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Environmental loading of Italian semi-intensive snail farming system evaluated by means of life cycle assessment

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ABSTRACT

In the recent years, heliciculture has rapidly developed in Italy both in terms of number of companies (about 8000) and average extension of snail farms (5000–10,000 m^2). Studies aimed to evaluate the whole environmental performance of heliciculture are still not available in literature. This paper presents a Life Cycle Assessment (LCA) performed for *Helix aspersa maxima* snail production in the South of Italy. The system boundary (*cradle to farm gate*) of the production chain considered the following stages: indoor breeding, outdoor fattening, cleaning out and packaging. The outdoor fattening displayed the largest part of total burdens (about 90%) for all impact categories due to the relevant contribution of its processes (enclosures set-up, fodder cultivation, supplementary feeding and irrigation). The process that highly affected all impact categories was the supplementary feeding used in fattening pens which reached the highest value for Terrestrial acidification (84%) and the lowest one for Ozone depletion (41%). Nevertheless, the impact of enclosures set-up and fodder cultivation appeared marked in particular for Ozone depletion (46%) and Marine Eutrophication (30%), respectively.

Results showed the key factors (supplementary feeding, HDPE mesh) to be considered and discussed to proper design a semi-intensive snail management in order to enhance benefits and constrain limitations.

Moreover, the snail farming highlighted a lower environmental load, for almost all impact categories, compared to literature data on conventional meat (beef, pig and chicken).

1. Introduction

Heliciculture in Italy, in the recent years, has been showing a notable growing, both in terms of farms number (about 8000 units) and average extension (5000–10,000 m^2), with about 5.2 thousand hectares concentrated in the South of Italy (Institute of Snail Rearing in Cherasco, 2015). Such development is the result of a considerable increase of snails consumption (faster than national production), with an annual sales volume of 265 million euro (data referred to 2013) (Avagnina, 2014), which entails Italy as country leader in the sector.

Heliciculture represents a thriving and accomplished activity thanks to its ancient food tradition in the rural areas of the country and, newly, also the snail slime is largely used in cosmetic market. Moreover, snail meat can represent an interesting alternative source of protein food for human nutrition, in the light of the current need in producing food with low environmental impact and the revaluation of the Mediterranean diet (Pairotti et al., 2015; Forte et al., 2016). As a matter of fact, studies report that demand for animal products is rising globally and it is expected to increase of 70–80% between 2012 and 2050 (Pelletier and Tyedmers, 2010; Steinfeld, 2012). In a future prospect at the global scale, edible invertebrates, including snail meat, could be considered as a fascinating source of protein for a growing human global population, which is expected to reach nine billion in 2050 (FAO, 2013a).

Snail meat provides an excellent source of protein and in general a high nutritive value. Edible snail meat contains each 100 g a calorie count of 280 kJ, protein content of 12.9 g (rich in essential amino-acids), fat content from 0.6 g to 1.5 g (large part polyunsaturated), phosphorus content of 1.6 mg, 2.4 g of minerals (Ca, P, Fe and Cu) and about 60 mg of vitamin A (INRAN, 2007; Picchi, 2003). *Helix aspersa maxima* (considered in this study) is

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commonly raised in Italy. It represents about 70% of the species, due to its high yield ascribable to: (i) its rapid growth, leading to aging in just 12 months of feeding and (ii) its strong reproductive capacity (lays about 100–120 eggs per year in two cycles) (Institute of Snail Rearing in Cherasco, 2015).

For the next future the need of integrating environmental and food safety issues has been pointed out by the Food and Agriculture Organization (FAO) referring to "*food production and security, food safety and quality, and the environmental sustainability of agriculture*" (Hayashi et al., 2006). Nowadays, the rearing snails for food production have been evaluated only in relation to the contribution of global warming (Forte et al., 2016). The snail carbon footprint (CF) resulted lower than the global warming potential of conventional meat sources (Forte et al., 2016). However, the CF method addresses the contribution of one impact category (climate change) and therefore cannot be used to assess the whole environmental performance of snail product life cycle. Furthermore, some assumptions may be deduced from the comprehensive study realized on edible insects (FAO, 2013b) which could be consequently applied to snail meat production. In comparison with conventional animal meat production (beef, chicken, pork), it is reasonable to assume a best whole environmental performance of snails production for several reasons: (i) higher feed conversion efficiency because snails are cold-blooded invertebrates; (ii) lower ammonia emissions (for macro-livestock mainly ascribable to the higher energetic inputs, enteric methane emissions and feed-to-meat ratio); (iii) lower land use (feed is expected as the major requirement for land use in snails farms, so no other land expansion should be necessary); (iv) lower risk of transmitting zoonotic infections to humans; (v) a low-tech and low-capital investment for farming management.

In the lack of extensive investigations, this study presents an attributional Life Cycle Assessment (LCA) of an experimental snail farming of *H. aspersa maxima* in the South of Italy, in order to: (i) identify the critical phases (with high environmental load) in its production chain and (ii) suggest recommendations for hotspots mitigation. The LCA approach (ISO 14040, 2006; ISO 14044, 2006; ILCD, 2010), which represents a widespread methodology, has been already applied to investigate the sustainability of proteins production from mealworms (Oonincx and de Boer, 2012) and various animal products (McAuliffe et al., 2016; Nijdam et al., 2012; de Vries and de Boer, 2010; Beauchemin et al., 2010; Roy et al., 2009; DIAS, 2004). In this study LCA has been performed to analyze and quantify the environmental load (and eventually environmental benefits) of snail farms for food production.

2. Material and methods

2.1. Snail farm's description

The study has been carried out in a semi-intensive (indoor breeding and outdoor fattening) snail farming system of 150 m^2 located in the province of Caserta (Maddaloni, Campania region). Primary data (see Forte et al., 2016 for a detailed description of farm management practices) were collected at the experimental site for all the snails production stages within the selected one-year timeframe (2014):

- indoor breading (eggs laying and hatching, broods of young per year, water input, feed and fodder supply for breeding snails, construction materials of breeding cage);
- outdoor growing phase inside fattening enclosures (cropped mix of cabbage and beet fodder, daily water supply, supplementary of well balanced mix of grain maize, field bean and limestone, HDPE mesh to avoid predation and wood poles for the enclosures set-up construction);
- cleaning out (6 PVC plastic crates, with an average load of about 22 kg and water supply for cleaning);
- packaging (flesh and shell snails were packed in 5 kg bags of single-use PE tubular net, to be sold and supplied outside farm boundary).

The LCA was performed scaling up the experimental snail farming (150 m^2) to 1 ha, by assuming for the large scale cultivation the employment and re-evaluation of regional not polluted marginal land (abandoned since not profitably cultivable for food purpose). The snail meat yield per square meter (2.6 kg m^{-2} yr^{-1}) and the agricultural practices for fodder cultivation (mix of cabbage and beet fodder) and supplementary feeding (mixture of grain maize, field beans and limestone) were considered similar to the pilot area (Forte et al., 2016). Otherwise the outdoor fattening system was designed on the basis of the ratio between free-range pens and the total cultivated area (about 70%) detected in the experimental site. In detail, 26 fattening enclosures (3 m wide, 90 m long and 1 m high) were assumed, interspersed with passageways of about 1 m. The fattening pens were defined by hardwood poles (4 cm diameter and 1.5 m high), every 5 m, inserted into the soil for 0.5 m depth and covered on all sides and on the top by HDPE mesh. Irrigation of water supply was assumed performed by gravity, through a nozzles spray system made by a HDPE pipe (main line, about 150 m long and 26 lateral lines of about 90 m long) fixed at the top of the central line of wooden poles inside each fattening enclosure. For reproduction was assumed, a newly designed multi-chamber breeding cage (1 m wide, 3 m long and 1 m high) with perimeter structure made by steel posts (external and internal diameter 40 mm and 37 mm, respectively). In order to increase the surface area for reproduction, 100 mesh netting frame in polyethylene (1 m large and 1 m high, weigh 90 g m^{-2}) were included inside the breeding cage and fastened by steel wires (2 mm thick) every 3 cm. According to the experimental pilot area about 9500 reproductive snails would be necessary considering two reproductive events (with about 100 eggs for each brood) and assuming an eggs viability of about 60%. For the nutrition of breeding snails and hatchlings, supplementary feeding (17 kg ha^{-1} yr^{-1}) and fresh fodder (planted inside the fattening pens) were included. The impact of food supply (the sum of fresh fodder and supplementary feeding) was above 99% in the outdoor fattening stage whilst it was negligible (below of 1%) in the reproduction phase.

2.2. Methods

Life cycle assessment (LCA) is recognized as one of the most suitable approach to assess the environmental impact of products and processes (Curran, 2006). In recent years, LCA has proven to be an internationally accepted method, used widely in the agricultural sector for integral assessment of the environmental impact and for identification of hotspots[1] (Thomassen et al., 2008; FAO, 2014). According to the ISO 14040 (2006), ISO 14044 (2006) and ILCD Handbook (2010), the LCA provides quantitative, confirmable, and manageable process models to evaluate production processes, analyze options for innovation and improve understanding of production systems. Stages of LCA methodology include: goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation of results (ISO 14040, 2006; ISO 14044, 2006;).

[1] A hotspot is an element that has a high contribution to the environmental burden of a product (Guinée et al., 2002).