OPTIONS FOR MANAGING LIVESTOCK PRODUCTION SYSTEMS TO ADAPT TO CLIMATE CHANGE

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Abstract

Climatic conditions determine the energy and nutrient metabolism of farm animals and have a major influence on livestock heath, welfare and performance. There are upper and lower critical temperatures for different animal species and age groups. Reducing thermal stress in animal production remains a topic of concern with producers and scientists alike. In order to limit the impact of extreme climate events in the long run, the most important measure consists in implementing preventive means at the level of the farming system itself.

This paper discusses recent research findings together with management schemes in preventing and managing of thermal stress by handling external and internal factors in livestock production systems. Preventive measures against thermal stress are described as basic structural adjustments and the modifications that can be implemented readily, according to animal health and welfare requirements and refer to (a) environmental modification and thermal comfort in various housing systems: pasture management, ventilation, stocking densities, resting pens, waste management, etc; (c) action on animals: genetic selection for breeds resistant to infectious disease, parasites and climate extremes, reproduction management, etc; (d) action on feed: feeding schemes, supplements and additives, vitamins, minerals, etc; and (e) action on staff: handling animals, milking, sharing, etc. Moreover, measures to be taken both in situations of chronic thermal stress and heat or cold strokes are presented as they are applied to (a) limit stress, (b) monitor the temperature felt by animals, (c) adapt diet and drinking water supplies and (d) correct physiological imbalances. Examples are given for different farm species (cattle, sheep, goat, poultry and pigs) and different production systems (intensive, extensive, alternative). The paper concludes with a practical guide for the effective handling of thermal stress at farm level, summarizing the results from recent research studies on the specific topic.

Keywords

Livestock production, management, thermal comfort

1. Introduction

Recent data and model predictions suggest that the climate changes will result in more extreme weather in different parts of the world leading to frequent changes of hot and cold temperatures. It appears reasonable the livestock sector to come up with new strategies in order to maintain and increase the production potential under altered climatic conditions.

Climatic conditions determine the energy and nutrient metabolism of farm animals and have a major influence on livestock heath, behavior, welfare and performance. There are five ways in which an animal may exchange heat with its environment: solar (shortwave) radiation gain, long wave radiation exchange, convective exchange, conductive exchange, and heat loss by evaporation. This heat exchange, in combination with the metabolic heat produced by the animal, defines the animal's heat balance. When a homeothermic animal cannot lose sufficient body heat (generated by metabolism, or gained from the environment) to maintain a stable body temperature, the animal experiences heat stress. In a cold environment when the same animal losses heat to the environment faster than metabolic heat is generated, or heat is gained from the environment, the animal experiences cold stress. Under conditions of heat stress, animals may seek a cooler environment in the shade, while under conditions of cold stress animals find relief by sheltering from wind, rain and snow [1, 2].

When an animal's microenvironment ventures outside its thermoneutral zone, a portion of the metabolizable energy typically used for production must be diverted to assure thermal balance. Direct effects include altered production, reproduction and resistance or susceptibility to disease. Indirect effects involve changes in pathogen and pest populations as well as animal behavior that can cause increases in exposure to pathogens and pests, such as lying in muddy and wet areas to cool themselves when heat-stressed.

The upper and lower critical temperatures for different animal species and age groups are shown in Table 1.

Table 1. The upper and lower critical temperatures for different animal species and age groups [3].

Animal species, age groups	Critical temperature (^{0}C)	
	Lower	Upper
Lactating sow with piglets	15ºC for sow 32ºC for piglets	26ºC for sow No practical upper limit for piglets
Prenursery, 3-15 kg	26	32
Nursery, 15-35 kg	18	26
Growing pigs, 35-75 kg	15	25
Finishing pigs, 70-100 kg	10	25
Sow, boar, 100 kg	10	25
Dairy cow	-12/-1*	24
Newborn dairy calf	8-10	35
1-day-old chicken	32	35
Finishing broiler	16	26
1-day-old turkey	35	38
Finishing turkey	16	26
Laying hen	16	27-29

*Lower critical temperature: -12 ºC for Holstein and Brown Swiss, -1ºC for Jersey

Heat stress is also a significant financial burden i.e., approximately $900 million/yr for dairy, and > $300 million/yr for both beef and swine in the U.S. alone [4,5]. A 2006 California heat-wave purportedly resulted in the death of more than 30,000 dairy cows [6] and a recent heat-wave in Iowa killed at least 4,000 beef cattle [7], illustrating that most geographical locales within the U.S. are susceptible to extreme and lethal heat. Advances in environmental management i.e. cooling systems and barn construction, have alleviated some of the negative impacts thermal stress inflicts on animal agriculture, but production still decreases during the summer months with some facets of production, notably reproduction, exhibiting losses several months after environmental conditions have cooled.

The detrimental effects of environmental heat stress on animal welfare and production will likely become more of an issue in the future if the climate of the Earth continues to warm as most predict [8]. Therefore, defining the biology and mechanisms of how heat stress jeopardizes animal health and performance is critical in developing approaches to ameliorate current production issues and is a prerequisite for generating future mitigation strategies to improve animal well-being and performance i.e., lactation, growth, and reproduction, thereby improving agricultural profitability.

Moreover, under changes in climate conditions, it will be strategic to optimise productivity of crops and forage (mainly improving water and soil management) as well as to improve the ability of animals to cope with environmental stress by management and selection. However, to guide the evolution of livestock production systems under the increase of temperature and extreme events, better information is needed regarding biophysical and social vulnerability, and this must be integrated with agriculture and livestock components.

Now days, reducing thermal stress in animal production remains a topic of concern with producers and scientists alike. In order to limit the impact of extreme climate events in the long run, the most important measure consists in implementing preventive means at the level of the farming system itself.

This paper discusses recent research findings together with management schemes in preventing and managing of thermal stress by handling external and internal factors in livestock production systems. Preventive measures against thermal stress are described as basic structural adjustments and the modifications that can be implemented readily, according to animal health and welfare requirements and refer to (a) environmental modification and thermal comfort in various housing systems: pasture management, ventilation, stocking densities, resting pens, waste management, etc; (c) action on animals: genetic selection for breeds resistant to infectious disease, parasites and climate extremes, reproduction management, etc; (d) action on feed: feeding schemes, supplements and additives, vitamins, minerals, etc; and (e) action on staff: handling animals, milking, sharing, etc. The paper concludes with a practical guide for the effective handling of thermal stress at farm level, summarizing the results from recent research studies on the specific topic.

2. Environmental modification and thermal comfort in various housing systems

Thermal stress occurs when any combination of environmental conditions cause the effective temperature of the environment to be higher/lower than the animal's thermo neutral (comfort) zone. Four environmental factors influence effective temperature: (1) atmospheric temperature, (2) relative humidity, (3) air movement and (4) solar radiation. These factors have received much scientific attention where individual elements are measured e.g. ambient temperature whilst the other factors are held constant.

In extensive systems, grazing animals spend many hours a day obtaining food and are frequently unable to use shade or shelter, and eat at the same time [9]. For such animals it is important to know when periods of heat or cold stress may occur, and to provide shade or shelter at these times. If air temperature, relative humidity, wind speed, solar radiation, rain or snow fall, and the animal's metabolic heat production are known, the heat balance of the animal can be estimated.

Moreover, the indirect effects of climate driven changes in extensive livestock systems result mainly from alterations in the nutritional environment. Research suggests that changes in climate would affect the quality and quantity of forage produced [10]. More specifically, the impact of climate change on pastures and rangelands may include deterioration of pasture quality towards poorer quality subtropical 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 [11, 12]. As a consequence, productivity of grazing livestock could be altered.

On the other hand, in intensive systems, the magnitude of the direct effects of climate change on animal welfare will be determined by the capacity and efficiency of the environmental control systems of the housing. Both increased average temperatures and an increased frequency of extreme events (hot and cold) will potentially place increased demands upon environmental control.

Both for extensive and for intensive production systems, different methods of environmental modifications to relief heat stress are found in the literature. To summarize, the main interventions for environmental modification include: shades, ventilation, combination of wetting and ventilation.

Shades

Shades in pastures, natural (trees) or artificial, are the most simple method to reduce the impact of high solar radiation. When enough natural shade is unavailable, artificial structures may be constructed.

Providing shade for feedlot cattle reduces respiration rate at the peak of the day in all environments and body temperature in moderate hot environments [13]. In a study performed in the central milk supply area of Santa Fe, protected animals presented lower afternoon rectal temperature and respiration rate and yielded more milk and protein while the artificial shade structure did not differ from tree shades, in terms of the effects on animal well-being [14, 15]. The currently limited knowledge on the effect of adverse weather on pastured cattle in temperate climates suggests that providing shelter will benefit their welfare and productivity. Further research is needed, however, to estimate the effectiveness of different types of shelter for different types of cattle [16], for instance those differing in age, breed, experience and productivity.

In a poultry study to measure organic broilers' preferences for different features of habitat in the outdoor area, it was concluded that wooden shelters and other additional features of habitat in the ourdoor areas can be used in organic broiler production to attract birds in the outdoor areas. The mean number of birds was significantly higher in paddocks where a shelter was provided and ranged from 4.01 (shelter) to 7.28 (feeder, drinker and shelter) *(P<=0.05)* [17].

Ventilation

Air moving is an important factor in the relief of heat stress, since it affects convective and, according to air humidity, evaporative heat losses.

Broilers, turkeys, fattening pigs, beef and dairy animals have traditionally used natural ventilation housing designs. Typical of these structures would be controlled openings at the building sides combined with an opening at the ridge. The need for tighter climate control for young immature animals has forced animal housing, over time, to more fan ventilated facilities. With multiple fans, staged according to animal needs and outside climatic forces, a much tighter climate control can be achieved. Farrowing sows, young immature pigs, pullets and laying hens have all greatly benefitted from tighter climate control afforded by fan ventilated barns [18].

Spray evaporating cooling

An effective way of cooling animals, mostly used in cattle production, is spray evaporative cooling. There are several methods available, mist, fog and sprinkling systems. In the literature, the effectiveness of those systems under confined production is discussed. The single use of a sprinkling and fan system for 30 minutes before milking, has proved to be useful to relief dairy cow heat stress, in terms of efficiency to reduce the impact of heat waves under a grazing system [19]. In the short term, cows must be helped to withstand high temperatures by modifying their environment. The major objective of a cooling system is to reduce the air temperature inside the cow shed, so as to keep the cow's body temperature as close as possible to normal (38.5 - 39.3^{o}C). Evaporative cooling can be accomplished in two ways. The first is by direct evaporation from the skin surface of the cows. The second is by indirect evaporation, by cooling the air around the cows with cooling fans and mist in an enclosed cattle shed. The benefits to sprinkled cattle have been proved to include: lowering body temperature, decreasing respiration rate and maintaining feed consumption [20]. Environmental modification comes at a high cost and in many cases these costs cannot be economically justified. Thus, in the beef industry where profit margins are very thin, there is little economic advantage to capital investment for production gains. In contrast, large capital investments are made in the dairy and poultry industries to modify environments in order to maximize profitability.

3. Action on animals

Genetic and phenotypic markers are useful tools to estimate animal susceptibility to thermal stress and support decision making process for increased production and thermal resistance to increased thermal load.

Genetic Selection Programs

Selection for tolerance to environmental stress has traditionally been counterproductive in domestic animal production while new molecular and genomic tools offer real opportunity to improve tolerance for environmental heat stress in domestic animals.

One of the main molecular responses that is activated in a cell under thermal stress is the heat shock protein response (HSPR), a genetic activation that occurs at the cell level in response to abnormal, stressfully high or low temperatures [21, 22]. As molecular chaperones, HSPs stabilize denaturing proteins and refold those that have already been denatured [36]. Thus, the HSPR could be considered an ecologically and evolutionarily important factor in thermal adaptation, setting thermal tolerance limits and improving an animal's tolerance to thermal stress [23, 24]. The constitutive elevation of heat shock protein gene expression has been shown to be cytoprotective against thermal injury in rats but has not yet been tested in domestic animals. Likewise, treatment of lactating dairy cows with bovine somatotropin has been shown to increase evaporative heat loss capacity [25]. Understanding the molecular basis for the increased evaporative heat loss capability offers new opportunities for increasing thermal tolerance of animals in warm climates. In pigs, there is genetic variation among animals for cooling capability, which suggests that more heat tolerant animals can be selected genetically. Cross breeding offers another opportunity [26].

Finally, unraveling molecular changes associated with seasonal acclimation will offer new insights into selecting domestic animals for thermal tolerance. Currently, several laboratories are in process of producing cattle, pig, horse and poultry gene expression microarrays in models of thermal acclimation to identify changes in gene expression during acute and chronic thermal stress.

Phenotypic Markers Selection

Some examples of phenotypic markers related to animal susceptibility to thermal stress are given below.

Goats with loose skin and floppy ears may be more heat tolerant than other goats. Angora goats have a decreased ability to respond to heat stress as compared to sheep and other breeds of goats. Dark-colored animals are more susceptible to heat stress, while light-colored animals may be prone to sunburn and females usually handle heat better than males. The heat is especially hard on fat animals. Horned animals dissipate heat better than polled (or disbudded) animals.

Colored breeds in cattle, such as Jerseys and Brown Swiss, seem to show greater tolerance to heat stress. Jerseys are also better producers of butterfat and protein, while needing a lesser quantity of high-quality feed. Holsteins are less heat tolerant and they require adequate attention in hot weather. In Pakistan, a thermotolertant indigenous breed, called Cholistani, can be utilized as a model to study the adaptive physiologic processes augmented by heat stress [27].

The increasing proportion of poultry production in tropical and subtropical regions makes it necessary to reconsider the long-term selection strategy of today's commercial breeding programmes. Also, the importance of the potential use of Nacked neck and Frizzle genes is accentuated [28]. Moreover, results from a recent study indicated that the density of contour feather can be regarded as a phenotypic marker for heat tolerance in chickens [29].

4. Action on feed

Heat stress causes reduction of dry matter intake (DMI) and nutrient utilization in animals which has as a consequence to reduce their productivity [30]. So, more nutrients are needed to be consumed into smaller volume of feed. Thus, feeding high concentrate diets during hot periods not only results greater consumption but also reduce heat production inside the ruminants body, since it is known that the metabolism of acetate leads to greater heat production in comparison with that of propionate. Indeed, feeding cows with low roughage diets (NDF) during the pre-partum period minimize the reduction in DMI and limits body fat mobilization and thus limits the effect of heat stress [31]. Additionally, Adin et al. [32] observed that diet with 12% NDF, as compared to 18% NDF, has improved DMI and milk yield of cows fed TMR under heat conditions. However, taken into account that a minimum quantity of forages is needed in order to prevent acidocis conditions, feeding high quality of forage decreases the heat fermentation associated with lower quality.

The maintenance of adequate nutrient intake during heat conditions can be also achieved by adding fat to the ruminant diets since fats have low heat increment [33]. Indeed, when heat stressed cows fed with diets supplemented with fats not only improve their milk yield and milk fat content [34] but have also significant lower early morning respiration rate [35].

Despite the fact that the improvement of milk yield of heat stressed cows as a result of use fats, more concentrates and reduced fiber content in ruminant diets are well documented on the other hand, responses of heat stressed cows to modifications in dietary protein content and quality are less clear. However, Arieli et al. [36] conclude that a dietary crude protein (CP) content of 15.3% is adequate to maintain production in heat exposed cows produce 35 kg of milk/day provided that the force evaporative cooling and the ratio of rumen degradable organic matter to rumen degradable protein is appropriate.

Although feeding fats increase milk yield in hot conditions there is a limit to which they can incorporated into the diet because even by-pass fats decrease fiber digestion, cause milk fat depression and reduce DMI [37]. Alternatively, supplemental dietary modifiers and exogenous fibrolytic enzymes may increase digestion efficiency.

Yeasts addition may be such an option since stabilizes rumen environment, increases fiber digestion and flow of microbial protein in the rumen while moreover improves feed intake and milk production [38]. A number of studies suggest that yeasts are more effective when the animals are under stress, particularly heat-stress [39, 40] while others confirm only slight reduction in animals body temperature without any effect on DMI and production [41, 42]. The discrepancy in the results of the above studies may be due to differences in the rations, lactation stage and the level of heat stress.

Recently, plants derived feed additives have also been proposed to offset the consequences of heat stress, since diet supplementation with antioxidants before the beginning of months of heat stress, and also, during stress period may decrease oxidative stress [43]. Among the natural products phenolic compounds and isoflavones seem to be potential candidates. Indeed, Liu et al. [44] observed an increase on production performance as well as an enhancement on the body ability and resistance to heat stress in cows fed a diet supplemented with daidzen which is a natural plant isoflavone. Further to those antioxidants such as vitamin C and E can also have adverse effects on heat [45].

Another future concept is the use of niacin in ruminant diets. Niacin is a feed additive that can be face heat stress and can modify animals productivity, through the improvement of energy utilization. Indeed, Zimbelman et al. [46] reported that the inclusion of rumen protected niacin in cows diets increased evaporation heat loss during thermal load and caused slight reduction in rector and vaginal temperatures when the animals experienced in a moderate heat stress. However, the results concerning the effects of rumen protected niacin on milk production variables, were differed depending on the level of heat stress experienced and on the stage of lactation [47].

Finally, research also indicated that increasing the dietary cation-anio difference for lactating animals the milk yield was increased, when sodium bicarbonate and potassium carbonate were added to the diet, excessive concentrations of dietary sulfate and chloride should be avoided during heat stress.

The majority of the above nutritional strategies (fat supplementation, lower fiber content of the diet, increase concentrate percentage, increased antioxidants, yeasts, etc.) can be also used in non-ruminant animal such as poultry and pigs, in order to reduce the heat production [48]. However, in those animal species as well as in high producing dairy animals the ideal protein is also important. The so-called ideal protein refers to a well –defined amino acid pattern, which expresses the requirements of essential amino acids. Amino acid conversion and N excretion are the lowest when diets are formulated according to ideal protein concept. Excess amino acids that cannot be used in protein synthesis, due to a limiting factor (such as a limiting amino acid or energy supply) are metabolized in the body. Compared to other nutrients, the oxidation of amino acids yields the most heat contribution to the total heat production. Furthermore, recent studies recommend the use of betaine in pigs and poultry feeds during heat stress [49].

Other strategies could also be used to provide an extra feeding or two in a day during the cooler times of the day. Also, increasing the amount of feed during these cooler periods of the day (early morning or late evening) is another alternative to avoid reduction in feed intake during hot periods. Additionally, in non-ruminant animals the water addition to the feed may be another option to increase feed intake.

On the other hand, at low ambient temperature animals should consume more feed in order to cope with the increased energy requirements used for thermoregulation. Thus, in cold environment a reduction in energy density of the rations is needed in order to increase animals' feed intake and to meet the extra demands of thermogenesis. Additionally, the use of feeds containing high percentage of fermentable fibers and protein, increase animals' heat production. However, protein overfeeding is not recommended either from economical or environmental point of view.

5. Action on staff

In animal husbandry, indoors or outdoors, animals and birds are subjected to a multiple of environmental elements and are usually in their own microclimate. Most elements are inter related none more so than ambient temperature and relative humidity. It is important therefore that farmers and staff involved understand the environmental elements in which their animals and birds will perform best. For ease of understanding this is called the "zone of comfort".

Producers should ensure that all staff are able to recognise the early signs of heat stress and that senior stockmen and certain other staff are familiar with the ventilation systems built into the sheds. Plans should be made in advance to deal with hot weather emergencies. Such plans should include action to be taken and by whom both during normal operations and while the animals are depopulated and transported.

Moreover, contingency plans should cover either a partial or complete breakdown of equipment (such as backup systems failing) and designate different roles to members of staff as necessary. Emergency instructions should be clearly displayed for all staff and these should include telephone numbers of veterinary surgeons and equipment engineers. A person should be available or on-call at all times who has authority to take whatever decisions are necessary to protect the welfare of the animals.

Stockmanship, plus the training and supervision necessary to achieve required standards, are the key factors in the handling and care of livestock under thermal stress. A management system may be acceptable in principle but without competent, diligent stockmanship, the welfare of animals cannot be adequately safeguarded [50].

Stewardship has to be supported by stockmanship in an effort to identify skills and competencies in commercial practice through the full food production chain of animal origin, and suggesting practical steps that may be appropriate for them in moving toward sustainable animal production. When doing this duties and obligations address careful and responsible management. Farm animals are sentient creatures. Therefore attention has to be paid to a variety of factors, such as standards of stockmanship, especially animal welfare. Good welfare status can be achieved through a high standard of stockmanship, effective management, adequate housing and well-maintained equipment.

Basic rrequirements are as follows:

(1) Animals should be provided by adequate management and stockmanship which ensure that appropriate quantities of suitable feed and water are available daily and are distributed in a manner which facilitates access for all animals. Improvements in understanding of digestive physiology and nutrient requirements. Properly managed livestock should not suffer from inadequate nutrition.

(2) Provision of artificial protection from the weather conditions where no natural shelter is available. When housed, a well-ventilated shed, a comfortably bedded, dry lying area and frequently cleaned passageways are necessary to avoid discomfort and to reduce the risk of injury.

(3) In diseases we need better understanding of the causes. The problem can be resolved by improved environment, nutrition and breeding. The incidence of infectious diseases can, in many cases, be reduced by routine preventive actions.

(4) When housed, it is essential that building design and good stockmanship allow animals to behave naturally and do not adversely affect their welfare.

(5) Fear and distress is seldom completely unavoidable in any husbandry system. Stockpersons can minimise fear and distress by careful supervision and by sympathetic handling.

6. Monitoring thermal stress in practice

In practice, to prevent and monitor thermal stress it is recommended to act as following:

Cattle production

An effective prevention scheme for extreme cold and wet weather conditions should take into account the following: (a) Be prepared to prevent and treat bloat when cattle increase grazing after a hard rain, (b) Maintaining water consumption to encourage feed consumption during prolonged cold stress. Warming devices will aid in preventing freezing of water and preventing salt poisoning in animals, (c) Monitor body condition of cattle under prolonged cold stress and adjust the ration accordingly.

Strategic use of bedding can help reduce stress. Increase bedding during cold temperatures. In open lots bedding should be placed on the slope downwind from prevailing winds. Thinner hided cattle (such as dairy beef) have less insulation and may require more frequent bedding than British-breed cattle. Drinking water is extremely important in times of heat stress. Intake may increase by 20 to >50% during heat stress. Clean, fresh water must always be available close at hand. This is done by having adequate watering devices or space (minimum of 2-3 inches per cow) on hand, making sure pressure is adequate to refill waterers (quickly for light plastic tubs), and providing more water sources in the pasture if travel distances or sight-distance issues arise. Other potential adjustments include providing portable shades or sprinklers in the pasture and grazing cows only at night and keep them in the barn during the day. If kept in the barn during the day, the barn will need cooling equipment, such as fans and sprinklers. Night grazing is also recommended during hot periods. Letting the animals graze out in the night is a good way of helping them lose heat. Stocking density is a particularly crucial factor underlying both heat stress and animal welfare. The optimum facility for confinement of domesticated animals should provide ample space so that stock remain clean and healthy while maintaining them in the lower range of their comfort zone. At extreme temperatures, the animals would be comfortable, produce just enough metabolic heat to remain stable without using any energy for dissipation and, provided that adequate amounts of a balanced and palatable diet are provided, feed intake and productivity should be maximized. Practical considerations prevent such luxury on a continuing basis but good units provide near ideal environments most of the time. Finally, thermal stress can be reduced by reducing ground reflection (by coverage of landscape around the shed with grass, shrubs and bushes), attached shade (projection of roof), minimizing the solar radiation (suitable method and material for roofing) etc. Painting the roof white may increase the level of sunlight reflected, thus reducing the amount of absorbed solar energy.

It is foreseen that as we get more days of hot weather and/or more prolonged periods, we can expect less milk production and growth in animals. We can make some adjustments in rations and animal management strategies. However, these will probably not be adequate to totally counteract the detrimental effects of heat stress. It will most likely take some additional changes to assist in minimizing the effects of heat stress, such as changes in cattle breeds used, genetic selection within breeds or cross-breeding, coat color of cow, the animal’s environment, times of day for grazing to the cooler periods, and forage types and rotations.

Poultry production

Current production methods often involve large numbers of birds being housed together making them susceptible to heat stress. It is recommended to act as following:

Building designs: Roof colour, reflectivity, pitch and orientation and whether the building is in the shade or not, are also factors which will have a small bearing on solar heat gain. Expert advice should be sought at the design stage.

Ventilation and air distribution: Even when there is enough air in the house it is necessary to distribute it uniformly to all of the birds. Modern ventilation systems are designed to achieve this, but unfortunately there are still many inherently poor systems in use.

Circulation fans: It is important to distinguish between internal circulation fans, which do not change the air, and the main ventilation fans which do.

Evaporative devices: There are now devices available for evaporative cooling. However, they should only be used when the house air is hot and dry, not during hot humid weather. It could be dangerous to use evaporative cooling when the relative humidity exceeds about 70%, as the efficiency of the birds' heat loss through panting may be impaired.

Stocking density: Where possible, and in particular in older broiler houses with less efficient ventilation equipment, it is sound practice to reduce stocking densities in the summer.

Sheep and Goats

While heat stress (exhaustion or stroke) is not very common in sheep and goats in temperate climates, it may occur, especially if stock is handled during the hottest part of the day. Clinical signs of heat stress include continual panting, rapid breathing, weakness, inability to stand and an elevated rectal temperature (over 105ºF/40.6ºC). If rectal temperature exceeds 107ºF (41.7ºC), death may occur, as the animal's cells begin to degenerate. Under normal circumstances, livestock are able to maintain their body temperature at a safe range, so long as they have shade and plenty of water. In extreme heat, they will decrease their grazing time and spend more time in the shade, especially during the heat of the day. They will graze mostly in the evening and early morning hours. They should be allowed to rest during the heat of the day.

Animals suspected of being heat-stressed should be moved to a cool, shaded area with good air circulation. The obvious goal of treatment is to lower body temperature. Sheep should be cooled by applying rubbing alcohol to the area between their rear legs. Besides not being covered with wool, this area has a lot of vascular activity. Wooled sheep should not be sprayed with cool water as this will prevent cooling. Air will not be able to pass through the wetted fleece. Other cooling treatments include ice applications, submersion in ice and cool water enemas.

Heat-stressed animals should be offered ample water and encouraged to drink small amounts. It may be necessary to administer fluids to animals that have become dehydrated as a result of their exposure to extreme heat and/or humidity. Woolly or hairy animals should be sheared as conditions allow.

Pigs

Pigs subjected to high temperatures not only suffer as a result of heat stress, but also productivity is reduced with a lower growth rate in finishing pigs and lower fertility in sows and boars. The use of good ventilation design and insulation combined with the use of evaporative cooling techniques for indoor pigs, and the combination of shade and evaporative cooling for outdoor pigs, can alleviate heat stress in pigs under most cases.

There are a number of methods and areas producers can evaluate and utilize to minimize heat stress in their pigs.

Water Supply: Ensuring adequate quantities of quality water are available is extremely important to ensure pigs to not become dehydrated. Waterers need to be adjusted and functioning properly, with enough waterers available to allow adequate access.

Wet Skin Cooling: Pigs, under natural conditions outdoors, wallow in mud to cool themselves. The mud itself does not provide significant cooling directly, but instead evaporative cooling occurs as the mud dries, while it also provides a protective barrier against the sun. In confinement systems, water sprinkler systems and drip coolers can also provide effective supplemental evaporative cooling. In group pens, sprinkling water in 1 to 2 minute intervals every 20 – 30 minutes allows moisture to evaporate off the pig's skin before wetting and starting the cooling process over again, and is more effective than leaving waterers on continuously. For sows individually housed in gestation or farrowing stalls, dripping water on the necks and shoulders combined with air movement also provides direct evaporative cooling.

Nutrition: Pigs will reduce voluntary feed consumption at temperatures above their ideal range in order to reduce the amount of heat being generated due to digestion. Therefore, diets should be reformulated in the summer to be more nutrient dense, ensuring nutrient needs (amount/day) are still being met. Including higher levels of fat, such as beef tallow, choice white grease, or vegetable oil, will increase caloric density while also reducing the amount of heat generated during digestion. Fat is typically added at levels of 2 – 6% of the diet. Fibrous ingredients, such as soybean hulls, wheat midds, alfalfa, etc. should not be fed during hot weather, since caloric density is much lower and will also contribute towards higher heat liberation during digestion.

Adequate Ventilation: Rapid air movement over pigs increases the rate of evaporative and convective heat loss and is particularly important in confinement buildings. Providing and operating supplemental fans over pens to increase air velocity to at least 3 mph is very effective in warm conditions. Additionally, air exchange in mechanically ventilated buildings should be increased in hot weather to increase the removal of humid air from barns.

Floor Space: Under conditions of heat stress, it is encouraged to increase the minimum floor space allowed per pig when possible. Increased floor space improves the ability of each pig to dissipate heat and is particularly important in larger pigs that are more vulnerable to increased temperatures.

Adequate Insulation: Properly designed and maintained buildings should contain ample levels of insulation to not only prevent excessive heat loss during the winter, but also help minimize solar heat build-up during the summer.

Shade: Pigs that are reared outdoors must have areas shaded either naturally via trees or have structures built to provide relief from the sun. Shade provides relief by blocking a significant proportion of the radiant heat load from the sun. If constructing artificial sources of shade, excellent roof materials include un-insulated aluminum or bright galvanized steel.

6. Conclusions

A combination of fans, wetting, shade and well-designed housing can help to alleviate the negative effect of thermal stress on animals. Careful management and feeding strategies are important in achieving the optimum animal performance. While there are many methods of reducing thermal stress, selection of the most appropriate technique and its proper application is essential. If one method proves successful in one place, this does not guarantee success elsewhere. There are also limitations related to the local climate, the educational level of farmers and the amount of money farmers can afford to invest.

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The Programme worked to help communities adapt to climate change by boosting their coping mechanisms and broadening their options for earning a living. The Programme assisted three communities by pumping water from the Limpopo River to units which combined crop growing with fish and livestock production. While the Programme solely served semi-arid communities, it demonstrated great potential for replication where sufficient water existed to fill out the tanks from small rivers or lagoons.Â Water is central and critical to climate change adaptation in Chicualacuala and similar areas. The current and future water resource, from all sources, must be scientifically assessed and used sustainably in order to adapt to climate change and support long-term development. OPTIONS FOR MANAGING LIVESTOCK PRODUCTION SYSTEMS TO ADAPT TO CLIMATE CHANGE E. N. Sossidou1, E. Tsiplakou2 and G. Zervas2 Veterinary Research Institute, Hellenic Agricultural Organization-DEMETER, Thessaloniki, Thermi, 57001, Greece 2 Nutritional Physiology and Feeding, Agricultural University of Athens, Athens, 11885, Greece 1 Presenting author email: , Tel.Â However, to guide the evolution of livestock production systems under the increase ofÂ Moreover, the indirect effects of climate driven changes in extensive livestock systems result mainly from alterations in the nutritional environment. Research suggests that changes in climate would affect the quality and quantity of forage produced [10]. Adapting for Climate Change completes our suite of sustainability master plans. The strategy is based on the latest climate science that shows how our climate has already changed, the changes that are projected into the future, and how they will impact on the City of Sydney.Â Consequently, we must also ensure we have the systems in place to refine and change the Climate Adaptation Strategy in response to new information. The City will incorporate climate adaptation considerations into all future decision-making at Council and establish a climate risk and adaptation reference panel that will review the Climate Adaptation Strategy over time.Â Time lines for managing climate change are longer than most government strategic planning.