particularly if considering that goats are usually characterized as opportunistic with regards to their feeding behavior. Browse is typically rich in tannins and gaining optimal adjustment to tannin-rich diet requires time; thus, skilfully, goats prefer to safeguard their advantage in utilizing food that is available to them at all seasons.

There is a positive interaction between the enhanced recycling rate of urea and a superior digestion of such food in goats adapted to harsh environment. The rumen plays an important role in the developed adaptations by its use as a huge fermentation container and water tank. The water stored in the rumen is utilized during dehydration, and the rumen serves as a container, which accommodates the ingested water upon rehydration. The rumen, the salivary glands and the kidney coordinately take action in the regulation of water intake and water distribution following acute dehydration and rapid rehydration. Some of the physiological features of ruminants defined as intermediate feeders such as a big salivary gland, the large absorptive area of their rumen epithelium, and the capacity to rapidly change the volume of the foregut in response to environmental changes are most likely responsible for the goat's superior digestion.

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Adaptation to tropical climate and research strategies to alleviate heat stress in livestock production

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Over the last decade, livestock production of tropical and subtropical countries has considerably expanded in order to meet a rising population, international meat exchanges and consumer demand. Despite many challenges facing animal producers including environmental problems, diseases, economic pressure, and feed availability, it is still predicted that animal production in developing countries will continue to sustain the future growth of the world's meat production. In these areas, livestock performance is generally lower than those obtained in Western Europe and North America. Although many factors can be involved, climatic factors are the first limiting factors of development of animal production in warm regions. While heat stress can be considered as an occasional problem during summer heat waves occurring in temperate countries, it is a constant challenge in the tropics and subtropics. In addition, global warming will further accentuate heat stress related problems. Livestock animals are homoeothermic and are able to maintain relatively constant body temperature despite widely ranging ambient temperatures by balancing heat production and/or heat loss. Heat production (HP) is the sum of energy for maintenance and metabolic heat associated with the utilization of energy for productive purposes. Consequently, HP is positively related to the production level of an animal. Genetic selection for a rapid growth rate, egg production or high milk production results in animals with high metabolic HP without significant changes in their ability to lose heat. As a result, modern genotypes are more sensitive to heat stress than non-selected or indigenous animals. To sustain the rapid demand for livestock products, high-performance animal stocks are now being imported to developing countries and farmers are advised to use expensive management practices to control ambient temperature in their facilities to maximize performances.

Heat stress is recognized as a critical problem for livestock production. There has been a great deal of research and development into ways of reducing heat stress of livestock animals subjected to short or extended periods of high ambient temperature and humidity. The objective of this paper is to review the effective strategies to alleviate heat stress in the context of tropical livestock production systems. These strategies can be classified in three groups, those increasing feed intake or decreasing metabolic heat production, those enhancing heat loss capacities, and those involving genetic selecting for heat-tolerance. Under heat stress, improved production should be possible through modifications of diet composition that either promotes a higher intake by decreasing diet-induced thermogenesis (low protein or low fiber diets) or compensates the low feed consumption by providing high energy or protein dense diets. Dietary modifications should also include a provision of minerals, vitamins, electrolytes, amino acids, or other additives to cover specific needs of heat-stressed animals. In addition, altering feeding management such as a change in feeding time and/or frequency, are efficient tools to avoid excessive heat load and improve survival rate especially in poultry. Maximizing water intake by providing a sufficient amount of clean and fresh water should also help to maintain feed consumption and facilitate heat loss by increasing water turnover under hot temperature. Methods to enhance heat exchange between the environment and the animal and those changing the environment to prevent or limit heat stress can be used to improve performance under hot climatic conditions. The increase of heat exchange generally involves an increase of heat loss from the body surface by an addition of water to the skin (drip cooling), by enhancing air flow to increase the rate of evaporative or convection heat losses (fan cooling), or by giving access to a cooling zone to improve conductive heat loss (floor cooling). A basic and cost-effective method for protecting animals from heat stress during the day is a simple shade. Supplemental cooling attempts to reduce heat stress by lowering ambient temperature.

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This can be achieved by the evaporation of water into warm air using high pressure fogging or evaporative pad systems. When selecting a heat abatement system, one must consider production goals, breeding facilities (closed or semi-open buildings, water supply) and climatic environment (temperature and relative humidity). While differences in thermal-tolerance exist between livestock species (ruminants > monogastrics), there are also large differences between breeds of a species and within each breed. Consequently, the opportunity may exist to improve thermal tolerance of the animals using genetic tools. Generally, most probably genes that are involved in acclimation to heat stress are also involved in development of thermal tolerance. The adaptive capacities of tropical breeds are generally related to an improved ability to lose heat (hair coat characteristics, special appendices…) and/or to a reduced metabolic HP due to their lower production level or small size. These characteristics could be used to improve thermal tolerance in commercial breeds using crossbreeding strategies or gene introgression. Selection based on rectal temperature measurements and inclusion of a THI in the genetic evaluation models are promising in pigs and dairy cattle. However, further research is needed to quantify the genetic antagonism between adaptation and production traits to evaluate the potential selection response. With the development of molecular biotechnologies, new opportunities are available to characterize gene expression and identify key cellular responses to heat stress. These new tools will enable to improve the accuracy and the efficiency of selection for heat tolerance. Epigenetic regulation of gene expression and thermal imprinting of the genome could also be an efficient method to improve thermal tolerance. Such techniques (e.g. perinatal heat acclimation) are currently being studied in chicken.

In conclusion, a variety of technologies can be used to alleviate heat stress and improve production level under hot climate. The ability of the producers to access to these technologies will depend on availability and prices of water and energy and on the livestock production system (intensive vs. extensive).

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Physiology of adaptation to nutritional stress in farm animals: from production characterization to proteome profiling

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Introduction

Farm animals have adapted to the constraints of their production systems. Seasonal weight loss (SWL) is the major constraint to animal production in tropical regions (Almeida and Cardoso, 2008). Coupled to production studies, the study of the metabolic changes to food restriction, highlighting energy and protein metabolic saving mechanisms, can be a useful approach to identify the physiological pathways relevant in breed selection and to identify genetic biomarkers that could be used in animal selection. Our research has been focused on several aspects related to weight loss. Here we present major results and conclusions obtained.

Weight Loss, serum amino acid and myofibrillar protein profiling in Boer goats

(Almeida *et al.*, 2004, 2006) The aim of the work was to determine serum free amino acid and 1D gel electrophoresis myofibrillar protein (skeletal muscle) profiles in Boer goat bucks following protein and energy undernutrition (20% weight loss). Control animals showed higher concentrations (μmol L^{-1}) of Ala, Tyr and Cit, whilst the restricted group showed higher concentration of Val, Ile, Leu, Thr, Met, Lys, Tau, Orn, Hyp and 3-metyl histidyne (Me3His), while Gly, Ser, Asp, Glu, Arg, His and Pro were similar in both groups. The restricted group showed myofibrillar protein degradation of protein C and α -actinin. It can be concluded that the degradation of small carbon chain amino acid has a higher efficiency than degradation of long carbon chain amino acid and a disruption of muscle structure at the level of the A band (protein C) and the matrix of the *Z* line (α-actinin).

Weight Loss and skeletal muscle proteomics profiling in the rabbit

(Almeida *et al.*, 2010) In this study, a 20% weight reduction was induced in two rabbit breeds: NZW – New Zealand White, a meat producer, and wild rabbit, aiming to determine differential protein expression in the skeletal muscle within control (*ad libitum*) and restricted diet animals, using two-dimensional gel electrophoresis (2DE) and peptide mass fingerprinting. Results show that L-lactate dehydrogenase, adenylate kinase, enolase, aldolase and glyceraldehyde 3-phosphate dehydrogenase, which are enzymes involved in energy metabolism, are differentially expressed in the restricted diet experimental animal groups. Breed differences were also noticed since NZW rabbits show higher expression of structural proteins. These proteins are available to be further tested as relevant biomarkers of weight loss and objects of manipulation as a selection tool towards increasing tolerance to SWL.

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