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Anatomical and physiological adaptation of domestic animals to ecosystem constraints: the example of the camel in arid lands

The local breed or species used as farm animals are generally well adapted to their environment. This adaptation is based on three main components: the ability to support thermal stress by a specific thermoregulation process, the management of the seasonal and/or inter-annual fluctuation in the feeding resources, and the resistance to diseases linked to the local environment. These three components are discussed with special emphasis on the camel model, one of the more adapted species in arid lands.

***Keywords*:** Adaptation, thermal regulation, fat storage management, disease resistance, camel.

Face to the increasing demand in animal protein all over the world, especially linked to the growing urbanization, the decision makers think often that the solution is into the introduction of high productive exotic animals (Delgado et al., 1999). The most emblematic example is the massive introduction of Holstein dairy cows, even in desert countries. It is possible to see now giant dairy farms with high productive dairy cows under air conditioned and all modern technology to produce more milk without taking in account the environmental constraints (hot climate, low natural resources, water restriction). Unfortunately, this vision of the livestock farming is not sustainable and not environmentally friendship. Moreover, it provokes an irremediable erosion of the biodiversity if all the countries adopt similar livestock policy. In the same time, the countries submitted to these high environmental constraints, aggravated by the current climatic changes (Lioubimtseva and Henebry, 2009) have among their livestock population, different animal species or breed, well adapted to the anthropo-ecosystem thanks to generations of co-evolution between local farming practices, environmental conditions and feeding resources (Faye et al., 1999).

The present paper aims to list some advantages of the anatomical and physiological particularities of local livestock, especially in countries submitted to the progressive dryness of their milieu, reflecting their adaptation and their ability to satisfy the local requirements. Some examples regarding camel will be reported.

The components of the adaptation

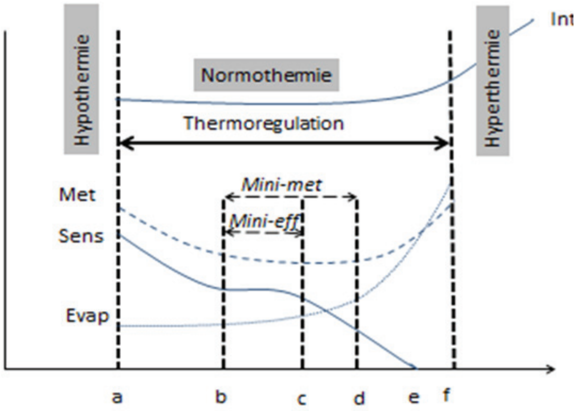
The geographical distribution of the livestock over the world reflects their ability to support extreme climatic conditions (very hot or very cold temperatures, extreme humidity or dryness) and extreme variability of the feeding resources. Consequently, the main components of the adaptation of farm animals are their ability (i) to resist to thermal stress by a specific thermoregulation process, (ii) to manage the seasonal and/or inter-annual variability of the feeding resources, and (iii) to resist to the diseases linked to their local environment (Mandonnet et al., 2011).

The thermoregulation in livestock

One of the main constraints for the well-being and the productivity of farm animals is the thermal stress (Kadzere et al., 2002). The thermoregulation is the physiological function keeping the internal temperature in the physiological limit (homeothermy) by the control of the balance between heat production and heat loss. The heat production is a by-product of the metabolism. The heat loss are achieved by sensible way (radiation, conduction or convection) or by latent way (sweeting, perspiration). When the ambient temperature increases above the thermoneutral zone (between b and d in figure 1), the mechanisms of regulation (decrease of the thermogenesis/increase of the thermolysis) are saturated, the internal temperature cannot be maintained and the animal is submitted to a heat choc leading to death (Silanikove, 2000).

The camel is one of the best adapted farm animals to the heat variability thanks to different mechanisms. Among them:

- The concentration of the adipose storage in the hump (more than 80% of the fat reserve) which facilitate the heat cutaneous dissipation through the skin;



Mini-met: zone of minima metabolism; Mini-eff: zone of least effort for thermoregulation (thermal confort); Met= metabolic heat; sens= sensitive heat loss; evap = heat loss by evaporation; a = minimal critical t°; b= critical t°; c= limit of heat loss by evaporation; d=maximal critical t°; e=point where ta=tb; f= maximal critical t°

Figure 1 – Relations between ambient temperature (ta) and body temperature (tb)

- The long legs of the camel which let the body far away from the soil when it is hot (or cold). Even when the camel is sitting, the sternal pad maintains the airflow around abdomen;
- The skin is covered by long insulating wool in winter, falling down spontaneously in summer;
- The thick skin with sweeting glands working when the body temperature is above 42°C;
- The feeding behavior leading the camel to use the forage-trees during the hot time of the day in order to eat under the shadow of the trees (Faye and Tisserand, 1989);
- The internal temperature varies all along the day according to the ambient temperature (the internal temperature could change from 34 to 42°C) (Yagil, 1985);
- The blood remains fluid even in case of dehydration maintaining the heat transfer from the periphery (more fresh due to the evaporation) to the heart;
- The decrease of the thyroid activity occurs during hot period (increasing bromide production) which contributes to the decrease of the general metabolism (Etzion et al., 1987).

In consequence, it is not necessary to put the adapted animals under artificial climate conditions contrary to the exotic breed or species which pay an important tribute to their discomfort (production loss, diseases, risk of mortality).

The adaptation to the underfeeding and to water restriction

In difficult conditions, the resilience of the farming system is based on the adaptive potential of animals to the underfeeding and on the efficiency of the behavioral and physiological regulations involved in the adaptive response (Blanc et al., 2004). In ruminants, 3 morphophysiological types of animals were identified among 150 species (Hofmann, 1989): (i) forty % of the ruminants are "selector-concentrator", mainly wild herbivorous, able to digest easy assimilable plants (fruits, leaves, seeds), rich in soluble components; (ii) twenty-five % are grazers (cattle, sheep, buffalo) and are adapted to the digestion of grass rich in fibers, (iii) thirty-five % are rather browsers (goat, camel), able to adjust their intake according to the seasonal fluctuations. These 3 groups of ruminants are characterized by different anatomical particularities of their digestive tract: from types 1 to 3, a decrease of the selective ability, secretion of HCl, amylolytic activity and of papillary surface, increase of cellulolytic digestion and of intestinal length (Hofmann, 1989).

The digestive physiology of the camel is entirely turned to the valorization of poor nutritive resources. The ruminal flora, the nitrogen recycling or the slow transit (Al-Jassim and Hogan, 2012) allow the camel to increase the ratio resources/productions by a better efficiency than other ruminants. Even though the microbial population is qualitatively the same, the cellulolytic activity of the bacteria is much more important in the camel forestomach and the retention time of solid particles in the forestomach is much longer. The evolution of these two parameters is responsible for a better digestion of organic matter and of the cellulosic fractions of the diet. Due to better buffered digesta, the addition of large amounts of starch to a forage-based diet has not the negative effects on microbial cellulolysis usually observed in ruminants. Furthermore, camels excrete less nitrogen in the urine and efficiently recycle urea via the mucous wall of the forestomach. This economy of nitrogen allows them to maintain a minimal production of microbial proteins for cases when dietary nitrogen is insufficient. In consequence, the digestibility in camel is 4 to 5% more important than in other ruminants receiving the same diet (Jouany, 2000).

In all ruminants, the mobilization of the fat storage is the main mechanism for managing the alternation between under and overfeeding periods. In camel, the mobilization of the fat storage in the hump is slower than in other species (Bengoumi et al., 2005) because its ability to decrease its energetic metabolism as underlined above. The fat destocking, contrary to cattle, doesn't lead to change in the glycemia (close to monogastric) and doesn't provoke any ketone bodies production.

Regarding adaptation to water shortage, the ability of camel to survive in ecosystems with low water resources makes its reputation as "ship of the desert". The camel being able to stay several days without drinking water, it can use rangelands far away from the water points, and thus decrease the pressure around them, contrary to cattle and small ruminants that are unable to stay more than 2 days without drinking water (Brown, 2006). The adaptation of camel to dehydration is based on two main mechanisms: (i) decrease of the water loss by decreasing urine excretion, decreasing the water content in fecal excretion, recovering the water in expired air by the vein network in sinus, stopping the sweating, slowing down the basal metabolism, varying the body temperature according to the external temperature, (ii) maintenance of the homeostasis by limiting the variation of the vital blood parameters and by excreting efficiently the metabolic wastes through the kidney (Bengoumi and Faye, 2002).

The disease resistance. The pressure due to pathogens (bacteria, virus and parasites) in some ecosystem contributed to the selection of the more adapted animals. The trypanotolerance and the resistance to internal parasites are the most common examples (Kaufmann et al., 2010; Hanotte et al., 2003). Many researches are done in the world to identify the genes contributing to the resistance of breed or species to different types of diseases: for example Coppieters et al., 2009 for the gastro-intestinal resistance, or O'Gorman et al., 2009 for trypanosomosis. Regarding the example of camel, it appears that it is not sensitive to the main infectious diseases affecting the other ruminants (foot-and-mouth disease, rinderpest, bovine contagious peri-pneumonia,….), but few researches were achieved on genetic resistance aspect. However, some preliminary results showed that the sensitivity to trypanosomosis, the main parasitical disease of camel, varies according to the coat color of the animal (El-Wathig and Faye, 2013).

Conclusion. Ramsay et al. (2000) summarized the importance of the adaptation of animals in these terms "There is no universal breed". So, to optimize the productivity of livestock in the ecosystems with high constraints and offset their deleterious impacts, the choice of practices considering these constraints and the most suitable genotype (or even of the species) are the two levers available for the farmers. The tendency to the standardization of the livestock farming (in-door system, standard feeding, high-producing animals selection, low breed variability), doesn't take in account the complexity of farming systems. So, it is urgent to move towards the integration of various components, including adaptation of the farm animals. However, the contribution of the characters of adaptation to the overall productivity of the herd remains poorly documented. The analysis of these characters must be deepened both conceptually (modeling of resource allocation) and by experimental design (thermo-tolerance, feeding system, disease resistance, behavior).

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