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Assessing the sustainability of a combined extensive/intensive beef production system: the case of French suckler cow-calf farms integrated with Italian beef fattening herds

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Abstract. This study aimed to analyse the sustainability of the beef system based on the integration between pasture-based suckler cow-calf farms in France (Massif Central) and cereal-based fattening farms of northern Italy. Two indicators were considered: carbon footprint (kg CO_2-eq/kg body weight, BW, sold), and the human-edible feed conversion ratio computed as the ratio between the energy content in human-edible feedstuffs and the energy content of human-edible animal products (HeFCR). The reference unit was the batch (i.e. a group of stock calves homogenous for origin, finishing period and fattening farm). We considered 73 Charolais young bulls batches (4882 heads), born in France (Massif Central), sold to northern Italy beef herds at 405 ± 13 kg BW after a 1.16 ± 0.13 kg/d weight gain and slaughtered at 729 ± 23 kg BW, after a 1.52 ± 0.09 kg/d weight gain during fattening. Mean carbon footprint of overall beef production system averaged 13.0 ± 0.6 CO_2-eq/ kg BW, and the French suckler cow-calf phase accounted for 65% of global emissions. Conversely, the French suckler cow-calf phase was more efficient than the Italian beef finishing phase in terms of food supply for the human consumption, as the HeFCR averaged 2.9 ± 0.4 and 4.6 ± 0.8 MJ/MJ in the French and Italian phases, respectively. Therefore, our results suggest that the evaluation of global sustainability of mountain livestock systems would require the use of different indicators and approaches.

Keywords. Beef – Sustainability indicators – Mountain pastures – Intensive fattening.

Evaluer la durabilité des systèmes naisseurs engraisseurs en bovin viande. Analyse de la filière broutard française et de l'engraissement en Italie

Résumé. *Une évaluation de la durabilité du système bovin viande Charolais combinant la phase de naissage sur prairies françaises du Massif Central et la phase d'engraissement sur maïs ensilage de la plaine d'Italie du nord, a été réalisée en considérant 73 lots de jeunes mâles engraissés en 2014. Ces lots observés étaient homogènes pour la race, le sexe, le type de finition et les lieux d'engraissement. Deux indicateurs ont été calculés sur l'ensemble des deux phases naissage et engraissement: (i) l'empreinte carbone brute (CO_2/ kg PVif vendu) calculée par méthode ACV, et (ii) l'efficience de production de la viande, produit consommable par l'homme (ratio = énergie consommable par l'homme dans les aliments utilisés / énergie de la viande produite = HeFCR). Les observations regroupent 4882 têtes arrivées en Italie au poids vif moyen de 405 ± 13 kg (GMQ naissance-vente 1,16 ± 0,13 kg/j). Ils ont été abattus au poids de 729 ± 23 kg BW soit un GMQ d'engraissement de 1,52 ± 0,09 kg/j. L'empreinte carbone moyenne du système est de 13,0 ± 0,6 CO_2-eq/ kg PV. La phase de naissage correspond à 65% des émissions globales. Mais par l'importance de l'herbe ingérée, cette phase a l'indice HeFCR moyen le plus bas 2,9 ± 0,4 contre 4,6 ± 0,8 MJ/MJ pour la suivante. Ces résultats suggèrent l'importance d'évaluer la durabilité de ces systèmes en combinant toujours plusieurs approches.*

Mots-clés. *Bovins viande – Indicateurs de durabilité – Paturages de montagne – Engraissement intensif.*

I – Introduction

The beef production system causes a relevant environmental impact, in particular because of greenhouse gases (GHG) emission (Gerber *et al*., 2013). On the other hand, it contributes to food security converting not-edible feedstuffs into edible products with a favourable contribution to output/input ratio of human-edible feedstuffs (Wilkinson, 2011). The integrated France-Italy beef production system represents a particular situation, characterized by a geographical separation of the suckler cow-calf herds, located mainly in a mountain area of Central France (Massif Central) and based on extensive pasture (Brouard *et al*., 2014), and the fattening farms in North-East Italy, which rear the imported stock calves using total mixed rations based on maize silage and concentrates (Gallo *et al*., 2014). This study aimed to analyse the sustainability of the integrated France-Italy beef production system through carbon footprint indicator (kg CO_2-eq/kg body weight, BW, sold, computed according to Life Cycle Assessment method) and the human-edible feed conversion ratio computed as the ratio between the metabolisable energy (ME) content in human-edible feedstuffs and the energy content of human-edible animal products (HeFCR).

II – Materials and methods

This study involved 73 Charolais breed fattening batches (i.e. animals homogenous for origin, finishing herd and Italian fattening period) with a total of 4882 heads reared during 2014. The cradle-to-farm gate system boundaries included three steps: the suckler cow-calf herd, the transport of stock calves to Italy and the Italian fattening period until slaughter. The suckler cow-calf period combined the inputs and emissions due to the reproduction step (suckler cows during one lactating and one not-lactating period, reproduction heifers during the same period, pre-weaned calves from birth to weaning) and due to the pre-fattening of male calves destined to Italy (from weaning to the sale to Italy). A mass method was used to allocate the emissions due to the reproduction step to the pre-fattening male calves destined to Italy. The reference unit was the batch and the functional unit 1 kg BW sold at the end of the fattening period.

Data about the French suckler cow-calf phase were derived from INRA Charolais Network (Lienard *et al*., 1998), which provides long term information about herd management, agricultural surfaces and their management (type and amount of fertilizers), use of off-farm inputs (concentrates, fuel, plastic). In order to connect the fattening batches with the suckler cow-calf herds, a cluster analysis of the fattening batches was performed. The variables were the birth date, age and BW at sale to Italy. Three clusters were obtained. Mean ± SD range, calculated for the BW and age of pre-fattened young bulls per cluster, was used to identify those France farms which sold animals with the most similar characteristics to those found for each Italian cluster. A mean suckler cow-calf farm was obtained by using the mean information derived from the farms selected for each cluster.

Diet composition and dry matter intake (DMI) per animal category (suckler cows, reproduction heifers, breeding bulls and calves) were computed using rations derived from Brouard *et al*. (2014); a resolution model (Office Excel software) was used to constrain the DMI per head within the range of 1.8 and 2.0% BW. Data for the Italian fattening period were collected from 14 North-East Italy fattening farms. For each batch, data about number of animals, date of arrival and sale to slaughterhouse, BW at the sale to Italy (BWS), at arrival to Italy (BWI) and at the end of the fattening period (BWF) were collected. Feed intake per head and per day, diet composition and diet samples at the manger for the chemical composition were monthly collected for each batch. Dry matter intake (kg DM/head/day) was calculated as the mean of monthly feed intake, weighted by the time period between two following diet samples. Average daily gain (ADG, kg BW/d) was calculated as the difference between BWF and BWI, divided for the total animal presence (heads x days). Nitrogen and phosphorus input-output flows were calculated using the Environmental Resource Management (ERM, 2002) procedure. Agricultural inputs for on-farm feedstuffs and materials (plastic, fuel, lubricant, bedding materials) for herd management were derived from official and farmers' documents.

Transport of stock calves to Italy was based on a mean distance from Clermont-Ferrand (Central France) to Padua (North-East Italy) and 32-ton trucks, while soybean was supposed to arrive from Brazil and fattening off-farm maize and sugar beet by-products from Ukraine.

Greenhouse gases emissions were estimated using the equations proposed by Sauvant *et al*. (2011) for enteric methane (CH_4) and by IPCC (2006) for CH_4 and nitrous oxide (N_2O) due to manure management (Tier 2) and for N_2O due to the spread of fertilizers and manure (Tier 1, IPCC 2006). The emission factors for the off-farm feeds, the production of agricultural, industrial and bedding materials and for the stock calves transport were derived from Ecoinvent (Ecoinvent, 2014) and Agri footprint (Blonk, 2014) databases. The procedure proposed by Wilkinson (2011) was used to compute HeFCR, on the basis of the mean energy value of 1 kg BW derived from Pelletier *et al*. (2010) and of ME content of diets, calculated using procedure suggested by INRA (2007). The edible fraction of different feedstuffs was derived from Wilkinson (2011).

III – Results and discussion

The batch size was 67 ± 33 heads on average, showing a large variability in the availability of stock calves during the year. Mean BWS was 405 ± 13 kg, with a range from 350 to 426 kg. The mean BW loss due to transport from France to Italy amounted to 4.8 ± 0.4% on average. The BW at the end of the fattening period was 729 ± 23 kg on average, with an ADG of 1.52 ± 0.09 kg BW/d during the 226 ± 11 days of fattening, and an overall ADG of 1.27 ± 0.09 during the 542 ± 36 days of the whole production cycle. DMI was 6.8 ± 0.4 kg DM/head/day for the overall cycle, and 10.6 ± 0.5 kg DM/head/day during the fattening period on average. Table 1 shows the results of the carbon footprint and HeFCR. For the overall beef production cycle, mean GHG emission was 13.0 ± 0.6 kg CO_2-eq/kg BW sold on average, with a mean share due to suckler cow-calf phase of 65 ± 3%. Mean HeFCR was 3.8 ± 0.5 MJ diet edible/ MJ edible in animal products, showing a larger variability than the carbon footprint. The carbon footprint of the overall French-Italy beef production system was comparable to those of other studies, even if the methods for enteric CH_4 computation differed (Beauchemin *et al*., 2010, Nguyen *et al*., 2012).The HeFCR for the entire production chain was comparable to values for beef systems found in Wilkinson (2011).

Table 1. Carbon footprint (CF) and efficiency to produce human edible products (HeFCR, MJ diet edible/ MJ edible in animal products) for the integrated France-Italy beef sector (cradle-to-end of the fattening period gate) at Italian fattening batch level (N = 73)

Variable	Unit	Mean	SD	Min	Max
CF, suckler cow-calf phase	kg CO_2-eq/ kg BW sold	15.1	0.7	14.3	15.9
CF, fattening phase	kg CO_2-eq/ kg BW gained	9.6	1.0	7.7	12.1
CF, France-Italy beef sector	kg CO_2-eq/ kg BW sold	13.0	0.6	11.8	14.4
HeFCR, suckler cow-calf phase	MJ/MJ	2.9	0.4	2.6	3.7
HeFCR, fattening phase	MJ/MJ	4.6	0.8	3.0	6.9
HeFCR, France-Italy beef sector	MJ/MJ	3.8	0.5	2.9	5.3

Carbon footprint and HeFCR were negatively correlated ($r = -0.41$, $P<0.001$), with suckler cow-calf showing a greater carbon footprint and a lower HeFCR than the fattening phase. This implies a trade-off situation, for which the reduction of HeFCR, to optimize the conversion ratio of human-edible feedstuffs, could lead to an increase of GHG emission intensity. We have also to consider that the pasture-based livestock systems offer several positive externalities in terms of ecosystem services (Rodríguez-Ortega *et al*., 2014) and carbon storage, with related influence on the net GHG emission. Consequently, the exclusive use of indicators of environmental impact, such as the carbon footprint, to assess the sustainability of beef systems could be distortive, especially for grassland-based farms in mountainous areas.

V – Conclusions

The integration between pasture-based suckler cow-calf farms in France (Massif Central) and cereal-based fattening farms of northern Italy allows optimizing the use of the resources offered by different agro-ecosystems for beef production. The pasture based livestock systems in mountainous areas showed a convenient human-edible feed conversion ratio but high GHG emissions per unit of product, while the opposite was found for the intensive, cereal based fattening systems. The trade-off observed between carbon footprint and human-edible feed conversion ratio highlighted how the use of different indicators permits to address a more holistic evaluation of livestock systems sustainability. The approach used in this study can be extended to other indicators and other production systems (i.e. dairy sector) for the evaluation of sustainability of mountainous livestock systems.

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