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Insights into heat stress physiological modifications of Libyan dairy cattle during summer season

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Abstract
Libya is a Mediterranean Sea country located in North Africa and characterized with five different climatic zones dominated by both Mediterranean and Saharan. During summer season, the massive increase in temperature and humidity has become a major concern for farmers and dairy producers due to its heat stress induction, which significantly affect milk production, causing large economic losses. Heat stress in dairy cattle have been associated with significant behavioral, nutritional physiology and biochemistry of dairy cattle. This review delivers a comprehensive discussion regarding the state of dairy cows in Libya and the effect of summer season high temperature and humidity on the nutritional physiology and biochemistry of the Libyan dairy cattle. Physiological and behavioral modifications as well as milk production and negative energy balance in lactating cows also highlighted. Presenting the potentials, challenges and future prospective to combat heat stress for dairy cows.

Keywords: Dairy cattle, heat stress, milk production, physiological modifications

Introduction
Worldwide livestock production systems have recently intensified in terms of productivity per animal. Dairy cows during summer season in many countries expose to heat stress, which encounter impaired welfare leading to significant production losses [1]. As the frequency and magnitude of heat stress events increase due to global warming in the coming decades, a focus on heat stress reduction studies becomes important. Heat stress is an event resulted from the increase in environmental condition and affects the homeostasis and health of the animals due to induction of physiologically harmful heat load [2]. Initial responses to the heat stress are considered homeostatic mechanisms and include increased water intake, sweating and respiration rates, reduced heart rate and feed intake [3, 4].
Libya is a Mediterranean Sea country located in north Africa and characterized with five different climatic zones dominated by both Mediterranean and Saharan [5]. In winter, the weather is cool with some rain on the coast and in the desert the temperature can drop to sub-freezing at night. However, the Sahara is very dry and hot in summer and cool and dry in winter [6]. Less than 2% of the national territory receives enough rainfall for settled agriculture. Temperatures in the summer can reach 50 °C during the day but more commonly are around 40 °C. Various studies have reported the influence of this massive increase of temperature on livestock production including dairy cows [7]. When the cattle expose to high temperature, heat acclimation in animals body (if survivable) is achieved via processes of acclamatory homeostasis [1]. If the heat stress remain for long time, this acclamation may not remain homeostatic, and thereby the cow will initiate a physiological condition known as homeorhetic mechanisms, which make it to dissipate incremental heat load and acclimatize to stress conditions [8].
This review delivers a comprehensive discussion regarding the state of dairy cows in Libya and the effect of summer season high temperature on the nutritional physiology and biochemistry of the Libyan dairy cattle. Physiological and behavioral modifications as well as negative energy balance in lactating cows also highlighted. The review also presents the potentials, challenges and future prospective to combat heat stress for dairy cows.

Livestock production in Libya
In many parts of Libya, crop and livestock production considered an important source of food security especially after the recent conflict and political instability, which directly affected the individuals as well as the country's economy and institutions [9].

In 2001, the livestock population of Libya included 220,000 head of cattle, 4,125,000 sheep, 1,265,000 goats, 46,000 horses, 72,000 camels and 25,000,000 chickens. However, many factors significantly affected these sectors such as disease and drought, that led to major losses of more than 60%. Lacking the access animal feed or land, veterinary services, vaccines, and medicines due to the economic crisis are other challenges that caused marked decrease in livestock production. As an oil dependent country, Libyan economy is mainly depends on oil export, and thus, most of farmers became a government employees. Before oil dependent transformation, Libyan livestock was a significant sector that provide transport, clothes, food, and even skins for traditional tents [10]. In 2018, only 12% of households have been engaged in different livestock production including diary, with the highest proportions observed in the south of Libya, particularly in Sebha city (50 %) followed by Wadi Ashshati (40%) and the east of Libya Al Jabal al Akhdar (31%). Livestock production in Libya (Figure 1) was found to be less common along the more urbanized coast, as most of top producers came from interior areas of the country.

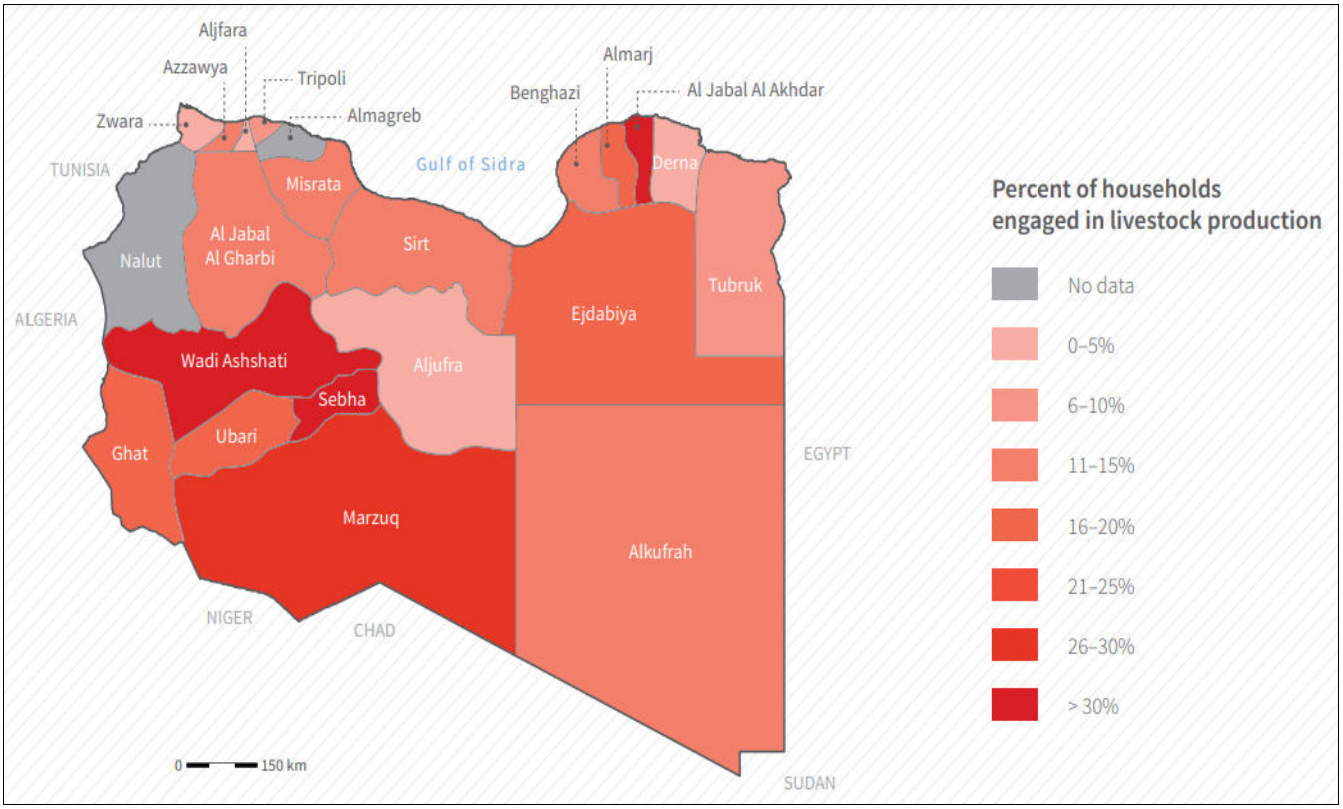

Fig 1: Illustration of Livestock production in Libya

Heat stress in Libyan dairy cattle

Heat stress is an event resulted from the increase in environmental condition and affects the homeostasis and health of the animals due to induction of physiologically harmful heat load [2, 11]. The massive increase in temperature during the summer in Libya and other Mediterranean Sea countries led to heat stress in all the livestock including dairy cattle. Ji *et al.* [7] reported that the welfare and comfort of dairy cows are increasingly seen as moral and practical concerns. Under these condition of heat stress, the optimal welfare of dairy cows can be compromised via decreased feed and water intake, resting and rumination time. However, numerous behavioral and physiological modifications have been observed in dairy cattle upon the exposure to heat stress as discussed in the following subsections.

Heat stress and behavioral modifications of dairy cattle

Animal discomfort have been observed due to heat stress that happened during the summer season, which was reported as the main cause of production losses in the global dairy industry [12]. Dairy cattle prioritize resting in most of day and night times over other behaviors, spending roughly of 8 to 16 hours per day lying down [13]. Weather was found to have significant effect on the time the cows spend on lying down, as well as bedding material and other factors. Reich *et al.* [14] reported that cows prefer to spend more time during the hot conditions to lying down when the bedding is deep, soft, and dry. Behavioral coping strategies have been observed in dairy cows during summer season including modified drinking and feed intake (e.g., increased water intake and shifting feeding times to cooler periods during the day), increased standing time and shade seeking, and decreased activity and movement. Von Keyserlingk *et al.* [15] reported that how the animal feels as it experiences and perceives its surrounding conditions is central to dairy cows, and developing validated measures of these states is one of the most challenging components of animal welfare science. The duration of elevated temperatures has an inverse relationship with dry matter intake, and a short, simulated heat wave (29°C, ~50% relative humidity for 4 days) has been shown to suppress feed intake as soon as 1 day after the rise in temperature [16]. Pearce *et al.* [17] reported that when the stomach is empty, the cows secrete a hormone known as Ghrelin by ghrelinergic cells in the gastrointestinal tract to increase hunger and gastrointestinal

mobility and increase food intake.

The expression of ghrelin was found to increase during the heat stress, particularly from small intestines of broiler chickens and the glandular stomach. We postulate that despite "voluntary" decreases in dry matter intake, dairy cows subjected to heat stress may have increased ghrelin secretion and may be experiencing hunger [18, 19]. Allen *et al.* [20] revealed that cows under increased heat load change their behavior in an effort to improve cooling. Particularly, heat stressed dairy cows have been reported to increase their standing time, and in turn decrease lying time and walking activity, to expose more surface area for heat abatement, sensible water loss, radiating surface area, and air movement via convection. Several studies examining the lying time of cows in free stalls report a range of 11 to 14 hours under thermo-neutral conditions, with a 30% reduction when ambient temperatures increase [21].

Nutritional and physiological modifications of the cattle during heat stress

The massive dry weather in Libyan Sahara induce Increases heat dissipation in the cattle through evaporative heat loss, leading to reduction of feed intake as well as milk yield [22]. During this season, the cows increase their water intake as a response to heat stress to adapt this situation [23]. Collier *et al.* [8] reported that when the cows expose to high temperature, the heat loss various mechanisms such as vasodilatation and sweating as a results of hypothalamus heat stress. During these conditions, the cows were found to consume less feed and consequently ruminate less, resulting in significant decrease in buffering agents entering the rumen [24]. Not surprisingly, these challenges of farmers and dairy cattle are greatest in geographic areas such as Libya where the summer season is long (4 to 6 months) and there is a constant presence of radiant solar energy and high humidity especially in the coastal areas, resulting in minimal relief from the heat [25].

Redistribution of blood flow in the animal's body to the periphery was found to reduce blood delivery to the gastrointestinal track, leading to disturbing the digestion process. However, the typical cow in mild summer season have been reported to consume 12 to 15 meals per day, but these eating frequencies reduced to only 3 to 5 meals per day during heat stress [26]. Decreasing eating frequency of cows can be accompanied by consuming larger amount of food, resulting in possible gut health consequences [27]. In a recent investigation, Sammad *et al.* [28] reported that high body temperature due to heat stress could induce a series of physiological responses in dairy cows such as excessive flow of energy and energy depletion. Which can lead to deteriorated living conditions, reduced reproductive efficiency of cows, reduced welfare or even death if the animal did not activate heat adaptive mechanisms to increase the external net energy flow. Schütz *et al.* [29] reported physiological coping strategies that dairy cattle used during hot seasons including sweating, panting, increased respiration rate, reduced reproductive performance and reduced milk yield. Various studies have reported that dairy cattle modify their feeding and drinking behavior during these conditions, which lead to significant increase heat production and thus originating enhanced energy expenditure as a result of high physical adaptive activities like panting and sweating [30].

Heat stress and milk production

Libyan farms are experiencing an increasingly uncertain production context of milk during the summer season due to the significant increase in temperature and water shortages. These extreme events was found to decrease the production yields and increase their variability [31]. Purwanto *et al.* [32] reported that lactating dairy cows in most of countries have an increased sensitivity to heat stress compared with non-lactating cows, which was explained by the same authors to be due to milk production elevating metabolism. Furthermore, owing to the positive relationship between milk yield and heat production, higher yielding cows are more challenged by heat stress than lower yielding animals [16]. Various researchers have reported an immediate coping mechanism during heat stress of cows to reduce dry matter intake, causing a decrease in the availability of nutrients used for milk synthesis [33]. Significant increase in basal metabolism during these conditions have been reported to cause by activation of the thermo-regulatory system. Mild to severe heat stress can increase metabolic maintenance requirements by 7 to 25%, further exacerbating both the existing metabolic stress and the decrease in milk production [1, 24].

In coastal area of Libya, the high humidity in July and August each year causes significant decrease in milk production. However, mastitis and other diseases have been also reported to cause reduction in milk production [11, 34]. When dairy cows expose to stressful or unfamiliar condition, especially high humidity or heat stress, their behaviors, food intake are significantly changes and thus milk yield declines instantly. Despite the reported challenges of changing the behavior and food intake, recent evidence reported changing in milk composition within these conditions, which can be useful to assess cows in immediate heat stress [35].

Potentials and challenges to combat heat stress for dairy cows

Numerous farm mitigation techniques have been used to combat heat stress and control the animals' thermal environment. However, the high cost of air conditioning systems can be economically feasible for many farmers and thus limitate their installation [19, 36]. Kanjanapruthipong *et al.* [37] reported that adjusting the animals diet (to reduce the negative effects of heat generation associated with increased metabolism) can be a potential mitigation option, especially for cows in their early lactation stage. Keeping in mind the huge economic concerns, immediate short as well as long-term strategies of mitigation for dairy cows should be based upon providing suitable cooling measures and improved feeding practices and relevant supplementations [38]. Figure 2 illustrates the main score of mitigation strategies that could be applied by the farmers or large-scale producers at a dairy operation. These strategies will provide a suitable conditions for cows and relieve the untoward effects of the heat stress and thus improve production.

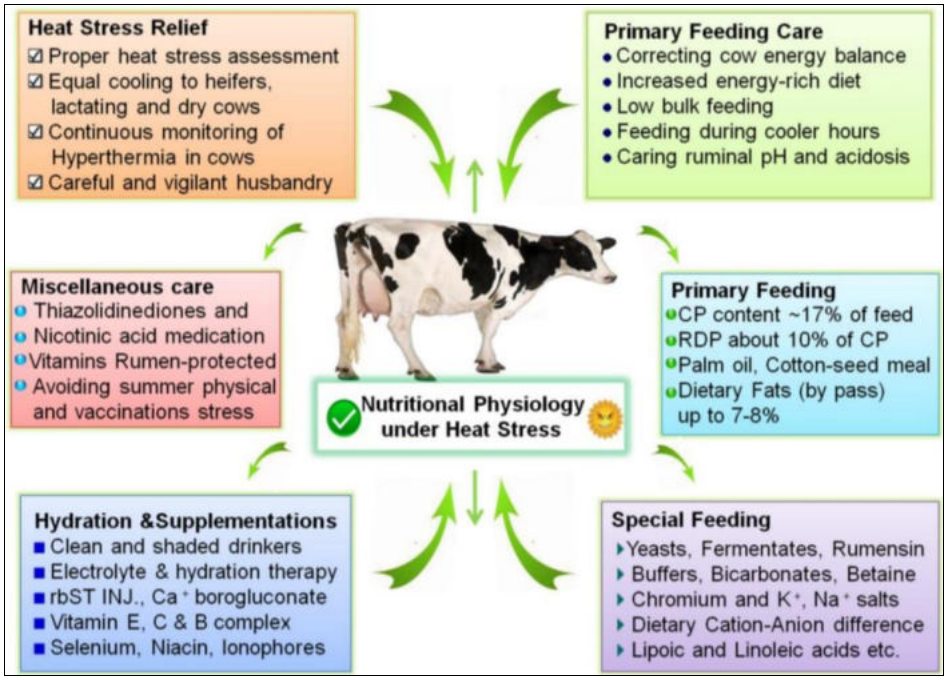

Fig 2: Illustration of various impact mitigation strategies to improve the production and welfare of dairy cows and support heat stress-related physiological and biochemical disequilibrium. Adapted from Sammad *et al.* [39]

The ability to thermo-regulate in lactating and non-lactating cows is an evolutionary adaptation that allows these cattle to maintain their natural biological functioning in spite of environmental temperature fluctuations. As the environmental temperatures continuously increasing due to global warming, we predict that an ever-increasing number of cows will be subjected to heat stress and that taking advantage of the animal's natural ability and morphological differences to thermo-regulate will become increasingly important. Von Keyserlingk *et al.* [40] discussed the alternative management avenues available through gene editing that could result in a cow better able to cope with the challenges associated with heat stress will no doubt increase in number over the next decade. However, despite the advances predicted with these types of technologies, it remains to be seen whether society will accept them in the long-run, given the current criticisms regarding the perceived unnaturalness of these types of technologies. It has been reported that sprinkler systems may wet the dairy cows with large water droplets, leading to cooling the animals and thus rely less on good water holding capacity in the air than misting and fogging systems do [7, 41]. Legrand *et al.* [42] conducted a study on voluntary use of "dairy cattle showers" by heat stressed cattle and revealed that the animals would use showers for, on average, 3 hours per day.

Conclusion

The massive increase in temperature during the summer season in Libya and North Africa countries has become a major concern for farmers and dairy producers due to its heat stress induction to dairy cattle and the associated decreases in milk production and large economic losses. As the environmental temperatures continuously increasing due to global warming, we predict that an ever-increasing number of cows will be subjected to heat stress and that taking advantage of the animal's natural ability and morphological differences to thermo-regulate will become increasingly important. This review discussed the state of dairy cows in Libya and the effect of summer season high temperature and humidity on the nutritional physiology and biochemistry of the Libyan dairy cattle. In addition to the physiological and behavioral modifications, milk production and negative energy balance in lactating cows also highlighted. Presenting the potentials, challenges and future prospective to combat heat stress for dairy cows. Future research is needed to determine whether cow-side tests that monitor acute changes in milk composition in response to heat stress can be practically implemented on farms.

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