APPLICATION OF CIRCULAR ECONOMY PRINCIPLES TO LIVESTOCK PRODUCTION IN VIETNAM

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ABSTRACT

Global food production is under pressure to produce more from limited resources, with further expectations to reduce waste and pollution and improve social outcomes. Circular economy principles aim to design out waste and pollution, minimise the use of non-renewable external inputs and increase the lifespan of products and materials. Waste sources on Viet Nam livestock farms and options to reduce waste and improve circularity were reviewed. Waste reduction should begin with systems design, while recycling should be at the bottom of the hierarchy. On-farm resource use efficiency has been widely studied, but there are also opportunities to repurpose waste and integrate systems. The use of organic waste products as feed occurs to some extent, but they present both opportunities and challenges. More farm waste recycling opportunities are becoming available, with new products available from waste processing, such as. Circular strategies in Viet Nam livestock require more analysis to determine economic, social, cultural and environmental outcomes.

Keywords: *material flow, recycling, resource use efficiency, waste management*

INTRODUCTION

Among the agricultural sectors, livestock plays an essential role in the supply of global food security. In this way, 34% of the protein consumed worldwide comes from meat, eggs, and milk. Besides the nutritional importance, economically, 25.26% of the Viet Nam agricultural gross domestic product derived from livestock. Livestock activities are still a means of livelyhood for many farmers, emphasizing the importance of this sector to society. However, the growth of the livestock sectors has affected the environment, driving the depletion of natural resources, pollution, and greenhouse gas (GHG) emissions. These factors compromise these practices' sustainability and future viability (Bosch-Serra et al., 2020).

According to GSO (2022), livestock sector discharges 60.4 million tons of manure. Besides, more than 100 million tons of agri-byproducts are derived from agricultural activities, of which only 52.2% have been collected and used (DSTE, 2022). Furthermore, food waste from big cities have not been separated and treated properly so that it causes waste large feed source for livestock and pollutes environment. South Korea banned food scraps from its landfills almost 20 years ago and turned food waste into animal feed, fertilizer and fuel for heating homes (John Yoon, 2023).

The management of waste, especially agricultural waste, considering the principles of circular economy (CE) is crucial for the future viability of these activities, the recovery of by-products, energy, nutrients, and water reuse are fundamental to the closure of the materials cycle (Awasthi et al., 2019; Wainaina et al., 2020).

Here, we give an overview of current examples of application of circular economy principles in livestock farming, noting some costs and benefits, and outlining the gaps in knowledge that need addressing to improve circularity in Viet Nam livestock sector.

Approach

We searched literature using the Google database, with the search terms in the title of "circular economy in livestock production" and "review", producing 41 articles. Titles were assessed for their potential application to agriculture. Relevant articles from this search, along with those referenced within them, information sourced via the website and from a search of circular terms such as farm waste and recycling, nutrient, water and energy efficiency, organic fertiliser and integrated enterprises.

RESULTS AND DISCUSSION

Resource use and waste on livestock farms

Anually, Viet Nam agricultural production generates more than 100 million tons of by-products, of which 40-50 million tons of rice straw, 11 million tons of maize, over 50 million tons of other crops (Derpartment of Crop Production, 2022). The proportion of crop waste and by-products (peanut husks, corn stalks, rice straw, cassava stalks, soybean husks, etc.) collected and used is only 52.2%. There have 29% of agri-byproducts been used as livestock feeds, 45.9% burning in fields, 7% for making bedding for livestock, growing mushrooms, covering the roots of crops, etc (Derpartment of Crop Production, 2022). A significant amount of straw is burned right in the fields in some places in the North and Central regions, causing air pollution, obstructing traffic, affecting human health. Meanwhile, the market for collecting, packaging, transporting and trading rice straw in the Mekong Delta is increasingly developing. In the 2021 Winter-Spring crop in Dong Thap province, the selling price of straw is about 55,000-75,000 VND per 1,000 m^2 of rice field, equivalent to 400 VND/kg, the price of straw near the inter-commune road is 15,000 VND/bundle, equivalent to 1,250 VND/kg. If transported far away, the selling price of straw at the facility for livestock farming, mushroom growing, gardening... is about 25,000 VND/bundle, equivalent to 2,083 VND/kg. Thus, rice farmers, in addition to harvesting rice, can also earn an average of 550,000 VND/ha of straw if sold after harvesting. Besides that, huge amount of food processing by-products such as durian peels, passion fruit, pineapple peels, etc. and poor quality fruit products that cannot be sold, do not handle properly, cause polluting the environment.

According to estimates in 2020, the total herd of livestock and poultry in our country discharged over 60.4 million tons of manure and over 290 million m^3 of urine (General Statistics Office, 2020). In addition, every year there are millions of tons of litter discharged from the livestock industry, but there is no survey data to assess the source of this by-product.

Opportunities to minimise inputs or increase efficiency

A large number of Vietnamese farms have installed biogas digesters for swine manure management. By the end of 2018, the country had a total of over 662,000 biogas plants to treat livestock waste, an increase of over 230,000 plants compared to 2015 (DLP, 2020). From 2003 to the end of September 2019, the Ministry of Agriculture and Rural Development was the managing ministry of 4 projects related to supporting the construction of biogas plants, including the Biogas Project for the Livestock Industry (BP Phase I, II, III) funded by the Royal Government of the Netherlands, the Project to Improve the Quality and Safety of Agricultural Products and Develop a Biogas Program (QSEAP) with a loan from the Asian Development Bank, the Livestock Competitiveness and Food Safety Project (LIFSAP) with a loan from the World Bank and the Low Carbon Agricultural Support Project (LCASP) with a loan from the Asian Development Bank. The total number of biogas plants supported by the 4 projects is

283,787, accounting for 42.3% of the total biogas plants in the country, of which the BP Project accounts for 61.3%, the LCASP Project is 20.9%, the QSEAP Project accounts for 10.9% and the LIFSAP Project contributes 6.9%. The total number of biogas plants managed by the Ministry of Agriculture and Rural Development has significantly contributed to the completion of the target of building 500,000 biogas plants by 2020 if Vietnam implements it itself and 800,000 biogas plants if there is support from the international community as committed by Vietnam in the National Self-Determination Commitment and surpassing the time limit of nearly 2 years. Among the biogas-related projects managed by the Ministry of Agriculture and Rural Development as the above-mentioned Ministry, the BP Project is the first project in Asia to have successfully registered with the Gold Standard International Certification Organization (GOLD STANDARD) on voluntary greenhouse gas emission reduction from biogas plants within the framework of the Project for the first credit period since 2013 with 05 credit issuances. As of September 2020, the Project has successfully issued 5 credit periods with a total of over 3.2 million credits, commercializing all of these credits on the international market, earning the project over 170 billion VND to reinvest over 50% of project activities (DLP, 2020).

Biogas have been used as fuel for cooking, lighting and electricity-generator. Phan Van Hoa (2014) reported that one biogas system of 7.8 m^3 requires an initial investment of 7.6 million VND, but it can bring an average income amount of 2.6 million VND/year and the cost can be fully clawed back after three years. Tran Sy Nam et al. (2021) study the community biogas renewable energy (CBRE) model in Can Tho province. The results were that a medium-scale livestock around 37 pigs per farm (ranging between 26 and 52 pigs) in the CBRE model provided enough biogas used by 5 households with 25 members in total (i.e. 1.5 pigs for a person), with the average of biogas-combustible time and biogas-consumption of each household volume was 1.87 h/day and 0.74 m^3/day, respectively. The CBRE model helped farmers reduce GHG 12.9 tons CO_2eq/year (~70%) in terms of the utilization of traditional energy sources combined with biogas, and with shared biogas, farmers reduced GHG 2.58 CO_2eq/year. Cost savings was 1.04 million VND/year per household. Phan Qui Tra and Dao Xuan Han (2015) studied a case of install a system to recover biogas produced from swine manure to generate electricity. The results indicated that a farm with 7000 head can created about 607m^3 biogas/day; which can generate 653.2 kWh/day if used for power generator on average. This can save about 24 million VND/month. The utilization of biogas for power generation can reduce CO_2 emmision by 192.4 tons per year (Phan Qui Tra and Dao Xuan Han, 2015).

Barries to biogas technology

Water is used for three main purposes in swine production: animal drinking, animal cooling, and facility/equipment washing. Animal drinking consumption was approximately 80% of total water usage (Muhlbauer et al., 2010). Swine facility and equipment washing water usage were obtained and analyzed primarily from the producer survey and found to account for 5-10% of total site water usage (Muhlbauer et al., 2010). Swine producer use a lot of water for cleaning animal sheds. In Vietnam and other Asian countries, swine manure is managed as slurry, and as liquid and solid manure from in-house separation (Cu Thi Thien Thu et al., 2012). The SNV organization advises farmers to feed the digesters with manure and water at a ratio of 1:3. This advice had not reached all farmers, and they therefore used an arbitrary amount of water for cleaning the pigpen and flushing manure into the bio-digesters they stopped adding water when the pigpen was clean. In Hanoi, the average ratio of manure to water was about 1:9 in the summer and 1:8 in the winter, and in Hue the numbers were 1:20 and 1:16, respectively.

Consequently the manure is very dilute and biogas production is low due to a low retention time (Cu Thi Thien Thu et al., 2012).

Almost all farms used chemicals to clean pigpens (Cu Thi Thien Thu et al., 2012). The chemicals such as powdered lime, iodine and chloramine are used to clean the pigpen af ter a batch of fattening pigs has been removed to avoid spreading disease to the new batch of pigs. Farmers are aware that chemicals can affect the fermentation process and have installed a separate pipeline that carries washing water with chemicals around the digester (Cu Thi Thien Thu et al., 2012).

Opportunities for re-use

Over 304 million m^3 of wastewater were discharged from the main livestock species (DPL, 2020). The industry needs to find a way to treat and reuse waste to reduce greenhouse gas emissions, thus protecting the livestock environment. Nguyen Thi Huong Giang et al. (2021) investigated 123 intensive swine farms located in four provinces throughout Viet Nam (Ha Noi, Thai Binh, Ha Tinh and Dong Nai). The result indicated that there were 37% of total surveyed farms irrigating their fruits, 15% of farms used wastewater for cash crops or wooden trees, 9% using wastewater to irrigate vegetable and only 4% irrigated paddy rice by swine wastewater. However, the wastewater samples analysis of some farms pointed out that, many other components of swine wastewater might be harmful for environment and other living organism, especially coliform contamination. The authods reported that reusing wastewater is an appropriate solution to increase the efficient use of water in swine production (Nguyen Thi Huong Giang et al., 2021).

Ministry of Agricultural and Rural Development issued Circular No. 28/2022/TT-BNNPTNT dated 30 December 2022 (Promulgating national technical regulation on livestock wastewater used for crops), in which the levels of heavy metals must be below the allowable values for crops to limit environmental pollution and human health.

A large amount of Vietnam's food waste (FW) ends up in landfills, only 20% of which are sanitary (Nguyen et al., 2020). This causes significant environmental problems such as greenhouse gas emissions, high carbon footprint, leachate, and landfill-related conflicts. The FW generation in Ha Noi was 0.65, in Ho Chi Minh city was 0.76 and in Da Nang was 0.52 kg/person/day (Pham et al., 2021). According to Kato et al. (2012, 2015), a large amount of food waste is collected by pig breeders in urban areas of Da Nang, with the amount collected dependent on the number of pigs on the farm and the number of collection trips per day. The study found that farmers collect about 26.3 metric tons of organic waste every day, which is equivalent to 4.1% of the domestic solid waste collected by the local government. Agrifood waste, even when not fit for human consumption, can be used in animal feed (Westendorf, 2000). For Dou, Toth and Westendorf (2018), safely integrating food leftovers into animal feed appears to be a sustainable option for developing countries from both a socioeconomic and environmental perspective.

More recently, the African swine fever epidemic in Asia, particularly in China and Vietnam, is raising new questions about these scientific conclusions and is a challenge. According to Juan Lubroth, FAO's Chief Veterinary Officer, half of the spread of the disease in Asia is due to the contamination of vehicles and personnel working on farms, and one third is due to feeding pigs food waste (Cesaro et al., 2019). Adequate heat treatment of food waste would be sufficient to inactivate viruses and kill other micro-organisms, but more insight is needed also in other hazards, such as non-infectious pathogens, physical and chemical contaminants (Dame-Korevaar et al., 2021).

DPL (2020) reported that bio-bedding have been used for livestock production in Viet Nam for more than a decade. The whole country has over 7.58 million m^2 of bio-bedding applied at both household and farm scales, of which household scale accounts for 67.9% and farm scale accounts for 32.1%. Bio-bedding is mainly applied for poultry farming (accounting for 88.4%), pigs (accounting for 11.0%), cows (0.5%) and buffaloes (0.2%) (DPL, 2020). The use of biological padding in beef cattle breeding has reduced the concentration of H_2S and NH_3 gases in the barn to improve the environment in the barn to help the herd grow evenly, healthy, and maintain growth. In addition, it helps to save care work, clean cages and bring high economic efficiency (Phan Tùng Lâm et al., 2023).

Deep bedding with agri-byproducts have been used widely in the world. The use of deep bedding, widely accepted for poultry, remains low in Brazil for pig production (Hötzel et at., 2009). A number of studies report better performance in pigs reared with rather than without bedding substrate (Lyons et al., 1995; Guy et al., 2002; Ramis et al., 2005). Deep bedding can be presented as an alternative to improve the welfare of pigs (Hötzel et at., 2009).

The daily turnover of the bio-bedding fosters suitable temperature and humidity conditions by incorporating the waste from housed animals, thereby enhancing aerobic microbial activity and facilitating the composting process (Leso et al., 2020; Silva et al., 2023). At the end of the animals' housing period, the resulting residue is commonly used as a source of organically derived nutrients for fertilizing agriculturally essential plants (Tomazi and Gai, 2022). This residue exhibits high levels of nitrogen (N), phosphorus (P), and potassium (K), reducing costs associated with mineral fertilizers for food production (Caldato et al., 2020).

An important benefit of composted bedding material is as a source of organic matter and nitrogen fertilizer for the soil (Llonch et al., 2021; Llonch et al., 2020). Trang Linh limited company, in Ba Ria – Vung Tau province, is raising more than 38,000 pigs, of which more than 90% are fattening swine and around 10% are sows. They use biological bedding for manure management in closed cool pens. The company built a factory specializing in producing organic microbial fertilizers from used bio-bedding. By applying this circular process, the company has solved the problem of environmental pollution in livestock farming, and also has an additional source of income from selling organic fertilizers for crops.

Opportunities for recycling

DLP (2020) indicated that composting is a traditional livestock waste treatment method commonly applied by livestock farmers. Over 2.88 million livestock households and 7,073 livestock farms compost livestock manure into organic fertilizer. The rate of livestock facilities applying livestock manure composting is 43.9% for poultry, 25.7% for pigs, 20.3% for cows and 7.9% for buffaloes.

Raising insects that eat livestock waste such as earthworms and black soldier flies in many localities has brought double benefits to livestock farmers, obtaining protein from insects for livestock and aquaculture and organic fertilizer from insect feces. This is a sustainable solution and very suitable for household livestock farming to proactively handle livestock waste and increase income from selling insects and organic fertilizers from insects.

Le Duc Thao et al. (2023) evaluated the effect of the ratio of pig manure to dried cassava residue on the growth and chemical composition of earthworms. The results showed that the increase in earthworm biomass, growth rate and feed conversion efficiency tended to enhance according to the increasing ratio of fresh pig manure in the diet for earthworms. However, it did not affect the chemical composition of the earthworms.

Black soldier fly larvae (*Hermetia illucens L.*) have been experimented and used to treat livestock manure and organic waste in Viet Nam. Nguyen Thi Bich Hao et al. (2017) indicated that under local conditions, black soldier fly larvae grows well on soya pulp and mix of chicken manure and soya pulp. Soc Trang Solid Waste Treatment Joint-stock Enterprise carried out a trial, in which the Black soldier fly eggs were hatched and raised on vegetable and fruit by-products such as sweet potatoes, okra, bell peppers, etc. Each 10 grams of black soldier fly eggs can process 100 - 150 kg of organic waste and in 10 days, 10-12 kg of Black soldier fly larvae can be collected (SPWC, 2018). The protein content of black soldier fly larvae (BSFL) is at a low level for insects, accounting for about 40 % or more of the dry weight, but the essential amino acid composition is more balanced, with high levels of Arg, Lys and Met to supplement the essential amino acid deficiency (Zulkifli et al., 2022). Its crude fat content is higher than most insect foods, and it is also a better source of lipids. The meal and oil of BSF larvae have been considered as animal grade substitutes for fish meal (FM) and fish oil for feeding carnivorous fish and other animals (Belghit et al., 2019; Wang et al., 2017). Therefore, using Black soldier fly larvae to treat livestock manure and organic waste is promissing way to solve environmental pollution and supply good protein source for livestock farming.

Regenerative use of waste products

Ruminant livestock can have a critical role in circular economies through utilising crop residues and wastes from human food production and processing (Burggraaf et al., 2020). Crop waste and by-products have the largest volume in the total volume of agricultural waste and by-products and can be used as sources of animal feeds. DSTE (2022) reported that post-harvest crop waste from rice straw accounts for a large volume (42.8 million tons), corn stalks (10 million tons), vegetables and fruits (3.6 million tons), cassava stalks (3.1 million tons), cashew nuts (3.1 million tons) and others (6.1 million tons). By-products from agricultural processing in the crop industry include: 8.6 million tons of rice husks, 3.5 million tons of sugarcane bagasse, 1.4 million tons of corn cobs, 1.3 million tons of cassava husks and 2 million tons of others (DSTE, 2022). Ago-byproducts have been used widely as animal feeds. They are chemically or biologically treated by using urea, lime or effective microorganism to improve nutritive values.

Integrating crop-livestock systems

Integrated Crop-Livestock Systems are ecologically/environmentally sound because all byproducts are being recycled by crops and livestock within the farm and hence there is no waste or polluted materials flowing outside the system and no or very less emissions of greenhouse gases from these systems (FAO, 2024).

In Vietnam, the combination of rice farming with duck rearing has proven successful. Ducks forage in rice paddies, consuming insects and weeds, which reduces the need for chemical pesticides and manual weeding. The ducks also provide an additional income source through egg and meat production (Phong et al., 2007). Another example is integrated production model of cows - earthworms - grass/corn – livestock/poultry – fish. The model of utilizing livestock manure to raise earthworms; using earthworm manure to fertilize grass/corn; earthworms are used as feed for livestock, poultry, fish. This results in bringing high economic efficiency, reducing greenhouse gas emissions, protecting the environment.

CONCLUSIONS

Viet Nam farmers have a suite of options available to follow circular economy principles that design out waste and reduce harm to the environment. Resource use efficiency will continue to improve on farm as new knowledge and technology becomes available that improves profit, lifestyle or helps to meet environmental regulations. For livestock to address circularity at a larger scale, more research is required to quantify and determine the best use of biological resources and their associated waste across enterprise types, determining the skills and technologies required and the economic, social, cultural and environmental impact of this amongst the associated supply chains. However, optimal benefits may not be achieved unless industries work together, and appropriate policies are implemented to reduce waste.

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