K2-2

Development of Blue, Green, and Yellow Protein Sources in Northern Europe

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Introduction

The development of sustainable protein feedstuffs for pigs is crucial for several reasons. Firstly, the global demand for animal protein is increasing, putting pressure on existing feed resources. Traditional protein sources, such as soybean meal, are often imported from distant regions, leading to significant environmental and economic costs. The reliance on imported soybean meal contributes to deforestation, biodiversity loss, and greenhouse gas emissions associated with land-use change and long-distance transportation, and this has made soy bean meal a key ingredient to replace in numerous research projects at Aarhus University and elsewhere.

Moreover, the agricultural sector faces the challenge of ensuring food security while minimizing its environmental footprint. Developing local alternatives to imported soybean meal can enhance the sustainability of pig farming by reducing dependency on global supply chains, promoting regional agricultural practices, and supporting local economies. Local protein sources should be produced using sustainable methods that improve soil health by crop rotation, reduce the need for chemical inputs, and lower the nitrogen leaching and carbon footprint of animal feed production.

In addition, diversifying protein sources can improve the resilience of the feed supply chain against market fluctuations and geopolitical uncertainties. By exploring and utilizing a variety of protein sources, such as blue, green, and yellow proteins, the pig farming industry can mitigate risks associated with monoculture and enhance the nutritional quality of pig diets. This approach not only supports environmental sustainability but also aligns with consumer preferences for ethically and sustainably produced animal products.

The following examples of feedstuffs for pigs illustrate the diversity of options. Some products are still at low TRL, while others like rape seed cake, are well known by the industry, despite further improvements needs to be done. Some products can only be produced in rather small quantities, while others seem to have no upper limit for their potential production.

Blue Mussels

Blue mussels are cultivated on lines or nets in waters rich in nutrients, giving raise for blooming of algae, which are filtered by mussels. This method of farming is highly productive, yielding over 125 tons of wet weight per hectare and removing significant amounts of nitrogen and phosphorus from the water. The resulting mussel meal is a valuable protein source, containing 60% crude protein, up to 16% fat, and 6% ash in dry matter. The digestibility of the crude protein is high, ranging from 83% to 86%. The lipids in mussels, which vary seasonally, are also of interest. Hydrolyzed mussel amino acids are readily absorbed, making mussel an excellent protein source for animal feed. However, the shells must be removed before feeding to pigs. Industrial production of mussel meal has been developed, but there are challenges related to the location of production facilities due to local opposition.

Starfish

Starfish, which are considered pests in mussel farming, can be easily and gently harvested and processed into starfish meal. This meal contains 39% crude protein, 45% ash, 13% calcium, and 8% fat. Nutrient composition vary greatly by season, so it is essential to analyze the nutrients before use.

Experiments have shown that starfish meal has a standardized ileal digestibility (SID) of crude protein of 80%. In pilot and full-scale experiments, starfish meal has successfully been used to replace fish meal. The recommendation is to dose starfish meal up to the maximum recommended dietary calcium level. Vestjyllands Andel, a Danish feed manufacturer, includes starfish in their organic diets.

Seaweed

Seaweed is a high-value food for human. It accumulates nutrients, making it useful for nutrient mitigation in the sea. Sugar kelp can be farmed on an industrial scale and processed into various products, including dry intact seaweed meal, fermented dry meal, and extracts of bioactive components. The nutrient content of seaweed varies significantly, with sugar kelp containing 7-13% crude protein and 14-38% ash. Seaweed is not a good primary protein source due to its high indigestible fiber content. However, some seaweed species have documented health-promoting effects. The impact of processing on the bioactive compounds in seaweed is an area of ongoing research.

Rape Seed Cake

Rape seed products, including cake and meal, are produced in large quantities locally and are beneficial for crop rotation. However, their production is challenged by dependency on pesticides. The main product of rape seed is oil, with cake or meal as byproducts. Rape seed cake contains about 29% crude protein and 11% fat, while the meal contains approx. 34% crude protein and 4% fat. Phosphorus content is high and digestibility low, which may cause challenges regarding phosphorus leaching. Improving the quality and digestibility of these byproducts is essential for their use in feed for young pigs. Avoiding the solvent extraction process in the cake production may facilitate better quality of cake than meal. Research needs to be done to improve nutrient digestibility. New white rape seed varieties can lead to less use of pesticides, and because of lower tannin concentrations, improved protein digestibility.

Green Protein From Biorefinery

Northern Europe is well-suited for growing grass, which can be sustainably and organically produced in large quantities. Grass has a relatively high crude protein content of around 20% in dry matter. The production methods for green protein are well known, but there are challenges in handling and processing grass from lab to full-scale production. The quality of green protein is good, with crude protein content ranging from 30-70%, 5-6% ash, and 10-15% fat in dry matter. The amino acid profile of green protein is comparable to soybean meal, with a SID of crude protein between 66% and 80%, depending on the input materials. Two commercial factories in Denmark produce green protein, which is used in organic production with positive responses on growth and carcass from the pigs.

Single-Cell Protein Products

Single-cell protein products, such as algae protein and microbial protein from methanogenic bacteria, offer alternatives for animal feed, that may be sustainable. Algae protein can be produced from organic low-value products or inorganic compounds, with a crude protein content of 47-57% in dry matter. Methanogenic bacteria can convert methane, ammonia, oxygen, and minerals into microbial protein sold as Uniprotein, with a crude protein content of over 65%, 8-10% fat, and 6-7% ash in dry matter. The SID of this crude protein is 81%, and the amino acid profile is comparable to other high-quality proteins. Other products are on their way into commercial production, and one example is Proton, which is microbial fermentation based on H_2 and O_2 and with CO_2 as carbon source, expected to lead to a crude protein content of above 70%.

Black Soldier Fly Larvae

Black soldier fly larvae are efficient converters of low-value biomass into protein and oil products. They have a low environmental and climate impact and can be produced on a factory scale. In Denmark, facilities like Enorm Biofactory are leading the production of black soldier fly products. Meal of the larvae contains about 43% crude protein and 34% fat, while the meal of defatted larvae contains approx. 57% crude protein and 12% fat. The defatted product of black soldier fly larvae is particularly attractive as a feedstuff, although the SID of crude protein is low, suggesting a need for optimized processing. Piglets respond well to diets containing 8% defatted black soldier fly larvae. The climate impact of black soldier fly production is favorable, with significant variation in carbon load depending on the substrates used to grow the larvae.

Concluding Remarks

The development of sustainable protein feedstuffs for pigs is a multifaceted challenge that requires balancing productivity, environmental and climate impact, and economic viability. While blue, green, and yellow protein sources offer promising alternatives to traditional feedstuffs, each comes with its own set of challenges and opportunities.

One significant challenge is ensuring that the production of these sustainable feedstuffs does not negatively impact biodiversity. According to the WWF 2024 Living Planet Report, our global food system is a primary driver of biodiversity loss. Habitat loss driven by agriculture threatens over 80% of all threatened terrestrial bird and mammal species. The near extinction of certain pollinators jeopardizes 5-8% of agricultural production, and crop diversity is declining, with 86% of humanity's energy intake coming from just 17 crop plants.

For example, while green protein from large fields of grass can be sustainably produced, it may lead to monoculture practices that are detrimental to biodiversity. Monocultures can reduce habitat diversity, making ecosystems more vulnerable to pests and diseases and less resilient to environmental changes. Therefore, it is essential to develop and implement agricultural practices that promote biodiversity, such as crop rotation, intercropping, and the use of cover crops.

In conclusion, the pursuit of sustainable pig feed protein sources must consider the broader ecological impacts and strive to create a balance between agricultural productivity and environmental stewardship. By diversifying protein sources and adopting sustainable farming practices, the pig farming industry can contribute to a more resilient and sustainable food system.

O2-1

Effect of replacing soybean meal with alternative proteins in growing-finisher diets on performance, carcass characteristics, and life cycle assessment

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Keywords: alternative proteins, growing-finishing pigs, performance, carcass characteristics, LCA

Introduction

In the EU, the interest in soybean meal (SBM)-free diets has increased in the swine industry for sustainability and circularity purposes, because nearly 90% of soybean production is concentrated outside Europe (Lopez et al., 2020). Thus, while the EU largely relies on imported SBM, several alternative protein sources are available in the EU, including legumes and oil seed by-products with attractive protein content and AA profile, but with nutritional limitations due to the relatively high concentration of antinutritional factors (ANF). Therefore, it is of interest for the feed industry to evaluate the effect of replacing SBM inclusion in diets for alternative EU protein sources, including peas, sunflower meal (SFM), and rapeseed meal (RSM), on growth performance, carcass characteristics, and life cycle assessment (LCA) of pigs during the growing-finishing period.

Material and methods

In a randomised complete block design, 120 pigs (23.4 ± 1.87 kg) were allotted to two dietary treatments and three blocks. Pigs were blocked by gender and weight within block (room). There were two replicate pens per room and 10 pigs (5 gilts and 5 boars) per pen. Each pen was equipped with one IVOG® feeding station. The treatments consisted of a control diet containing 16.0, 12.0, and 8.2% of SBM and a SBM-free diet containing 35.1, 28.2, and 26.5% of a combination of sunflower meal, rapeseed meal, and peas in the starter, grower, and finisher phases, respectively. Diets were formulated to have equal concentrations of NE and SID Lys. Dietary treatments were fed in three feeding phases based on pig body weight (BW): Starter (25-50 kg), grower (50-80 kg), and finisher (80-120 kg). Growth performance parameters and carcass characteristics were calculated at individual level and analysed in Genstat® by ANOVA with room as random effect, treatment as fixed effect, and pen as the experimental unit. Using the mean values for performance and carcass data, the Opteinincs® tool was used to estimate the environmental impact (climate change) of the dietary treatments, thus, no statistical analyses were performed.

Results and discussion

No difference in pig performance was observed between the control and the SBM-free diet in the starter phase, whereas during the grower phase, pigs fed the SBM-free diet had higher ADFI (2.023vs. 1.92 kg; P= 0.02) and ADG (0.945 vs. 0.883 kg; P= 0.01) than pigs fed the control diet. However, dietary treatment did not significantly influence growth performance during the finisher phase or for the entire experimental period. At the end of the trial, pigs fed the control diet had 120.1 kg and 112 d in the trial, whereas pigs in the SBM-free diet had 121.6 kg and 111 days in the trial. None of the carcass characteristics evaluated were affected by dietary treatment. Overall, this indicates that sunflower meal, rapeseed meal, and peas are good alternative sources for SBM in growing-finishing pig diets as feed intake and growth rate were improved, and carcass quality was not penalised by totally replacing the SBM. Regarding the LCA data indicated that the environmental impact expressed as kg CO_2 eq. /ton carcass generated by the SBM-free diet was 20% lower than that generated by the control diet (Fig. 1). This was due to the lower feed impact (-1,046 kg CO_2 eq. /ton carcass) in the SBM-free diet compared to the control diet containing SBM from South America. Based on the data for the environmental impact expressed as CO_2 eq. /ton feed, in the starter and finisher phases, the environmental impact was 44-50% lower than in the control diet, whereas in the grower phase, the reduction was only 18% lower in the SBM-free than the control diet (Fig. 2). This is a consequence of the higher (+0.83%) inclusion of palm oil in the SBM-free compared to the control diet in the grower phase. Thus, as expected, removing SBM from growing-finishing diets reduced the environmental impact of pork production.

Conclusion and implications

Sunflower meal, rapeseed meal, and peas are good alternative sources for SBM in growing-finishing pig diets as growth performance and carcass quality are not compromised, but the environmental impact of the production is considerably reduced.

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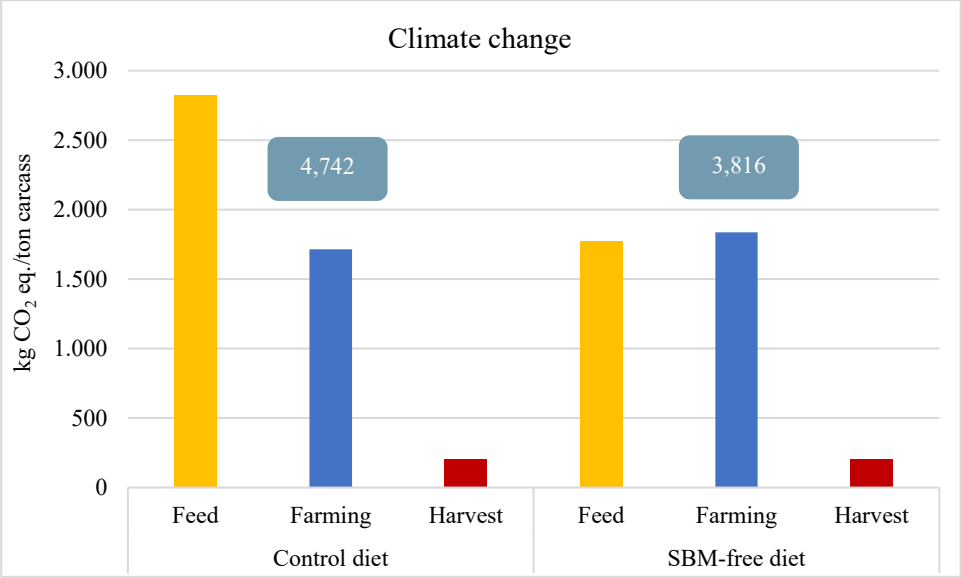

Figure 1. Effect of dietary treatment on climate change based on the LCA of the full chain and expressed as kg CO_2 per ton of carcass weight. The light blue square represents the total value per treatment.

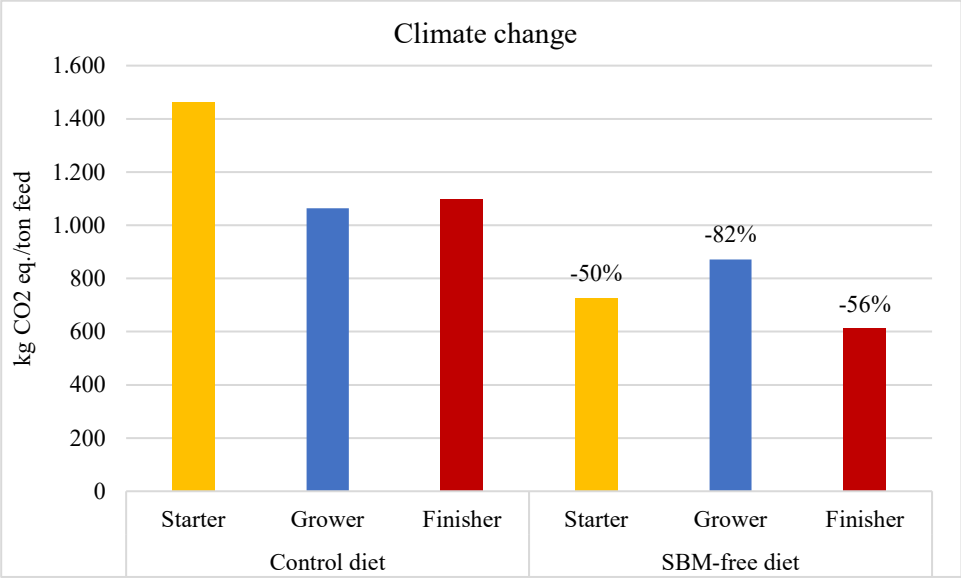

Figure 2. Effect of dietary treatment on climate change based on the LCA of the full chain and expressed as kg CO_2 per ton of feed.

O2-2

Pig diets in a circular food system; consequences and challenges

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Keywords: pigs, circularity, human inedible co-products, nutritional value, nutrient metabolism

Introduction
Circularity of food production will be increasingly important to reduce its environmental impact and feed-food competition. In circular food systems, crop land is primarily used for plant-based food production, while crop residues, co-products from the food and biofuel production, grass from marginal land, and food waste will be used in diets for production animals. This contribution aims to review and simulate consequences for pig diets, and identify and address research questions.

Material and methods
We reviewed the availability and composition of major co-products available for pig production in a circular food system, simulated composition and changes in pig diets, and identified and addressed potential nutritional, physiological and metabolic consequences from literature and recent studies.

Results and discussion
Future pig diets contain less cereals and soybean meal and include a higher proportion of human inedible ingredients. These diets are characterized by a lower starch content, and a higher content of fibre, protein, fat, and phytate compared to present diets. These changes may have an effect on nutrient digestion and utilisation, animal performance and (gut) health. Use of these diets has diverse effects on different sustainability characteristics. The potential impact is summarised in Figure 1.

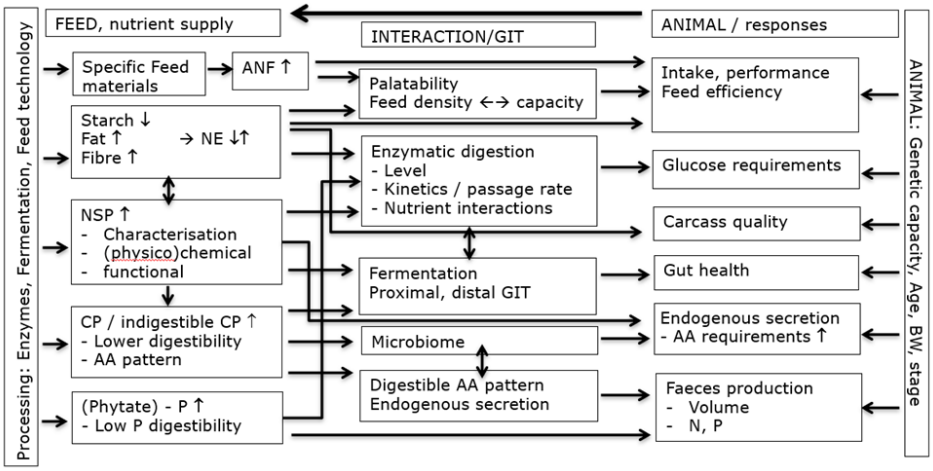

Figure 1. Diagram with characteristics of pig diets in a more circular food production system, interactions in the digestive tract and influences on animal performance and health. ANFs = antinutritional factors; NE = net energy; NSPs = non-starch polysaccharides; AAs = amino acids, GIT = gastro-intestinal tract. (Reproduced from: Bikker and Jansman, 2023)

Conclusion and implications
Pigs can play an important role in circular food production systems, because of their ability to use a wide range of by-products as part of their diet, but consequences of using such diets need to be considered and other than classical criteria than e.g. feed conversion ratio may be required to evaluate their contribution.

Acknowledgements
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O2-3

Title: Quantification of the benefits of reducing dietary crude protein level for fattening pigs in terms of global warming potential depending on the origin of amino acids: a meta-analysis

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Key words: Pig, Protein, Global Warming potential, Amino acid origin, Soybean meal

Introduction

The environmental impact from animal production has become a major concern in the past decades. This impact is mostly caused by feed production and emissions from manure. At the feed production step, the main impacts are climate change linked to energy consumption, nitrous oxide emissions from the fields, and the land-use change impact of crops cultivated on recently converted forests or grasslands. This mostly concerns soybean meal (SBM) produced in South America and used widely in Europe as a source of protein for animal feed. Reduction of dietary crude protein (CP) content is a strategy that has been widely studied and implemented in pig production to reduce environmental impacts. This reduces N emissions from manure while maintaining animal performance thanks to feed-grade amino acids (AA) to cover animal requirements. Low-CP diets are usually implemented by replacing protein sources, generally SBM, with cereals and feed-grade AA and possibly alternative protein sources and co-products. In this context the contribution of the feed-grade AA in the climate change impact of the pig production is getting more important and must be considered. The objective of this meta-analysis was to quantify the benefits of reducing dietary CP level in terms of global warming potential (GWP) depending on the AA origin.

Material and methods

Experiments collected were published after 2000, tested at least three dietary CP levels for fattening pigs between 20 and 125 kg body weight (BW) and provided the ingredient composition of the experimental diets. Experiments were selected for the meta-analysis if they kept the standardized ileal digestible lysine and net energy content stable, and all indispensable AA at constant levels or above requirements across treatments. Moreover, only experiments where CP reduction was performed by gradually replacing soybean-feedstuffs by cereals and/or other protein-rich feedstuffs and feed-grade AA were selected. For each diet, the GWP (CO_2-eq per kg of feed) was calculated using feed composition and two databases: GFLI for the main feedstuffs (Blonk Consultants, 2019) and the peer-reviewed study by EVEA performed for Metex Noovistago on the life cycle assessment values (including GWP) of feed-grade AA depending on their origin. This value was then multiplied by the feed conversion ratio (FCR), to calculate the GWP per kg of pig BW. Zootechnical performance (average daily feed intake (ADFI), average daily gain (ADG) and FCR) were considered for the total period. For the GWP assessment, the starter, grower and finisher phases were considered independent. It resulted in a database of 10 experiments and 17 diets, where the dietary CP varied from 20.6 to 9.3% and the reduction in CP reached up to 7.5 points. The dependent variables were ADFI, ADG, FCR, SBM inclusion in the diet and GWP per kg of pig BW using 1) AA produced in EU and 2) AA produced outside EU. Data were analysed using Minitab (2019) with a general lineal model, including the "Experiment" or "Diet" as fixed factor and "CP level", "AA origin" and their interaction as covariable. Probability of significance is defined for $P < 0.05$.

Results and Discussion

The meta-analysis shows that the reduction of dietary CP leads to a reduction of the soybean-feedstuffs inclusion in the diet by 32.8 kg/T per point of CP reduction ($P < 0.001$). Cereals are increased by 24 kg/T ($P < 0.001$) while the inclusion of feed-grade AA increases by 2.9 kg/T ($P < 0.001$) per point of CP reduction. These changes in the diet do not have any effect on the zootechnical performance of pigs. The dietary CP reduction has indeed no effect on ADFI ($P = 0.378$), ADG ($P = 0.754$) and FCR ($P = 0.421$), showing that it is possible to reduce the dietary CP level without affecting performance when using a balanced AA profile.

The average contribution of the feed-grade AA to the GWP per kg of feed was 4.9 ± 0.75% when using AA from EU and 10.7 ± 1.51% when using AA from outside EU, illustrating the relevance to take into account their origin. The interaction CP level×AA origin appears to be significant ($P < 0.001$): using AA from EU origin ($P < 0.001$) leads to a reduction of the GWP by 0.148 kg CO_2-eq per kg of pig BW for each point of CP reduction while it is only by 0.076 kg CO_2-eq per kg of BW when using AA from outside EU ($P < 0.001$). These results indicate that reducing the CP level in pig diets has a remarkable beneficial effect on climate change when EU sourcing is used for AA.

Conclusion and implications

Thanks to the increase usage of feed-grade AA, it is possible to further reduce the dietary CP level, as well as the inclusion of soybean-feedstuffs while maintaining pig performance. Moreover, reducing the dietary CP allows to reduce the GWP of pig production. Using AA from EU allows to reduce twice more the CO_2 emissions compared to non-EU AA. Reducing the dietary CP with EU AA sourcing is thus a successful solution to reduce the GWP impact of pig production while maintaining growth performance of fattening pigs.

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O2-4

Full title

Exploring sustainable alternatives to soybean meal in post weaning pig diets: Impact on growth, nutrient digestibility, and carbon footprint

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Introduction

Imported soybean meal (SBM) is widely used in post-weaning pigs' feed. Despite its relevance, the environment impact and reliance on feed materials from third countries raise sustainability concerns. This study aimed to evaluate the effects of partially or fully replacing dietary soybean meal with alternative oilseed meal products or legume seeds on piglets' performance and nutrient digestibility, thereby enhancing the circularity of food production.

Material and methods

A total of 240 weaned pigs (6.5±0.9 kg) were allocated in weight blocks and randomly allotted to 6 dietary treatments: (C) control diet containing 14% soybean meal (SBM); (C + Oil) 50% of SBM was replaced with oil seed meals (5.9% sunflower meal, 5.9% rapeseed meal and 1.4% linseed expeller); (Oil) 100% of SBM was replaced with oil seed meals (11.8% sunflower meal, 11.8% rapeseed meal and 2.8% linseed expeller); (C + LS) 50% of SBM was replaced with legume seeds (7% peas, 6.5% faba beans and 6.5% lupins); (LS) 100% of SBM was replaced with legume seeds (14% peas, 13% faba beans and 13% lupins); (Oil + LS) 100% of SBM was replaced with a 50/50 mix of oil seed meals and legume seeds. Each treatment had 8 replicates with 5 pigs per pen. Piglets were fed experimental diets from day 7 to 40 after weaning. Performance was registered on days 7, 14, 21, and 40 after weaning, while on day 34 fresh feces were collected to evaluate apparent total tract digestibility (ATTD) of nutrients. On day 40, from treatments C, Oil and LS, two average weight piglets per pen were euthanized for dissection and to determine ileum digestibility of CP (crude protein). The carbon footprint (CFP) was calculated using the Nevedi-GFLI database, including land-use change (LUC).

Results and discussion

In the first two weeks of the experimental period (Day 7 to 21), the AFDI (mean: 449 g/d) and the ADG (mean: 367 g/d) were not influenced by the treatments ($P>0.10$). Nonetheless, the FCR tended to be slightly lower for piglets receiving Oil diet compared to those fed C-Oil and Oil-LS diets (1.18 vs 1.25 and 1.26, respectively, $P = 0.099$). The digestibility of all nutrients was significantly affected by the dietary treatments ($P<0.001$). Replacement of SBM (C) by oil seed meal (Oil) reduced the ATTD of dry matter (DM), organic matter (OM), CP, ash, and phosphorus (P), while increased the ATTD of fat and non-starch polysaccharides (NSP). On the other hand, LS reduced the ATTD of DM, OM, CP, and fat, but enhance the ATTD of NSP, ash, and P. The combined Oil-LS diet reflects these effects with a lower ATTD of DM, OM, CP, a higher ATTD of fat and NSP and no difference in ATTD of ash and P compared to the C diet. Overall, ATTD of NSP was the highest for LS and the lowest for the C diet ($P<0.001$), yet the total NSP content for the alternative diets was 20 to 40% higher than for the C diet. The apparent ileal digestibility of CP was substantially increased by LS when compared to C diet ($P<0.05$). The total CFP (Table 1) was lower with the OIL and LS seeds diets than with the SBM diet and it was particularly affected by the inclusion of LUC. Of the total footprint, the portion related to LUC for soybean meal and soybean oil is about 82% and 71%, respectively, while for rapeseed meal and sunflower meal, LUC contributes 17 and 10%, other ingredients range between 0 to 7%. Therefore, the replacement of soybean meal by other oil seed meals and legume seeds contributed to a large reduction in CFP when LUC is included. The reduction in footprint was greater with the Oil (-27%) compared to the LS (-17%).

Table 1. Calculation of the CFP of the experimental diets.

		C	C-Oil	Oil	C-LS	LS	Oil-LS
Total Off Farm	g CO2eq/kg	605	612	618	672	738	678
Land Use or Change	g CO2eq/kg	420	274	129	264	108	118
Total CFP	g CO2eq/kg	1025	886	747	936	846	797

Conclusion and Implications

The results indicate that soybean meal can be totally or partially replaced by either legume seeds, oil seed meals or a combination of both, without impacting growth performance and with only minor effects on nutrient digestion. Replacing SBM by oil seed meals and legume seeds not only sustains growth performance but also contribute to a more sustainable agricultural practice.

O2-5

Are Growth Performance and Fecal Score in Weaning Pigs Affected by the Inclusion Level of Potato Protein Concentrate and the Enclosed Glycoalkaloids in Iso-Nitrogenous Diets?

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Keywords glycoalkaloids, α-solanine, α-chaconine, potato protein concentrate, piglet feed, piglet growth performance, fecal score

Introduction

Potato protein concentrate (PPC) from potato starch production has been used as an ingredient in pig diets, but with limited inclusion levels, due to content of toxic glycoalkaloids (GA), mainly solanine and chaconine. However, the content of lysine and other essential amino acids is relatively high in PPC, making it an ideal protein source, especially for weaners. In Denmark, it is advised not to exceed inclusion levels above 5% or 200 ppm solanine [1]. In the EU legislation, there is no maximum limit established for animal nutrition, due to insufficient data according to the scientific opinion of EFSA [2]. There is a lack of studies with PPC substituting other protein ingredients while keeping the diets iso-nitrogenous, to isolate effects of GA not mixed up with differing levels of digestible protein and amino acids. Through processing, it is possible to reduce GA significantly. However, these processes are energy intensive, and thus including PPC with standard GA content without compromising productivity and health, potentially increases the sustainability and profitability of using PPC in pig diets.
The main objective of the present study was to investigate the effect of increasing amounts of standard PPC in weaner pig (7-30 kg BW) isonitrogenous diets, as a substitute to protein ingredients, mainly soy protein concentrate (SPC), to determine the maximum tolerated level of α-solanine and α-chaconine from PPC, and its effects on piglet performance. It was hypothesized that increasing the levels of standard PPC in isonitrogenous pig diets from 0 to 45 days after weaning would affect growth performance negatively, because of the increasing GA content.

Material and methods

A total of 720 pigs (7–30 kg, [Duroc x (Landrace x Yorkshire)], mixed gender) were fed one of the following four diets within three feeding phases (days 0–13, 13–24, and 24–45): control (CTRL), PPC standard inclusion (PPC-S; 4%, 2%, and 0%), high PPC inclusion (PPC-H; 8%, 3.5%, and 2%), and extremely high PPC inclusion (PPC-EH; 12%, 5%, and 3.5%). The content of GA in the applied batch of PPC was 1180 ppm *a*-solanine and 1707 ppm *a*-chaconine. All diets within each phase were formulated to be iso-energetic, as well as isonitrogenous, on a digestible basis. In addition, the amount of digestible essential amino acids (lysine, methionine, cysteine, threonine, tryptophane, and histidine) was balanced between the diets within each phase. Furthermore, digestible phosphorus was also balanced between the diets within each phase. All feed recipes met the nutrient requirements as recommended by SEGES Innovation [3]. Across the four diets from CTRL to PPC-EH, SPC was gradually substituted with PPC. To meet the nutrient requirements, the additional feed ingredients were adjusted within each diet when necessary. Bodyweight (BW), average daily gain (ADG), average daily feed intake (ADFI), feed conversion ratio (FCR), and fecal score were recorded.

Results

Pigs in the CTRL group displayed no difference in BW, ADG, ADFI, or FCR compared with pigs in the PPC-S, PPC-H, or the PPC-EH group during the first period (0–13 days) of the experiment. During the second period (13–24 days), pigs in the PPC-H group displayed greater ADFI ($p < 0.001$) compared with pigs in the CTRL group and PPC-EH group but did not differ from the PPC-S group. In the same period (13–24 days), a difference was also observed in BW ($p < 0.001$) and ADG ($p = 0.001$), with pigs in the PPC-S group having significantly higher values than CTRL and PPC-EH for both parameters. In the last period of the experiment (days 24–45), BW again differed significantly between groups ($p < 0.001$), but pairwise comparison revealed no differences between groups. In the overall experimental period (0–45 days), pigs in the PPC-H group displayed greater ($p = 0.010$) ADG compared with pigs in the CTRL group but did not differ from the PPC-S and PPC-EH groups. The pigs in the PPC-H group also reached the greatest ADFI ($p = 0.024$) compared to pigs in the CTRL group. In the overall experimental period (0–45 days), the pigs displayed no difference in FCR between groups. The present study could not detect a statistically significant difference in the predicted probability of diarrhea when increasing levels of standard PPC, hence increasing the levels of GA in piglet diets.

		CTRL	PPC-S	PPC-H	PPC-EH	SEM	*p*-value
Parameters	**Exp. period**						
BW, kg	Day 0	7.04	7.04	7.04	7.04		ns
	Day 13	10.43	10.57	10.66	10.36	0.17	0.567
	Day 24	14.84	15.91	15.47	15.09	0.30	<0.001
	Day 45	29.64	29.28	30.11	29.89	0.38	<0.001
ADG, g/kg	Day 0-13	211	221	226	207	10.36	0.549
	Day 13-24	428	528	485	447	29.76	0.001
	Day 24-45	702	690	733	727	20.15	0.081
	Day 0-45	463[a]	492[ab]	508[b]	480[ab]	9.50	0.010
ADFI, kg/day	Day 0-13	0.19	0.21	0.21	0.19	0.01	0.323
	Day 13-24	0.62[a]	0.67[ab]	0.67[b]	0.61[ac]	0.02	<0.001
	Day 24-45	1.07	1.05	1.08	1.08	0.02	0.232
	Day 0-45	0.65[a]	0.68[ab]	0.70[b]	0.66[ab]	0.01	0.024
FCR, kg/kg	Day 0-13	0.92	0.97	0.93	0.93	0.04	0.736
	Day 13-24	1.52	1.32	1.42	1.37	0.09	0.181
	Day 24-45	1.52	1.52	1.48	1.50	0.04	0.455
	Day 0-45	1.40	1.39	1.38	1.37	0.02	0.620

Conclusion and implications

It was concluded that increasing levels of standard potato protein concentrate (up to 12%) and hence increasing levels of glycoalkaloids (up to 346.44 ppm; 141.6 ppm α-solanine, 204.84 ppm α-chaconine) did not negatively affect growth performance nor fecal score in the first 13 days, nor for the remaining experimental period (13–45 days), when fed isonitrogenous diets from day 0 to 45 after weaning when mainly substituting SPC. On the contrary, ADG and ADFI were greater when including PPC in high amounts, and therefore relatively high dietary GA concentrations as compared with the control group, which did not include standard PPC.

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P2-1

Sustainable European protein sources peas and lupins can replace soy in piglet feed without compromising performance

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Introduction
Soy is one of the most used vegetable protein sources in the feed industry. Although soy has a good protein content, it is often not considered as a sustainable protein source. Therefore the question raised whether European protein sources such as peas and lupins could replace soy in a pig diet without compromising the growth performance. To study this objective, two digestibility trials and one performance trial were conducted.

Materials and methods
All trials were executed at the Denkavit Innovation Centre located in Voorthuizen (the Netherlands) using TN70 x Tempo piglets.

For the digestibility trials, piglets were weaned and weighed at 21 days of age. Based on the registered weights, the feed level per piglet based on the energy level for maintenance was calculated. Feed- and water intake were recorded- and faecal and urine samples were collected per day during the sampling weeks. In the first digestibility trial (48 piglets), the experimental group received a weaner- and rearing diet where soy bean meal was (partly) replaced by 19% lupins. In the second digestibility trial (46 piglets), piglets received a weaner diet with either 18% soy bean meal or 7.5% peas (partly replaced soy), followed by a rearing diet with either 8% soy bean meal or 15% peas (partly replaced soy).

In the performance trial (393 piglets), piglets were weaned at 27 days and allocated based on weaning weight to one of three dietary treatments. Group A received a control weaner- and rearing diet, group B received a weaner diet with 7.5% peas and a rearing diet with 15% peas, and group C received a weaner- and rearing diet with 5% and 10% lupins, respectively. During the trial, weight and feed intake (day 8, 15, 36) and faecal scores (day 5, 8, 15, 19, 22, 29, 36) were registered per pen.

Results and discussion
In the first digestibility trial, the nitrogen (N) absorption was similar between treatments (2nd week post-weaning; 79.6% vs. 81.3% and 5th week post-weaning, 82.0% vs. 82.1%). Also the N-retention (2nd week post-weaning: 74.9% vs. 75.6% and 5th week post-weaning: 73.0% vs. 74.1%) and fat absorption (2nd week post-weaning: 77.1 vs. 80.6% and 5th week post-weaning: 75.2 vs. 79.0%) were similar between treatments in both weeks.

In the second digestibility trial, N-absorption (2nd week post-weaning: 79.4% vs. 80.0%; 4th week post-weaning: 78.8% vs. 77.5%) and N-retention (2nd week post-weaning: 70.1% vs. 69.6% and 4th week post-weaning: 69.4% vs. 68.6%) did not significantly differ between groups. Fat absorption was statistically similar in the second week post-weaning (66.6% vs. 66.9%), but was significantly higher for the piglets fed the rearing diet with peas in the 4th week post-weaning (68.5% vs. 72.8%; $P<0.001$).

Results on feed intake, weight or feed conversion ratio did not significantly differ between treatment groups in the performance trial.

Conclusion and implications
The results of the performance trial show that both peas and lupins are able to (partly) replace soy in a weaning and rearing diet. Also the nutrient digestibility is comparable, or even improved, when replacing soy by lupins or peas.

Preferred method of presentation: oral.

P2-2

Live black soldier fly larvae in the nutrition of suckling piglets

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Keywords: Insect, Hermetia illucens L., alternative protein sources, sustainability, natural feedstuff

Abstract:
In nature, piglets are accustomed to a wide range of solid feedstuff (such as plants, nuts, insects, etc.) over several months, whereas commercially reared piglets are usually weaned abruptly at the age of 3-4 weeks. At this age, piglets have little to no experience with consuming solid feed. Studies show that 30-60% of piglets have not ingested any solid feed before weaning and some may not eat for up to 80 hours after weaning (Bruininx et al., 2002, 2004).

Therefore, the aim of this study was to accustom piglets to solid feed as early as possible to adjust their digestion ("enzyme training concept") for the post-weaning period. One possible strategy is the supplementation of live black soldier fly larvae (BSFL). These are low in dry matter content (28-30%) and rich in protein (approx. 50% in DM) and fat (approx. 25% in DM) and could thus be a suitable feed for piglets accustomed liquid milk.

In this study, the piglets from a total of 20 litters (sows) were equally divided into two feeding treatments: CON = pre-starter feed, LAR = pre-starter creep feed + live larvae. Creep feed and larvae were weighted daily and offered fresh each day. If a feed trough was empty by the next day, the amount of feed and/or larvae was increased to simulate ad libitum feeding. After all piglets were born, a litter equalization was performed (14 piglets/sow). To document feed intake, larvae and feed were offered in separate troughs. Each litter had access to two troughs to ensure the same feeding space availability (CON: 2x pre-starter feed, LAR: 1x pre-starter feed, 1x larvae). Furthermore, video recordings of 3 pens/treatment were made to observe piglets´ feeding behavior.

Piglets fed live larvae showed a numerically higher average daily pre-starter-feed intake (ADFI) compared to the CON group. In the last week before weaning, there were a tendency higher ADFI in LAR, compared to CON. The feeding of live larvae had no significant effect ($p>0.05$) on the weaning weight of the piglets on day 28 (CON = 7.3kg±1.83kg; LAR = 7.5kg ±1.70kg). Initial observations showed that the LAR fed piglets showed high preference for live larvae early in their days of live, favoring them over pre-starter creep feed (see Figure 1).

The results of this study indicate that live BSFL are consumed with high motivation by the suckling piglets, lead to an increased in overall feed intake during the suckling period and facilitate the uptake of a diverse range of feedstuffs.

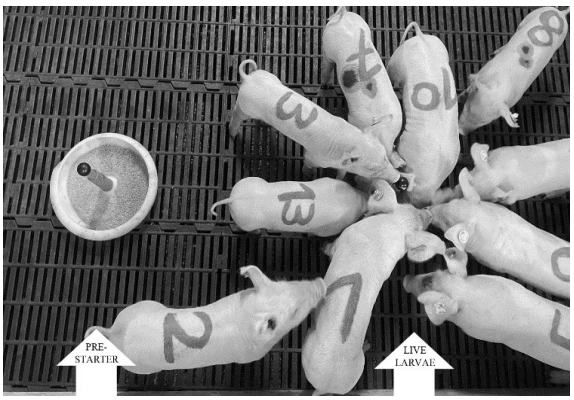
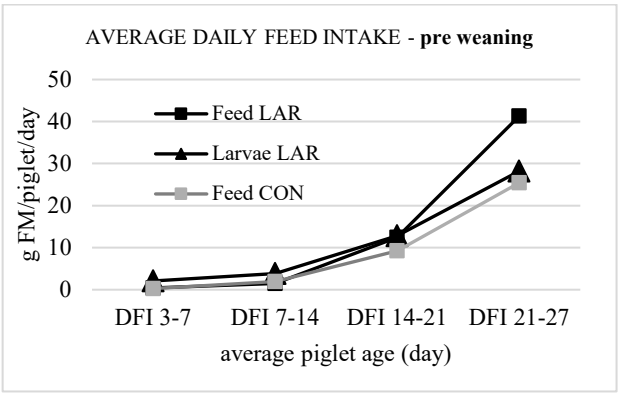


Figure 1: 3-week-old piglets fed pre-starter creep feed (trough left) and live larvae (through right)



Graph 1: ADFI of creep feed or live larvae in the suckling phase

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P2-3

Producing Black Soldier Fly Larvae on Nepalese Organic Byproducts as a Sustainable Protein Source for Pigs

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Introduction

With the growing demand for animal protein, the number of commercial farms, particularly pig farms in Nepal is on the rise (Khanal et al., 2022). However, these animals are often fed human-edible foods, an unsustainable practice (Wilkinson & Lee, 2018). Black Soldier Fly (BSF) larvae present a promising solution as they can efficiently convert organic waste into high-quality protein. This study explored the use of locally abundant organic byproducts in Nepal as substrates for BSF larvae production and examined the effects of rapeseed cake supplementation on larval growth and nutrient composition. This study aimed to enhance BSF larvae's potential as a sustainable protein source for feed, contributing to more eco-friendly livestock production.

Material and Methods

Seven different organic byproducts commonly available in Chitwan, Nepal, from fruit and vegetable markets, food processing industries, and agricultural farms, were evaluated as substrates for rearing BSF larvae. Each substrate was tested both with and without 25% rapeseed cake supplementation. Six-day-old BSF larvae were reared on these substrates for 14 days. The larvae were reared inside a plastic tray (20 x 30 x 16) at a density of 6 larvae/cm^2 and a feeding rate of 25 mg DM (dry matter) per larvae per day. The growth, survival rates, and nutritional composition of the larvae reared on these substrates were analyzed.

Results and Discussion

BSF larvae performed well on most organic waste substrates, except for butchery waste and banana pseudo-stem. Survival rates were consistently high, exceeding 80% for larvae reared on food industry waste. However, substrates with high moisture content, such as vegetable waste, negatively impacted survival. Larval growth was highest in mixed vegetable waste (14.7 mg/day) and bakery waste (11.5 mg/day), likely due to better nutrient availability. In contrast, no significant weight gain was observed in larvae reared on banana pseudo-stem or butchery waste. The larvae's weight gain appeared to be influenced by the presence of soluble carbohydrates in the feeding substrates, which may have been converted into fats within the larval biomass. While fruit, vegetable, and agricultural wastes exhibited poor bioconversion rates, food industry byproducts had conversion efficiencies similar to that of chicken feed. This difference could be attributed to the high fiber content in fruit and vegetable wastes, which may have reduced overall bioconversion efficiency. In summary, Nepalese organic wastes are generally suitable for BSF larvae production, though larval performance can vary depending on substrate composition.

Rapeseed cake supplementation significantly enhanced both the growth and nutritional quality of BSF larvae when added to organic waste substrates. Larvae reared with rapeseed cake supplementation exhibited higher protein content and lower fat content, making them a more attractive protein source for pig feed. However, larvae reared on 100% rapeseed cake had reduced growth rates, likely due to the compact texture and lower availability of soluble carbohydrates in substrate. Thus the inclusion of rapeseed cake can further improve growth performance of larvae and provide a more balanced nutrient profile, enhancing the suitability of BSF larvae as a sustainable protein source for pig feed.

Conclusion and Implications

This study shows that Most of the organic byproducts produced in Nepal are suitable for BSF larvae production. Additionally, organic waste supplemented with rapeseed cake can produce protein-rich BSF larvae suitable for pig feed. Incorporating BSF larvae into pig feed diets could reduce reliance on traditional protein sources such as soy, promoting more sustainable and competitive pig production. Future research should explore combining different organic wastes to optimize the nutritional balance and moisture content of BSF rearing substrates.

Keywords:

Black Soldier Fly, rapeseed cake, organic waste, pig feed, sustainable protein

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P2-4

Mineral-enriched yellow mealworm (*Tenebrio molitor*) larvae through a seaweed-based dietary manipulation for pig production

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Keywords: Gut microbiome; Heavy metal; Mealworm; Mineral; Sugar kelp

Introduction
Yellow mealworm larvae (YML) have been shown to be a sustainable nutrient source for feed applications, primarily due to their ability to transform various bioresources, while turning themselves into highly nutritious larval biomass. Although YML are a beneficial source of protein and fat, many diverse mineral compositions in response to their diet and few have widely the enrichment of their minerals (Syahrulawal et al., 2023). To use yellow mealworm larvae as a viable alternative feed source for pig production, their mineral compositions can be optimized in the ratio to levels that are most suitable for meeting nutritional needs. The differences in the mineral ratio are primarily attributable to dietary factors as the minerals are not synthesized in the YML body (Noyens et al., 2023). In this regard, brown seaweed *Saccharina latissima* has been recommended as an alternative mineral source due to its rich in minerals, bioactive polysaccharides, and polyphenolic compounds (Dhakal et al., 2024). This implies that dietary substrates may enhance the mineral properties of mealworm larvae. Given that the presence of gut microbes plays a pivotal role in the feed digestion process and enzyme activity in the gut of YML (Mamtimin et al., 2023). Therefore, this study aimed to investigate whether supplementing a diet with brown seaweed may improve the nutritional profile of YML, particularly the mineral content, and modulate the gut microbiome community of YML.

Material and methods
This study examined the nutritional profile and the composition of the larval gut microbiome of YML reared on the non-conventional marine bioresource, brown seaweed *Saccharina latissima*. We allocated the YML into three different groups of feeding substrates: one group being fed fully wheat-based by-products as a control diet group (CN; 100% wheat bran) and two *S. latissima* diet groups (SL25; 75% of wheat bran + 25% *S. latissima* meal and SL50; 50% of wheat bran + 50% *S. latissima* in dry matter basis (DM). The larvae grew until ~16 weeks of age and the mealworm experiments were performed on four replicates (n=4).

Results and discussion
We found that a 50% dry matter inclusion of *S. latissima* in the feed significantly increased the YML mineral content, particularly P (~27%), Na (~120%), K (~49%), Ca (~35%), Mg (~35%), and I (~161-fold) compared to a control diet ($P < 0.001$ for all). Heavy metals As (up to 1.4 mg/kg DM), Cd (up to 0.23 mg/kg DM), Pb (up to 0.03 mg/kg DM), and Hg (up to 0.007 mg/kg DM) were also found to be higher with the seaweed-based diet than a control diet in YML ($P < 0.05$ for all). The YML larval gut microbiome was dominated by Firmicutes and Proteobacteria, but a seaweed-based feed uniquely modulated the larval gut microbial community structure. In particular, *S. latissima* in the feed promoted beneficial bacterial species, such as *Lactobacillus fuchuensis* ($P < 0.001$) and *Lactobacillus graminis* ($P < 0.001$), while suppressing *Lactococcus taiwanensis* ($P < 0.001$) and *Staphylococcus succinus* ($P < 0.001$) in the YML gut. Our study indicates that the inclusion of brown macroalgae as a feed ingredient for YML could be an effective dietary manipulation to enrich the mineral content and modulate the larval gut microbiome structure of YML.

Conclusion and implications
A seaweed-based diet enhances the macro minerals content (P, Na, K, Ca, and Mg) and trace minerals (I) of YML. Additionally, the seaweed-based diet could increase the levels of heavy metals As, Hg, Pb, and Cd in YML, however at low concentrations remained within the safe levels set by regulations for feed application. Furthermore, changes at the individual species level, such as higher levels of *Lactobacillus* species and a reduction in *Staphylococcus* species, suggest a possible improvement in gut health and a decreased susceptibility to harmful bacteria. Overall, our findings indicate that incorporating brown seaweed *S. latissima* into the diet could improve the nutritional profile of YML, especially in mineral content, and could also serve as a "tool" to manipulate the gut microbial community in YML. Mineral-enriched mealworms by seaweed will be relevant as an alternative pig feed resource in the future.

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