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Effect of ambient temperature and sodium bicarbonate supplementation on water and electrolyte balances in dry and lactating Holstein cows

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ABSTRACT

The aim of this study was to quantify the effect of the interaction between 2 constant ambient temperatures [thermoneutrality (TN; 15°C) and high temperature (HT; 28°C)] and 2 levels of Na bicarbonate supplementation [calculated to provide diet Na contents of 0.20% DM (Na−) and 0.50% DM (Na+)] on water partitioning in dairy cows. Treatments were compared on 4 dry and 4 mid-lactation Holstein cows according to 2 Latin squares (1 for each physiological stage) over the course of 4 periods of 15 d. Diets consisted of a total mixed ration based on maize silage. Dry cows were restricted to their protein and energy requirements, whereas lactating cows were fed ad libitum. The daily average temperature-humidity index was 59.4 for TN and 73.2 for HT. Lactating and dry cows had higher vaginal temperatures at HT than at TN, but the increase was more pronounced in lactating cows (+1.05 vs. +0.12°C for vaginal temperature, respectively). Dry matter intake (DMI) of lactating cows decreased by 2.3 kg/d at HT. Free water intake (FWI) and estimated volume of water lost to evaporation increased at HT in both lactating and dry cows; no interactions were observed between temperature and physiological stage. When expressed as a proportion of DMI, the increase in evaporation that occurred with increasing temperature was completely compensated for by an increase in FWI for both physiological stages. The urinary water excretion increased slightly at HT in lactating cows but not in dry cows, which may be related to the low chloride content of the offered diet. High Na supplementation increased DMI slightly in lactating cows, but milk yield was not affected. Sodium supplementation did not limit the decrease in DMI observed in lactating cows at HT; this observation is likely due to the high diet electrolyte balance of the offered diets. Sodium supplementation increased FWI in lactating cows and urinary flow in both physiological states. The interaction between ambient temperature and Na supplementation did not affect either water intake or water evaporation. This study demonstrates that the development of predictive models for water intake that include environmental variables could be based on mechanistic models of evaporation.
Key words: water intake, water excretion, high temperature, dairy cow

INTRODUCTION

Even though dairy herd drinking water represents only 1 to 2% of the total amount of water needed to produce milk on a national scale (Mekonnen and Hoekstra, 2012), its supply is vital for dairy herds. A loss of 20% of body water is fatal to cows (NRC, 2001), and an inadequate supply of drinking water will rapidly cause a marked reduction in intake and milk production (Steiger Burgos et al., 2001). At high ambient temperatures, a lack of drinking water will also impair the ability of cows to adapt to heat (Silanikove, 2000). In intensive systems, drinking water can be supplied by the public water service, which can be very expensive. In this context, it is important to rely on accurate modeling of dairy herd drinking water requirements to ensure that the water supply is not limiting for the herd (especially during warm and dry weather periods) or to build tools that can be used to detect water leaks on farm water distribution networks.

Numerous empirical equations have been developed to predict water intake in dairy cows (Murphy et al., 1983; Holter and Urban, 1992; Khelil-Arfa et al., 2012); however, most of these equations were established in the context of thermoneutrality and, thus, rarely incorporated meteorological measurements as predictors. The increase in water loss by evaporation is the first heat adaptation mechanism of homeothermic animals. For producing dairy cows, homeostatic mechanisms aim to maintain homeothermy by increasing heat dissipation via evaporation at ambient temperatures of 14°C or higher (Maia et al., 2005a,b). When meteorological measurements were included in the abovementioned equations, they were generally introduced in the

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form of multiple regressions from data obtained from a single experimental farm. The risk of this method consists of the possible confounding of meteorological variables, the physiological stage, production level, or diets of the cows throughout the year. An alternative more mechanistic way of including meteorological or environmental variables in predictive equations would be to use published models of the effects of ambient temperature on water evaporation in cows obtained from instantaneous measurements taken in numerous environmental conditions with animals on various feeds and at different physiological stages (Turnpenny et al., 2000; CIGR, 2002; Maia et al., 2005a). This could allow the inclusion of environmental variables in such a way that the predictive equations could be used across geographic contexts. However, this method also assumes that we are cognizant of the effects of an increase in water evaporation on the drinking water requirements of a dairy cow and, more generally, how this increase will affect water partitioning in cows.

Dairy cows lose water through evaporation, urine, feces, and milk production, and the pool of the cow's body water is maintained through water intake from drinking (free water intake, **FWI**), feed, and metabolic oxidation in body tissues. When ambient temperatures increase above 14°C, the increase in evaporated water is generally accompanied by a clear increase in FWI (McDowell et al., 1969; Seif et al., 1973; Kurihara et al., 1984). However, it has also been observed on dry cows that urinary water excretion can increase during heat exposure (El-Nouty et al., 1980; Kurihara et al., 1984). Given that the observed increases in urinary water flow at high ambient temperatures in dry cows was reported on the very first days of heat exposure (El-Nouty et al., 1980; Kurihara et al., 1984) and given that these very first days are characterized by a high and transient increase in the amount of water in the body (Richards, 1985), it is unclear whether the increase in urinary water excretion with increasing temperature is specific to dry cows or to the first days of heat exposure.

High ambient temperatures also strongly modify the electrolyte and acid-base balance of dairy cows for 3 reasons: first, because potassium is the main cation encountered in bovine sweat (Jenkinson and Mabon, 1973); second, because Na is excreted with bicarbonates to compensate for the respiratory alkalosis that can occur during heat stress in cows (West, 2003); and third, because the diurnal excretion of bicarbonates can induce metabolic acidosis during the cooler periods of the day (Schneider et al., 1988). A better adaptation of dairy cows to high temperatures can be achieved by increasing Na and K bicarbonate supplementation in the diet (West, 2003). However, the effects of this practice on water needs and water partitioning in dairy cows that are exposed to heat stress have not been assessed. Given that Na is the most important electrolyte of the extracellular pool and a major ion involved in the regulation of the renal reabsorption of water and urinary volume (Meyer et al., 2004), Na supplementation may strongly increase urinary water excretion and water requirements of cows.

The overall objective of the present study was to determine the effects of high ambient temperatures on water and electrolyte partitioning (in relation to acid-base regulation) in dry or lactating cows fed diets supplemented with 1 of 2 levels of Na bicarbonates during a second week of heat exposure. The first objective of the study was to determine if the increase in water evaporation at high temperatures was compensated for by an increase in FWI when body water pools were stabilized; if so, thermic models of ruminants could be used to predict the water requirements of cows associated with certain environmental conditions at various geographic sites. The second objective of the study was to determine whether the effect of Na supplementation on urinary water excretion and drinking water was similar at high ambient temperatures and under thermoneutral conditions.

MATERIALS AND METHODS

Animals and Experimental Design

The 4 treatments consisted of a factorial arrangement of 2 ambient temperatures [thermoneutrality (**TN**; 15°C) or high temperature (**HT**; 28°C)] and 2 levels of feed Na [high (**Na+**) or low (**Na−**) levels of supplementation]. These treatments were compared in 4 lactating multiparous Holstein cows [98.5 ± 3.32 DIM; 42.1 ± 5.1 kg/d milk yield (**MY**); 653 ± 35.2 kg of BW] and 4 dry Holstein cows (702 ± 95 kg of BW) over the course of 4 periods of 12 d according to two 4 × 4 Latin square designs (1 for each physiological stage). None of the cows was pregnant at the beginning the experiment. The ambient temperatures were concomitantly produced with 2 climatic chambers housing 2 lactating and 2 dry cows and 2 cows on Na+ and 2 cows on Na−. The succession of treatments was organized to avoid 2 consecutive HT periods for the same cow. In each chamber, the ambient temperature was maintained constant throughout the day with a thermostatic convective heating system. Hygrometry was not regulated. The dry bulb temperature, relative humidity, and air speed were controlled in both chambers. In the chambers, cows were housed in individual tie-stalls (1.4 × 2.0 m) with individual troughs and individual water bowls providing free access to water. The four 12-d periods comprised 8 d of adaptation to treatments