Climate change: Effect on growth of animals

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Asian countries are characterized with humid subtropical climate and is subject to extended periods of high ambient temperature and relative humidity. As the primary non-evaporative means of cooling for the domestic animals (radiation, conduction, convection) become less effective with rising ambient temperature, the domestic animals become increasingly reliant upon evaporative cooling in the form of sweating and panting. Increasing air temperature, temperature-humidity index and rising rectal temperature above the critical threshold levels are related to decreased dry matter intake (DMI) and milk yield and to reduced efficiency of milk yield. Body weight and growth is affected due to hyperthermia.

Keywords: Climate change, Growth, Heat stress, Thermoregulation.

INTRODUCTION

Climate is defined as the mean physical state of the climatic system, which is constituted by intimately interconnected components viz. atmosphere, hydrosphere, cryosphere, lithosphere and biosphere. Thus, the climate is determined by a set of time-averages of quantities that describe the structure and the behaviour of the various parts of the climatic system, as well as by the correlations among them (Peixoto and Oort, 1992). Simply put, climate is the average weather conditions experienced in a particular place over a long period. Weather is the state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity and barometric pressure for short period of time. On physical basis climate can be divided in to two types viz. Microclimate and Macroclimate. Microclimate is the climate of a very small or restricted area, especially when this differs from the climate of the surrounding area. Macroclimate is the climate prevailing over a large area i.e. country, continent or the planet.

The world is divided in different climatic conditions. Peel et al. (2007) compiled a new digital Köppen-Geiger world map on climate classification for the second half of the 20th century, which has six primary types viz. A) Tropical (megathermal) B) Dry (arid and semi-arid) C) Temperate (mesothermal) D) Continental (microthermal) E) Polar and F) Alpine. The six primary classifications can be further classified secondarily into rain forest, monsoon, tropical savanna, humid subtropical, humid continental, oceanic climate, mediterranean climate, steppe, subarctic climate, tundra, polar ice cap and desert (GPCC, 2011).

Global warming and its effect on animals

The impact of climate change on human, animals, ecosystems and energy is enormous. Climate change cycles have been long-term and short-term with many of them being dramatic and rapid. The present average global air temperature is 1.4 °F higher than that at the start of the 20th century, and has risen about 1.1 °F over the last 30 years. Average global temperatures are likely to rise by another 2 to 11.5 °F by the year 2100 (Intergovernmental Panel on Climate Change (IPCC), 2007). The major concern is that changes in the climate are anthropogenic i.e. caused by humans, mainly due to greenhouse gases resulting from burning of fossil fuels which lead to the production of CO₂ and methane. Deforestation reduces the capacity to store carbon, and the carbon is released in the atmosphere. The gases, especially CO₂, act like a blanket and restrict the rate at which Earth’s surface can radiate heat to space resulting in global warming. As a result the current levels of carbon dioxide in the atmosphere are higher than at any time during the last 6,50,000 years.

Higher temperature and higher humidity are most conducive for growth and proliferation of disease producing microbes. Within body systems, a higher body
temperature implies all metabolic reactions taking place at a higher rate (Q10 effect) and reducing body’s capacity to fight the disease. The breakdown of body immune system further worsens the capacity of the animal to resist diseases. Multiple attacks of FMD outbreak coincident to climate change. Temperature and humidity with water logging are most favorable for parasitic (ecto and endo) and disease vectors. Helminthes infestation connected with climate in South-east Asia cause 25 and 23-63 percent respective reduction in growth rate among sheep and goats. The global reduction figure is estimated to be 12 percent (Abraham, 2011).

The larger sufferers of global warming would be ruminants as most of them depend on pastures and grazing lands. Increased temperature increases lignifications of plant tissues and therefore reduces the digestibility (Anon., 2009). Since, frequent onset of droughts cause considerable losses of animals due to scarcity of fodder, it is vitally important to supplement pasture amelioration with fodder trees and shrubs in order to minimize such losses (WMO, 2004). These trees and shrubs will not only supply food for animals, but also serve as a shelter from the solar radiation and create a microclimate more favourable for regrowth of grass spoiled by the dry conditions (Onyewotu et al., 2003).

**Thermoregulation by domestic animals**

Reactions of homeotherms to moderate climatic changes are compensatory and are directed at maintaining or restoring thermal balance (West, 1999). However, when the environmental temperature becomes near the cow’s body temperature, high ambient relative humidity percentage (RH%) reduces evaporation, overwhelms the cow’s cooling capability, and the body temperature rises. This is due to the negative effects of high RH% on dissipation of body heat, because of the decline in effectiveness of radiation, conduction and convection, in addition to the decline in the efficiency of evaporative cooling needed to maintain the heat balance (West, 1993).

There is a vast source of information suggesting that the Supra Chiasmatic Nucleus (SCN) in hypothalamus regulates the circadian and seasonal rhythms of most biological functions – particularly reproductive function and behaviour in mammals (Pando and Sassone-Corsi, 2001) and also regulates the phasic and tonic release of hormones, oestrus and in some cases the gonadal size (Buijs et al., 2003). There is evidence suggesting that the SCN is sensitive to changes in ambient temperature, with some cells being more responsive to cold and others more responsive to heat, though photoperiodic variation exerts a strong influence.

The interaction between anatomical and physiological factors decides the ability to thermoregulate and thermal tolerance in ruminants is more than that in monogastric animals. The properties of the skin and hair, sweating and respiration capacity, tissue insulation, the relationship between surface area per unit body weight or relative lung size, endocrinological profiles and metabolic heat production are factors that influence heat load, but the underlying physiological, behavioural or genetic mechanisms are largely unknown (Hall, 2004 and McManus et al., 2008).

**Heat stress**

Homeotherms have Optimal Temperature Zones (OTZ) / Thermo Neutral Zones (TNZ) for production within which no additional energy above maintenance is expended to heat or cool the body (Berman et al., 1985). Heat stress results from a negative balance between the net amount of energy flowing from the animal to its surrounding environment and the amount of heat energy produced by the animal (Farooq et al., 2010).

Means of estimating the severity of heat stress i.e. the Temperature Humidity Index (THI) was proposed using both ambient temperature and relative humidity (LPHSI, 1990; Marai et al., 2001). The various equations used to determine THI are as follows:

i) \[ \text{THI} = \text{db} ^\circ \text{F} - [(0.55 - 0.55 \times \text{RH})(\text{db} ^\circ \text{F} - 58)] \]

ii) \[ \text{THI} = \text{db} ^\circ \text{C} - [(0.31 - 0.31 \times \text{RH})(\text{db} ^\circ \text{C} - 14.4)] \]

iii) \[ \text{THI} = (1.8 \times \text{Tdb} + 32) - [(0.55 - 0.0055 \times \text{RH}) \times (1.8 \times \text{Tdb} - 26.8)] \]

iv) \[ \text{THI} = \text{Tdb} + 0.36 \times \text{Tdp} + 41.2 \]

v) \[ \text{THI} = (0.35 \times \text{Tdb} + 0.65 \times \text{Twb}) \times 1.8 + 32 \]

vi) \[ \text{THI} = (0.55 \times \text{Tdb} + 0.2 \times \text{Tdp}) \times 1.8 + 32 + 17.5 \]

vii) \[ \text{THI} = (0.15 \times \text{Tdb} + 0.85 \times \text{Twb}) \times 1.8 + 32 \]

viii) \[ \text{THI} = [0.4 \times (\text{Tdb} + \text{Twb})] \times 1.8 + 32 + 15 \]

ix) \[ \text{THI} = (\text{Tdb} + \text{Twb}) \times 0.72 + 40.6 \]

x) \[ \text{THI} = (0.8 \times \text{Tdb}) + [(\text{RH/100}) \times (\text{Tdb} - 14.4)] + 46.4 \]

N.B.: db – dry bulb temperature

RH – Relative Humidity

Tdb – Temperature dry bulb

Twb – Temperature wet bulb

$^\circ \text{F}$ – degree Fahrenheit

$^\circ \text{C}$ – degree centigrade

The Heat stress (HS) levels in different species as reported by different authors is tabulated below Table 1.
Table 1. Heat stress levels in different animals

<table>
<thead>
<tr>
<th>Species</th>
<th>Level of stress</th>
<th>Stress level (°C)</th>
<th>Species</th>
<th>Level of stress</th>
<th>Stress level (°C)</th>
<th>Species</th>
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<th>Stress level (°C)</th>
<th>Species</th>
<th>Level of stress</th>
<th>Stress level (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rabbit</td>
<td>Absence of HS</td>
<td>&lt;27.8</td>
<td>Sheep and Goat</td>
<td>Moderate HS</td>
<td>27.8 to &lt;28.9</td>
<td>&lt;82 to &lt;84</td>
<td>&lt;22.2</td>
<td>22.2 to &lt;23.3</td>
<td>72 to &lt;74</td>
<td>&lt;25.6</td>
<td>74 to &lt;78</td>
</tr>
<tr>
<td></td>
<td>Severe HS</td>
<td>28.9 to &lt;30</td>
<td></td>
<td>Severe HS</td>
<td>28.9 to &lt;30</td>
<td>84 to &lt;86</td>
<td>23.3 to &lt;25.6</td>
<td>74 to &lt;78</td>
<td>&lt;25.6</td>
<td>74 to &lt;78</td>
<td>23.3 to &lt;25.6</td>
</tr>
<tr>
<td></td>
<td>Extreme severe HS</td>
<td>&gt;30</td>
<td></td>
<td>Extreme severe HS</td>
<td>&gt;30</td>
<td>&gt;86</td>
<td>25.6</td>
<td>&gt;78</td>
<td>&gt;25.6</td>
<td>&gt;78</td>
<td>&gt;78</td>
</tr>
</tbody>
</table>

Importance of growth in animals

The key objective in animal production is to achieve maximum growth and productive output such as milk or wool, within the context of an efficient use of feed and other necessary resources and inputs. Animal growth, in simplest terms, can be defined as an increase in size. An increase in size, however, has many implications. Growth may be viewed much differently if one refers to growth of the whole animal or to growth of cells, tissues and organs or to growth before and after birth or before and after puberty. As an animal grows from conception to maturity, its body proportions and composition change because growth rates of the different organs and tissues of the body vary as the whole animal grows. The order of growth of the different tissues is similar for all species of farm animals and seems based on the relative importance of the functions of the body parts or tissues for survival of the animal (Beitz, 1985).

Effect of climate on growth of animals

Growth, the increase in live body mass or cell multiplication, is controlled genetically and environmentally. The average daily gain (ADG) is influenced by factors like available nutrients, hormones, enzymes and environmental factors like increased ambient temperature (Hafez, 1987).

Ruminants

Exposure of sheep to elevated temperatures results in the decrease of body weight, average daily gain (ADG), growth rate and body total solid, which is reflected by impaired reproduction (Marai et al., 2000 and Shelton, 2000). As per NRCC (2007) the crossbreds and buffaloes are affected more than indigenous livestock. Since the crossbreds and buffaloes are more sensitive to temperature rise than indigenous cattle, a rise of 2-6 °C due to global warming will negatively impact growth, puberty and maturity of crossbreds and buffaloes and attainment of puberty is delayed by one to two weeks.

Under high ambient air temperature and solar radiation, steers reduce daily dry matter intake, causing a decrease in average daily gain, carcass weight and fat thickness (Mit‘ohner et al., 2001). However, incidence of disease can increase. The effects of heat stress on feed intake are remarkable even in buffaloes. Morand-Feher and Doreau (2001) reported a decline in feed intake ranging from 40 to 60% in 15 month old buffaloes caused by variation of temperature and humidity from 21.5 to 38.5°C and from 59.0 to 76.5 RH, respectively.

Exposure to hot environment negatively affects growth of young calves. Nardone et al. (2006) found lower wither height, oblique trunk length, hip width (−35, −26 and −29%, respectively) and body condition score (0.0 vs. +0.4 points) in six 5 month old female Holstein Friesian calves exposed to hot conditions as compared with a control group (the corresponding six sisters of six pairs of twins), kept under thermoneutrality conditions. Decrease in body growth and body reserves between birth and puberty, especially during the first few months, can be detrimental for milk production of the future cow and can increase the replacement rate later (Chillard, 1991). High temperatures during late pregnancy and the early post partum period markedly modify colostrum composition (Chillard, 1991).

Animals exposed to chronic environmental stress undergo metabolic adaptations to elevate them. This include changes in endocrine function, basal metabolism, metabolism of water and electrolytes, acid-base balance, and in ruminants an alteration in rumen fermentation. Rumen VFA production is increased in cold stress, due to increased feed intake and decreased heat stress. Selective forage intake during high environment temperature with alternative rumen fermentation cause a decrease in acetate and alters acetate: propionate ratio, which causes reduced milk fat yield during heat stress (Collier, 1985).

Pig

High ambient air temperature causes reduced appetite and growth in pigs. The heavier the pigs the more they are affected. Since protein deposits require more energy than fat deposits, the carcasses are leaner at slaughter (Xue et al., 1997). Compared to those reared in an optimal climate, Rinaldo and Mourot (2001) found that Large White pigs (between 35 and 94 kg body weight) reared in a tropical climate had a lower voluntary feed.
intake (−9%, −13%) and daily weight gain (−9%, −12%), leaner carcass, higher pH, lower moisture loss and decreased lipid content of leaf fat in the entire backfat, concluding that tropical climate may have a favourable effect on pork quality. The adaptation in pigs to heat affects carcass characteristics by the re-allocation of fat depots from subcutaneous sites (bardiere) towards inner sites (panne) to facilitate thermal conductance (Le Dividich and Rinaldo, 1989).

Effects of Climate on Animal Size

Warmer temperature stunts the growth of animals and plants and could also affect food production in coming years. Sheridan and Bickford (2011) opined that the survival of small individuals can increase with warmer temperatures, and drought conditions can lead to smaller offspring, leading to smaller average size. They further observed that many of earth’s species from the toughest polar bears to the smallest house sparrow seem to be shrinking in size. Sheridan and Bickford (2011) in their compilation of past studies found that 38 of 85 animal and plant species, respectively showed documented reduction in size over decades. This included a type of Scottish sheep that is five per cent smaller today than it was in 1985 (Louis Bergeron, 2009). Their results are presented in the table below which summarizes the number of species showing each type of response. Table 2.

<table>
<thead>
<tr>
<th>Organism type</th>
<th>Negative response</th>
<th>Positive response</th>
<th>Equivocal response or no change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fish</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Terrestrial ectotherms</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Birds</td>
<td>19</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Mammals</td>
<td>6</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>38</td>
<td>9</td>
<td>38</td>
</tr>
</tbody>
</table>

Studies conducted by the National University of Singapore showed that the species are reducing in size due to climate warming and this will have repercussions across many food webs and also exert potentially synergistic negative effects on biodiversity (Karen Loh, 2011). Biological rules which explain the effect of climate on body size are listed below (Hafez, 1968):

**Bergmann’s rule**

Has been interpreted as an adaptation to ambient temperature. Animals in warmer ecological region are smaller sized and that in cooler localities are large sized i.e. the relatively larger body surface area of the smaller breeds serves as an efficient heat dissipater in warm climates, while relatively small body surface area may help in heat conservation in cold climates.

**Allen’s rule**

States that in warm blooded animals the relative size of the exposed portions of the body decreases with decrease in mean ambient temperature i.e. extremities, tails, ears and bills are relatively shorter in cooler part of the ecological range than in warmer part.

**Gloger’s Rule**

This is a zoological rule which states that within a species of endotherms, more heavily pigmented forms tend to be found in more humid environments, e.g. near the equator. i.e. animals in arid region have an accumulation of yellow and reddish brown phaeomelanin pigmentation where as in cold climate this pigment is reduced.

**Wilson’s rule**

States that insulation cover based on length of hair and thickness of adipose tissues is related to climate.

**Cope’s rule**

States that population lineages tend to increase in body size over evolutionary time. While the rule has been demonstrated in many instances, it does not hold true at all taxonomic levels or in all clades. Larger body size is associated with increased fitness for a number of reasons, although there are also some disadvantages both on an individual and on a clade level (Ridley, 2004).

**Rensch’s rule**

This is an allometric law concerning the relationship between the extent of sexual size dimorphism (SSD) and which sex is larger. Across species within a lineage, size
dimorphism will increase with increasing body size when the male is the larger sex, and decrease with increasing average body size when the female is the larger sex (Szekely et al., 2004).

Thus environmental change, including climate change, can cause rapid phenotypic change via both ecological and evolutionary processes. Because ecological and evolutionary dynamics are intimately linked, a major challenge is to identify their relative roles (Ozgil et al., 2009).

Fossil records reveal that many species of plants and creatures such as spiders, beetles, bees, ants and cicadas have shrunk in size over time in relation to climate change. Other specimens include cotton, corn, strawberries, bay scallops, shrimp, crayfish, carp, Atlantic salmon, frogs, toads, iguanas, hooded robins, red-billed gulls, California squirrels and wood rats. Each degree of warming also reduces the body size of marine invertebrates by 0.5 to 4 percent and for fish the reduction is even more i.e. 6 to 22 percent (Sheridan and Bickford, 2011).

Changes in body size are a normal phenomenon, when conditions are favourable, there is an increase in size or higher rates of reproduction, and when conditions are deteriorating, the opposite occurs (Yom-Tov et al., 2011). Cold-blooded animals (most of the animals on Earth) are directly affected by changes in temperature, which affect their metabolic rates. This indicates they need more food to maintain their body sizes, or they will shrink. Temperature also affects cold-blooded creatures by increasing their development rates, so the animals reach maturity at smaller sizes (Parry, 2011). However, climate change (increase environment temperature) is expected to increase the growing and feeding season in high-latitude places, and hence allow organisms to get bigger (Parry, 2011).

Yom-Tov et al. (2006 and 2011) tested the prediction that global warming has caused recent decreases in body weight (Bergmann’s rule) and increases in wing length (Allen’s rule) in 14 species of passerine birds at two localities in England. They opined that though many species are indeed shrinking, global warming cannot be exclusively blamed.

CONCLUSION

Climate change has significant effect on growth and production characteristics of animals. The study by various scientists have been reviewed extensively and compiled together in the present article to provide a better understanding of the effect of climate change on animal growth.

REFERENCES


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