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Heat stress affects reproductive performance of high producing dairy cows bred in an area of southern Apennines

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ABSTRACT

A 5-year retrospective (from 2008 to 2012) survey was carried out by analyzing data of high producing dairy cows reared in farms located in an area of southern Apennines. The indicators of fertility obtained were related to either season variations or temperature–humidity index (THI). Conceptions were evaluated per month on an annual basis (NCY), i.e., a parameter obtained by subtracting gestation length to the calving date. A significant reduction of NCY was found during the summer months; furthermore, this parameter decreased along with THI increase. The number of heats detected varied similarly to NCY and represented the main cause of lower fertility consequent to heat stress (HS). The age at first calving was not significantly affected by either the season or the THI. The mean number of AI/pregnancy in relation to the calving date was significantly affected by the season but it was not related to THI. The number of days open was significantly larger in the animals calved from January to July than from August to December (163 ± 33 vs 123 ± 36 days; $P<0.001$); this causes an annual economic loss of several thousand euro in each farm analyzed. In conclusion, HS causes severe economic loss in dairy farms located in southern Apennines that is mainly due to a lower number of heats detected as well as to a larger number of days open and semen doses used.

1. Introduction

Declining productive and reproductive performance of livestock in tropical and subtropical areas is a well-known phenomenon that limits high production dairy cattle breeding (Gauly et al., 2013; Kadzere et al., 2002). Global warming and the breeding of selected animals that are more and more sensitive to environmental effects have made this phenomenon, named heat stress (HS), particularly relevant even in temperate areas (Ferreira, 2013; Nardone et al., 2010). The origin of HS comes from the attempt to counteract hyperthermia induced by the high environmental temperature using mechanisms of thermal dispersion. These mechanisms are, however, also influenced by other input variables, such as relative humidity, ventilation, radiant energy and rainfall (Igono et al., 1992). Complex indexes, which combine some of the above climate parameters involved, have been proposed to monitor the effects of HS. The temperature–humidity index (THI), that combines the maximum temperatures with the minimum relative humidity, is the most used one (Ravagnolo and Misztal, 2000).

The infertility caused by the HS is due to both direct and indirect causes that affect reproductive performance. In particular, HS may act directly by reducing the quality of the gametes. In the male, there is an increase of oligo-astheno-teratospermia (Meyerhoeffer et al., 1985). In the female, several alterations are described either in the processes of folliculogenesis, as prolongation of follicle dominance and co-dominance phenomena (Badinga et al., 1993; Wolfenson et al., 1995) with a significant reduction in follicular estradiol (Badinga et al., 1994), or luteogenesis,

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as well as a delayed luteolysis (Wilson et al., 1998b) and a compromised luteal activity during the postpartum period (De Rensis et al., 2008). The follicle and oocyte maturations are compromised and the mature oocyte has a reduced competence for fertilization and embryonic development (Mihm et al., 1994; Rispoli et al., 2011; Roth, 2008). Lowering of the estrogen levels by the growing follicles translates into a lower intensity of estrous signs (Badinga et al., 1994). This latter finding has been recently challenged by novel considerations on the role of GnRH in the control of estrus behavior in ruminants (Caraty et al., 2002). The decrease of GnRH levels during stress (Smith and Dobson, 2002) suggested a possible involvement of GnRH in decreasing estrus behavior signs in cows during the HS (van Eerdenburg, 2008b).

The reproductive failures attributable to HS involve follicular growth and oocyte function even before the antral phase (42 days) or primary follicle (85 days) (Lussier et al., 1987; Picton et al., 1998; Torres-Junior et al., 2008) and are prolonged up to two or three estrous cycles from the end of the high environmental temperature (Roth et al., 2001). These effects are reduced with the progress of the embryo–fetal development (Biggers et al., 1987). Indirect effects due to HS may consist in a reduction of dry matter intake, which is responsible for deepening and extension of the negative energy balance postpartum that results in a decreased fertility (Lucy et al., 1992).

Further problems related to HS are attributable to an increase of some reproductive diseases, such as ovarian cysts (Lopez-Gatius, 2003). Dairy cows with high productive performance are more sensitive to environmental effects (Kadzere et al., 2002) and HS causes a decrease of sexual cyclicity and increases the incidence of inactive ovaries (Lopez-Gatius, 2003).

Several techniques have been proposed in order to counteract the effects of HS on reproductive activity, as the use of awnings, showers, fans (Hansen and Arechiga, 1999; Kendall et al., 2006; West, 2003); however, these strategies can alleviate the productive inefficiency without solving reproductive failures. New strategies to combat infertility are geared to accelerate the follicle renewal by hormonal treatments or ovum pick-up (Roth et al., 2001) as well as by using reproductive procedures that do not require estrus detection, as fixed-time artificial insemination (Arechiga et al., 1998) and embryo transfer (Al-Katanani et al., 2002).

The purpose of this study was to evaluate in an Apennine area of Southern Italy, namely the province of Potenza, the magnitude of the effects exerted by HS on reproductive performance in high producing dairy cows, the consequent economic loss and the compliance of the THI for HS evaluations. The geographical area considered is characterized by a Mediterranean climate with mountain winter temperatures, hot summer and large diurnal temperature variations.

2. Materials and methods

2.1. Animals

Reproductive data from January 2008 to December 2012 were collected from a total number of 1743 Holstein Friesian (HF) cows bred in three dairy farms (named A, B and C) in the province of Potenza. Cows were barn-housed throughout the year and milked twice a day. Average milk production in 305 days was 9656 ± 188 kg and ranged among farms from 9534 (Farm C) to 9873 (Farm B) kg. The voluntary waiting period varied between 40 and 45 days. Clinical veterinary assistance was provided by private veterinarians employed by the Basilicata Breeders' Association (ARA). Data were collected on the dates of birth, calving, insemination and culling. The pregnancy length was postulated to the last 284 days on the basis of the information provided by the Italian Holstein Friesian Association (ANAFI) and updated to 2012.

2.2. Estimation of reproductive parameters

Based on the above collected data, reproductive parameters were developed (Ferguson and Skidmore, 2013), as follows: number of conceptions evaluated per month on a per year basis (NCY). The conception date has been obtained by subtracting postulated pregnancy length (i.e., 284 days) from the calving date. The NCY was obtained by relating the number of conceptions on a month basis to the total conceptions per year. Number of heats detected per month on a per year basis (HDY) was calculated by relating the number of heats followed by an AI on a month basis to the total number of heats followed by AI detected each year. Conception Rate (CR) has been obtained by relating, on a month basis, the number of cows which conceived following an AI to the number of AI performed. Age at first calving (AFC), was the number of days from the birth to the first calving. Number of AI/pregnancy (NAIP) was the number of inseminations necessary to obtain a full term pregnancy. These data were related to the month of the previous calving. Number of days open (DO) was obtained by subtracting the postulated pregnancy length (i.e., 284 days) to the number of days between two consecutive parturitions (VanRaden et al., 2004). These data were related to the month of the first of the two parturitions.

2.3. Climate data

Daily weather records from 2008 to 2012 were obtained from the three most nearby meteorological stations (less than 3 km) located at the same altitude of the examined dairy farms. These records were used to estimate means, variances, and covariances of monthly minimum and maximum temperatures, minimum and maximum relative humidity, and to calculate the temperature–humidity index (THI), using the standard THI equation in which the maximum temperature (T) was combined with the minimum humidity (H) (Ravagnolo and Misztal, 2000), as follows:

$$THI = (((9/5)T) + 32) - ((11/2) - (11/2)H)(((9/5)T) - 26))/100$$

THI classes were ranged according to arbitrary intervals in order to simplify further data analysis. A total of 9 THI classes were obtained, as follows: < 70, 70–79, 80–89, 90–99, 100–109, 110–119, 120–129, 130–139, and > 140.