Reducing rumen starch fermentation of wheat with 3% NaOH has the potential to ameliorate the effect of heat stress in grain-fed sheep.

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Summary

Thirty-one Merino x Poll Dorset wethers were housed in two climate-controlled rooms and were fed either corn (CD), wheat (WD) or 3% NaOH treated whole wheat grain (TWD) plus forage during three experimental periods: P1) 7 d of thermoneutral conditions and 1.8 times maintenance intake; P2) 7 d of heat stress (HS) and 1.8 times maintenance intake; and P3) 7 d of HS and 2 times maintenance intake. Rectal temperature (RT), respiration rate (RR) and skin flank temperature (FT) were measured. All physiological parameters were elevated during HS, especially during P3. Sheep fed CD had lower RR and RT than WD and TWD especially during HS. Sheep fed TWD had lower RR and RT than WD. FT was higher for WD, while no differences were observed between CD and WTD. These data confirm that reducing the rate of fermentation with TWD improves tolerance to heat stress in grain-fed sheep.

Introduction

Despite having well developed thermoregulatory mechanisms, ruminants, especially European breeds, are very susceptible to heat stress (HS) because of the excessive heat released during feed fermentation in the rumen (Tajima et al. 2007). Wheat is a rapidly fermentable grain commonly used as energy source for ruminants in Australia and other parts of the world. The rapid rate of rumen starch fermentation of wheat is associated with sub-acute acidosis, laminitis (Nocek 1997) and heat stress (HS) (Mader et al. 1999). By contrast, slowly fermentable grains, like corn, are associated with a reduction in the heat from fermentation (Ørskov 1986; Owens et al. 1986) and better responses under HS (Gonzalez-Rivas et al. 2015). Alkaline treatment of grains with NaOH affects the rheological properties of the starch and it has been associated to slower in vitro rumen fermentation of wheat (Tománková and Homolka 2004) and reduced in vivo rumen starch fermentation and susceptibility to rumen acidosis (Schmidt et al. 2006). The objective of this experiment was to determine whether the reduction of rumen starch fermentation of wheat with 3%NaOH improved tolerance to HS in grain-fed sheep.

Materials and Methods

Ethical approval was provided by The University of Melbourne Veterinary and Agricultural Sciences Animal Ethics committee before experimentation.

Thirty one Merino x Poll Dorset crossbred wether lambs (11-12 mo, 46.3 ± 2.8 kg BW and 30-40 mm of fleece cover) were allocated to one of three diets in a randomized control experiment. The experimental diets were either 50% grain (39% starch, WD, N=10 ) or 3% NaOH treated whole grain (42% starch, CD, N=10), crushed wheat grain (39% starch, WD, N=10) or 3% NaOH treated whole wheat (39% starch, TWD, N=11) with 25% of oatens and 25% lucerne chaff. Whole wheat was treated with 3% NaOH according to the technique described by De Campeneere et al. (2006). Water was available ad libitum. The daily ration of feed was split into 3 equal meals fed at 0900, 1300 and 1700 h. Sheep were randomly allocated into individual metabolism crates housed in two climate controlled rooms for a total of 21 d divided into three experimental periods; P1) 7 d of thermoneutral conditions (TN) (18–21°C/40-50% relative humidity, [RH]) and 1.8 times maintenance feed intake; P2) 7 d of HS (28–38°C/30–50% RH) and 1.8 times maintenance feed intake; and P3) 7 d of HS as P2 and 2 times maintenance feed intake. The level of HS was quantified measuring rectal temperature (RT), respiration rate (RR) and skin flank temperature (FT) for a total of 21 d divided into three experimental periods; P1) 7 d of thermoneutral conditions and 1.8 times maintenance intake; P2) 7 d of HS and 1.8 times maintenance intake; and P3) 7 d of HS and 2 times maintenance intake. Rectal temperature (RT), respiration rate (RR) and skin flank temperature (FT) were measured. All physiological parameters were elevated during HS, especially during P3. Sheep fed CD had lower RR and RT than WD and TWD especially during HS. Sheep fed TWD had lower RR and RT than WD. FT was higher for WD, while no differences were observed between CD and WD. These data confirm that reducing the rate of fermentation with TWD improves tolerance to heat stress in grain-fed sheep.

Results and Discussion

Heat stress increased RR (P1 vs P2) and it was further elevated by increased ADFI during HS (P2 vs P3) (66, 149 and 171 breaths/min for P1, P2 and P3 respectively; P <0.001). Respiration rate increased over the day reaching the maximum during the afternoon before declining overnight (107, 138, 156 and 114 breaths/min at 0900, 1300, 1700 and 2100 h respectively; P <0.001). There was a main effect of diet on RR such that sheep fed CD had lower RR, followed by TWD and WD (119, 128 and 138 breaths/min for CD, TWD and WD respectively, P<0.001).

Heat stress increased RT (P1 vs P2) and RT was further elevated by increased ADFI during HS (P2 vs P3) (39.3, 39.6 and 39.7 °C for P1, P2 and P3 respectively; P <0.001). Rectal temperature increased over the day reaching the maximum during the afternoon before declining overnight (39.3, 39.6, 39.7 and 39.5 °C at 0900, 1300, 1700 and 2100 h respectively; P <0.001). There was a main effect of diet on RT such that sheep fed CD had lower RT than those fed WD and TWD (39.4, 39.5 and 39.6 °C for CD, WD and TWD, P<0.001).

Heat stress increased FT (P1 vs P2 and P3) and no differences between LFT and RFT were found during P2 and P3 (38.5/38.4, 38.9/38.9 and 39.0/39.0 °C LFT/RFT for P1, P2 and P3 respectively; P <0.001). Flank temperature increased over the day reaching the maximum during the afternoon and then declining overnight (38.6/38.6, 39.0/38.9,39.0/39.0

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fermentable grains were confirmed; sheep fed CD had lower NaOH treatment RR and FT were reduced to a level similar reducing the rumen starch fermentation of wheat with 3% RR, RT and FT that WD and it was also demonstrated that by in the rumen, the heat from fermentation can be reduced hypothesizing that by reducing the rate of starch fermentation et al. In our experiment differences among slowly and rapidly responses (Tománková and Homolka 2004; De Campeneere large fluctuations in the rate of fermentation (Ørskov 1979; starch and produces a slow release of the starch preventing utilisation due to smaller losses of energy as heat (Reynolds 2006). The use of processed grains to increase the rumen fermentation allows ruminants to utilize plant materials otherwise indigestible and convert non-protein nitrogen and microbial protein into body amino acids. However, ammonia, methane and heat are end-products of fermentation that represent loses of nitrogen and energy (Hungate 1966). The heat from fermentation, although convenient in cold climates, represents an extra burden at high ambient temperatures. It has been estimated that the heat from fermentation accounts for approximately 30% of total heat production (Webster et al. 1976). Among the various grains fed to ruminants, there are differences in starch content, fermentability and digestibility (Herrera-Saldana et al. 1990). A previous study carried out in grain-fed sheep demonstrated a positive relationship between highly fermentable grain content in the diet, heat increment and heat stress susceptibility; sheep fed a slowly fermentable corn diet had lower RR, RT and FT than sheep fed a wheat diet under HS conditions (Gonzalez-Rivas et al. 2015). It has been hypothesized that protecting the starch from rumen fermentation improves the efficiency of ME utilisation due to smaller losses of energy as heat (Reynolds 2006). The use of processed grains to increase the rumen escape of starch has been largely studied; alkaline treatment of grains with NaOH affects the rheological properties of the starch and produces a slow release of the starch preventing large fluctuations in the rate of fermentation (Ørskov 1979; Roberts and Cameron 2002). This mechanism has been associated with slower in vitro and in situ rumen starch fermentation, higher rumen pH and improved productive responses (Tománková and Homolka 2004; De Campeneere et al. 2006).

In our experiment differences among slowly and rapidly fermentable grains were confirmed; sheep fed CD had lower RR, RT and FT that WD and it was also demonstrated that by reducing the rumen starch fermentation of wheat with 3% NaOH treatment RR and FT were reduced to a level similar to those of corn under HS. These data support the hypothesis that by reducing the rate of starch fermentation in the rumen, the heat from fermentation can be reduced which could be of benefit to summer production systems.

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