IS016

How to solve the (un)sustainability dilemma

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Sustainability is a systems property and the use of systems indicators is a starting point to try to overcome the sustainability dilemma. Sustainability is an ideal state, and therefore it is difficult to measure per se. What can be measured is the distance from the ideal point of sustainability, i.e. UNsustainability. A key to the quantification is offered by H. Daly's principles of sustainability: 1) resources should be used at a rate that allows their re-formation (sustainable yield); 2) wastes should be produced at a rate which allows the environment to absorb them. It is possible to quantify what is used and/or what is released too fast and too much into the environment. These principles also show that unsustainability is related to the total amount of available resources and of waste produced (and to the speed of their formation/production). But up to now efforts to find indicators able to describe the sustainability level of a system have partly failed. This is probably due to the complex nature of the problem: if we try to divide it but still cover all its aspects we will have an exorbitant number of indicators (e.g. one for the concentration of any possible pollutant).

Unsustainability is an extensive problem because it is linked to the total and limited availability of resources and to the possibility of a limited system (e.g., the Earth) to absorb waste and pollutants. The improvement of intensive parameters (e.g., energy efficiency, CO_2/person or CO_2/$) is not enough to reduce the distance from the desired state of sustainability. Therefore, it is not possible to assess sustainability/unsustainability by means of intensive parameters, because the problem is strongly correlated with the size of the system.

In recent years, indicators and methodologies have been proposed to represent sustainability. However, it is important to point out that these methods do not lead to the same information because they have different goals and horizons of application. For this, integrating information generated by each indicator becomes essential to have an all-comprehensive global picture of the system under study.

If we want to analyse animal production from a sustainability viewpoint, we have to consider also the complexity given by the fact that very often these productions do not have only one output, but multiple ones. Life Cycle Assessment (LCA), for example, if carried out on outputs such as bovine meat and milk, or chicken meat and eggs, sheep meat, wool and milk, can give quite arbitrary results due to the use of different allocation criteria. Emergy tries to solve this problem by introducing the "co-products" category to which the total emergy needed for the process is completely assigned. But also this can provide equivocal results if blindly applied. Ecological footprint chooses to identify only one output from each of the land types in which it can be divided. We will give criteria for a sound use of sustainability indicators for animal production systems.

IS017

Environmental impact of animal production

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Nowadays, the development of a sustainable farming system (in terms of environmental and economic sustainability) is a priority to preserve the natural resources and the environment and to guarantee the production of animal food. Moreover, the estimated increase in world population and the increasing demand for food of animal origin require a long-term global strategy to develop more intensive and sustainable animal production systems. The mission of agriculture and animal husbandry is to supply food nutritionally adequate, safe and healthy, maintaining the natural resources needed to produce it. The environmental sustainability of food production (of plant or animal origin) depends also on the types of human diet: increasing incomes and urbanization are heavily changing human diets, with a shift from the traditional diets to diets richer in refined sugars and fats, oils and meat. By 2050 these trends, if not checked, will increase the greenhouse gases (GHG) emission from food production by 80% (Tilman and Clark 2014).

The global livestock sector is characterized by a dichotomy between developing and developed countries. Total meat production in the developing world tripled between 1980 and 2002. In developed countries, on the other hand, consumption of livestock products is growing slowly although at high levels. In this regard, an excessive consumption of red meat and processed meat (>50 g/d) has been associated to some health issues (World Cancer Research 2007). However, the higher rate of chronic diseases associated with Western diets is also due to an excessive consumption of refined cereals, fried foods, soft drinks, sweets and energy-dense, nutrient-poor food products; overall, an ideal diet should include plenty of fruit, vegetables, nuts, legumes, unrefined cereals, and moderate amounts of meat, fish and dairy products (World Health Organization 2003).

Among the different livestock species, ruminants have a major environmental impact, mainly for the methane emission and the low feed efficiency, although they may utilize fibrous feeds, differently from monogastrics and humans. Particularly, beef production has the highest impact with a wide variability depending on the breed and the farming system (e.g.: intensive *vs* extensive; conventional *vs* organic; suckler *vs* dairy calf; high or low forage/concentrate ratio in the diet). A review on the environmental impact of beef production systems (de Vries at al. 2015) showed, per functional unit, a lower global warming potential (GWP), energy use and land use for dairy-based compared with suckler-based systems and for concentrated diets compared with roughage based diets. In suckler based system, maintaining the mother cow is the major contributor to all impacts; in the intensive systems (high concentrate diets) the lower impact is attributable to the faster growth rate and the more favourable feed conversion ratio; no large differences in GWP were found between organic and conventional systems. On the other hand, in central Italy, Buratti et al. (2017) found a higher carbon footprint with organic than with conventional systems (24.6 *vs* 18.2 kg CO_2eq/kg LW, respectively) in agreement with Meier et al. (2015) who showed that organic systems not always allow lower impacts than conventional systems. The adoption of organic systems reduces the environmental impact per unit of area, but not necessarily per unit of product (Tuomisto et al. 2012).

Considering pork, the impact on the environment is lower than beef. The Italian pig sector is mainly focused on the production of heavy pigs, with higher environmental impacts than light pigs. Bava et al. (2017) reported a wide variability in the environmental impact categories considered in 5 commercial farms of Northern Italy; for instance, GWP ranged from 2.7 to 5.8 kg CO_2eq/kg LW of heavy pigs, as compared to an average of 3.1 kg CO_2eq/kg LW of light pigs calculated from 12 studies reported by the authors. In the heavy pig production, feeds, especially protein sources, have the highest impact and some feeding strategies, such as lowering the dietary crude protein according to the physiological phase and supplementing diets with amino acid, should be implemented (Galassi et al. 2010; Schiavon et al. 2015).

Concerning milk production, it has to be underlined that most of the Italian dairy farms of the lowland areas are characterized by high stocking rates and intensive forage systems; hence, high inputs are required, for example N fertilizers which increase GHG and lower biodiversity. A higher use, consistent with the stocking rate, of legume and grass forages and of permanent pastures in place of maize silage, can reduce the purchase of N fertilizers and protein supplements on one side, and increase the C sink in the soil on the other side. Properly managed grass systems preserve soil C; particularly, replanting grasses in lands previously sown with annual crops can result in a significant increase in soil C, and in some cases the soil C gain more than offset all the GHG emissions from the farming system (Guyader et al. 2016). In this regard, as reported by Battini et al. (2016) a higher use of maize silage does not necessarily reduce the GWP per kg milk, due to the higher soybean meal import and the consequent carbon footprint associated to the land use change. In their study the lowest GWP (1.6 kg CO_2eq/kg milk) was registered for a farm of the intensive production Parmesan cheese area characterized by a crop rotation based on lucerne and grass hays; by contrast, the highest GWP (2.0 kg CO_2eq/kg milk) was estimated for a less intensive Parmesan cheese farm located in the hill/mountain area. Bava et al. (2014) found an average value of GWP equal to 1.3 ± 0.2 kg CO_2eq/kg milk, and a negative correlation with milk yield, dairy efficiency (kg milk/kg DMI) and stocking density.

The application of extensive farming systems, the reduction of external nutrient inputs, and the efficient use of nutrients at farm or regional levels have been described as advisable strategies for environmentally sustainable farming activity. However, extensive farming and strategies to decrease nutrient inputs are difficult to develop in several areas of the country (for example in the Po plain) and it must be underlined that intensive systems are generally less environmentally impacting than extensive ones when considered per kg product (meat, milk, eggs) or protein. Moreover, improvements in management techniques related to animal fertility (i.e. lower culling, lower replacement rates) can also reduce GHG/kg product (Crosson et al. 2011).

In conclusion, differences among cattle and pigs in terms of environmental impact are basically related to three factors: enteric methane emission, feed efficiency, and reproduction performance. Within each of these categories, significant improvements can be achieved applying specific strategies (e.g. starch/NDF ratio, lipid supplementation; Pirondini et al. 2015). However, it must be underlined that although technical measures can significantly reduce the environmental impacts attributable to agricultural and animal farming practices, other issues related to citizen education in the developed countries should be pursued. Among these, the importance of healthy balanced diets, lower food and energy intake, and less food waste should be emphasized to attain a more significant reduction of the environmental impacts.

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IS018

Foodborne pathogen: the case of *Campylobacter* in poultry

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Campylobacter is the leading cause of foodborne illness in humans worldwide, with the majority of cases attributed to the consumption of poultry. There are other sources of *Campylobacter* including environmental, cattle, pigs, wild animals and companion animals in particular puppies and kittens. However, there can be no doubt that poultry is the major reservoir of *Campylobacter* and the two species commonly found in poultry, *C. jejuni* and *C. coli*, are also those most commonly identified in the human population. *Campylobacter* has a long standing association with poultry, it is well suited to 42 °C, the body temperature of chickens, and is commonly found in the gastrointestinal tract of these animals. *Campylobacter* spp. are isolated throughout poultry production, including rearing and at slaughter and their occurrence is well documented. There are two main routes of transmission from poultry to humans, firstly cross contamination during processing and secondly via spread of the bacterium from the intestines to other organs including the liver. The chicken gut is colonised with high numbers of *Campylobacter* spp. and during processing, which is highly automated, these bacteria cross-contaminate the external surface of the carcass. *Campylobacter* can also be aerosolised and contaminate the carcass that way. More recently it has been shown that *Campylobacter* has the ability to leave the gut and infect other organs, the liver being the predominant one. Extra intestinal spread is a major public health issue: there have been several outbreaks of human campylobacteriosis linked to the consumption of chicken livers indicating that perhaps extra intestinal spread is more common than previously thought. The ability of *Campylobacter* to leave the gut is poorly understood and requires further investigation. A recent study at Swansea University examined isolates obtained from the ileum, caecum and liver of the same broiler chickens and found that there were more similarities between the isolates in the ileum and liver compared to those in the caecum and liver, suggesting that *Campylobacter* are leaving the gut from the ileum. It has also been shown that *Campylobacter* interacts with other intestinal pathogens, and takes advantage of damage to the gut epithelial cells. The interaction of *Campylobacter* with *E. coli* is particularly interesting, as it has been shown that these two pathogens interact with each other to cause damage to the gut. As above, recent studies at Swansea have shown that *C. jejuni* invasion into avian epithelial cells increased in the