ANIMAL PRODUCTION IN A CHANGING CLIMATE: IMPACTS AND MITIGATION

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Introduction

Climate affects animal production in four ways: (a) the impact of changes in livestock feed-grain availability and price; (b) impacts on livestock pastures and forage crop production and quality; (c) changes in the distribution of livestock diseases and pests; and (d) the direct effects of weather and extreme events on animal health, growth and reproduction (36).

The impact of changes in livestock feed-grain availability and price has been considered in several studies (1, 9, 16, 33).

The indirect effects of climate driven changes in animal performance result mainly from alterations in the nutritional environment. Research suggests that changes in climate would affect the quality and quantity of forage produced (5, 41). The impact of climate change on pastures and rangelands may include deterioration of pasture quality towards poorer quality subtropical C_4 grasses in temperate regions as a result of warmer temperatures and less frost; however, there could also exist potential increases in yield and possible expansion of area if climate change were favorable as a result of increase in CO_2 (14, 32). As a consequence, productivity of grazing livestock could be altered (6, 17, 42).

Climatic restrictions on vectors, environmental habitats and disease causing agents are important for keeping many animals diseases in check (37). Alterations of temperature and precipitation regimes may result in a spread of disease and parasites into new regions or produce an increase in the incidence of disease, which, in turn, would reduce animal productivity and possibly increase animal mortality (5).

Direct effects involve heat exchanges between the animal and the surrounding environment that are related to radiation, temperature, humidity and wind speed. Under present climate conditions, the lack of ability of animals to dissipate the environmental heat determines that, in many areas in the world, animals suffer heat stress during, at least, part of the year. Heat stress has a variety of detrimental effects on livestock (18), with significant effects on milk production and reproduction in dairy cows (27, 47, 49). Extreme events, such as heat waves, may particularly affect beef (25) and dairy (54) cattle. Under climate change conditions, these responses could be enhanced and even extended to other areas around the world.

The present paper deals with the direct effects of climate change and will be mainly focused on the response dairy cattle. Different alternatives to reduce heat stress, will be discussed.

Direct impacts on animals

Uncertainty is the most problematic aspect of climate change, thus limiting the usefulness of climate change impact assessments (29). At best, a range of impacts bound by a high and low extreme with a defined probability distribution can be produced (28). Quantitative simulation studies estimating impacts of future climate change directly on livestock are few. However, weather and extreme events have well documented effects on several aspects of animal production.

There is a range of thermal conditions within which animals are able to maintain a relatively stable body temperature by means of behavioral and physiological means (11). Heat stress results from the animal's inability to dissipate sufficient heat to maintain homeothermy. High ambient temperature, relative humidity and radiant energy compromise the ability of animals to dissipate heat. As a result, there is an increase in body temperature, which in turn initiates compensatory and adaptive mechanisms to reestablish homeothermy and homeostasis. These readjustments, generally referred to as adaptations, may be favorable or unfavorable to economic interests of humans, but are essential for survival of the animal (38).

Thus, an increase in air temperature, such as that expected in different scenarios of climate change, would affect directly animal performance by affecting animal heat balance. There are four modes of energy transfer: radiation, convection, evaporation, conduction, which are governed by physical laws. Several physical parameters control heat transfer by each mode. Air temperature affects energy exchanges through convection and evaporation (19). When temperature increases, evaporation becomes the most important way of heat loss, since it does not depend on a temperature gradient (25). Under that circumstances the combination of temperature and humidity acquire more relevance, since humidity enhances temperature effects. Therefore, it is universally accepted to evaluate the environment, from the heat stress stand-point, through the temperature humidity index (THI), developed after (40).

Dairy cattle show signs of heat stress when THI is higher than 72 (3). The comfort limit depends on level of production. Animals presenting higher level of production are more sensitive to heat stress (21, 27).

Not only intensity of stress, but also the length of the daily recovery period is important in determining animal responses (24). In the central Santa Fe milking area, the most important dairying area in Argentina, average daily stress hours, i.e. hours above 72, during the hottest month (January) are 13 (48). When considering a global change scenario, as determined by paleoclimatological studies (12) the daily stress hours would increase to 17 by 2025 (48). The implications of such a change are that the already compromised summer dairy performance in the area, measured in terms of reduced milk production (49, 50) and lower conception rates (47), could be further impaired. Present and predicted daily stress hours for January in the main Argentine milking areas are presented in table 1.

Present production losses in the region, and have projected those losses if the global change scenario were produced have been presented by (30). Estimations were done after (8), for cows producing 15, 20 and 25 kg milk/day. They concluded that, under the global change scenario, milk production declines estimates suffer an average 60% raise.

One way to look at possible effects of global change is analyzing how animals respond during extreme weather events, such as heat waves. Under global change scenarios extreme events are expected to increase their frequency and severity (26).

A Heat wave is defined as a period of abnormally uncomfortable hot and usually humid weather of at least one day duration, but conventionally lasting several days to several weeks (2). An operational definition (23), is 3 to 5 consecutive days with maximum temperatures above a selected threshold. During these heat waves, animal heat exchange is affected. They fail to dissipate the extra heat load accumulated during days when there are several hours with THI well above the comfort limit, and little opportunity to recover. Therefore, thermoregulation and feeding behavior are affected (22, 31). In a retrospective analysis of heat wave events, (23) summarize that the results support an environmental profile for single heat waves that create highly likely lethal conditions for *Bos-taurus* cattle in feedlots: when THI-hs at or above a base of 84 exceed 15 per day for 3 or more successive days with limited or no nighttime recovery opportunity, some death losses can be expected if relief measures are not provided. Based on heat waves definition and characteristics proposed by (23, 24), an analysis of milk production responses of grazing Holstein animals in the central milk supply area of Santa Fe was performed (51). It was concluded that heat waves produce an impact in performance of high producing dairy cows in a grazing system. Two heat waves were detected during the trial. Animals presented a 10-14% decrease in milk production, when comparing values reached before and after the 3-day long heat wave. They never recovered, and did not respond to the second heat wave, recorded one month later, even when it was more severe than the previous one. The authors consider that animals were less sensitive to heat stress when the second wave occurred, because of their lower production level. Milk productions before, during and after the heat waves are shown in table 2.

Mitigation

Since climate change could result in an increase of heat stress, all methods to help animals cope with or, at least, alleviate the impacts of heat stress could be useful to mitigate the impacts of global change on animal responses and performance. Three basic management schemes for reducing the effect of thermal stress have been suggested (7): (a) physical modification of the environment; (b) genetic development of less sensitive breeds and (c) improved nutritional management schemes. In the present paper, item (a) will be discussed. The analysis will be focused on dairy cattle.

Physical modification of the environment. Several reviews of different methods of environmental modifications to relief heat stress are found in the literature (10, 21, 44).

Just to summarize, the different methods of environmental modification include: shades, ventilation, combination of wetting and ventilation.

Shades are the most simple method to reduce the impact of high solar radiation. Shades can be either natural or artificial. Tree shades have proved to be more efficient (20). When enough natural shade is unavailable, artificial structures may be constructed. Different aspects concerning design and orientation of shades have been published (10, 13, 21, 44). Shades are effective in reducing heat stress in the dairy cow. In a study performed in the central milk supply area of Santa Fe (49) we found that protected animals presented lower afternoon rectal temperature and respiration rate, and yielded more milk and protein (table 3). The artificial shade structure did not differ from tree shades, in terms of the effects on animal well-being (50).

Air moving is an important factor in the relief of heat stress, since it affects convective and, according to air humidity, evaporative heat losses. Where possible, natural ventilation should be maximized by constructing open-sided constructions (10). Forced ventilation, provided by fans, is a very effective method, if properly designed.

An effective way of cooling cattle is spray evaporative cooling. There are several methods available: mist, fog and sprinkling systems. There is literature available about these systems (4, 20, 35, 39, 43). They discuss the effectiveness of these systems under confined production schemes. However, the single use of a sprinkling and fan system, for 30 minutes before milkings, has proved to be useful to relief dairy cows heat stress, in terms of efficiency to reduce the impact of heat waves under a grazing system (51) (Table 2). Responses in rectal temperature and respiration rate are presented in figures 1 and 2, respectively.

Physical modification and climate change. In a study developed in Australia (29), they have considered two critical THI thresholds, after (15):

> 72 milk yield starts to decline for cows with no shade

> 78 milk yield starts to decline for cows with shade and a sprinkler system

Under current climate, average milk losses for cows with no shade represent 3.3% of annual production. By the year 2030, milk loss for those same cows could increase to 4% of annual production. By 2070, the milk loss would be 6% of annual production.

The authors also show the benefits of adapting by installing shade and sprinklers. Milk losses under current climate are reduced to 0.8% of annual production, a 2.5% improvement on having no shelter. In 2030, adaptation could restrict losses to 1% of annual production. Finally, in 2070, milk losses would be reduced to 3 to 4% of annual milk production, by installing environmental modifications.

According to (29) preliminary costing indicates a financial benefit from adaptations to current climate, and shows that those benefits will increase under climate change. This means that current practices will be suitable for adapting to future climates if the economics of heat stress management do not change radically.

Concluding remarks

Farmers decide what to produce and how to produce it, i.e. they have to take decisions driven by different forces, either endogenous or exogenous. By the time when they have to take such decisions, they are not sure about exogenous factors such as climatic conditions, prices, costs, and so on, which may affect the outcomes. This forces not only affect individual farms, but also other farms in the region, the process thus affecting decision at the regional level (figure 3).

In a study performed by (36) over a 5-year period, the results suggested that: (a) farmers experience effects of climate, but simply absorb them and do not make strategic changes in their operations in response; (b) problematic climatic conditions are translated into economic stimuli, so that changes are attributed to economic rather than climatic forces; and (c) the effects of climate are swamped by those of variations in costs, prices, technology, and so on. However, the study also showed that the effects of climatic variations are sometimes reflected in conscious decisions, which include short-term, tactical, and long-term, strategic.

Researchers should be aware of the need farmers have of well performed investigative results that may help them take those important decisions, that could even reach the point of a complete change in their operations, to counteract impacts of climate change.

It is not an easy issue, since many aspects of climate change remain yet to be elucidated. However, there are regions in the world where there are seasonal effects, or extreme events, which characteristics may be used to provide some managerial tools to face global warming scenarios.

Summary

Climate change could affect animal production and well-being, specially because of increases in air temperature. However, the knowledge of animal responses to heat stress during the hot months in several areas of the world, as well as during extreme heat events, may be used to evaluate the impacts of global change. Some current practices to reduce heat stress in dairy cows, such as shades, sprinklers and ventilation will be suitable for adapting to future climates if the economics of heat stress management do not change radically. However, farmers are not quite aware about the impacts global warming can produce in their operation. Therefore, good research work is needed to help them take strategic and tactical decisions.

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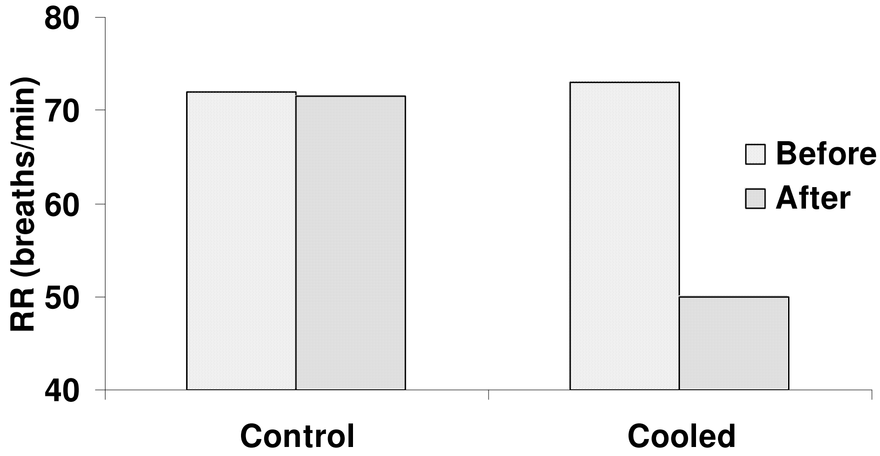

Figure 1. Rectal temperature (RT) before and after pm milking in control and cooled cows. Cooling was performed by a combination of sprinklers and fans in the holding pen.

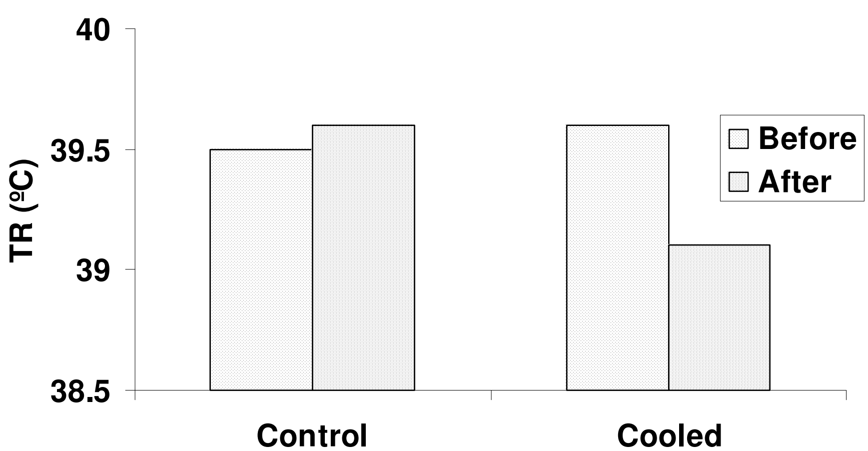

Figure 2. Respiration rate (RR) before and after pm milking in control and cooled cows. Cooling was performed by a combination of sprinklers and fans in the holding pen.

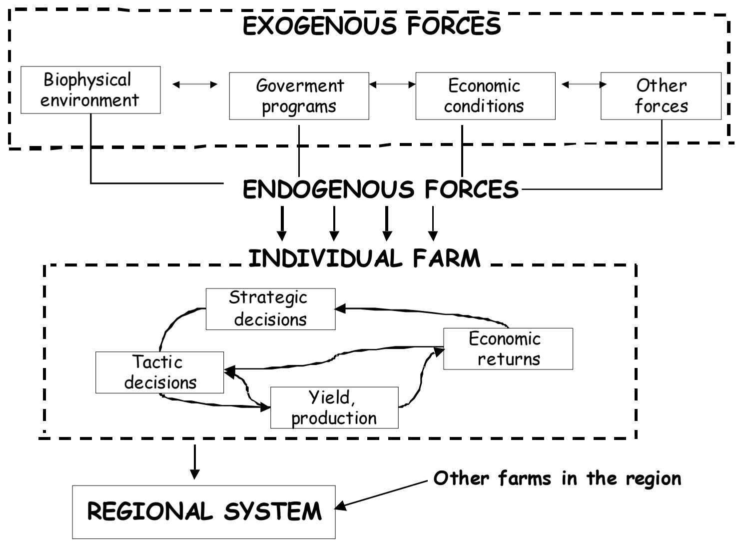

Figure 3. Forces affecting decision making processes, at individual and regional levels (Adapted from Smit *et al.*, 1996).

Table 1. Daily stress hours (THI > 72) during the hottest month (January) in the most important areas of milk production in Argentina. Present values (PV) and values estimated for global change for year 2025 (GCV) on the basis of paleoclimatological studies.

Milking area	***PV***	***GCV***
Buenos Aires (fluid milk)	8	10
Córdoba and Río Cuarto (fluid milk)	10	13
Rosario (fluid milk)	11	14
Entre Ríos	13	16
Western Buenos Aires Province	9	11
Santa Fe and Córdoba	13	17
Tandil	5	8

Table 2. Milk production (average ± sd) for control (C) and treated (T) cows before during and after two heat waves detected during the experimental period, in a trial where effectiveness of evaporative cooling (sprinklers + fans) before milkings was evaluated. Probabilities of significance of the differences are also indicated.

		Before	**During**	**After**	**Prob.**
First Heat Wave	**C**	24.4 ± 0.32	22.9 ± 0.73	20.9 ± 1.24	0.007
	T	25.6 ± 0.38	24.7 ± 0.57	22.8 ± 0.89	0.001
	Prob.	0.003	0.009	0.023	
Second Heat Wave	**C**	22.4 ± 0.41	21.9 ± 1.71	21.6 ± 0.37	0.371
	T	23.1 ± 0.31	22.7 ± 0.53	22.2 ± 0.33	0.727
	Prob.	0.043	0.077	0.051	

Table 3. Variation in rectal temperature (VT) and respiratory rate (VR) between morning and afternoon, milk yield and protein contents in Holstein dairy cows during a trial where shades and supplementation were evaluated in multiparous and primiparous animals. Adapted from (50)

Treatment			***VT***	***VR***	***Milk***	***Protein***
A*	**B***	**C***	(ºC)	(resp./min)	(Kg/c/d)	(%)
S	0	M	0.26±0.24***a***	10.7±4.7***a***	16.9±1.5***a***	2.77±0.13***a***
S	0	P	0.25±0.22***a***	9.5±4.5***a***	15.1±1.7***b,e***	2.77±0.15***a***
S	1	M	0.37±0.14***a***	11.3±6.1***a***	19.2±2.3***c***	2.85±0.14***a,b***
S	1	P	0.25±0.16***a***	9.7±5.6***a***	15.9±1.8***b***	2.94±0.19***b***
NS	0	M	1.18±0.30***b***	24.4±4.9***b***	15.3±3.1***b***	2.81±0.15***a***
NS	0	P	1.16±0.28***b***	21.4±2.8***b***	12.4±2.3***d***	2.85±0.08***a,b***
NS	1	M	0.91±0.11***b***	23.8±3.9***b***	16.8±2.4***a***	2.96±0.11***b***
NS	1	P	1.16±0.07***b***	24.0±4.9***b***	14.8±1.4***e***	2.94±0.13***b***

*A, Protection system: S, shade; NS, no shade.
B, Supplementation level: 1, 3.5 kg concentrate/cow/day
C, Cow parity: M, multiparous; P, primiparous
Within columns, different letters: $p<0.05$