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Optimizing Nutrient Modeling in Organic Pig Production through Refining Feeding Strategies

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Abstract

Organic pig farming practices are linked to significant ammonium losses, leaching of nitrates in sow pasture designs, and a reliance on imported proteins feed ingredients like soybean cake. Additionally, there is a shortage of information on leakage variables and models that take into consideration nutrient balancing for organic farming processes in ecological nutrient modeling methodologies. As a result, the current research was aimed at investigating feeding practices in sustainable pig farming using sophisticated nutritional modeling techniques. Six consuming circumstances were examined using a Eco balance analysis life cycle method: Reduced non-degradable protein in food sources for female pigs and porkers (S1), reduced proteins concentrations in food sources for female pigs and porkers (S2), and reduced the amount of compound food that female pigs and female pigs and porkers consume (S5 and S6, respectively). Typical production data were acquired, and information on organic production (nitrogen levels in manure, pigsty and residence ammonia emission factors) was found. Sucker, porkers, feed, compost, and inputs production were the six components that were taken into account and regulated properly. Five ecological impact categories were evaluated: land occupancy, Eutrophication potential (EP), Acidification potential (AP), Abiotic factors depletion (AD) of fossil fuels, and climate alteration (CA)(including changes in soil carbon).It was shown that in comparison to merely adding female pig, the feeding techniques had noticeably greater results when incorporating both female pig and developing piglets. The lowest amounts of compound feed to female pig and growing pigs were predicted to be responsible for the greatest reductions for the majority of the evaluated environmental effects.

Keywords: pig production, organic production, nutrient modeling, refines feed, ecological balance.

Introduction

Pig rearing and management, commonly referred to as swine production, involves raising pigs for a variety of objectives, such as generating meat, reproduction and experimentation (1). Pigs are very adaptable creatures that are grown primarily for their flesh (pork), but they also produce by-products like lard, skin, and tissues that have applications in industry(2). Systems for producing pigs may differ greatly based on the size of the enterprise, where it is located, and the particular goals (3). Pig production methods may be divided into two categories: intense or industrial manufacturing and vast or historical farming (4). The growing demand of organic pork is prioritized together with the care of the pigs, conservation of the environment, and sustainable agricultural practices (5). The diet is one of the most important components of organic pig farming. Pigs raised on organic feed aren't provided with any chemical-based pesticides, fertilizers, or GMOs (6). Usually, a blend of organic cereals, legumes, biomass, and other all-natural elements make up the feed. In order to produce superior, organic pork, organic pig agriculture places a strong focus on the well-being of animals and the preservation of the environment (7). In order to estimate and manage the nutritional requirements for particular animal species or industrial systems, nutrition modeling makes use of computer techniques and scientific understanding. Nutrient modeling may provide helpful insights into creating feeds that satisfy the nutritional demands of naturally raised pigs while improving efficiency and decreasing waste by taking into account elements including pig biology, development stage, surroundings, and dietary content (8). In order to satisfy the needs of the animals, organic pig nutrition must depend on alternate sources of nutrients, such as organic feed components and supplements. To maintain a well-rounded and effective diet, a thorough knowledge of the nutritional makeup of naturally produced feed products and how they relate is required. In order to improve feeding practices for organic pig development, it is required to evaluate and modify several feeding-related factors, including feed composition, feed frequency, feed delivery, and nutrient supplement (9). An organized and data-driven method for evaluating how these variables may affect the general nutrient consumption as well as performance of organic pigs is nutrition modeling (10). Producers can increase feed efficiency, decrease nutrient waste, and improve pig welfare and health by improving the nutritional blend and delivery techniques (11). Additionally, nutritional analysis may help growers of organic pigs handle particular issue; such maximizing the utilization of pasture and fodder supplies. Providing pigs with a diet based on pasture and encouraging exposure to the outdoors are key components of organic farming methods. By balancing the needs for nutrition and the use of natural resources, nutrient modeling may assist establish the right percentages of pastures and forage plants to include in the diet as a whole. As a result, the purpose of this research was to investigate the impact on the ecosystem that would result from implementing alternative feeding methods for organic young female pigs and growing pigs, as opposed to the conventional feeding practises that are now used by organic herds. Improve the methods to nutrients modelling for sustainable pig farming by taking into consideration the components and making use of organically-specific information and release variables. The modifications to the feeding methods comprised the following: i) a decrease in the quantity of non-degradable protein included in the diets; ii) a rise in the percentage of locally sourced proteins food concurrent with a decrease in the quantity of non-degradable protein contained in the diets; and iii) a decrease in the quantity of compound food utilized. The study examined the impact on the environment of various "GCB" integration situations in both traditional and sustainable pig farming practises. (11). Research assessed the growth, sanitation, and nutritional effects of feeding liquid meals of forage juice from greener bio processors to pigs (12). The investigation assessed how pig development and carcass attributes were affected by dietary approach and pre-treatment processes of grass/clover hay. (13). The investigation compared the development, feed effectiveness, carcass and quality of meat, and intestinal micro biota of pigs given either a fluid nutrition blend or an industrial fluid nutrition combo that additionally included silage juice (14).

Materials and Methods

The ecological consequences of consuming practices in “organic pig production in Denmark” were examined using an eco-balance approach. The study took into account the whole

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manufacturing process up to the field gate. The following components were taken into consideration: (i) trefoil farms for female pig and piglets (a place where compost was deposited), which includes the crops grown lacking extra development after trefoil; (ii) sucker and expanding pig rearing; (iii) administration of gathered manure; (iv) the generation of feed; and(v) production of inputs like energy . The new-born were moved from the housing spaces with sucker to the accommodations with porkers after they were delivered in the pigsty. These dwelling units' manure collection was seen as a co-product, notably as a resource for nutrients.

Stock information

The majority of breastfeeding female pigs in organic pig farming systems remain outside, in grassland settings, till their offspring undergo weaning at an absolute minimum of eight weeks. On the fifth day after being weaned, the female pigs are kept inside for insemination. The pigs are kept inside with extensive litter or partially caged flooring, and they also have access to external fields with 50% drained floors and 50% perforated flooring. The kind of debris employed also reflects this trend, with female pig consuming 20% of the total energy in debris; whereas suckers and porkers consume diets involve 2.8% and and 2.6%, accordingly, fodder (Table 1).

Table (1): Important statistics for typical organic pig production per year

Content	Young female pigs with piglets	sucker	porker
Litters, no per sow per year	1.97		
new born piglets	15.6		
sucker	11.6		
Rate of killing,%	32.6		
Death rates,%	10.1		
Milk production duration	52		
Weight	15	31	115
Every day increase		521	883
Percentage of death among infants	25.9	3.3	4.6
Consumption of food			
Young Female pig food	1801		
Piglets food	104		
silage	201		
grazed trefoil	147		
Food (live gain)		2.11	2.92
Roughage use, FU per produced animal		10.93	5.69
Housing environment			

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average			
splayed flooring	8.9/0	40.4	61.7
contain deep litter	4.6/0	22.8	31.9
Free-range	86.7/101	37.1	6.7
Energy usage			
Energy	154	3	12
Straw	221	7.6	41
Offspring output, heads per sows per year	22.6	21.9	20.9

Food production

The present regular diet utilized in sustainable pig herds has been compared to six different feeding techniques. S0, the default situation, reflected in the present feeding. A lower quantity of crude protein was produced by altering the proportions of soy, peas, and barley in comparison to the conventional diet (S0) as part of the consuming plan adjustments. Both sows solely (S1) or sows and fattening piglets (S3) were affected by these alterations. In scenarios S2 for female pigs and S4 for both female pigs and porkers, different protein food sources (toria) that delivered Dietary protein levels in S1 and S3 revealed. At Last, the impact of enhanced food efficiency was investigated for sows (situation S5) and both female pigs and porkers (S6) with the identical food composition as in situation S0.The three different components utilized to manufacture the naturally produced food products for the various situations Conventional grains, rapeseed, fava bean, and pea cultivated, crops farmed in combination with pigsty; and foreign food. Information Conventional feeding schedule (Table 2) per characteristic, with additional details provide daily food consumption and its nutritional values, the yields in the pigsty regions were calculated.

Table (2): Conventional feeding schedule

Content	**So Lact.Sows**	**Preg.sows**	**Piglets**	s_1&s_2 **Lact sows**	**Preg.Sows**	s_2&s_4 **Lact sows**	**Preg.sows**	s_4&s_6	**Pre.sows**
Soybean cake	14.6	2.6	13.1	11.1	0.6	0.1	0.1	15.5	2.6
Peas	6.0	4.6		3.1	2.6	0.1	6.0	4.1	4.6
Barley	36.1	25.1	41.0	41.5	28.6	27.1	25.1	36.1	25.16.0
Fish meal			4.5						
Fava Beans			5.1			15.1	3.0		
Rapeseed cake						12.1	4.1		

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Dry years			2.5						
Crude protein	15.9	11.6		13.6	11.2	13.6	11.3	14.6	11.6
Energy content	2.00	0.96	2.00	2.00	0.96	0.98	0.95	2.00	0.96

Assessment of losses

According to the" IPCC's" guidelines, methane releases at the level of a herd were calculated using the gross energy information for livestock rations of food gathered. Additionally, methane and nitrogen emissions from animal dung discharged by the Livestock were chosen for storing and keeping. The feeding methods used here are different from those in traditional systems since they were utilized as organic habitation structures (16). Using the mass equilibrium method, Nitrogen erosion levels in the pigsty containing young female pigs and piglets were also modeled. The pigsty comprised of the area enclosed by the structures in order to completely capture their unique characteristics. Using trefoil which livestock eat on and the region planted with without fertilizer barley after the trefoil. Input-output and loses were calculated initially. The livestock's food was the primary source into the region. Only the food provided to the piglets and young female pigs in the pigsty was taken into account. However, the data provided also covered nitrogen from the atmosphere deposits and fixation of nitrogen for trefoil. The resulting product was then made up of the suckers LW growth, the trefoil hay, and the barley yields harvested from the farms after the trefoil while the livestock were outside. Sources for the barley farms that would grow after the trefoil included a fertilizer impact for the crop that followed for trefoil and a processed Nitrogen amount of 70 kg N per ha. In addition, Nitrogen releasing levels were calculated for the entire pigsty, as well as an average per ha of the trefoil area.

Managing dead livestock

The meat from slaughtered young female pigs and the piglets that emerged were both taken into account when economical distribution was utilized to spread the effects at the amount of sow-piglet combinations (17). On the basis of the average pricing for sows and piglets from 2011–2021, a distribution rate of 96% was calculated for the piglets that were developed. Both the animal fat and the pork and bone- meal that were generated by the livestock that had died at the level of the herd and been ordered to be destroyed were utilized in the manufacturing of biodiesel and fertilizer, respectively (18).

Manure usage and production

It may be difficult to accurately account for nutrient balances when doing nitrogen modeling of natural systems. In this research, nutritional equilibrium was sought for by calculating an estimate about the quantity of natural fertilizer created by the pigs and the quantity that was required for the manufacture of food. This was done in an effort to determine whether or not

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there was an imbalance in the levels of nutrients. Following the matching of the overall area needs of the various crops with the food demands, the nutritional needs of the crops (in terms of nitrogen, phosphorus, and potassium) were compared with the estimated quantity of nutrients that were released from storage as a result of pig production (19). When there were less amounts of manure previous storage accessible than were required, the excess quantity that was anticipated to be filled by mineral fertilizers was credited to pig production, and the release for the manufacture and utilization of these fertilizers was prescribed to pig development as well. When there was a surplus of compost compared to what was required for farming, the worth of the unused industrial manure was attributed to the production of pigs. Although the use of manure from traditional farming practices is permitted in organic agriculture, the use of mineral fertilizers is prohibited in organic agriculture (20). However, it was anticipated that this would have the same impact. In the end, the disparate volumes of manure were brought into harmony with the use of industrial fertilizer.

Impact evaluation technique

To calculate the Climate change, EP, AP, and AD effects, and the CML baseline impact assessment technique was employed.

Result and discussion

The standard organic pig farming was shown to produce 5.1 kilogram nitrogen dioxide, 45 kg ammonia, and 56.1 kg methane outputs per sow with progeny annually. To generate 2.56 t LW per sow annually, 11.1 t of blended feed (75% of the total feed utilized) and roughage were combined. This number is typical of the areas with trefoil-covered livestock and the areas where grain is grown was established after trefoil (where the additional compost used for trefoil is utilized). Effects based on typical organic pig production (Table 3) on the ecosystem. Due to a large proportion of compound substances in livestock diets, the Climate change effect per kg Live weight (LW) increased by 0.50 kg carbon dioxide when soil Carbon changes were taken into account.

Table (3): Environmental impacts

Environmental impacts	Scenarios s_0	s_1	s_2	s_3	s_4	s_5	s_6
Climate change	2.8(3.1)	2.8(3.1)	2.6(3.1)	2.6(3.1)	2.6(3.1)	2.7(3.1)	2.5(2.9)
Eutrophication potential	32.8	32.8	31.1	30.8	30.9	30.6	28.8
Acidification potential	48.2	47.6	47.8	43.5	42.8	45.9	42.3
Abiotic depletion ,fossil fuels	13.7	13.5	12.6	11.9	8.5	13.5	11.7
Land occupation	8.9	8.9	8.9	8.9	8.4	8.6	8.1

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When yearly crops are grown for compound feed, as opposed to crops that are perennial, soil Carbon stores are released. However, the coefficient created for traditional crops is based on the production rate of the crops and is used for calculating the quantity of below-ground agricultural leftovers and Carbon input to soil. Effects of eutrophication on normal organic pig output per kg of LW in comparison to other feeding methods (Figure 1).

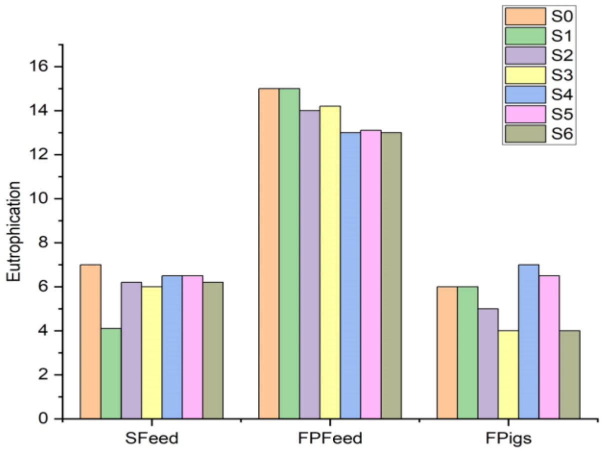

Figure (1): Effects of Eutrophication

Climate change (without soil Carbon alterations) was mostly contributed by feed generation, with EP , AP, and Land occupation effect groups accounting for 60, 76, 99, and 100%, respectively, of the total effects. Effects of acidification on normal organic pig output per kg of LW in comparison to other feeding methods (Figure 2).

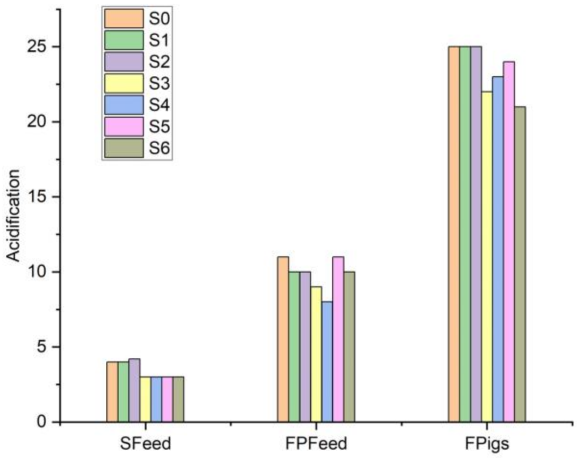

Figure (2): Effects of acidification

The greatest share came from the food used to fatten pigs since this group uses more feed per kg of lean meat than female pig with piglets or sucker. Cereals and feed products that contain protein (such as soybean cake, fava beans, etc.) had the biggest proportion of the influence of feed. Effects of abiotic depletion of fossil fuels on normal organic pig output per kg of LW in comparison to other feeding methods (Figure 3).

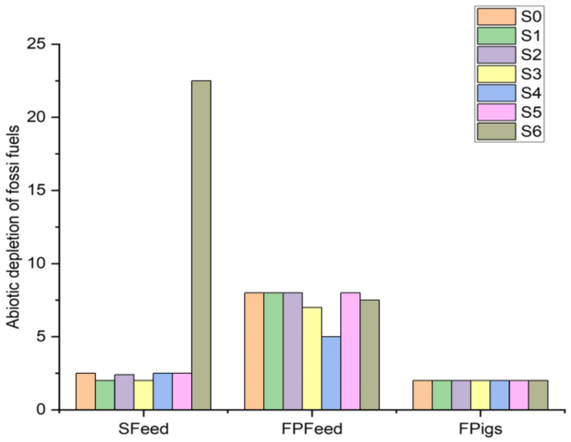

Figure (3): Effects of abiotic depletion

For AP, the area of greatest impact and source of 70% of the overall effect were emissions from livestock farming, mainly ammonia released from organic matter from developing pigs. The EP effect was also influenced by ammonia emission levels, accounting for 30% of the total effect. Effects of land occupation on normal organic pig output per kg of LW in comparison to other feeding methods (Figure 4).

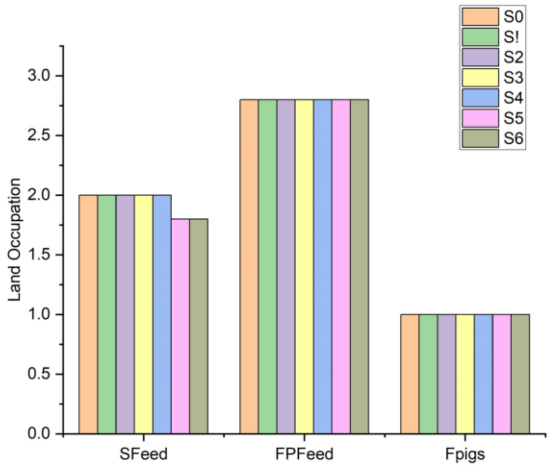

Figure (4): Effects of land occupation

When the influence of soil carbon modifications is taken out, the nitrous dioxide (from compost while habitation and storing) and methane (from intestinal fermentation and waste treatment) releases from livestock production account for 45% of the overall Climate change influence. Effects of Climate change on normal organic pig output per kg of LW in comparison to other feeding methods (Figure 5).

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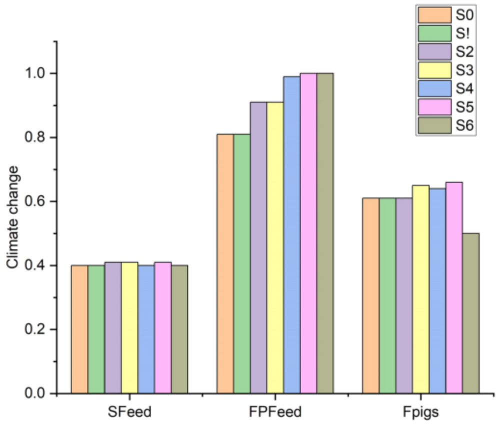

Figure (5): Effects of climate change

However, the strategy utilized in the current research to calculate feed Nitrogen emissions at the pigsty level found greater Nitrogen releases which is based on evidence from experiments with cattle. Because of this, EP effect were 12% more than what claimed. Due in large part to revisions in the effects of soybeans cake, vitamins, and mineral on Abiotic depletion, the results obtained in the current research are 27% greater than those discovered. When direct ecological alterations as well as modifications to soil carbon content are not included, the Climate change effect of organic Danish pork is 17% greater than normal Danish pork. However, when these factors are taken into account, typical Danish pork has a greater Change with 0.6 kg carbon dioxide per kilogram LW due to the usage of Latin American soybean meal, which is linked to elevated levels of deforestation. Then, although the effect of the production of traditional and organically Danish pigs is comparable, the EP, AP, and Land occupation effects of organic pork are 2.5, 1.8, and 2.4 times more, respectively, than those of AD traditional pork. Increased Nitrogen releases and decreased productivity in organic animal and feed production account for these significant discrepancies. Reduced animal food consumption correlated with increased production efficiency of the system, which was advantageous for all adverse environmental impacts. Small decreases in nitrogen releases were reported when the non-degradable protein content of the food consumption. When compared with S0, decreasing the amount of food that livestock consumed correlated to an improved productivity within the manufacturing system, and this was good for all of the repercussions on the environment, notably in S6. Although the effects of the impacts of EP, CC, and LO / kg LW remained the same in S6 as they were anticipated to be in S4, and the AP were equivalent. Smallest and could be in all of the situations. In addition to decreases in the inputs from food for porkers and young female pig with piglets, there was a drop in the release of ammonia, nitrogen dioxide, and methane notably for porkers in S6 compared to S0. This was due to the fact that the amount of manure Nitrogen released varies depending on the food that was consumed.

Conclusion

Finally, optimizing nutrition modeling in organic pig production by optimizing techniques for feeding improves the system's effectiveness and environmental sustainability. Farmers may improve the health of livestock, well-being, and efficiency while reducing the ecological impact by carefully monitoring and optimizing organic pig nutritional needs. Assessing organic pigs' dietary demands at different stages of growth helps optimize nutrient modelling. Producers can make sure animals get the right nutrients for maximum growth, reproduction, and immune system performance by adapting food tactics to these demands. Optimising food practises entails choosing and controlling organic pig feed components. Use local obtained organic foods, eliminate artificial fertilisers and growth stimulants, and concentrate on organic and environmentally friendly alternatives. Farmers can encourage organic farming, retain accreditation as organic, and supply customers with superior organic pigs while doing so. Nutrient modelling in organic pig production must also take into account animal behaviour, habitation circumstances, and farm operations practises. Pigs need space stimulation, and socialization to encourage their natural behaviours and alleviate stress. Using advanced nutrition LCA modeling techniques for organic pig farming. As a result, particular information on the nutritional value of compost was gathered, and for the pigsty and the housing sector, emission factors customized for organic circumstances were applied. The conventional consumed ratio (S0) was contrasted with six different feeding situations for female pig or female pig and porker lets. These included different sources of protein and lower protein levels in feed rations (S1, S3), decreased compounded intake of feed (S5, S6), and decreased protein content in feeding rations and alternate protein sources (S2, S4).

References

[1] Yue, S., Li, Z., Hu, F. and Picimbon, J.F., 2020. Curing piglets from diarrhea and preparation of a healthy microbiome with Bacillus treatment for industrial animal breeding. Scientific reports, 10(1), p.19476.

[2] Tolosa, J., Rodríguez-Carrasco, Y., Ruiz, M.J. and Vila-Donat, P., 2021. Multi-mycotoxin occurrence in feed, metabolism and carry-over to animal-derived food products: A review. Food and Chemical Toxicology, 158, p.112661.

[3] Groher, T., Heitkämper, K. and Umstätter, C., 2020. Digital technology adoption in livestock production with a special focus on ruminant farming. Animal, 14(11), pp.2404-2413.

[4] Zhang, Q.F. and Zeng, H., 2022. Producing industrial pigs in southwestern China: The rise of contract farming as a coevolutionary process. Journal of Agrarian Change, 22(1), pp.97-117.

[5] Ndue, K. and Pál, G., 2022. Life Cycle Assessment Perspective for Sectoral Adaptation to Climate Change: Environmental Impact Assessment of Pig Production. Land, 11(6), p.827.

[6] Dale, B., 2019. Farming for system change: The politics of food sovereignty and climate change in Canada (Doctoral dissertation, University of Toronto (Canada)).

[7] Kruger, S.D., Zanin, A., Durán, O. and Afonso, P., 2022. Performance measurement model for sustainability assessment of the swine supply chain. Sustainability, 14(16), p.9926.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 2 (2023)
http://www.veterinaria.org
Article Received: 08 April 2023; Revised: 22 May 2023; Accepted: 18 June 2023

[8] Moyo, L.B., Simate, G.S. and Mutsatsa, T., 2022. Biological acidification of pig manure using banana peel waste to improve the dissolution of particulate phosphorus: A critical step for maximum phosphorus recovery as struvite. Heliyon, 8(8), p.e10091.

[9] Blavi, L., Solà-Oriol, D., Llonch, P., López-Vergé, S., Martín-Orúe, S.M. and Pérez, J.F., 2021. Management and feeding strategies in early life to increase piglet performance and welfare around weaning: A review. Animals, 11(2), p.302.

[10] Wang, L., Hu, Q., Wang, L., Shi, H., Lai, C. and Zhang, S., 2022. Predicting the growth performance of growing-finishing pigs based on net energy and digestible lysine intake using multiple regression and artificial neural networks models. Journal of Animal Science and Biotechnology, 13(1), pp.1-13.

[11] Rauw, W.M., Rydhmer, L., Kyriazakis, I., Øverland, M., Gilbert, H., Dekkers, J.C., Hermesch, S., Bouquet, A., Gómez Izquierdo, E., Louveau, I. and Gomez-Raya, L., 2020. Prospects for sustainability of pig production in relation to climate change and novel feed resources. Journal of the Science of Food and Agriculture, 100(9), pp.3575-3586.

[12] Zira, S., Salomon, E., Åkerfeldt, M. and Röös, E., 2023. Environmental consequences of pig production scenarios using biomass from rotational trifoil leys as feed. Environmental Technology & Innovation, 30, p.103068.

[13] Presto Åkerfeldt, M., Friman, J., Dahlström, F., Larsen, A. and Wallenbeck, A., 2022. Juice from silage in green bio refineries–a potential feed ingredient in liquid diets to weaned pigs. Acta Agriculturae Scandinavica, Section A—Animal Science, pp.1-7.

[14] Friman, J., Lundh, T. and Presto Åkerfeldt, M., 2021. Grass/clover silage for growing/finishing pigs–effect of silage pre-treatment and feeding strategy on growth performance and carcass traits. Acta Agriculturae Scandinavica, Section A—Animal Science, 70(3-4), pp.151-160.

[15] Keto, L., Tsitko, I., Perttilä, S., Särkijärvi, S., Immonen, N., Kytölä, K., Alakomi, H.L., Hyytiäinen-Pabst, T., Saarela, M. and Rinne, M., 2021. Effect of silage juice feeding on pig production performance, meat quality and gut microbiome. Livestock Science, 254, p.104728.

[16] Bertasini, D., Battista, F., Rizzioli, F., Frison, N. and Bolzonella, D., 2023. Decarbonization of the European natural gas grid using hydrogen and methane biologically produced from organic waste: A critical overview. Renewable Energy.

[17] Dione, M.M., Dohoo, I., Ndiwa, N., Poole, J., Ouma, E., Amia, W.C. and Wieland, B., 2020. Impact of participatory training of smallholder pig farmers on knowledge, attitudes and practices regarding biosecurity for the control of African swine fever in Uganda. Transboundary and emerging diseases, 67(6), pp.2482-2493.

[18] Hu, Y., Hu, M., Jiang, H., Yu, P. and Yang, W., 2023. Co-liquefaction of livestock manure and food waste: Synergistic effects and product combustion performance. Applied Energy, 341, p.121073.

[19] van Loon, M.P., Hijbeek, R., Ten Berge, H.F., De Sy, V., Ten Broeke, G.A., Solomon, D. and van Ittersum, M.K., 2019. Impacts of intensifying or expanding cereal cropping in sub-Saharan Africa on greenhouse gas emissions and food security. Global change biology, 25(11), pp.3720-3730.

[20] Rempelos, L., Baranski, M., Wang, J., Adams, T.N., Adebusuyi, K., Beckman, J.J., Brockbank, C.J., Douglas, B.S., Feng, T., Greenway, J.D. and Gür, M., 2021. Integrated soil and crop management in organic agriculture: a logical framework to ensure food quality and human health?. Agronomy, 11(12), p.2494.