

CHALLENGES, OPPORTUNITIES AND DRAWBACKS IN INTENSIFYING GOAT FEEDING SYSTEMS IN THE CONTEXT OF CLIMATE-SMART AGRICULTURE

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Abstract

As a ruminant species, goats are able to valorize fibrous feeds and non-protein nitrogen to produce meat and milk in extensive feeding systems. They are also able to attain high production levels when they have the potential and receive a diet of high nutritive value. There is a trade-off between the cost of the diet and increased production, which needs to be evaluated in the context of climate-smart agriculture. Climate change may modify both the availability and the types of feed for ruminants, the animals' physiology and – thus – their requirements. Increasing levels of production can be achieved by increasing the percentage of concentrate feed in the diet. Intensification of feeding systems might modify feeding behaviour and have impacts on intake and rumen metabolism, increasing negative outputs of nitrogen or methane. All these aspects have to be taken into account when proposing new sustainable goat feeding systems.

Key words: goat; nutrition, intensification, climate-smart agriculture, feeding systems

Introduction

In extensive feeding systems, goats are able to valorize fibrous feeds and non-protein nitrogen in order to produce meat and milk. They also are able to reach high production levels when they have the potential and receive diets of high nutritive value in the non-limiting quantities that correspond to intensive feeding systems. Nowadays, it is also important to take into account the concept of climate-smart agriculture. According to FAO (2010), climate-smart agriculture is agriculture that sustainably increases productivity and resilience (adaptation), reduces or removes greenhouse gases (mitigation), and enhances the achievement of national food security and development goals.

The aim of this paper is to study the challenges, opportunities and drawbacks facing the intensification of goat feeding systems in the context of climate-smart agriculture, focusing on feeds, animals and feeding systems.

Feeds

Like cattle, goats are able to eat and valorize the available biomass from forage resources, crop residues, agro-industrial by-products and non-conventional feed resources. In all areas where goats are present or can be bred, it is important to know the availability, environmental constraints and nutritive value of feed resources so they can be matched to the animals' requirements under very different climates and locations.

Some agro-industrial by-products that are currently used rarely, such as pineapple bran, can also be valorized by ruminants instead of being discarded and becoming pollutants (Heuzé, Tran and Giger-Reverdin, 2013). However, they need to be used near where they are produced, because they are very rich in water and thus cost too much to transport or dry, unless they are sun-dried. They are also difficult to preserve. This example highlights the importance of conceiving integrated systems from the feed resources to the animals, including processing, distribution and consumption methods that do not incur prohibitive intermediary costs. However, in some countries, there is competition with other uses, such as biofuel generation, for some potential feeds, such as cereal by-products (Makkar, 2012).

Studies on the nutritive value of many plants exist, but most of them are dispersed and it is very difficult to synthesize the information – even when it can be collated – because the literature is heterogeneous in terms of both the information provided and the languages used (Morand-Fehr and Lebbie, 2004). In this context, an approach such as the recently established Web site Feedipedia (INRA et al., 2013) is valuable (Devendra and Leng, 2011). This open-source resource provides data sheets of information on the physical description of a wide range of feeds, their availability and environmental impacts, feeding recommendations and updated nutritional values for the main species of farm animals. Its first goal is to improve the identification and characterization of local feed resources to improve the technical and economic performance of farms. A key issue for ensuring the usefulness of this information is the need for accurate estimation of nutritive values, which must be based on standardized methods for all feeds, whatever their origins.

Some chemical methods are standardized well, such as the ash, crude fibre and nitrogen methods. However, the crude fibre method lacks precision in estimating the energy value of feeds and has often been replaced by the Van Soest method for lignin and cell wall estimations (Giger, 1985; Giger-Reverdin, 1995). However, the Van Soest method also has drawbacks because it was conceived for roughage with low starch, protein, lipid and tannin contents and requires amylolytic or other pre-treatments (Giger et al., 1987). There are now many variants of the Van Soest method and it is often difficult to compare results

coming from different laboratories. Plants from hot countries might contain considerable amounts of tannins, which can also be measured by a large variety of methods (Schofield, Mbugua and Pell, 2001). Among the *in vitro* methods that mimic what happens *in vivo*, the HFT method of Menke (Menke et al., 1979) is valuable, but needs standardization and is especially useful for screening or comparing feeds (Long et al., 1999).

It is necessary to measure not only the energy and nitrogen values of feeds, but also other criteria, such as their mineral contents (deficiencies or excesses), palatability, and anti-nutritional factors such as saponins (Wang, Ye and Liu, 2012). Feeds have to be evaluated from a multicriteria point of view, examining a broad enough range of characteristics to allow nutritive values to be weighted according to local conditions, and periodically calibrating this evaluation against animal performances observed on farms. Even with traditional proximate analysis, some plants have a high nutritive value, but their growth and composition depend largely on agricultural constraints such as the climate (temperature and humidity throughout the year) and the soil quality (salty soils face specific constraints). Feed evaluation is further complicated by the interactions between feeds, which can be beneficial. Grass–legume associations are of practical interest from two points of view: legumes retain nitrogen in soils and improve soil fertility, while grasses decrease the overall degradation rate of the feed in the rumen and thus the risk of acidosis.

Global climate change will alter the local profiles of plants, with some plants becoming no longer viable while new opportunities arise for importing plants from other areas with similar agricultural constraints; these constraints must be taken into account before new plants are introduced, and competition with native plants also needs to be studied. It is also necessary to know the soil composition and its potential evolution under climate change. Projects such as the European e-SOTER⁴⁷ project should be developed all over the world. The relevant question is: What are the feeds available for goats in a specific area, and during which period of the year? It is necessary to know the nutritive value of these feeds at different stages of their development and to see whether a sufficient range of plants is available to sustain animal husbandry throughout the year, even in periods when food and water are scarce. If this can be achieved, production can be intensified over the years. As well as these technical points, the costs of the different diets should also be taken into account in the context of climate-smart agriculture.

Animals

Intensifying goat production in a context of climate-smart agriculture means increasing the feed efficiency along with the milk yield. The criterion generally used is the dry matter intake (DMI) per kilogram of raw milk yield (RMY), with DMI decreasing as RMY increases (Sauvant et al., 2012):

$$\text{DMI/RMY} = (0.39 \text{ RMY} + 1.21)/\text{RMY} \quad (n = 147, \text{RSD} = 0.24)$$

Milk yield increases with the percentage of concentrate feed used, and the substitution of forage with concentrate (the decrease in the quantity of forage ingested when concentrate quantity increases) also needs to be taken into account (Sauvant et al., 2012). Digestive efficiency generally decreases when the intake increases, because the higher rate of passage limits degradation in the rumen. Even when general features of ingestion in ruminants are known, the specific features of ingestion in goats bred in different environments (from harsh to intensive ones) also need to be defined. For example, it is known that: some digestive interactions occur in the rumen; readily available starch

47 The e-SOTER project is a regional pilot platform established as the European Union's contribution to a global soil observing system. <http://www.esoter.net>

decreases fibre digestion; and goats are believed to be more efficient than sheep and, particularly, cattle in nitrogen recycling (Devendra, 1978). The digestive interaction and the specificity of goats have to be considered when evaluating feeds and either taken into account at the feed level (i.e. modification of the feed value when associated with other feeds) or the animal level (i.e. modifications of requirements). Based on information from a database of our laboratory, the response of milk yield to concentrate intake (DMIconc) is curvilinear (Sauvant et al., 2012):

$$\text{RMY (kg/d)} = 1.81 + 1.08 \text{ DMIconc (kg/d)} - 0.17 \text{ DMIconc}^2$$

(n = 189, n_{exp} = 75, RSD = 0.25)

Milk composition is also modified: fat content decreases, while lactose content increases. Only protein content is not affected by an increase in energy input linked to an increased percentage of concentrate feed.

Chewing pattern is closely related to rumen pH (Desnoyers et al., 2011). In individual pens, goats fed the same diet can exhibit very different intake patterns, with consequences on rumen pH patterns and susceptibility to subacidosis. At the same level of intake (expressed in terms of body weight), goats presenting a long period of intake had a rapid drop in rumen pH after feeding, below the threshold of 6.0 under which feed degradation in the rumen is impaired (Oetzel, 2000). This was not the case of goats that alternated feeding and ruminating bouts (Desnoyers et al., 2011). These goats also produced about 170 g more milk per kilogram of DMI, and thus likely contributed more to total farm income over feed costs through milk sales (Giger-Reverdin, Sauvant and Duvaux-Ponter, 2013). More research is needed on phenotyping, especially chewing behaviour in relation to nutritional efficiency, and to identify the origins of these differences in feeding patterns.

Methane emission is another important factor to take into account when intensifying production. Methane production is highly dependent on rumen metabolism, and particularly on volatile fatty acid stoichiometry (Sauvant et al., 2011). The emission of this greenhouse gas per kilogram of animal product (meat or milk) will become increasingly important, whatever the feeding system considered. However, the greenhouse gas effect needs to be considered not only at the animal level, but also at a larger scale, including all the factors involved in production, such as pastures or fields that sequester carbon, and carbon emissions from the tractors used in cereal production or from fertilizer manufacture (Boadi et al., 2004; Cottle, Nolan and Wiedemann, 2011).

If the climate changes or water or feed shortages occur, the physiology of the animals will also change and their requirements will be modified (Silanikove, 2000); the importance of these modifications and the ability of the animals to cope with climate change or water restriction depend on the breed (Silanikove, 1985).

Feeding systems

The intensification of feeding systems needs to define inputs and animal requirements more precisely. In France, the Systali project involves about 30 researchers in updating the energy (UF) and protein (PDI) systems for ruminants (Sauvant and Nozière, 2013). Its target is to predict animal responses to very different diets and/or feeding systems. Most of the differences among diets depend on what happens in the digestive tract, especially the rumen. The project is based largely on interpreting large databases obtained from INRA and meta-analyses of the literature (Sauvant et al., 2008; St-Pierre, 2001). The methodology used is to study the meta-designs, especially their representativeness, the orthogonality among variates and experiment encoding. The latest update revisits five main points:

1. The transit outflow rates of feeds and water are a function of DMI expressed on a live-weight basis (DMI/LW) and of percentage of concentrate (PCO).
2. Digestive interactions are due to three factors: DMI/LW, PCO, and rumen protein balance (RPB). They are applied to the digestibility of organic matter (OM) and outflows of urine and methane.
3. Prediction of starch and protein degradation in feed is based on in situ measurements and validated when possible by in vivo duodenal flows.
4. Fermentable organic matter (FOM) in the rumen is defined as being closer to the true OM ruminal digestibility, taking into account digestive interactions.
5. Microbial protein flow at the duodenum is expressed as a function of PCO, RPB and FOM.

The major responses of digestion were integrated in a simple mechanistic model of the gut to check the consistency across all the equations. Outputs of the model were prediction of the flow of nutrients (volatile fatty acids, gas, glucose, fatty acids, essential amino acids) and prediction of the animals' responses to these flows, such as the links between nitrogen intake and nitrogen fluxes in dairy goats (Sauvant et al., 2012). This updating of the feeding system provides an opportunity for improving goat husbandry as it allows better comparisons among feeding systems and selection of the system that is best adapted to the given context.

In contrast to digestive efficiency, overall production efficiency increases with the level of feeding if the increase in intake translates into increased productivity, because there is a dilution of maintenance costs. Thus, efficiency is affected not only by intake but also by nutrient partition, i.e. the proportion of nutrients channelled to production relative to other life functions. Nutrient partitioning has been studied mainly in dairy cows (Friggens et al., 2013) with relatively little information or focus on small ruminants. This is an important limitation on the ability to manage nutrition efficiency in small ruminants. The counterpart of digestive efficiency is the excretion of potentially polluting factors such as nitrous oxide (Reynolds, Crompton and Mills, 2011), or increasing greenhouse gases such as methane (Sauvant et al., 2011). However, faeces and urine can increase soil fertility (Devendra, 2001), and methane can be used as a heat source on some intensive farms. Calculating global benefits is, therefore, far from easy, and will rest on multicriteria evaluation of feeds, considered in terms of local conditions.

Even when useful research has been carried out at experimental stations, it has had no positive impact for small farmers unless it has been disseminated, transferred and adapted to the farm context by extension services (Goetsch and Girma, 2009; Wadha and Bakshi, 2013). Farmers will accept a change in husbandry methods only when it is practicable and economically beneficial. This is a key point – not only for goats – for increasing the efficiency of research to benefit humanity.

Conclusions

Intensifying goat feeding systems in the context of climate-smart agriculture concerns more than the nutrition area. Other factors to be taken into account include feed availability, agricultural constraints, breed availability, farmers' knowledge, and society's demand for animal welfare and climate-smart agriculture.

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