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From environmental nuisance to environmental opportunity: housefly larvae convert waste to livestock feed

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ABSTRACT

The livestock sector is in urgent need for more sustainable feed sources, because of the increased demand for animal-source food and the already high environmental costs associated with it. Recent developments indicate environmental benefits of rearing insects for livestock feed, suggesting that insect-based feed might become an important alternative feed source in the coming years. So far, however, this potential environmental benefit of waste-fed insects is unknown. This study, therefore, explores the environmental impact of using larvae of the common housefly grown on poultry manure and food waste as livestock feed. Data were provided by a laboratory plant in the Netherlands aiming to design an industrial plant for rearing housefly larvae. Production of 1 ton dry matter of larvae meal directly resulted in a global warming potential of 770 kg CO_2 equivalents, an energy use of 9329 MJ and a land use of 32 m^2, caused by use of water, electricity, and feed for flies, eggs and larvae. Production of larvae meal, however, also has indirect environmental consequences. Food waste, for example, was originally used for production of bio-energy. Accounting for these indirect consequences implies, e.g., including the environmental impact of production of energy needed to replace the original bio-energy function of food waste. Assuming, furthermore, that 1 ton of larvae meal replaced 0.5 ton of fishmeal and 0.5 ton of soybean meal, the production of 1 ton larvae meal reduced land use (1713 m^2), but increased energy use (21,342 MJ) and consequently global warming potential (1959 kg CO_2-eq). Results of this study will enhance a transparent societal and political debate about future options and limitations of larvae meal as livestock feed. Results of the indirect environmental impact, however, are situation specific, e.g. in this study food waste was used for anaerobic digestion. In case food waste would have been used for, e.g., composting, the energy use and related emission of greenhouse gases might decrease. Furthermore, the industrial process to acquire housefly larvae meal is still advancing, which also offers potential to reduce energy use and related emissions. Eventually, land scarcity will increase further, whereas opportunities exist to reduce energy use by, e.g., technical innovations or an increased use of solar or wind energy. Larvae meal production, therefore, has potential to reduce the environmental impact of the livestock sector.

1. Introduction

The livestock sector is in urgent need for alternative, more sustainable feed sources, because of the increased demand for animal-source food and the already high environmental costs associated with production of livestock feed. The current livestock sector is responsible for about 15% of the anthropogenic emissions of greenhouse gases (Gerber et al., 2013), mostly related to production and utilization of feed (De Vries and De Boer, 2010). The sector also increasingly competes for scarce resources, such as land,

Abbreviations: FAO, Food and Agricultural Organization; SBM, soybean meal; DM, dry matter; EU, energy use; LU, land use; GWP, global warming potential; LUC, land use change; CO_2, carbon dioxide; CH_4, methane; N_2O, nitrous oxide; IPCC, Intergovernmental Panel on Climate Change.

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water, and fossil energy (Godfray et al., 2010; Steinfeld et al., 2006). Livestock production currently uses about 70% of the agricultural land (Steinfeld et al., 2006), mainly for pasture and production of feed crops. Expansion of the area for livestock production leads to deforestation in the tropics, i.e. 80% of new croplands are replacing forest, resulting in biodiversity loss and increased carbon emissions (Foley et al., 2007, 2011; Gibbs et al., 2010). Without major changes, therefore, the above described environmental concerns will only increase further. One of the major challenges, therefore, is sustainable production of livestock feed.

Recent developments indicate environmental benefits of rearing insects for livestock feed (Sánchez-Muros et al., 2014; Van Huis et al., 2013). Insects have a low feed conversion ratio (kg dry matter feed/kg product) and can be consumed completely, without residual materials as bones or feathers. The nutritional value of insects is high, especially as a protein source for livestock (Veldkamp et al., 2012). Insect-based feed products, therefore, can replace conventional feed ingredients, like fishmeal or soybean meal (SBM), which are associated with a high environmental impact (Van Huis et al., 2013; Veldkamp et al., 2012). The use of insects may reduce the environmental impact of livestock production. In contrast with cultivation of feed crops, production of insects is not necessarily land intensive, especially because insects can turn organic waste streams, such as manure or food waste, into high quality insect-based feed products (Sánchez-Muros et al., 2014; Van Huis et al., 2013; Veldkamp et al., 2012). In Western countries large amounts of manure are produced and, according to the FAO one third of the produced food is never consumed (Gustavsson et al., 2011). Already in the 1970s, it was proven that housefly larvae (*Musca domestica* L.) can be used for biodegradation of chicken manure (Calvert et al., 1970) and that larvae can grow on municipal organic waste (Ocio et al., 1979). Moreover, feeding houseflies reared on manure and food waste to livestock will reduce the competition for land between food and feed, because they can replace other feed ingredients that are directly edible by humans. As an example, about 70% of the cereal grains used in developed countries is fed to livestock (Eisler et al., 2014). Due to a rather inefficient feed conversion ratio of livestock – for chicken 1.6, for pigs 2.5 and cattle 5.1 (Šebek and Temme, 2009) – more people could be supported from the same amount of land if they did not consume meat from livestock fed with cereals (Godfray et al., 2010). Feeding waste-fed insects to livestock, therefore, might be an effective strategy as inedible waste streams for livestock and humans can be used to produce high quality food products, such as meat, milk, and eggs.

Altogether, waste-fed insects seem to be a promising feed source for livestock, and therefore can be part of the solution to fulfil the growing demand for animal-source food, within the carrying capacity of the earth.

To our knowledge, however, no study has been published that quantified the reduction of the environmental impact of including waste-fed insects in livestock feed. Only one peer-reviewed study analyzed the environmental impact of insects, in this case mealworms (Oonincx and De Boer, 2012). This study, however, focussed on production of mealworms for human consumption, and showed that the production of one kg of edible protein from mealworms resulted in a lower land use (LU), but a higher energy use (EU), and consequently also a higher global warming potential (GWP) than production of one kg of edible protein from livestock (Oonincx and De Boer, 2012). It is questionable, therefore, whether or not the production of waste-fed insects will result in environmental benefits.

The aim of this study, therefore, is to explore whether the environmental impact of livestock production can be reduced by the use of larvae of the common housefly grown on organic waste streams as livestock feed.

2. Materials and methods

Life cycle assessment (LCA) was used to assess the environmental impact of larvae meal production. LCA is an internationally accepted and standardized holistic method (ISO 14044, 2006; ISO 14040, 2006) to evaluate the environmental impact during the entire production chain (Bauman and Tillman, 2004; Guinée et al., 2002). LCA includes four phases: goal and scope definition, inventory analysis (data collection), impact assessment (encompasses classification and characterization of the emissions and resources used), and interpretation of results.

Goal and scope definition. The goal of this study was to assess the environmental impact of livestock production when larvae of the common housefly grown on organic waste streams are used as livestock feed, including also the environmental consequences to replace the original application of this waste. The functional unit was 1 ton larvae meal on dry matter (DM) basis.

Inventory analysis. Data related to the required inputs and outputs to produce 1 ton of larvae meal were obtained from a business model. This model was based on experimental studies and developed by four companies in the Netherlands (Jagran, an insect rearing company, supported by AEB and SITA, two waste processing companies, and Denkavit, an animal nutrition company).

Impact assessment. To assess the environmental impact, two types of impacts were considered: use of resources, such as land or fossil energy, and emission of pollutants, such as carbon dioxide or nitrous oxide (Guinée et al., 2002). The following impact categories were assessed: climate change, generally expressed as GWP, energy use and land use. Climate change and LU were chosen because the livestock sector contributes significantly to both emission of greenhouse gases and LU worldwide (Steinfeld et al., 2006). EU was included also because Oonincx and De Boer (2012) showed that rearing insects is energy-demanding, and because fossil energy is a scarce resource. The following greenhouse gases were considered: CO_2, CH_4, and N_2O. These greenhouse gases were summed based on their equivalence factors in terms of CO_2-eq (100 years' time horizon): i.e. 1 for CO_2, 25 for CH_4, and 298 for N_2O (Forster et al., 2007), and expressed per ton larvae meal (DM). LU was expressed in m^2 per ton larvae meal (DM) per year, whereas energy use (EU) was expressed in MJ per ton larvae meal (DM). Data related to emissions and resources were mainly obtained from databases and literature and are described in more detail in the next paragraphs. In case of a multifunctional process (e.g. production of soybean oil and meal), economic allocation was used, which is the partitioning of environmental impacts between co-products based on the relative economic value of the outputs (Guinée et al., 2002). Economic allocation is most commonly used in LCA studies of livestock products (De Vries and De Boer, 2010).

The direct and indirect environmental impacts related to the production of 1 ton of larvae meal were assessed (Fig. 1). Direct environmental impacts resulted from the use of resources and emissions of pollutants related to the housefly farm, such as use of water, electricity or feed, and emissions of greenhouse gases from waste during insect rearing. The indirect environmental impacts related to changes in use of farm inputs or outputs produced. Food waste, for example, used for insect rearing, might have been used originally to produce biogas. To evaluate the impact of using food waste for insect rearing, therefore, the environmental impacts of, for example, production of fossil energy needed to replace the original bio-energy function of food waste was included also. Below the direct environmental impact and indirect environmental impact are explained in more detail.

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