Potential of fly larvae from biogenic waste as a source of protein to replace soybean in Austrian livestock feeding

Das Potential von auf biogenen Abfällen produzierten Soldatenfliegenlarven als Proteinquelle in der Fütterung von Nutztieren in Österreich

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Summary

Austria cannot cover its livestock feed protein demand from domestic production. This paper analyses the production potential of larvae meal from Black Soldier Fly (BSF) reared on biogenic waste as protein feed for livestock in Austria. We present a profit comparison calculation for several scenarios on the production process and market. The results show cost effective production of BSF meal under certain conditions in Austria. Waste transport costs, feed conversion ratio of the larvae, and soybean price are determining variables. About 50,610 t of crude protein could be produced annually with biogenic waste from domestic households, restaurants and the food industry, which equals 24% of national soy imports. Thus, the potential of BSF as a source of protein is considerable if existing barriers, such as hygienic risks, are manageable.

Keywords: sustainable soy alternative, profit comparison calculation, fly larvae meal, Black Soldier Fly

Zusammenfassung

Der Proteinbedarf der österreichischen Viehwirtschaft kann mithilfe inländischer Produktion allein nicht gedeckt werden. Dieser Artikel analysiert das Potential von auf biogenen Abfällen produziertem Soldatenfliegenlarvenmehl als Ersatz importierten Sojas. Mittels Gewinnver-

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gleichsrechnung werden unterschiedliche Szenarien verglichen. Die Ergebnisse zeigen, dass die Produktion von Soldatenfliegenlarvenmehl unter bestimmten Voraussetzungen profitabel sein kann, wobei die Profitabilität vor allem von den Transportkosten, den Verkaufserlösen und der Futtermittelumwandlungsquote der Larven abhängt. Mittels biogenen Abfällen der Haushalte, Restaurants und Lebensmittelindustrie können jährlich 50.610 t Rohprotein erzeugt werden. Dies entspricht 24% der Sojaimporte. Das Potential von Soldatenfliegenlarvenmehl ist demnach sehr groß, wenn beträchtliche Herausforderungen, etwa das hohe Hygienerisiko, bewältigt werden können.
Schlagworte: Nachhaltiges Sojasubstitut, Gewinnvergleichsrechnung, Fliegenlarvenmehl, Soldatenfliege

1. Introduction

Global livestock production occupies about 75% of all agricultural land, consumes 35% of the world's grain and produces 14.5% of anthropogenic greenhouse gas emissions (Oonincx and de Boer, 2012; zu Ermgassen et al., 2016). About 80% of new croplands, among others for soy production, are replacing tropical forests, resulting in biodiversity loss and increased carbon emissions (Van Zanten et al., 2015). As domestic production is limited, Austria is struggling with a protein supply gap and has thus constantly been importing more than 80% of its soy feed demand (Pistrich et al., 2014). Most soy origins from the United States, Canada, Brazil and Argentina with often lower environmental and social protection standards and nearly 100% genetically modified production (exception Brazil: 35%) (AGES, 2014) – both despite public concerns in favour of sustainable feed production. At the same time biogenic waste volumes are increasing due to stricter waste separation policies in Austria. There are significant amounts from households, out-of-home food consumption and residues from food processing currently processed in thermal treatment, anaerobic digestion and as farm fertilizer.

Insects may serve as missing link between the rising demand of feed protein, deteriorating ecosystems and increasing levels of biogenic waste, as they can recycle inferiorly used nutrients. Insects can be reared on different sorts of waste like biogenic waste from households, slaughterhouse waste or manure, managing mass reductions of about 50%

(NEWTON et al., 2005). After reaching maturity, the insect larvae are dried, milled and processed to protein feed. The nutrient composition of many insect larvae is suitable to livestock such as poultry, pig and fish. This is not surprising, as insects are part of their natural diet.
This article analyses the profitability of larvae meal production from the black soldier fly (BSF) reared on biogenic waste in Austria under different scenarios to show the potential to replace imported soy for feed.

2. Methods and data

The method includes two major steps. First, literature and expert surveys of scientific, commercial BSF meal production plants (Enterra/Canada, Agriprotein/South Africa and Hermetia Baruth GmbH/Germany) and public administrative sources provide systems information and data necessary for economic calculations. Construction costs have been estimated for existing facility sizes or assumed were data was missing. Especially costs related to production processes, like energy and labour costs had to be assumed eventually based on similar production processes (e.g. biomass refineries).
This first step allowed to define alternative scenarios of BSF meal production to cope with the high uncertainties. In a second step, the profit comparison method (=capital budgeting) was used in order to compare discounted costs and benefits of the scenarios (Fig. 1). All variables that concern the production process of the facility, i.e. labour costs, investment costs and maintenance costs, were grouped and parameterized to three different scenarios, i.e. pessimistic, realistic, and optimistic. The conversion ratio describes BSF larvae meal (t DM) output from one tonne waste substrate (t FM). Three different scenarios were assumed: a realistic one (0.09, i.e. 9% conversion ratio), which is already met in small scale production trials, a pessimistic (0.05) based on observed industrial-scale facilities and an optimistic one (0.13). With respect to sales price, the pessimistic scenario (P1) sells DM BSF larvae meal at stock market prices of soybean meal (mean 2010-2015: 330 €/t). In P2 (550 €/t) and P3 (700 €/t) it is assumed that the sales price are higher due to eventually increasing global protein demand (e.g. growing world population). We consider transport costs of biogenic waste from individual households to the BSF production facility. Scenarios are based on revealed costs of biogenic waste collection in Upper Austria – which has been considered

as case study for particular parameter values – and take into consideration different settlement structures. T1.1 only considers waste from very densely populated areas with low transport cost of 45 €/km/t. T1.3 considers waste from all Austrian locations with high transport costs (87 €/km/t). T1.2 is an intermediate scenario considering all except very remote locations (65 €/km/t). Scenario T2 represents the status quo situation where transport costs are taken by the sources of the biogenic waste, i.e. households (0 €/km/t). All calculations are specific for a facility size defined by its annual treatment capacity of biogenic waste. The scenarios include four different facility sizes to explore economies of scale: 20,000 t, 40,000 t, 80,000 t and 160,000 t. Two of the largest facilities, Enterra in Canada and Agriprotein in South Africa, have a capacity of 36,500 t and 40,150 t respectively of biogenic waste per year. Thus, a facility size of 40,000 t/a represents current industrial-scale sizes and can be calculated with industry data. Parameters for facility sizes 20,000 t, 80,000 t and 160,000 t are all based on assumed values by considering expert opinions and the scientific literature on related industries.

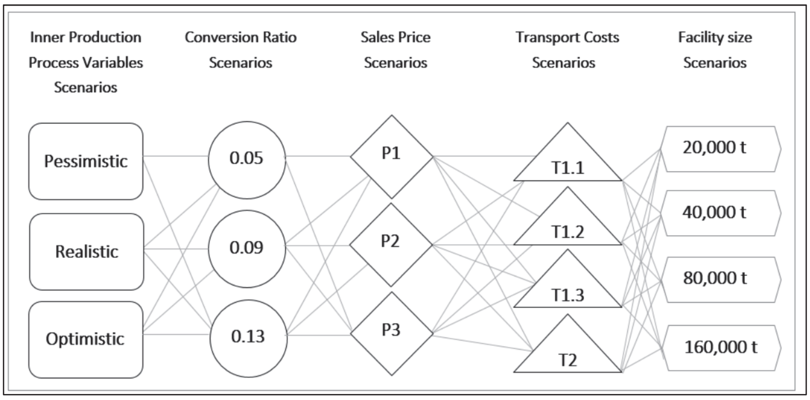

Fig. 1: Diagram of scenario variable combinations
Source: OWN FIGURE

These different variable combinations add up to 432 scenarios (Figure 1). We select representative scenarios to show the effects of transport costs, the conversion ratio and facility size in section 3. Certain variables and scenario combinations are correlated. For example, transport cost scenario T1.1 is based on biogenic waste collected in rural areas only. Consequently, less waste is collected and fewer facilities need to be built. Also, larger facilities face longer transport distances. Such effects are considered in the parameter assumptions. Full details on production processes, methods, data, and results are presented in BAUMANN (2016).

3. Results

3.1 Theoretical potential of soybean meal substitution in Austria

Biogenic waste suitable for BSF rearing results from households (except green cuttings from gardens), kitchen waste from restaurants and partly from the food industry. Summing up those waste categories from the Austrian waste report, approximately 937,200 t of biogenic waste (BMLFUW, 2015, 24ff) can assumed to be used. A conversion ratio of 0.09 would lead to 84,350 t DM of BSF larvae meal annually. Assuming a crude protein content of 60%, 50,610 t of crude protein can be generated, which equals 24% of the total imported soybean protein in 2012.

3.2 Profitability under different facility sizes

Table 1 shows the operating results for different facility sizes under particular scenario specifications. Costs include investment, capital, maintenance, energy, transport and labour costs. Three different components add to the total revenues of the fly rearing facility: BSF meal sales, sales of leftovers of larvae feeding (compost), and service charges for processing the waste substrate.

Table 1: Annual operating results [€] - scale effects of facility sizes

	Scenarios on facility size [t/a]			
	20,000	**40,000**	**80,000**	**160,000**
Costs [€/a]	1,800,000	3,060,000	5,370,000	9,770,000
Revenues [€/a]	1,400,000	2,800,000	5,590,000	11,190,000
Operating result [€/a]	-400,000	-260,000	220,000	1,420,000

Scenario specification: realistic inner production process, conversion ratio 0.05, BSF larvae meal sales price P1, transport costs T1.1.
Source: OWN TABLE

It can be seen that a facility in the size of current industries is not profitable with this scenario specifications but can become with significant cost reductions from economies of scale. The latter include energy costs reductions of up to 50% per produced unit and reduced labour (up to 280%, considering a high level of automatization) and investment costs (up to 150%).

3.3 Profitability under different conversion ratios

The calculation model is built in a way that a change in the conversion ratio does have impacts on the revenues but not on the costs (Table 2).

Table 2: Annual operating result [€] – effects of different larvae mass conversion ratios (t DM) from biogenic waste (t FM)

	Conversion ratio scenarios		
	0.05	***0.09***	***0.13***
Costs [€/a]	*3,060,000*	*3,060,000*	*3,060,000*
Revenues [€/a]	*2,800,000*	*3,280,000*	*3,760,000*
Operating result [€/a]	*-260,000*	*220,000*	*700,000*

Assumptions: a realistic inner production process, a biogenic waste treatment capacity of 40,000 t/a, BSF larvae meal sales price P1, and transport costs T1.1.
Source: OWN TABLE

Given the assumptions in 3.1 and a facility size of 40,000 t/a, a conversion ratio of 0.09 is required to generate a positive operating result. It has about the same effect as doubling the facility size. Currently composting facilities receive around 50 € per tonne of biogenic waste that is processed at their facility (guideline price of ARGE Kompost & Biogas).
Figure 2 demonstrates that the share of BSF larvae meal revenues is increasing with rising conversion ratios. The share of substrate processing revenues decreases, even if it stays the most important part of the total revenues, i.e. 71.5%, 61.0%, or 53.2% with a 0.05, 0.09, or 0.13 conversion ratio respectively. The substrate processing revenues are constant at 2,000,000 € for a facility size of 40,000 t/a. The revenues from sales of leftovers have a minor part and only contribute with 4.9%, 2.8%, or 1.2% of the total revenues at a 0.05, 0.09 or 0.13 conversion ratio.

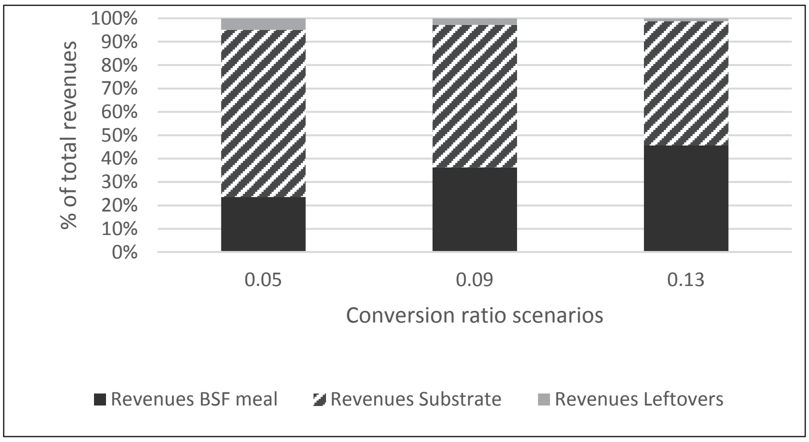

Figure 2: Comparison of annual revenue shares at a 0.05, 0.09 and 0.13 conversion ratio [%], assuming a realistic inner production process, a biogenic waste treatment capacity of 40,000 t/a, BSF larvae meal sales price P1 and transport costs T1.1.
Source: OWN DIAGRAM

3.4 Profitability under different transport costs

Four different scenarios were created reflecting assumptions regarding substrate transport costs. Table 3 shows the operating results for all transport cost scenarios. It can be seen that transport costs have a considerable impact on the profitability of a fly rearing facility.

Table 3: Annual operating result [€] – effects of different transport cost scenarios

	Transport cost scenarios [€/t]			
	45 (T1.1)	**65 (T1.2)**	**87 (T1.3)**	**0 (T2)**
Costs [€/a]	3,060,000	3,860,000	4,740,000	1,260,000
Revenues [€/a]	2,800,000	2,800,000	2,800,000	2,800,000
Operating result [€/a]	-260,000	-1,060,000	-1,940,000	1,540,000

Assumptions: a realistic inner production process, a biogenic waste treatment capacity of 40,000 t/a, BSF larvae meal sales price P1, and a conversion ratio of 0.05.
Source: OWN TABLE

If the facility does not have to cover the transport of the substrate a considerable profit of 1.5 million € can be generated assuming a realistic inner process production scenario, a biogenic waste treatment capacity of 40,000 t per year, a pessimistic BSF larvae meal sales price of 330 € per year (P1) and a pessimistic conversion ratio of 0.05. Even low biogenic waste transport costs of 45 € per tonne and km create a deficit of approximately 262,000 € per year. Figure 3 shows the significance of the transport costs compared to other cost components.

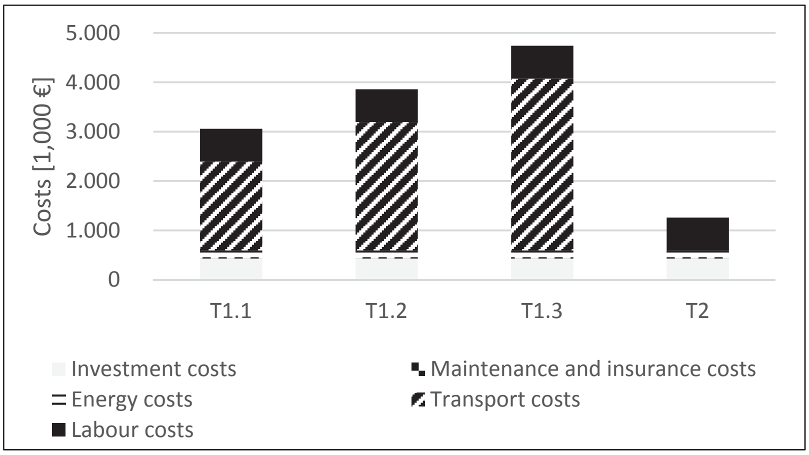

Figure 3: Comparison of annual costs [1,000 €] under different transport cost scenarios assuming a realistic inner production process, a conversion ratio of 0.05, BSF larvae meal sales price P1, and a biogenic waste treatment capacity of 40,000 t/a.
Source: OWN DIAGRAM

4. Discussion and Conclusions

Assuming a total amount of 937,200 t of biogenic waste streams suitable for BSF larvae rearing, a conversion ratio of 0.09 and a protein content of 60%, protein feed based on BSF larvae could replace about 24% of soybean imports. Besides this technical potential, the results of the profitability study are promising as well: Assuming that fly rearing companies do not have to pay for the transport of the biogenic waste – as is currently the case for compost treatment facilities in Austria – and given certain assumptions on conversion ratios, facility sizes, and production costs the majority of the scenario combinations show positive operating results. Transport costs, conversion ratio and BSF larvae revenues have been identified as variables with strong impacts on the operating result.

Insect meal can be very sustainable, too. Fly meal production on biogenic waste does hardly require additional land and water. Compared to soybeans, no pesticides and no additional transport is needed (VAN ZANTEN et al., 2015). In case of the utilisation of leftovers of the larvae in an adjoining biogas power plant, even the facility's energy use can be covered in a sustainable way. Considering these environmental benefits, the waste reduction potential and the potential to substitute soybean imports, one might wonder why BSF rearing is not more popular yet. There are a number of reasons: First, there are significant risks and uncertainties when waste streams enter the food chain. It has to be ensured that pathogens, heavy metals, etc. are not transferred to pig, poultry or fish. Lacking such proof, the European Commission will likely not adapt its policies but continues prohibiting BSF as a feed ingredient. Consequently, producers claim that they are facing a very unclear and often even conflicting legal situation which makes it hard to start or even continue production processes. Second, the biology of BSF rearing does not work properly on a large scale yet, which makes even facility sizes of 40,000 t/a unrealistic under current conditions. Third, low prices and sufficient quantities of imported soybean meal hinder innovations for substitutes in pig and poultry rearing. The latter may be the only inhibitive factor in the downstream production process, as the nutritional value including amino acids composition of BSF larvae meal appears high. Asking feed manufacturers and farmers whether they'd use BSF larvae meal, they name three critical points: availability, suitability and a reasonable price (EMATHINGER, 2014; personal communication). Thus, two out of three criteria are already fulfilled.

Thus, what is needed most urgently is further research in production processes in order to reach high conversion ratios under industrial-scale conditions. Research should reveal options to guarantee high hygienic and safety standards and to rule out hazards from contaminated larvae substrate. Furthermore, life cycle analysis shall show the environmental benefits of BSF reared on waste substrates.

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References

AGES (AGENTUR FÜR GESUNDHEIT UND ERNÄHRUNGSSICHERHEIT) (2014): Information zur Verwendung von importierter Soja bzw. Sojaestraktionsschrot als Futtermittel. Available at: http://www.ages.at/ages/ernaehrungssicherheit/gvo/soja-futtermittel/ (Accessed: 04.11.2014).

BAUMANN, V. (2016): Potential of fly larvae from biogenic waste as a source of protein to replace soybean in Austria. Master thesis. University of Natural Resources and Life Sciences.

BMLFUW (BUNDESMINISTERIUM FÜR LAND- UND FORSTWIRTSCHAFT, UMWELT UND WASSERWIRTSCHAFT) (2015): Die Bestandsaufnahme der Abfallwirtschaft in Österreich. Statusbericht 2015. Vienna.

EMATHINGER, W. (2014): Personal communication with the production manager of the feed manufacturer fixkraft. 21.11.2014.

NEWTON, G. L., SHEPPARD, D. C., WATSON, D. W., BURTLE, G. J., DOVE, C. R., TOMBERLIN, J. K. and THELEN, E. E. (2005): The Black Soldier Fly, Hermetia Illucens, as a manure management/resource recovery tool. State of the Science Animal Manure and Waste Management. San Antonio, Texas, 5 January.

OONINCX, D. G. A. B. and DE BOER, I. J. M. (2012): Environmental Impact of the Production of Mealworms as a Protein Source for Humans? A Life Cycle Assessment. PLoS ONE, 7, 12, pp. e51145.

PISTRICH, K., WENDTNER, S. and JANETSCHEK, H. (2014): Versorgung Österreichs mit pflanzlichem Eiweiß – Fokus Sojakomplex. Bundesanstalt für Agrarwirtschaft, Vienna.

VAN ZANTEN, H. H. E., MOLLENHORST, H., OONINCX, D., BIKKER, P., MEERBURG, B. G. and DE BOER, I. J. M. (2015): From environmental nuisance to environmental opportunity: housefly larvae convert waste to livestock feed. Journal of Cleaner Production, 102, pp. 362-369.

ZU ERMGASSEN, E. K. H. J., PHALAN, B., GREEN, R. E. and BALMFORD, A. (2016): Reducing the land use of EU pork production: where there's swill, there's a way. Food Policy, 58, pp. 35-48.

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