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Allocation between milk and meat in dairy LCA: critical discussion of the International Dairy Federation's standard methodology

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Abstract

Purpose Dairy products are of high importance for the food sector and LCA of cow milk is among the most common product LCAs. Different approaches have been used to deal with multifunctionality in dairy systems, like economic allocation, bio-physical allocation or system expansion, which makes the results hard to compare. This contribution critically evaluates the default allocation method between milk and meat proposed by the International Dairy Federation.

Methods The International Dairy Federation (IDF) proposed to use a physical allocation method to allocate environmental impacts between milk and meat in the dairy production. A linear approximation is used based on the ratio between the live weight of sold animals and the fat and protein corrected milk (FPCM). Only animals destined to the beef market are included, while heifers sold to another dairy are excluded. This linear relationship is a simplified approximation derived from a more complex model.

Results and discussion Two aspects can lead to biased or incomplete results depending on the system investigated: 1) the linear approximation and 2) the exclusion of heifers sold to another dairy. Since allocation is non-linear by definition, a linear relationship can approximate an allocation factor only in a very limited range. If the beef to milk ratio (BMR) is <3%, the linear approximation provides reasonable estimates. However, in more extensive dairy systems and by using multi-purpose cattle breeds, BMR values can be much higher. In addition all animals leaving the product system have to be considered.

We propose to calculate allocation factors based on the marginal net energy investments for 1 kg FCPM and 1 kg of average life weight gain, yielding values of 3.1 MJ/kg FPCM and 15-18 MJ/kg live weight.

Conclusions The allocation method between milk and meat in the dairy production proposed by IDF can be recommended, if BMR<3% and the whole dairy sector is investigated. For BMR>3%, alternative methods should be used to avoid underestimation of the environmental impacts of milk. If dairy production of a farm is analysed, also the heifers sold to other farms should be included in the outputs.

Keywords: *Allocation, dairy production, milk, meat*

Introduction

Dairy products are of high importance for the food sector and LCA of cow milk is among the most common product LCAs. Multifunctionality is an important issue in this context, since milk is inherently linked to co-products such as beef, leather, horn, or manure. Different approaches have been used to deal with multifunctionality in dairy systems, like economic allocation, bio-physical allocation or system expansion, which makes the results hard to compare. In order to standardize allocation in dairy LCA, the International Dairy Federation (IDF) has proposed a standard allocation method (IDF, 2015), which is now widely used in the LCA community. In this contribution, this method is critically evaluated, since in some cases the results can be strongly biased or incomplete.

IDF's recommended allocation

IDF (2015) has proposed to use a physical allocation method to allocate environmental impacts between milk and meat in the dairy production:

$$AF_{milk} = 1 - 6.04\ BMR \quad (1)$$

where

AF_{milk} = allocation factor for milk [%]

$BMR = M_{meat}/M_{milk}$ is the ratio between the live weight of sold animals (M_{meat}, including bull calves and culled mature animals) and the fat and protein corrected milk (FPCM) (M_{milk}). M_{meat} includes only animals destined to the beef market and excludes heifers sold for another dairy.

This linear relationship was derived from the study of Thoma *et al*. (2013) on 531 US dairy farms as a proxy for a more complex relationship. It is also used in the product category rules of the EU for dairy products (EU, 2018), so it is a common methodology used in numerous LCA studies.

Discussion of the recommendation

According to ISO 14040/44 a physical allocation method is preferable to the economic allocation, which is also widely used. The main advantage of using a physical allocation method are its constancy in time and in different contexts because prices are volatile and differ between countries, regions and contexts. Therefore, we support the choice of this physical allocation approach.

However, we see two problems with using Eq. (1) for allocation between milk and meat: 1) The linear approximation, and 2) the exclusion of heifers sold to another dairy.

Linear approximation: By principle, a linear relationship can approximate an allocation factor only in a very limited range of values. An allocation factor is calculated from a ratio, and therefore the function is not linear but hyperbolic. Using Eq. (1) with a BMR of 0.165 gives an allocation to milk of 0, higher values result even in negative allocation factors, which obviously makes no sense.

Excluding heifers: Heifers sold to another dairy should be excluded, according to IDF (2015). This was a reasonable choice in the original study, covering the whole US dairy sector (Thoma *et al*., 2013). However, if the system boundary is a single farm, these heifers should be considered, as they are an output of the system investigated. We argue that these animals should be considered in the same way as animal destined to the beef market, possibly with different factors for NE_{heifer}. Ignoring these animals is not consistent with the ISO standards, as these animals are outputs with a value. In general, all animals leaving the system that are further used as dairy cows, for fattening or directly slaughtered, should be included as outputs. If heifers are purchased from another dairy to replace dairy cows, they are counted as inputs and their respective environmental impacts need to be considered.

The situation is different for animals that die or have to be killed but cannot be used neither for dairy production nor for beef production. In this case, these animals must be considered as losses with no positive economic value. Furthermore, replacement calves used on the same farm stay within the system and therefore are not considered as outputs.

Alternative allocation method

Here we propose an alternative allocation method, based on physical principles, but remedying the weaknesses of Eq. (1). It is based on the net energy needed to produce milk and to build up the body mass. In Thoma *et al*. (2013) the dry matter intake of farm-specific rations needed to provide the net energy for milk or growth was used as the basis for allocation; however, net energy requirement alone can effectively, and more simply reflect the biophysical relationships and are also the basis for the calculation of enteric methane emissions. Allocation based on net energy is calculated as:

$$AF_{milk} = \frac{NE_{milk} * M_{milk}}{NE_{milk} * M_{milk} + NE_{meat} * M_{meat}} \quad (2)$$

where

NE_{milk} = net energy needed to produce 1 kg of FPCM and
NE_{meat} = net energy needed to produce 1 kg body weight (live weight) and
M_{milk} and M_{meat} = the production of milk and meat (inclusive of animals sold as replacement to other dairies) at the enterprise (kg).

We use the equations 10.3 (for pregnancy), 10.6 (for growth) and 10.8 (for lactation) from IPCC (2019) and the following rules:

- Only the net energy to produce milk and body mass (net energy for growth) is considered. Net energy for maintenance and for activity is ignored, which implicitly means that it is allocated according to the same ratio as the milk and meat production.
- Net energy for pregnancy is needed for the growth of the calf. This energy is accounted for as building of the body mass before birth.
- Different coefficients are applied for the growth of dairy heifers and of female and male fattening animals.

Net energy for milk production depends on the fat content, with a standard fat content of 4% we get NE_{milk} = 3.1 MJ/kg FPCM. Net energy for growth depends a.o. on the age and gender of the animal, the body weight, and daily weight gain. To calculate it, scenarios for the dairy herd are defined with following assumptions: 3 lactations per cow, duration of pregnancy of 285 days, weight of calf at birth 40kg, mature dairy cow 650 kg, sales weight for fattening cattle at slaughtering 600 kg. The four calves born (assuming 50% females and 50% males) would have the following destination: one calf is used to replace the dairy cow, 5% is considered as loss, the rest can be either sold after birth, or fattened on the farm. For the animals sold we define three scenarios (Table 1). Taking the average of all three scenarios results in 16.0 MJ/kg BW. This value could be used as default, if the exact composition of the herd is not known. NE_{milk} and NE_{meat} are independent of the level of milk yield.

Table1: Use of calves and NE for growth in 3 scenarios. BW = body weight (live weight)

Scenario	Unit	A) Calves sold after birth	B) Calves fattened	C) Female calves sold as heifers, male calves fattened
Replacement	#	1	1	1
Loss (5%)	#	0.15	0.15	0.15
Sold after birth	#	1.85	0	0
Female heifers	#	0	0	0.425
Females fattened	#	0	0.425	0
Males fattened	#	0	1.425	1.425
Total	#	3	3	3
Total output	kg BW	724	1760	1675
NE_{meat}	MJ/kg BW	18.1	14.9	15.0
NE_{meat} (average)	MJ/kg BW		16.0	

Comparing to the original source of Thoma *et al*. (2013) reveals that most values were in the range BMR<3% and all values were <7%. Up to BMR of 3% the approximation gives reasonable estimates. We used this formula in a Swiss case study, where the BMR were between 4 and 12% (Zumwald et al., 2018). This study investigated dairy farms, but the whole bovine sector was included (cows, calves, heifers and beef cattle). It became clear that the Eq. (1) is not applicable and would lead to a significant underestimation of the environmental impacts of milk (Figure 1).

If we use the above scenarios and three levels of milk yield (3000, 7000, 10000 kg/cow/year, roughly representing the global average, EU average, and US average), we find that BMR values >3% are likely to occur (Table 2), depending on the production system and the exact boundaries defined (farm, sector, dairy cattle or all bovines). This is particularly the case, if the calves are grown up at the farm.

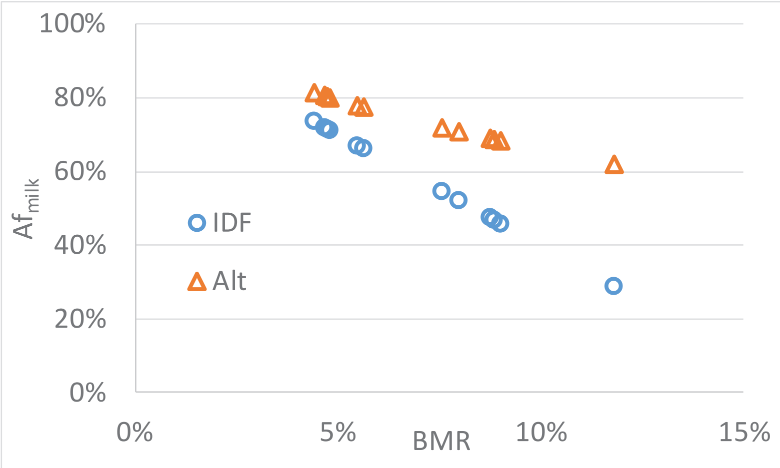

Figure 2: Comparison of the allocation factors for milk (AF_{milk}) with the formula from IDF (2015) and the alternative formula (Alt) for 12 Swiss dairy farms.

Table 2: BMR values for three scenarios (see Table 1) and three levels of milk yield.

	Milk yield [kg FPCM/cow/year]		
Scenario	3000	7000	10000
A) Calves are sold after birth	8.0%	3.4%	2.4%
B) Calves fattened	19.6%	8.4%	5.9%
C) Female calves sold as heifers, male calves fattened	18.6%	8.0%	5.6%

Using the described procedure, the allocation factors can be easily adjusted to the actual situation. The method considers only net energy, so it is well suited for energy-limited conditions. Including protein needs in addition to net energy could be a next development step to make the allocation more robust also in protein-limited conditions.

Conclusions

The allocation method between milk and meat in the dairy production proposed by IDF (2015) should be used with caution or in a adapted version: It is recommended to use Eq. (2) instead of Eq. (1), i.e. to calculate a ratio of the net energy needed to produce the milk and to build up the body mass instead of the linear approximation, as soon as BMR>3%. For the net energy needed, the following default values can be used: NE_{milk} = 3.1 MJ/kg FPCM and NE_{meat} = 16.0 MJ/kg BW. It is recommended to include also heifers leaving the system boundary in M_{meat}, rather than ignoring them.

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