertility problems not only with natural service but also with artificial insemination (Schuller et al. 2016). Heat detection rates in a herd can decline to 50% and, as a result, the percentage of culled animals may increase even up to 15% (Lautner and Miller 2003, Jaśkowski et al. 2005).

The primary symptoms of heat stress in cows, at an ambient temperature above +20°C, are believed to be sleepiness, excessive sweating, salivary secretion and abnormally rapid breathing (increase in CO₂ production) or even panting (more than 60 breaths per minute) (Atrain and Shahryar 2012, Soriani et al. 2013).

According to reference literature, in mixed breed cows with ≥93.7% of the Holstein Friesian breed (hf), individual susceptibility to heat stress depends more on environmental factors than it does on genetic factors (Boonkum et al. 2011). Heat stress was evaluated through tests with the stress threshold estimated on the basis of the value of the temperature humidity index (THI) as 72 for production and around 68 for reproduction (Table 1). THI values that describe mild heat stress range from 72 to 79, 78 to 89 refer to moderate heat stress and > 89 refer to severe heat stress (Boonkum et al. 2011).

### MILK PRODUCTION

Lactating dairy cows have an increased sensitivity to heat stress compared with dry cows (non lactating). Even high yield cows with genetic potential produce a lower yield during periods of high temperatures (Lacetera et al. 1996, Boonkum et al. 2011). Factors that are key to milk production, aside from the above-mentioned genetic factors, include specific environmental conditions such as: access to a specific type of feed, un-

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**TABLE 1. Temperature humidity index (THI) for production and reproduction (68%)**

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Temperature (°C)</th>
<th>Relative humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>72</td>
<td>22.2</td>
<td>45–50 (68%)</td>
</tr>
<tr>
<td>74</td>
<td>23.3</td>
<td>30–35 (68%)</td>
</tr>
<tr>
<td>76</td>
<td>24.4</td>
<td>15–20 (68%)</td>
</tr>
<tr>
<td>78</td>
<td>25.6</td>
<td>5–10 (68%)</td>
</tr>
<tr>
<td>80</td>
<td>26.7</td>
<td>0 (68%)</td>
</tr>
</tbody>
</table>
limited amount of water and an adequate indoor climate (Roth et al. 2000, Atrain and Shahryar 2012).

Cows subject to heat stress in peak lactation can yield even 5 litres less milk per day, which is 5 to 20% less per annum (St-Pierre et al. 2003, Cowley et al. 2015). The overall loss during the entire lactation time can reach even around 1,000 litres. Milk production declines and therefore the number of somatic cells in milk goes up to around 100,000 per millilitre. It is estimated that the components of milk produced under heat stress undergo change (Bernabucci et al. 2010, Cowley et al. 2015).

It was found that milk yielded by cows under heat stress contains on average 0.4% and 0.2% less fat and protein and increased numbers of somatic cells (±100,000 per millilitre) and showed a significant decrease due to heat stress condition (Wolfenson et al. 1995, Flammenbaum and Galon 2010, Gantner et al. 2017).

When temperatures rise, animals consume more water, which stimulates metabolism and the growth of microorganisms in the body (Kadzere et al. 2002, Bernabucci et al. 2010). The reference literature clarifies that in high yield animals body temperature is higher as a result of metabolic processes. Reduced feed intake and the associated insufficient amount of nutrients supplied to the body compromise the management of microelements (Soriani et al. 2013, Gao et al. 2017). Heat stress and increase in body temperature even of 1–2°C lead to increased temperature in the rumen. An increase of even +0.5°C in the rumen can trigger changes in the liver or inflammation of the udder or limbs (Sanders et al. 2009). In effect, lowered rumination reduces feed intake and the secretion of saliva (pH of 8–8.5), which is a natural buffer for the contents of the rumen, is inhibited (Maekawa et al. 2002, Sanders et al. 2009), therefore increasing the risk of development of acidosis (Kadzere et al. 2002, Bilik et al. 2012).

**FEED INTAKE**

High temperatures also lead to drying of feed blends on the feeding table, e.g.: TMR (total mix ration). Feed blends with pickled ingredient content spoil in high temperatures. In consequence, the nutritional value and taste of the feed deteriorate. Farm direction will have to increase the energy density of diet by reducing the concentration of forage and increasing the concentrate portion of the diet (Renaudeau et al. 2012). Partially spoiled feed blends are a real threat to animal health because they may compromise the immunity of animals and lead to fertility problems and abnormalities within the internal organs and reduce pH in the rumen (Nardone et al. 2010, Soriani et al. 2013). Moretti et al. (2017) presented in the study a significant unfavourable association between high temperature with humidity and rumination time in Holstein dairy cows. When temperature increases (i.e. increasing heat stress) a reduction in the rumen occurs. In the long-term, health conditions such as acidosis may lead to ketosis during the peri-calving period (Maekawa et al. 2002, Bilik et al. 2012). In addition, the decline in pH of rumen liquid lowers the digestibility of fibre (pH of <6.0 affects cellulolytic bacteria). The above-mentioned factors affect the
physical condition, metabolism and milk yield capacity of cows (Lacetera et al. 1996).

REPRODUCTION

Michalska (2011) points to cyclically rising air temperatures in early spring and spring in Poland. According to reference literature, the pregnancy rate is much lower in dairy cow breeds during the summer compared to winter months. High ambient temperatures affect the reproductive function of cows and the possibility of synchronising heat and births in a herd. Thermal stress is also harmful to the reproductive parameters of bulls in a herd (Zheng et al. 2009). The varying composition of semen during periods of elevated ambient temperatures has already been pointed out in reference literature (Mishra et al. 2013, Bhakat et al. 2014).

The parameters in reproduction groups deteriorate. Seasonal studies carried out in the summer and during periods of increased temperatures revealed that high temperatures and negative energy balance affect the function of the hypothalamus and gonadoliberin (GNRH) and luteinizing hormone (LH) (De Rensis and Scaramuzzi 2003, Włodarczyk et al. 2007). These hormones play a fundamental role in the maturation of ovarian follicles and ovulation. Blood progesterone and oestradiol levels in animals drop (Włodarczyk et al. 2007). Lowered hormone levels shorten the heat by 8 hours. As a result, there is an increased incidence of silent heat which leads to a decline in fertilisation rates in a herd (St-Pierre et al. 2003, Jaśkowski et al. 2005). Hyperthermia (elevated body temperature) in cows may lead to damage in maturing follicles, oocytes or embryos. Oocytes can become damaged even 105 days before ovulation, resulting in temporary infertility (Wilson et al. 1998, Sunil et al. 2011). Fertilisation rates indicate that there are seasonal differences in recipient cows (Hansen and Aréchiga 1999). Selecting for heat tolerance is hampered by the negative (i.e., unfavorable) genetic correlation with milk production. However, the results of the Bernabucci et al. (2014) study demonstrate that the inclusion of temperature with humidity covariate effects in the estimation of the sire ranking; sires with the same genetic value for milk production responded differently as the temperature has increased.

METHODS TO REDUCE HEAT STRESS

Taking steps to reduce heat stress will keep cows healthy and in good condition and allow animals with high genetic potential to develop and improve milk production and reproductive performance (Kadzere et al. 2002, Torres-Junior et al. 2008).

In the case of dairy cows kept in old-fashioned barns (stall barns), it is advisable to open windows and doors wide (Flamenbaum et al. 1986). A standard way to prevent heat stress used in the West (U.S., Germany, the Netherlands) is the widespread use of ventilators (Hansen and Aréchiga 1999, Kadzere et al. 2002). The right stream of air can transfer excess heat from animals out of the indoor areas in which they are kept. Scientists believe that an air exchange of 40 to 60 litres per hour will suffice
in the summer. The use of ventilators indoors is advised at temperatures higher than +20°C. During hot days, ventilators can help prevent the loss of 1/2 to 3/4 of a litre of milk in lactating cows. According to observations, high humidity levels make it more difficult for animals to transfer heat out of their bodies through evaporation (Flamenbaum et al. 1986, Daniel 2008, Bernabucci et al. 2010).

The most common ways of protecting cows from heat stress include: providing constant access to clean water (during hot summer days, high yield cows can drink more than 150 litres of water) (Angrecka and Herbut 2012). In the case of animals kept on pastures or yards, animals must be provided with access to a place in the shade. While freestall barns should feature ventilators near the feeding tables. Indoor areas with a large number of animals should be equipped with sprinkler systems at points where the animals tend to gather (waiting area, feeding table). Dry bedding which absorbs moisture is a good solution for barns that use thick bedding for support. The animals should restore the supply of mineral ingredients lost through perspiration on an ongoing basis, not only during periods of increased temperatures. It seems reasonable to prevent feed from becoming warm by increasing the frequency of administration to even 4 times per day. One more solution worth taking into consideration is serving more feed at night when the temperatures are lower.

Increased air velocity makes it easier for animals to cool their bodies. According to Branwell (2002), as cited in Heidenreich et al. (2005), in a temperature of +29.5°C, relative humidity of 50% and air velocity of 1.0 m/s, the temperature perceived by cows goes down to +24.4°C. Presumably, increased air velocity during hot days can lower the temperature perceived by cows.

A proven way of cooling animals, especially in countries where temperatures during the summer can reach +40°C or more (e.g. Israel, Italy) is sprinkling the animals combined with gusts of cool air (Table 2). The system is well known and has been widely used in barns for over 20 years (Flamenbaum et al. 1986). By cooling animals 5 times per day each time for around 30 minutes, cows that yield 25 to 30 kg of milk per day manage to maintain their body temperature below +39°C (Flamenbaum and Galon 2010).

The application of hormones in addition to cooling systems during periods that entail the greatest risk of heat stress for cattle might help keep reproduction

TABLE 2. Comparison of the intensity of cooling dairy cattle in Israel for high and low milk production

<table>
<thead>
<tr>
<th>Variables</th>
<th>High milk production</th>
<th>Low milk production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>intensive cooling</td>
<td>moderate cooling</td>
</tr>
<tr>
<td>Winter</td>
<td>39%</td>
<td>39%</td>
</tr>
<tr>
<td>Summer</td>
<td>19%</td>
<td>12%</td>
</tr>
<tr>
<td>Winter/Summer ratio</td>
<td>0.49</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Based on Flamenbaum and Galon 2010.
and milk production rates at a steady level. Research into the subject is already in progress.

CONCLUSIONS

Physical modification of the environment, nutrition, work organisation and selecting animals that tolerate climate change for reproduction are key to sustainable dairy cattle breeding in the warming climate (Atrain and Shahryar 2012).

More research is needed to identify improved comprehensive cow side effects of measurements that can indicate real time responses to elevated ambient temperatures. In conclusion, it is essential to introduce cow cooling systems in barns, especially during summer months when temperatures are high. All barns should feature ventilation systems (natural or mechanical ventilation). In barns featuring mechanical ventilation, alternative natural ventilation should also be present. Nonetheless, before these new technical solutions aimed at improving the comfort of animals and farm workers are introduced, there needs to be a focus on improving milk production and providing improved conditions for reproduction to ensure the high economic performance of a farm. The costs associated with rising ambient temperatures inside barns need to be estimated.

It should be expected that livestock maintenance systems (based on grazing, mixed breeding or industrialisation) will have increasingly negative effects on the climate (global warming). Further research and observation on dairy cattle breeding in warming climates all over the world are still required.

REFERENCES


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Streszczenie: Wpływ stresu cieplnego na hodowlę mleczną w okresie globalnego ocieplenia. Celem pracy było dokonanie przeglądu czynników wpływających na występowanie stresu cieplnego (HS) u krów mlecznych w okresie laktacji. Wpływ wysokiej temperatury otoczenia na hodowlę zwierząt gospodarskich początkowo zaznaczył się w północnych szerokościach geograficznych i była to reakcja na rosnącą globalnie temperaturę, dopóki nie uznano że nie jest ona ograniczona tylko na obszarach tropicalnych.
Stres cieplny w odmieniony sposób dotyka krowy mlecznej w wielu regionach świata i prowadzi do znacznego strat ekonomicznych poprzez szkodliwy wpływ na zdrowotność zwierząt, metabolizm, produkcję i reprodukcję stada. Krowy ras mlecznych są bardziej wrażliwe na HS i bezpośrednio wpływa on na ilość pobranjej paszy co zmniejsza tempo wzrostu zwierząt, jak i wydajność mleczną, parametry reprodukcji, a w ekstremalnych przypadkach może prowadzić do śmierci zwierząt. Główną reakcją zwierząt w warunkach zmian termalnych organizmu jest podwyższenie częstości oddechów, podwyższona temperatura ciała (>38°C) i szybsza akcja serca. Poprzez nadchodzącą ocieplenie klimatu w kolejnych latach, straty w hodowli mogą się pogłębić. Koniecznym, wydają się dalsze prace badawcze które obejmą wszystkie wskaźniki chowu i hodowli bydła mlecznego. Wnikliwe badania mogą pomóc wskazać niekwestionowane reakcje zwierząt w okresie podwyższenych temperatur otoczenia. Rezultatem mogły by być nowe ustalenia, które w przyszłości były by włączone do praktyk w zarządzaniu hodowlą bydła. Zrównoważona hodowla i produkcja mleczna pozostaje ogromnym wyzwaniem w tych zmieniających się warunkach klimatycznych na całym świecie.

Słowa kluczowe: bydło mleczne, zmiana klimatu, stres cieplny

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