Food Security and Dairy Cow Feeding: the Necessity for a Paradigm Shift

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Summary

We have seen fundamental changes in the feeding of cattle over the last 50 years. Previously, cattle were fed almost exclusively feeds that were unsuitable for human consumption. The availability of cheap fossil energy for the production of mineral fertilizers and pesticides, the cultivation of land and long-distance shipping of crops has made it possible and even profitable to feed even ruminants enormous amounts of grain and pulses. As a result, highly intensive animal production systems have emerged.

Grain and pulses, however, are potentially edible for humans. This means that these supposedly highly efficient animal production systems contribute to the increasing competition for arable land for crops. In dairy farming, to attain lactation of 10,000 kg/year and beyond, the amount of concentrates in the ration has to be maximized. Most of these concentrates are grain and pulse products.

This kind of dairy cow feeding is not only contradictory to the evolutionary adaptation of cattle, which allows these animals to be able to digest fibrous plant substrate, but has also resulted in an increasingly unfavorable food balance (i.e. animal-derived food per unit of feed input potentially edible to humans). The potential of ruminants to efficiently convert forages from grasslands, pastures, and fiber-rich by-products from the processing of plant-derived foods into milk and meat will soon be of great significance, because arable land is becoming scarce and the demand for human food is growing. The use of highly productive arable land to produce animal feed results in a net loss for the potential global food supply.

Key words

dairy cow, grain feeding, food security, competition, edible

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Introduction

The competition for arable land to grow food, feeds, and biomass for fuel production (mostly from grain) has reached an all-time peak. Recent publications suggest that crop production would have to about double to keep up with the estimated demands resulting from population growth, dietary changes (especially meat consumption), and increasing bioenergy use, unless there are dramatic changes in agricultural consumption patterns (Foley et al., 2011).

The production of animal-derived foods cannot be viewed independently from the global food security situation (Flachowsky, 1992). The Global Food and Agriculture Organization of the United Nations (FAO) estimates that global grain production will have to increase by 40% between 2006/2008 and 2050 in order to meet the increasing demand for food and feed (FAO, 2009). The additional demand for grain used to produce fuel is not included in this estimation and is therefore an element of uncertainty. Furthermore, it must be taken into account that the annual growth rate for the world's grain production sunk from 3.2% to 1.5% between 1960 and 2000 (FAO, 2009).

Since the 1960s, we have seen a fundamental change in the way cattle are fed in affluent countries. Up to that time, for economic reasons, cattle were fed almost exclusively forages. Increasing crop yields on arable land, facilitated by the use of mineral fertilizers and the application of pesticides, the reduced cost for long distance shipping of grains and pulses, and international trade opportunities have made it profitable to feed concentrates not only to monogastric animals, but also in increasing amounts to ruminants.

Sustainable animal agriculture

In the long run, humankind can only continue to exist in balance with nature. Nature does not need humans, but humans need a sound environment. For this reason it is our duty to make a long term co-existence possible (Dürr, 1996). This fundamental dependency on cultivated and permanently fertile agricultural land and the resulting responsibility for future generations were pointed out by the so-called Brundtland Report in October of 1987. When applied to our food system, it means we need a form of agriculture that meets the needs of the present without diminishing opportunities for the future (WCED, 1987). Heitschmidt et al. (1996) broadly defined sustainable agriculture as "ecologically sound agriculture" and more narrowly as "eternal agriculture, that is, agriculture that can be practiced continually for eternity". With regard to the form of energy driving agricultural production, Heitschmidt et al. (1996) observed that the grazing of indigenous grasslands is one of the most sustainable forms of agriculture known today, because it needs the least amount of exogenous energy subsidies to function.

Of the globally available land surface, only about 12% is arable land; about twice this is grassland and pastures. Together, these make up all agriculturally used land, the rest is forest and barren land (Blum, 2012).

The importance of ruminants

The domestication of wild animals was a major cultural achievement. Humans provided protection, shelter and care for their captive animals, fed them non-edible feedstuffs, and in doing so, gained a valuable source of animal foods. Domestic ruminants have played a unique role in animal agriculture, since they are able to feed on fibrous plant substrate, which is plentifully available on grasslands and pastures. Their digestive systems can make use of the nutrients and energy bound in fibrous plant materials in amounts that simple-stomached animals like pigs and chickens cannot. Small ruminants are at a disadvantage as compared to large ruminants with regard to the digestion of fibrous plant substrate. Rumination capacity (g neutral detergent fiber/min) increases proportionally with higher body weight, but energy requirements for maintenance are related to body weight to the power of three quarters (Van Soest et al., 1994). For this reason, cattle are superior to sheep and goats in producing animal foods from a given amount of fibrous plant material.

Feeding high-grain diets to ruminants

The provision of energy-dense diets to modern high-yielding dairy cows seems to be an inevitable necessity. As dairy cows' potential for milk synthesis has been continuously increased by efficient breeding measures over the past few decades, feed intake has not risen sufficiently to support the animals' higher nutrient and energy demand. In order to compensate for the growing gap between energy demand and supply, dairy cow ration formulation has moved towards the inclusion of high quality forages on the one hand, and the necessity of feeding concentrate (mostly grain) on the other. This way, an ever-increasing productivity, defined as milk output per unit of feed intake, has been realized.

The reason why more and more concentrate-rich rations are being fed not only to monogastric animals like pigs and chickens but also to ruminants over the course of the last few decades described Van Soest (1994a) as follows: "The feasibility of feeding all-concentrate rations to ruminants was in doubt before 1950, but the fact that the cost per unit of net energy was less for corn grain than for forage pushed ruminant nutrition research to solve the problems of digestive disturbances that frequently resulted from concentrate feeding. … Concentrates are fed to animals only in developed Western societies when the cost of food energy per unit is less for concentrates than for fibrous feed."

German veterinarian and biologist R. R. Hofmann questioned the scientific orientation in plant and animal production (Hofmann, 1983) as far back as 1983. His field observations 30 years ago resulted in a harsh criticism of the emerging and partially already established practice of intensive grain feeding, both to livestock in general and to ruminants in particular. Corn and other cereals are foods that are potentially edible by humans. The energy-intensive conversion of grain and pulses into protein effected by feeding concentrates to cattle and sheep adapted to high-fiber rations is an expensive and anti-biological paradox practiced by affluent countries (Hofmann, 1983). In the long run, this causes environmental damage and hinders the spread of regionally adapted ruminants.

This trend was sustained over the last two decades, but now seems to have reached its economic limits, as the prices for concentrates have increased greatly due to speculative trading with agricultural commodities around the globe and the emerging competition between food, feed, and fuel.

Milk yield and forage concentrate ratio

The dietary energy and protein requirements for the maintenance of a dairy cow are a substantial part of the total requirements, but they remain practically constant independent of milk performance (Bauman, 1995). In order to reduce the dietary cost for each kg of milk produced, it is desirable to increase milk performance in dairy cows through breeding, feeding, management, etc., allowing producers to distribute the nutritional load necessary to fulfill maintenance requirements over a greater amount of milk. A stronger dilution of the maintenance costs by increasing milk performance results in an improved productive efficiency (milk output in relation to nutrient intake).

When the targeted milk performance in dairy cows is very high over a short period of time (i.e. lactation performances of 10,000 kg and above), it is crucial that nutrient density and energy levels be maximized within the first half of the lactation period by including the highest possible amounts of concentrate in the ration. This results in a ration that is, both in composition and structure, completely contradictory to the evolutionary adaptation of cattle to fibrous low quality plant substrate, an evolutionary adaptation that is the product of millions of years of strict selection.

An average of over 40% concentrate in the ration (on a dry matter basis) is required when lactation performance is 9,000 kg and higher (Haiger, 2005). According to Breves (2007), a daily milk yield of 45 to 50 kg is achieved between weeks 7 and 14 of lactation, assuming a cow produces 10,000 kg of milk during a standard lactational period of 305 days. As the maximum daily dry matter intake capacity of such a cow is about 25 kg, it is necessary to push the daily use of concentrates to the limit to keep the negative energy balance as low as possible. However, the emergence of a strongly negative energy balance is unavoidable in these cows, even if the forage quality is optimal and the percentage of forage in the ration (dry matter) is only 40% (Breves, 2007).

Feeding ruminants in a manner that is so contradictory to their evolutionary adaptation with regard to their nutritional ecology also raises animal welfare and animal health questions in the long run. In addition, feeding ruminants large amounts of concentrates, which consist of components that are potentially edible to humans, needs to be critically evaluated from a resource conservation point of view as well.

Adequate protein supplementation

Although protein is a key nutrient for milk production and growth, energy supply is usually the first limiting factor in modern high-yielding dairy cows. The growing gap between possible feed energy intake and energy requirements in dairy cows during the first few weeks of lactation has become of increasing concern in practice and science over the past 4 decades as lactation performances have been continuously increasing. As a result, improving the energy efficiency of higher-yielding cows has been given a much higher priority than the efficiency of using feed protein to make milk protein.

In the light of the complexity of protein nutrition, the practical limitations in measuring feed nitrogen fractions and quantifying microbial protein synthesis as well as rumen-undegraded protein make it difficult to make accurate specifications for the feed protein fractions required by the animals. According to VandeHaar and St.-Pierre (2006), these are the reasons why protein efficiency has not increased as dramatically as energy efficiency. Furthermore, the economic consequences of underfeeding protein are greater than the risk of feeding protein in excess, so protein efficiency is more likely to be an issue when the prices of important protein sources like soybean meal rise considerably.

The immanent competition for human-edible plant substrate, along with the production of agrofuel and animal feed, will make it necessary to consider more seriously the efficient use of protein from grasses and forage legumes (Bocquier and González-García, 2010). Reducing farms'nutrient input by purchasing fertilizers and feeds, thus minimizing the stockpiling of nutrients on dairy farms, will even become more relevant from both an ecological and an environmental protection perspective in the near future.

Returns on edible inputs

In a progressively globalized market, the way we produce our food cannot be viewed independently from shortages and hunger in other countries, because non-renewable resources are being used (i.e. mineral fertilizers, pesticides, etc.) to increase crop production on arable land. It was again Hofmann (1989) who seriously questioned the forced trends in the development of ruminant nutrition and feeding: "There is no doubt, man has domesticated predominantly such ruminant species which can easily, by evolutionary adaptation, utilize fibrous low-quality diets (v. Engelhardt et al., 1985) unfit for human consumption. It appears anti-biological if not immoral that much of to-days ruminant livestock production in affluent countries is based on grain feeding."

As far as we know today, cattle, sheep, and goats were domesticated between 8,500 and 11,000 years ago, primarily to give people access to sustainable sources of animal foods based on energy and nutrients bound up in abundantly available pasture substrate. In the course of this co-evolution, ruminants and humans have never been competitors for food, which made ruminants tremendously important for the development of humans in many parts of the world.

At the University of California, Davis, USA, Oltjen and Beckett (1996), analysed rations fed to dairy cows with a lactation performance level of 8,600 kg to determine the percentage of plant-based foods (mainly grain) they contained that could directly serve as human food (Table 1).

The meat and milk resulting from feeding a ration consisting of half forage and half concentrates (Ration I) contained only 57% of the energy that the edible foodstuffs in the ration contained. The protein content of the resulting animal foods amounts to 96% of the protein in the ration, protein which would also have been digestible for humans. These numbers clearly demonstrate that a high percentage of concentrates made up of mostly grain and soybean meal in livestock rations actually leads to a decrease in food (energy and protein) available for human consumption.

A positive food balance can be achieved if the livestock ration consists of approximately 70% forages and 30% concentrates, and if the concentrates in the ration contain approximately 70%

Table 1. Food balance in dairy cow husbandry[1]

Item	Ration I (% dry matter)	Ration II (% dry matter)
Corn silage	20	35
Alfalfa hay	30	34
Corn grain	37	-
Soybean meal	10	-
Barley	-	9
By-products (milling and cotton industry)	-	22
	Humanly edible returns (milk and meat) % humanly edible ration inputs	
Energy	57	128
Protein	96	276

[1]Adapted from Oltjen and Beckett (1996)

by-products (Ration II). This dairy cow diet results in a 28% increase in energy for human consumption. The output in protein edible for humans is 176% higher as compared to the plant protein in the ration that would be directly consumable for humans.

Conclusions

Through their evolutionary adaptation, dairy cows can play a key role in converting high-cellulosic feeds not directly consumable by humans into highly desirable and nutritious animal foods. The increased availability of cheap grain since the 1960s has led to a fundamental change in ruminant feeding by adding concentrates to rations in proportions comparable to those for non-ruminants. In light of the increasing world population's growing demand for food and the declining availability of resources (arable land, fossil fuel, etc.) necessary for the production of cheap grain and pulses, it is no longer justifiable to feed high levels of feed grains to ruminants.

By using feed sources for ruminants, in particular for dairy cows, that are not directly usable by humans, a favourable food balance (i.e. animal-derived food per unit of feed input potentially edible to humans) can be achieved. A dairy production system based on forages, in which cattle are selected for increased cellulosic product utilization, would be a substantial contribution to the world's potential food supply.

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