Theriogenology 91 (2017) 145–153

Contents lists available at ScienceDirect

Theriogenology

journal homepage: www.theriojournal.com

Causes of declining fertility in dairy cows during the warm season

F. De Rensis [a, *], F. Lopez-Gatius [b], I. García-Ispierto [c], G. Morini [a], R.J. Scaramuzzi [d, e]

[a] Department of Veterinary Medical Science, University of Parma, Italy
[b] Transfer in Bovine Reproduction SLu, 22300 Barbastro, Spain
[c] Department of Animal Science, University of Lleida, Agrotecnio Center, Lleida, Spain
[d] Department of Comparative Biomedical Sciences, The Royal Veterinary College, Herts AL9 7TA, UK
[e] The Institute of Agriculture, University of Western Australia, Crawley 6009, Western Australia, Australia

ARTICLE INFO

Article history:
Received 9 September 2016
Received in revised form
14 December 2016
Accepted 14 December 2016
Available online 24 December 2016

Keywords:
Dairy cow
Warm season
Estrus
Fertility

ABSTRACT

In the Northern Hemisphere, from June to September and in the Southern Hemisphere from December to March, there are periods of reduced fertility (sub-fertility) in dairy cows that are described as summer infertility. Several factors contribute to sub-fertility during this time, such as ambient temperature, humidity and photoperiod. During the warm season there is a reduction in feed intake that may compromise the energy balance of the cow and/or induce an imbalance in the activity of the hypothalamo-hypophyseal-ovarian axis. These factors reduce the reproductive performance of the cow and compromise the quality of oocytes, embryos and corpora lutea. This paper reviews current knowledge on the metabolic and endocrine mechanisms that induce summer infertility and describe their effects on follicle, oocyte and embryo development in dairy cows.

1. Introduction

During summer, dairy herds in the both the Northern and Southern Hemispheres can experience a significant decline in fertility that is associated with increased levels of heat stress [1–4]. Heat stressed cows show sub-fertility with an increased number of cows suffering from anestrus, leading to a reduced pregnancy rate in the herd, an increased number of days open and higher pregnancy losses [2–14]. Several studies report that during the warm season there was a 20–30% reduction in conception rate [15–18] and in pregnancy rate [19–24]. In a large-scale retrospective study [25], the average pregnancy rate to the first post-partum artificial insemination (AI) and the rate of anestrus were 44% and 27%, and 1.2% and 12.9% for cool and warm periods, respectively. The greatest negative impact of heat stress on conception rate occurs in the period from 21 days before to 7 days after breeding [18,26–29] and the risk of ovulation failure is 3.9 times higher for cows inseminated in warm compared the cool seasons [30]. Because of reduced follicular development during the warm season, there is a consequent reduction in inhibin secretion, thus the concentrations of. plasma FSH levels are above normal and the process of follicle dominance is altered resulting in more double ovulations, an increased rate of twinning [31] and an increased risk of abortion. Cows bearing either singletons or twin fetuses were 3.7 and 5.4 times more likely to abort in the warm season compared the cool season [32,33]. Finally, during summer the risk of development of ovarian cysts it is also increased [34–36]. Along with these effects on fertility heat stress induced lethargic behavior, rapid shallows and diminished feed intake and consequently, milk [37–39].

An important aspect of heat-stress induced sub-fertility is that it persists into the autumn even though the ambient temperature has fallen and the cows are no longer to heat stressed. The delayed effect of summer heat stress on autumn fertility accounts for about one-third the sub-fertility associated with heat stress [40].

The aim of this review is to describe the metabolic and reproductive mechanisms that mediate the negative effects of effects of heat stress on reproduction in dairy cows. An understanding of these mechanisms may facilitate the development of strategies to improve their fertility during the summer months.

2. The temperature comfort zone for dairy cows

The comfort zone for dairy cows has been estimated to be an ambient temperature of between 5° and 25 °C) [41]. Unfortunately in tropical, sub-tropical but also in some temperate climatic regions

* Corresponding author. Department of Veterinary Medical Science, University of Parma, 43121 Parma, Italy.
E-mail address: fabio.derensis@unipr.it (F. De Rensis).

http://dx.doi.org/10.1016/j.theriogenology.2016.12.024
0093-691X/

the upper limit of ambient temperature 25 °C is frequently exceeded during the summer. Temperatures above 25 °C can disrupt both the general physiology and the reproductive performance of cows [2,25,28,29,42,43] not only during periods of high temperature but also in the following season [43–45]. In Florida, temperatures of 29.7 °C have been linked to mild hyperthermia (rectal temperature of 39.0 °C and temperatures above 31.4 °C to hyperthermia [19,46]. Rectal temperatures greater than 39.0 °C and respiration rates greater than 60/min indicate a level of heat stress [47,48], that will affect milk yield and fertility [49–52].

The adverse effect of high temperatures is exacerbated by high humidity especially in high producing dairy cows [29,53]. Therefore, it is more than the temperature alone that determines the level of heat stress in dairy cows. It is the combined effect of high humidity and high temperature that ultimately determines the level of heat stress in dairy cows. The combined effect of temperature and humidity can be quantified using the so-called temperature–humidity (THI) index. This index was developed by Thom in 1959 [54] to estimate the perception of heat in humans and its efficacy for the detection of heat stress in cows has been confirmed by several authors [17,51,55,56] who have estimated that a daily THI of 72 or above between the period from 35 days before to 6 days after the day of breeding decreased conception rate of lactating dairy cows by around 30% compared to cows with a THI of less than 72. In temperate zones (e.g., Central Europe, Northern USA, and Canada) the average THI can reach the threshold of 72 during the summer months. In Germany, a detailed study [57] in a commercial dairy barn observed that the THI threshold of 72 was reached on 162 of 756 experimental days and, when the mean THI was 73 or more, conception rate decreased from 31% to 12%. However, wind velocity and radiation can both affect the thermal status of cows and metabolic heat production with consequent effects on milk production. Furthermore, the farm environment will vary from farm to farm depending on the particular environmental situation. For this reason, the efficacy of systems designed to minimize heat stress such as fans, cool water and ventilation vary enormously among herds. Therefore, caution is needed when considering THI alone and the assumed THI threshold of 72. For example, in an extensive study of 10,964 inseminations [28], the conception rate was greatly decreased when the THI was 76 or greater on the day of insemination. However, in the same study, an analysis that excluded the THI but included rainfall and maximum temperatures as climate variables, showed that the maximum temperature the day after insemination was the best predictor of conception rate. In this study, temperatures higher than 20 °C significantly decreased the conception rate [28]. This observation further highlights the importance of heat stress even in temperate climates and we need to bear in mind that by 2080 the average US and global temperatures are projected to increase from 3 to 12 °F and 0.5–8.6 °F, respectively [58]. The negative effects of heat stress on fertility have increased over the last few decades [25,59,60] and they are likely to further increase if the levels of milk production are pushed beyond the already unsustainable levels of the modern high producing dairy cow. In addition, global climate change will increase both the level and duration of heat stress [61].

3. The effect of heat stress on the metabolic system (Fig. 1)

The effect of heat stress on the fertility of dairy cows is multidimensional and operates through several mechanisms that probably involve both direct reproductive effects and indirect metabolic and nutritional effects. One of the most important effects of heat stress is that it reduces voluntary feed intake (VFI) that is largely responsible worsening post-partum negative energy balance by augmenting its degree and extending its length [62]. A clear reduction in dry matter (DM) intake has been observed heifers [36,63,64] and lactating cows [65,66] under heat stress. The negative effect of reduced VFI on fertility is greater in high producing dairy cows because of their increased feed requirement and hepatic metabolism [67–70].

From a metabolic point of view, cows under heat stress generally have altered blood acid-base chemistry because of a shift from conductive, convective and radiant cooling to evaporative cooling [71]. This reliance on evaporative cooling increased thermal panting and altered the critical balance of carbonate to bicarbonate that is necessary for the maintenance of blood pH [72]. Panting also induced a loss of bicarbonate in saliva with a reduction in the buffering effect of saliva on rumen fermentation. The result is an altered acid-basic balance with negative effects on fertility.

During periods of heat stress principally because of its effect on the intake of DM, the blood concentrations of key metabolic hormones and growth factors, required for normal follicular development are reduced to sub-optimal concentrations [73]. In one study [74] it was shown that during the post-partum period, the plasma concentrations of insulin, insulin-like growth factor-1 (IGF-I) and glucose were lower in summer compared to winter. This is one mechanism by which heat stress and its associated reduction in DM intake can decrease fertility of dairy cows because insulin is required for the normal development of follicles and has beneficial effects on oocyte quality [75]. Both IGF-I and glucose are generally stimulatory to follicular growth and implantation and glucose is the primary metabolic fuel for the ovary [76]. Glucose is also directly involved in modulating pulsatile LH secretion [77,78] at a hypothalamic level.

Another factor by which heat stress can alter metabolism and disrupt fertility involves the generation of reactive oxygen species (ROS) [79,80]. In fact it has been reported that concentrations of thiobarbituric acid reactive substance (TBARS) in the blood of cows is higher during hot compared to cool weather [66,81,82] and it is known that ROS can damage both the oocyte and the preimplantation embryo [81–94].

There are suggestions that feeding a supplement of beta-carotene for at least 90 days beginning around 15 days after calving can increase the proportion of cows that become pregnant by 120 days post-partum (35% vs 21%) [95–97] but, in other studies, the administration of the antioxidant, vitamin E [98] or a combination of vitamin E and selenium [99,100] or beta-carotene [101] did not increase fertility in heat stressed dairy cows. Taken together, we conclude that the administration of antioxidants might protect the ovarian pool of oocytes from heat stress but, overall, more research is needed to identify an antioxidant regiment that can be effectively utilized.

4. The effect of heat stress during summer on the reproductive endocrine system (Fig. 2)

It has been observed that the effects of heat stress on reproductive function are not only influenced by reduced feed intake and its associated metabolic effect but, that there are also direct links between heat stress and the reproductive endocrine system [36]. During summer, heat stress can affect the activity of the HPO axis through a cascade of events mainly related to the decreased secretion of gonadotropins, presumably due to decreased secretion of GnRH, that results in the inhibition of ovarian activity. These mechanisms have been only partly elucidated; published data indicates a direct effect of heat stress on the HPO axis that is correlated, at least in part, with the modified secretion of cortisol. In fact, in cows under acute heat stress cortisol is increased [102,103] although it is reduced in cows under chronic heat stress [104–107], and this compromises fertility [108,109]. Since feed