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ANIMAL HUSBANDRY & VETERINARY SCIENCE | REVIEW ARTICLE

The potential role of crop wastes in Uganda's future pork and poultry meat production: A mini review

J. S. Kasima^{1,2*}, H. Muyinza², B. Mugonola³ and E. K. Ndyomugenyi¹

Abstract: In Uganda, it is projected that pork and poultry meat consumption will exceed any other livestock meat in the next decade. However, pork and poultry meat in most markets in Uganda is less healthy which may predispose consumers to risks of cardiovascular complications. This is due to the high fatty acid saturation of the two meat products on the market resulting from the compromise on feed quality. In an effort to contribute to meeting the projected demand, while ensuring low fatty acid saturation, the current review explores literature on potential low-



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PUBLIC INTEREST STATEMENT

There is a steadily increasing trend in the consumption of pork and poultry meat in Uganda. This increase in consumption necessitates establishment of a sustainable production system for both pigs and poultry, focusing on the production of nutritionally safe pork and poultry meat. This will only be possible if the feeding constraint is mitigated, especially among the smallholder farmers who produce most of the country's pork and poultry meat. The current review unearths the potential low-cost feed ingredients which, if judiciously included, can result in healthy pork and poultry meat with enhanced Poly Unsaturated Fatty Acid composition for a healthy meat market.

cost ingredients with low saturated fatty acid composition. The review focuses on post-harvest crop wastes that could be fed to pigs and/or poultry directly and those that can be used to develop other ingredients for use in pig and poultry diets. Sweet potato vines and pumpkin wastes have been found as potential ingredients for use in pig and poultry feeds to produce high-quality meat with enhanced polyunsaturated fatty acids. Other potential ingredients are biochar from crop wastes and insect meals raised on crop wastes. To ensure adoption of these post-harvest wastes for use in animal feeds, there is need to first build capacity of extension workers to train the farmers on the inclusion of post-harvest wastes in pig and poultry diets.

Subjects: Agriculture & Environmental Sciences; Environment & Resources; Food Additives & Ingredients

Keywords: biochar; insect meals; post-harvest wastes; pumpkin wastes; sweet potato vines

1. Introduction

Projections by the Food and Agriculture Organisation (FAO) show that by 2030, Uganda's pork and poultry meat consumption will be higher than meat of any other livestock species (FAO, 2011). In comparison with consumption levels in the year 2000, the report reveals a 70% and 74% increase in pork and poultry meat consumption by 2030, respectively, as opposed to a 62% and 66% increase in consumption of mutton and beef, respectively, in the same period. This calls for increase in pork and poultry meat production while ensuring that the meat produced is of high quality and nutritionally safe for the consumers.

Unfortunately, no projection exists on the expected consumption preferences of the future market of the two products. However, with the increasing urbanisation, a quality sensitive and responsive market is likely to arise. For this reason, organic production systems may easily obtain markets for their products. In the efforts to increase pork and poultry meat production, quality and nutritional safety should, therefore, be put into consideration by every producer.

The current review unearths the potential readily available ingredients that could contribute to achieving sustainable production of pork and poultry meat which are of high quality and nutritionally safe for consumers. Since consumption of meat with high fatty acid saturation has been linked to increase in cardiovascular-related diseases (Dugan et al., 2015; Michos et al., 2019), this review has equated "high-quality" pork and poultry meat to one with reduced fatty acid saturation to as low as applicable. The review focuses on low-cost ingredients which can produce meat with low fatty acid saturation at reduced feeding costs, affordable by smallholder producers.

2. Underlying problem

Uganda's agricultural sector is replete with challenges which at the same time could be opportunities for its improvement. Waste generation is one of the phenomenal challenges both in the crop and livestock sectors of the country. However, an analysis of the sector unveils untapped wealth in the so-called "wastes", whether from crops or animals, as resources for product development and utilisation in other value chains. For the current review, we are presenting more evidence on the use of "post-harvest crop wastes" and specifically on the potential of recycling these wastes and using them to ensure a more sustainable production of pork and poultry meat in Uganda.

The history of increase in waste generation in Uganda is partly due to a recent drive for increased agro-industrialisation (National Planning Authority, 2020). As a result of this increased drive for industrialisation, there has been an increase in agricultural production and a rise in consequential waste generation but with poor waste management (Famine Early Warning

Systems Network [FEWS NET], 2017). Among many farming communities, for example, agricultural wastes are disposed of either on open surface, and/or by burning (Kamoga & Ssekyewa, 2021), which increases environmental pollution threat. This is in spite of wastes being potential ingredients in the production of pig and poultry feed. Indeed, the utilisation of these wastes as feed could contribute to reducing the challenge of expensive feeds and seasonal availability of alternative ingredients which have chiefly constrained pork and poultry meat production in Uganda (Babigumira et al., 2019; Kasima et al., 2021, 2021; Oba et al., 2021; Okello et al., 2021).

Although crop wastes could contribute to mitigating feeding challenges in pig and poultry production (Enenebeaku et al., 2018), limited success in their usage has been achieved in Uganda. Even the intended increase in performance has hardly been achieved (Kasima et al., 2021), while quality of pork and poultry meat has not been given optimal attention. Nevertheless, reports from other countries have appraised post-harvest wastes' potential to improve production volumes and quality of pork and poultry meat (Bidura et al., 2021; Kisuule et al., 2021; Leontopoulos et al., 2021). The current review, therefore, draws lessons from research, mainly from other countries involving use of post-harvest crop wastes and infers the findings to Ugandan setting.

3. Research on the use of selected post-harvest wastes to enhance pork and poultry meat quality

Among the post-harvest wastes present in Uganda and with the potential of improving pork quality, pumpkin wastes and sweet potato vines are the most outstanding (Kisuule et al., 2021). Studies on the nutritional composition of sweet potato vines show that the vines are rich sources of proteins and unsaturated fatty acids (Omoba et al., 2020; Suárez et al., 2020) which could be essential in pig and poultry diets. Sweet potato vines are rich in Omega-3 fatty acids which contribute to retarding development of cardiovascular complications (Johnson & Pace, 2010). Sweet potato vines also contain Carotenoids and Isorhamnetin which are both cardioprotective compounds (Nguyen et al., 2021). In addition, the vines contain antioxidants and vitamin C which collectively reduce the risk of cardiovascular build up and suppress growth of cancerous cells (Grebla-Al-Zaben et al., 2021). A study to establish the effect of sweet potato leaves on the liver fatty acid profile of hypertensive rats revealed increased concentration of unsaturated fatty acids in livers of rats fed on sweet potato leaves compared to those fed on the control diet (Johnson et al., 2013).

As for pumpkin wastes (seeds, peel and pulp), these are also said to have high Poly Unsaturated Fatty Acid (PUFA) to Saturated Fatty Acid (SFA) ratio and can therefore produce meat with enhanced PUFA content (Kim et al., 2012). In broilers, inclusion of pumpkin seeds (PS) in their diets reduced glycemia level and cholesterol content, implying the potential of reducing nutrition-related cardiovascular complications (Meineri et al., 2018). Furthermore, there was enhancement of *n*-6 PUFA levels in breast muscles of birds fed on diets containing PS than when no PS was included (Meineri et al., 2018). Generally, the presence of anti-oxidants (α -tocopherol and β -carotene), especially in the peel and pulp of pumpkins, is paramount in improving the quality of poultry meat (Valdez-Arjona & Ramirez-Mella, 2019).

When pigs were fed on pumpkin wastes at 5% level of inclusion, feed intake was significantly increased as compared to the conventional control diet (Vlaicu et al., 2019). In addition, Vlaicu et al. (2019) reported a higher apparent fat absorption coefficient in diets containing pumpkin wastes. Since pigs are homolipoids, the fatty acid composition of pork is a direct derivative of the fatty acid composition of the diet (Trezona et al., 2004). This is possible because fatty acids in pig diets are absorbed from the gastrointestinal tract with minimal changes (Đorđević et al., 2016), hence the fatty acid composition of pork is a mimic of the fatty acid composition of the pig diet. Therefore, this high level of fat absorption could be exploited to improve the fatty acid profile of pork on Ugandan markets. Furthermore, pumpkin pulp and peels have high levels of antioxidants, especially α -tocopherols and β -carotene which are readily absorbed by pigs (Hussain et al., 2022;

Vlaicu & Panaite, 2022; Valdez-Arjona and Ramirez-Mella, 2019). Humans can obtain these antioxidants from meat of animals fed on diets containing pumpkin pulp and peels, and are essential in boosting the human immune system (Valdez-Arjona & Ramirez-Mella, 2019). Besides being rich in essential nutrients, sweet potato vines and pumpkin wastes are readily available since they are mainly discarded as wastes (Achilonu et al., 2016). In addition, sweet potato vines and pumpkin wastes are rarely consumed as food in Ugandan human dishes. Using them in feeding pigs and poultry would be an option to utilise their nutrition importance in the production of high-quality pork and poultry meat with enhanced PUFA levels.

4. Alternative products from post-harvest wastes for use in pork and poultry meat production

4.1. Biochar

Biochar is a product of pyrolyzing organic materials at temperatures between 300 and 600°C in the absence of air, or in its presence but in limited amounts (Panwar et al., 2019). Although primarily used as a soil amendment, biochar has gained importance, especially with the increasing interest in products of organic livestock production.

Several researchers have gained interest in investigating the use of biochar in poultry diets. When biochar was added into broiler diets at as low as 0.005%, there was an increase in body weight and a reduction in the negative effects of aflatoxin B₁ (Rashidi et al., 2020; Schmidt et al., 2019). Generally, mycotoxins cause liver damage in poultry. Treatment of mycotoxin-contaminated feeds with biochar was reported to increase liver activity and reduce damage in poultry (Schmidt et al., 2019). At 2% level of inclusion of biochar in duck diets, Farghly et al. (2023) realised a significant increase in dressing percentage with tenderer meat produced. Furthermore, at 1.5% level of inclusion, biochar improved the weights of breast muscle, thigh and wing weights of finisher broilers (Mohammed & Billa, 2018). At higher levels of inclusion of biochar (6%) in poultry diets, the average daily gain and feed conversion ratio were improved (Dim et al., 2018; El-Ghalid et al., 2022; Kalus et al., 2020). El-Ghalid et al. (2022) also reported a reduction in concentrations of low-density lipoproteins (LDL) and general cholesterol levels at the end of the experiment. Reducing cholesterol levels renders the meat healthy for human consumption as it reduces the risks of contracting cardiovascular infections, once consumed (FERENCE et al., 2018; Michos et al., 2019). When biochar was used to replace mineral premixes in broiler diets, performance indices were not affected (Kashef et al., 2022). Instead, the meat quality attributes were improved upon inclusion of biochar in the diets (Schmidt et al., 2019). Furthermore, a 2% inclusion of biochar produced anti-pathogenic effects in chicken (Willson et al., 2019). This could counter the use of synthetic antibiotics in poultry production and outwit the barriers due to restricted use of antibiotics. Although these restrictions are not operational in Uganda, serving the small market of quality-sensitive consumers, especially who would prefer organic products, would necessitate exploring the potential of using biochar in poultry meat production.

With the above in mind, the aflatoxin binding properties of biochar should be further assessed and potential of using it to produce nutritionally safe meat further studied. Furthermore, the potential of completely replacing mineral premixes with biochar is another promising venture that poultry meat producers would exploit.

Besides the above benefits, when chickens are raised on deep litter beddings, biochar acts as a good litter amendment without negating the performance or health of the birds (Linhoss et al., 2019). It also significantly reduces on concentration of ammonia from poultry houses (Kalus et al., 2020), thereby ensuring an environmentally safe poultry meat production operation.

Although limited research to assess the effect of biochar inclusion in pig diets exists, the few studies conducted have realised the potential of biochar in contributing to production of high-

quality pork. Generally, inclusion of natural sorbents in pig diets, biochar inclusive, improves fatty acid profile of pork muscles, and kidney and back fat quality (Domaradzki et al., 2022). These findings tally with those in poultry, and the above-mentioned uses could also be explored in pork production. In addition, biochar has the potential to reduce offensive odour production, and this application may be essential in reducing offensive smell from pig houses (Sobol & Dyjakol, 2022). As a result, a sustainable pork production system would be developed which broadly bases on alternative ingredients for production.

4.2. Insect meals

Most of the applauded insects with the potential of replacing conventional protein ingredients in pig and chicken diets are raised on post-harvest wastes. Consequently, this opportunity should not be overlooked. Globally, insects have gained importance as potential alternative cheap protein sources in both human and animal diets (Hong & Kim, 2022; Nischalke et al., 2020; Sebatta et al., 2018). This is because insects require a very small space to be raised and their production has minimal impacts to the environment (Guiné et al., 2021). However, acceptability of insects and their products for direct consumption (entomophagy) by humans is very low in most communities all over the world (Hajj et al., 2022). Conversely, the use of insects in animal feeds is highly promising as they are converted into readily acceptable meat.

Insect meals can replace soybean and/or fish meals which are the commonest sources of proteins used in pig and poultry diets, notwithstanding them being expensive and primary proteins in human diets (Hong & Kim, 2022; Huis, 2021). Fortunately, meat from animals raised on diets containing insect meals is preferred by most consumers of foods of animal origin (Kim et al., 2019). Since pork and poultry meat are the most consumed livestock meat globally (Camilla et al., 2022), insect meals may suffice the demand for protein sources in the diets of these animals.

To avoid competition, it is recommended to utilise less human-edible insects in Ugandan culture for use in pork and poultry meat production, such as black soldier fly (BSF) larvae which are abundant but less acceptable as food by most consumers in Uganda. Other possible alternatives are house crickets, even though they are more acceptable as human food. With the multicultural setting of Uganda, there could be changes in consumption preferences (Olum et al., 2021), and the latter might also become less acceptable as human food but highly important in the animal feed industry.”

Initially, the BSF larvae were chiefly used in organic waste management. With the rising concern of expensive animal protein sources, it was considered that BSF could play a dual-role of recycling wastes and as a cheap alternative source of proteins in pig and poultry diets (Astuti & Komalasari, 2020; Mardewi et al., 2022; Ndotono et al., 2022; Pérez-Pacheco et al., 2022). BSF larvae are rich and well balanced in the limiting amino acids in pig and chicken diets, Lysine, methionine and Threonine. The BSF larvae also have an amino acid profile better than that of soybean meal, one of the key ingredients in poultry diets (Abd El-Hack et al., 2020). Since BSF larvae are readily raised on organic wastes, they are undoubtedly a potential cheap alternative to soybean meal and ensure an environmentally sound pork and poultry meat production system. Several crop residues have been used to raise BSF, and the substrate is said to determine growth performance and nutritional composition of the resulting larvae (Ewald et al., 2020; Galassi et al., 2021; Pliantiantgam et al., 2021; Scala et al., 2020; Shumo et al., 2019). For example, millet brew waste and decomposing avocado were reported to produce weightier black soldier fly larvae with comparable crude protein content as cattle and swine manure (Hudson et al., 2019). A mixture of fruit and vegetable wastes produces BSF larvae with similar protein content as larvae fed on a broiler feed, but with reduced lipid content (Addeo et al., 2021). Irrespective of the substrate used, however, several studies have proven the potential of utilizing BSF larvae in production of good poultry meat.

When fed to broiler chickens, BSF larvae produce heavier carcasses than chicken fed on soybean meal (Altmann et al., 2020). In addition, Altmann et al. (2020) also reported an enhanced effect on

marbling although not significant. To the contrary, full replacement of soybean meal with BSF larvae was not recommended by Murawska et al. (2021) owing to the reduced meat-eating qualities of juiciness and taste intensity. However, the feed conversion ratio was improved at total substitution of soybean meal with BSF larvae. To avoid compromising eating quality, it is recommended that replacement should not exceed 50%, and not more than 10% of the entire diet (Kawasaki et al., 2019; Murawska et al., 2021). Although studies by Abd El-Hack et al. (2020) and Cullere et al. (2019) realised an enhanced SFA composition, the former authors acknowledged that the cause was the fatty acid composition of the substrate onto which the BSF larvae were reared. Hence, there is a need to explore the suitable substrate combination which can produce BSF larvae with enhanced PUFA concentration. Alternative options could be exploring the potential of developing BSF meals augmented with ingredients rich in PUFA like sweet potato vine powder and pumpkin peel and pulp to potentially counteract the high SFA content.

Also, in pork production BSF has been proven to have the potential to increase production volumes with minimal costs. BSF meal is one of the cheapest protein sources with potential to replace fishmeal and soybean Meal (SBM) in pig diets (Biasato et al., 2019; Chia et al., 2020; Herrera et al., 2022). As earlier mentioned, BSF meal is rich in lysine, which is also the most limiting amino acid in pig diets. Its ileal digestibility is 88%, which is higher than for fish meal (86%) and bone meal (84%) and comparable to the 89% of SBM (Crosbie et al., 2020).

Unlike in chicken meat, BSF meal has been reported to improve the fatty acid profile of pork when it replaced SBM at 100% level (Herrera et al., 2022). The authors reported an increase in mono- and poly-unsaturated fatty acids composition, and precisely, the Omega-6 fatty acids were significantly improved. In addition, pigs have been reported to generally like eating BSF larvae, probably due to the experienced nutritional consequences (Ipema et al., 2021). Utilising them for improving pork production might, therefore, meet high acceptability by the pigs.

In both cases (for pork and poultry meat), however, consumer acceptability studies need to be conducted and consumer willingness-to-pay for the products ascertained.

Housefly larvae and mealworms are mentioned as potential meals that could be used as protein sources at varying levels without compromising the performance and meat quality attributes (Huis, 2021; Kim et al., 2019). The house cricket (*Acheta domestica*) was also reported as a potential alternative protein source for use in pig and poultry diets (Hajj et al., 2022; Hong & Kim, 2022) to enhance pork quality.

4.3. Strategies to enhance adoption of crop wastes in pork and poultry meat production

Any strategy to promote the use of these postharvest wastes in pig and poultry production should prioritise first building the capacity of extension service providers. Using these wastes in pork and poultry meat production will require a holistic training exercise to the producers. Although these wastes are available, farmers lack knowledge on the utilisation of these feedstuffs to produce high-quality pork and poultry meat. Hence, training them would be important in the pursuit to have these wastes used in feed formulation. Valorising these wastes would also be important, especially, to ensure production of clean materials. Quality checks to ensure that crop wastes are free from heavy metal contamination, especially, those grown in soils laden with heavy metals, for example, around steel processing industries (Mpewo et al., 2023), should be put in place. Moreover, in order to prevent possible food-borne outbreaks, microbiological controls for detection of at least *Salmonella* spp., *Campylobacter* and *Listeria Monocytogenes* should be carried out.

In view of Uganda's National Animal Feeds Policy, the proposed innovations in the current review curb the challenge of bulkiness, which deters the use of crop wastes. If adopted, there could be reduction in the feeding costs which is also a strategy in the policy as a means of ensuring profitability of livestock enterprises in general. However, a standard for the use of post-harvest wastes and products from post-harvest wastes needs to be developed by Uganda National Bureau

of Standards (UNBS) to regulate their inclusion in pig and poultry diets. The standard should specify the treatments on wastes and hygienic handling to avoid microbial contamination as this may be a source of infection to the animals. The standard should also elaborate the rearing standards for the insects to be used in pig and poultry diets.

5. Conclusion

Uganda has the potential to meet the demands of pork and poultry meat for the respective consumers. The high cost of feeding has, however, constrained production of the two products, and worst of all, made most farmers compromise the quality of meat they produce, especially in terms of fatty acid balance. The current review has revealed the potential of using readily available low-cost ingredients to enhance the volumes of production of pork and poultry meat, while enhancing the quality of the two products. It is recommended that capacity of extension workers be built in this subject. These will be at the forefront in efforts to ensure farmers adopt judicious utilisation of these postharvest wastes for production of high-quality pork and poultry meat.

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Data availability statement

All the necessary data for this work is included within the paper.

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