Reprinted from NOVEMBER 2022
The Manager
Published by Progressive Dairy

PRO-DAIRY Education & Applied Research

Leaky gut and the warning signs of heat-stressed dairy cattle

Ananda Fontoura and Joseph McFadden

Since pre-industrial times, global surface temperatures have risen considerably and most of the warming occurred in the past 40 years. Reflective of this global trend, temperatures in the United States northeast region have also increased, and projections indicate additional warming that can reach up to 40.6°F by 2100, and estimate an increase in the intensity and frequency of extreme heat weather events, and a decrease in the intensity and frequency of cold extremes for North America. If these predictions come to fruition, higher occurrence of periods of extremely high temperatures will most likely affect both animal and human health, and will increase the incidence of heat-related illnesses. Due to this, heat stress will likely become more prevalent in the future. And indeed, the effects of climate change on production systems have often been highlighted as one of the main challenges currently faced by crop and animal-based systems. This is important to United States dairy systems because of the inherently increased heat production of high-producing dairy cows, which makes them more sensitive to warmer climates and heat fluctuations. Therefore, a better understanding of the mechanisms by which heat stress compromises the production of dairy products is important because it will allow us to develop heat stress alleviation therapies.

"Overall, these results highlight important mechanisms that might account for milk production losses and health impairments caused by heat stress independent of reductions in feed intake."

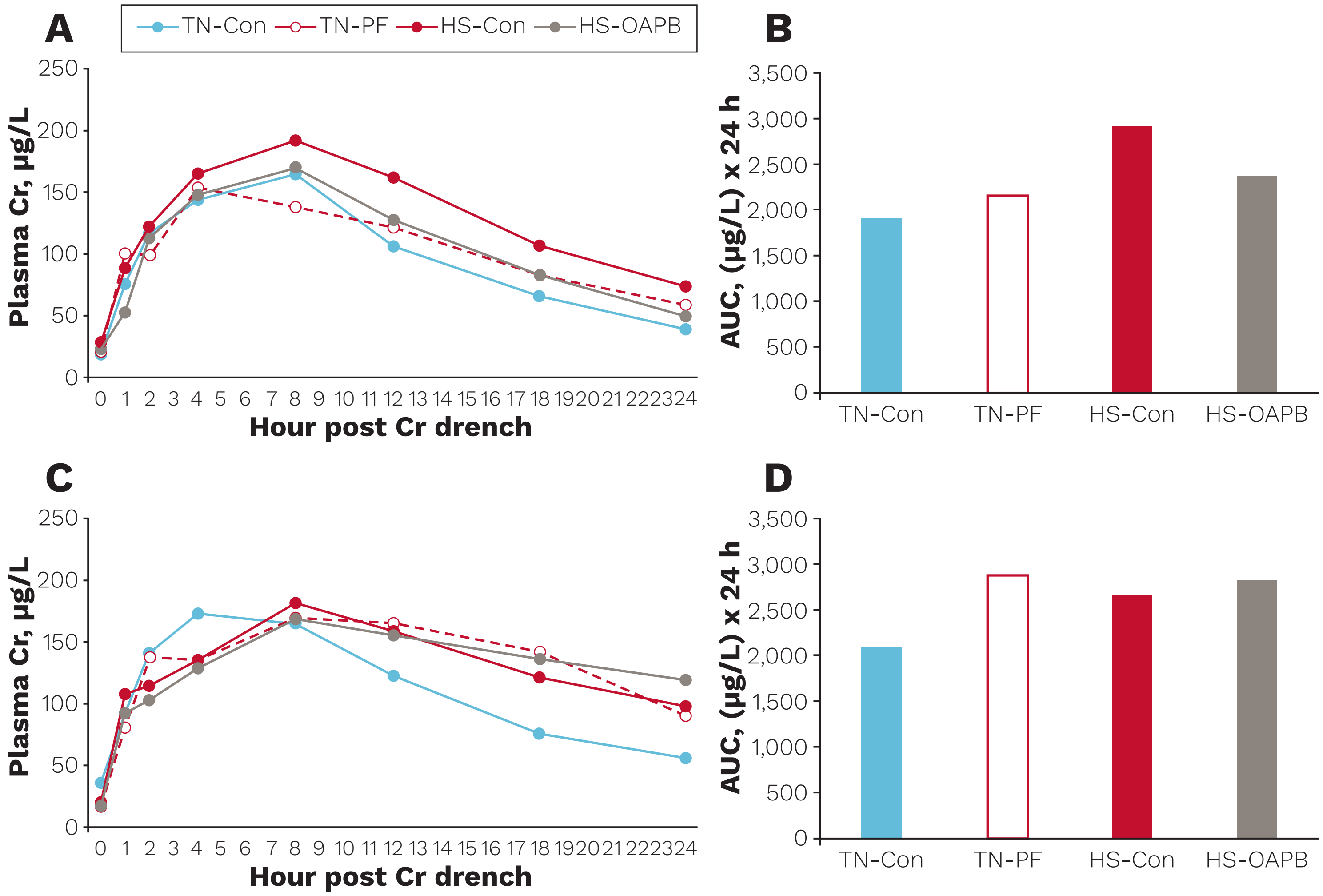
Exposure to high ambient temperature leads dairy cows to be heat-stressed, a consequence that comes from their inability to dissipate thermal energy from their body into the environment. To survive these periods of increased heat load, they undergo behavioral and physiological adaptive changes that allow survival. These changes include, but are not limited to, increased respiration rate, sweating, reduced feed intake, diminished physical activity, reduced productive (e.g., growth and lactation) and reproductive performance (e.g., pregnancy rates, and in-utero deleterious effects to the progeny). Current research in non-ruminants (e.g., rodents, pigs, and humans) indicates that heat-stressed mammals experience modifications in gastrointestinal health and barrier. As means of improving body cooling, animals shunt blood supply from the visceral organs, including the intestines, towards the skin surface. This weakens the protective barrier of intestinal cells and allows for bacteria and its products such as endotoxins to enter the blood circulation. This increased gastrointestinal permeability is commonly called "leaky gut" and is highlighted as one of the factors that can trigger the immune system and cause systemic inflammation. Thus, it is important to confirm if heat stress evolves with leaky gut in lactating dairy cows because the immune system relies on glucose availability to fight infections, which in turn, can further jeopardize milk production during heat stress.

Current heat abatement practices focus on providing shade, fans, sprinklers, and misters to enhance cow comfort and improve heat stress resilience in dairy cattle. These practices are common but only partially reduce the effects of heat stress by improving the means of internal heat dissipation. They also demand

Continued on page 2

FIGURE 1

Effects of heat stress and dietary organic acid and pure botanical supplementation on gastrointestinal permeability measured by plasma Cr concentrations (A, C) and Cr AUC (B, D) after a Cr-EDTA drench challenge in pregnant multiparous and lactating Holstein cows. Figure A and B are relative to day three whereas Figure C and D are relative to day 13 of heat stress conditioning.



“ … it is important to confirm if heat stress evolves with leaky gut in lactating dairy cows because the immune system relies on glucose availability to fight infections, which in turn, can further jeopardize milk production during heat stress.”

water and increase fossil fuel utilization to operate, which in the grand scheme of sustainability practices might also be a problem in the future. Because of this, current dairy science research is focused on identification of nutritional strategies to alleviate the effects of heat stress. There is a plethora of nutritional strategies using commercially available feed additives and in a broader sense, these supplements are aimed at improving inflammation, oxidative stress, and intestinal health of heat-stressed dairy cattle.

Dietary supplementation of organic acids (OA; e.g., citric and sorbic acids) and pure botanicals (PB; e.g., thymol and vanillin) represents a promising strategy to support and reduce antibiotic usage in livestock production systems. These compounds have unique antimicrobial, anti-inflammatory, antioxidant, and immunomodulatory properties, which when combined, have potential to improve gastrointestinal health by controlling pathogenic bacteria growth and enhancing intestinal barrier. Studies in poultry and swine indicate that supplementation of OA/PB improves intestinal barrier and decreases inflammation, which resulted in improved bodyweight gain and feed efficiency in those species. Our research team also evaluated OA/PB supplementation in heat-stressed weaned dairy calves and observed that supplementing OA/PB increased starter intake of heat-stressed calves and improved average daily gain when compared to the unsupplemented heat-stressed group. Upon completion of the trial, OA/PB supplemented calves had heavier bodyweights and hot carcass weight relative to unsupplemented calves.

At Cornell University, our team recently completed a trial where we evaluated the effects of heat stress and dietary OA/PB supplementation on gut permeability and milk production. We wanted to test the hypothesis that exposure to extreme heat would cause leaky gut and consequently decrease milk production and that OA/PB supplementation (25 percent citric acid, 16.7 percent sorbic acid, 1.7 percent thymol, 1.0 percent vanillin, and 55.6 percent triglyceride; AviPlus R®, VetAgro, Inc.; 75 mg/kg of live weight) would alleviate these outcomes. 46 multiparous pregnant and lactating Holstein cows were enrolled in the study.

Cows were randomly assigned to one of four groups for 14 days:

1. Thermoneutral conditions (TN-Con, n = 12; temperature-humidity index [THI] 68)
2. HS conditions (HS-Con, n = 12; diurnal THI 74 to 82)
3. TN conditions pair-fed to match HS-Con (TN-PF, n = 12)
4. HS fed OA/PB (HS-OAPB, n = 10)

Cows were milked twice daily and fed a corn silage-based total mixed ration top-dressed without (triglyceride only) or with OA/PB. Acute and chronic changes in gastrointestinal permeability were evaluated using the paracellular permeability marker Chromium (Cr)-EDTA on days three and 13, respectively.

We observed that HS-Con cows had increased gut permeability starting after four hours post Cr drench and remained elevated until 24 hours (**Figure 1a**) on day three, relative to TN-Con cows. Importantly, this increased permeability seems to be independent of feed intake, as TN-PF cows had smaller Cr area-under-the-curve (AUC) when compared to HS-Con (**Figure 1b**). In addition, we also observed decreased permeability in cows that were supplemented with OA/PB, relative to HS-Con. On day 13, HS-Con cows had similar plasma Cr AUC relative to TN-PF and TN-Con (**Figure 1d**); however, TN-PF cows tended to have greater plasma Cr concentrations from 12 to 24 hours post bolus, relative to TN-Con (**Figure 1c**). In terms of productive performance, HS-Con had greater water intake, and lower yields of milk and milk lactose and protein, relative to TN-PF cows. HS-OAPB cows consumed more water and tended to consume more feed, relative to HS-Con. In addition, HS-OAPB also had greater energy-corrected milk yields relative to HS-Con cows, which could be explained by the greater milk protein yield of HS-OAPB cows. Overall, these results highlight important mechanisms that might account for milk production losses and health impairments caused by heat stress independent of reductions in feed intake. In addition, dietary OA/PB supplementation represents a means to partially restore milk production in dairy cattle experiencing heat stress, and thus can be incorporated into already existing feeding strategies to optimize production of heat-stressed cattle.

Ananda Fontoura (abf63@cornell.edu) is a Postdoctoral Research Associate with the Department of Animal Science, Cornell University. **Joseph W. McFadden** (jwm43@cornell.edu) is an Associate Professor of Dairy Cattle Biology with the Department of Animal Science, Cornell University.