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The net contribution of dairy production to human food supply: The case of Austrian dairy farms

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ABSTRACT

Due to their ability to convert human-inedible fibrous plant materials into high quality animal products, ruminants have always played an important role as net food producers. However, to meet the animals' nutritional requirements, today's rations for high yielding dairy cows also contain substantial amounts of potentially human-edible feeds (e.g. cereals and pulses), which increases competition between animal feed and human food availability. The aim of the present study was therefore to calculate the human-edible feed conversion efficiency (heFCE) for 30 Austrian dairy farms operating under different production systems in order to evaluate their contribution to net food production. The heFCE was calculated at farm gate level on a gross energy and crude protein basis, and was defined as potentially human-edible output in the form of animal products (milk and meat) divided by the input of potentially human-edible feedstuffs. The potentially human-edible fraction of all feedstuffs used on the 30 farms was estimated based on available literature using a "low," "medium," and "high" scenario, representing low, average, and above average extraction rates of human-edible nutrients from feedstuffs, respectively. The human-edible fraction ranged from 0% for some fibrous feedstuffs up to 100% for some cereals in the high scenario. For the "medium" scenario, heFCE ranged from 0.50 up to 2.95 for energy and from 0.47 up to 2.15 for protein. About half of the analysed farms showed a heFCE below 1, indicating a net loss in food supply. For both energy and protein, heFCE was negatively correlated with the amount of concentrates per kg milk and the total amount of concentrates per cow and year. In addition, we found a positive correlation between heFCE and the area of grassland utilized per ton of milk, as well as a negative correlation between heFCE and the area of arable land required per ton of milk. Therefore, feeding large amounts of concentrates to dairy cows has to be questioned in terms of the heFCE. The results of this study clearly show that grass-based dairy production highly contributes to net food production, particularly if the amount of concentrates per kg milk is reduced.

1. Introduction

With their ability to convert human-inedible plant material into high quality human food, animals have always played an important role in human nutrition and food security (Bradford, 1999; Leng, 2010). When livestock is produced based on grassland or other human-inedible resources, animal production makes an important contribution to total food supply (FAO, 2011; Foley et al., 2011). However, in intensive livestock systems, animals are often fed substantial quantities of potentially human-edible crops, such as grains and pulses, which is a very inefficient way to provide human food and which represents a net drain in total human food production (Cassidy et al., 2013; CAST – Council for Agricultural Science and Technology, 2013; FAO, 2011). An increasing world population, together with a higher per capita consumption of animal products, will increase the pressure on livestock systems with regard to food efficiency (Cassidy et al., 2013). In order to obtain more sustainable livestock production systems, it is inevitable that less potential human food is fed to animals (Eisler et al., 2014; Herrero and Thornton, 2013). Among various existing concepts to evaluate competition between animal feed and human food, the most promising one is to relate the human-edible output in the form of the animal products to the potentially human-edible input via feedstuffs (FAO, 2011; Oltjen and Beckett, 1996; Wilkinson, 2011). The relation of human-edible output per human-edible input can be described as human-edible feed conversion efficiency (heFCE). As compared to monogastric animals, dairy and grass-based beef and lamb production systems show generally favourable net food production rates (Wilkinson, 2011). From their nutritional ecology, cattle are specialists in digesting fibrous plant materials (e.g. forages) and do not necessarily rely on feeds that could potentially serve as human food

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(Gill, 2013; Hofmann, 1989). However, due to enormous increases in animal performance during the last five decades, the inclusion of grains and pulses in cattle's diet has become necessary to meet the animals' nutrient and energy requirements (Knaus, 2013). As a result, in some cases beef and dairy production systems even show a heFCE below 1, indicating a net food drain (CAST – Council for Agricultural Science and Technology, 1999; Oltjen and Beckett, 1996; Wilkinson, 2011). Although heFCE has already been calculated for dairy cows based on data from model calculations (Oltjen and Beckett, 1996; Wilkinson, 2011), whole country data (CAST – Council for Agricultural Science and Technology, 1999), or short term feeding trials (Ertl et al., 2015), an analysis of field data from a range of practical dairy farms regarding their heFCE is still lacking. The aim of the present study was therefore to calculate the heFCE for Austrian dairy farms in order to evaluate the potential range of the contribution of dairy production to the net food supply. A major problem when calculating the heFCE for a single animal or a whole production system is evaluating the potential human-edible input via feedstuffs (Ertl et al., 2015; Le Cotty and Dorin, 2012; Wilkinson, 2011). Therefore, the second aim of this study was to provide literature-based estimates for the human-edible fractions (heF) of feedstuffs used on the selected farms.

2. Materials and methods

2.1. Data source

On farm data were taken from a national research project on the integrated assessment of the sustainability of selected Austrian milk production systems (Hörtenhuber et al., 2013). On the basis of IACS data (Integrated Administration and Control System of the European Union), 31 Austrian dairy farms were selected for this project. These farms were distributed over the whole country and consisted of 24 conventionally and 7 organically managed operations, which, according to the national statistical database (BMLFUW – Bundestministerium für Land- und Forst-, Umwelt und Wasserwirtschaft, 2014), roughly reflect the actual distribution of conventional and organic dairy farms in Austria. From the overall data set, data related to milk production (e.g. milk yield and composition, amount and composition of concentrates used, livestock sales and purchases), averaged over two years (2010 and 2011) were used for the current study. Due to unusually high animal sales (more than twice as high as the average farm), one of the organic farms had to be excluded from the calculations. According to their milk quota, regional location, and points in the mountain farm register (which identifies and classifies site-related natural and economic challenges affecting individual farms), the remaining 30 farms were assigned to one of the following six production systems: alpine (AL), alpine intensive (AI), hilly-pasture (HP), hilly-arable (HA), lowlands-mixed (LM), and lowlands-specialized (LS). Table 1 presents average production data for each production system.

2.2. Calculation of the human-edible feed conversion efficiency

The heFCE was defined as human-edible output in the form of animal products divided by potential human-edible input via feedstuffs as MJ gross energy (GE) and kg crude protein (CP), at farm gate per year. To calculate the human-edible input via feeding, the potential heF for the GE and CP content of feedstuffs were estimated, based on available literature on food processing or food usage of these commodities (sources given in Table 2 below). The estimated heF were then multiplied with the amount of GE and CP per kg of the respective feedstuff and with the total quantity of each feedstuff fed (kg dry matter). Since calculations were performed at farm gate level, feedstuffs used for dry cows and young stock were also included in the calculations. The human-edible output comprised the amount of GE and CP represented by the milk sold and the net quantity of beef leaving the farm in the respective year. Milk sold was standardized for 4% fat and 3.4% protein (energy corrected milk, ECM). Therefore, 34 g CP and 3.17 MJ per kg milk were presumed (Buttchereit et al., 2010). The net quantity of beef leaving the farm was calculated as the total live weight of cattle leaving the farm minus the total live weight of cattle entering the farm within this year. The human-edible proportion of the live weight of fattening cattle is about 43% (de Vries and de Boer, 2010). However, the human-edible proportion of cattle's live weight is different between beef and dairy cattle. In Austria, average carcass yield is 49 and 53% for cows and heifers, respectively (Statistics Austria, 2014). About 74% of the carcass can be considered as saleable meat (Minchin et al., 2009; Vestergaard et al., 2007). Presuming an average carcass yield of 51% for dairy cows and heifers, the human-edible proportion of the animal's live weight was set at 38%. This human-edible meat was assumed to have an average protein content of 19% (de Vries and de Boer, 2010) and an energy content of 6.48 MJ/kg (Bauer et al., 2007).

2.3. Estimation of human-edible fractions

For grasses, dried beet pulp, dried distiller's grains with solubles, lucerne cobs, brewers' grains, and maize gluten feed no noteworthy potential food uses were found and their heF were therefore estimated to be zero. The basis for estimating the heF for each of the remaining feedstuffs are shown in Table 2. The heF of feedstuffs cannot be seen as one fixed and generally applicable value because they depend on the technology available and other circumstances, such as the degree of food availability. Therefore, heF

Table 1
Main characteristics (average ± standard deviation) of dairy production systems.

Item	Production system[a]					
	AL	AI	HP	HA	LM	LS
Farms (conventional/organic, n)	3/1	2/3	4/1	4/1	5/0	6/0
Herd size (lactating cows, n)	9 ± 4	27 ± 8	20 ± 5	32 ± 5	27 ± 10	50 ± 18
ECM[b] produced (kg/cow/year)	6818 ± 848	8248 ± 824	6355 ± 446	7533 ± 793	8058 ± 625	8403 ± 1178
ECM sold (kg/cow/year)	5880 ± 754	7648 ± 962	5614 ± 498	6837 ± 737	7129 ± 448	7746 ± 1160
Concentrates (g DM/kg $ECM_{produced}$)	337 ± 72	227 ± 33	229 ± 82	292 ± 72	294 ± 51	338 ± 46
Maize silage (g DM/kg $ECM_{produced}$)	18[c]	51[c]	0	162 ± 99	204 ± 93	187 ± 49
Required arable land (ha/t $ECM_{produced}$)	0.063 ± 0.007	0.047 ± 0.006	0.058 ± 0.010	0.077 ± 0.021	0.085 ± 0.013	0.083 ± 0.019
Required grassland (ha/t $ECM_{produced}$)	0.225 ± 0.006	0.112 ± 0.051	0.216 ± 0.065	0.056 ± 0.020	0.041 ± 0.014	0.056 ± 0.020
Required total land (ha/t $ECM_{produced}$)	0.288 ± 0.010	0.159 ± 0.056	0.274 ± 0.056	0.133 ± 0.016	0.126 ± 0.013	0.139 ± 0.014

[a] Based on milk quota and points in the mountain farm register; AL – alpine, AI – alpine-intensive, HP – hilly-pasture, HA – hilly-arable, LM – lowlands-mixed, LS – lowlands-specialized.
[b] Energy corrected milk.
[c] In this group maize silage was fed on one farm only, therefore no standard deviation is given.