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Recycling of Livestock Manure in a whole Farm Perspective

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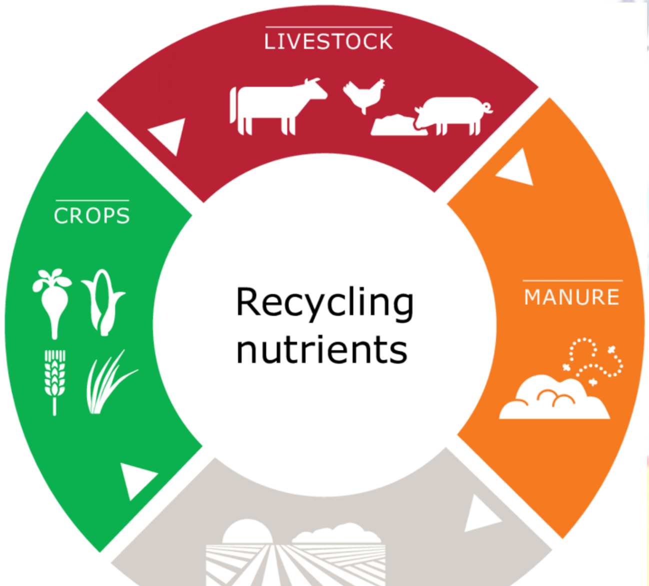
ABSTRACT

Intensification increases the environmental impact of livestock production systems. Efforts to recycle nutrients in livestock manure for crop production will effectively reduce several pollution problems, although general solutions are difficult to devise in view of the diversity in production systems, management strategies and legislation between countries and regions. This paper argues that a whole-farm perspective taking side-effects and on-farm interactions into account is needed to determine the cost-effectiveness of strategies to mitigate pollution from livestock manure management. Animal feeding plays a key role in the control of nutrient flows on livestock farms, since the diet affects the composition of excreta. There is a great potential for manipulating manure composition by diet manipulations. Manure is a significant source of heavy metals in soil, and in Europe the permitted levels of Cu and Zn in livestock diets have been lowered to reduce their environmental impact. A variety of environmental technologies are being developed for treatment of manure, many of which have a significant potential for reducing nutrient losses. Internationally agreed and enforced regulations that link pollution control with the adoption of best available technologies could provide the demand that is needed to drive research and development. In the past, policy-makers have typically focused on individual environmental problems. It is essential, however, that the efforts to close nutrient cycles on the farm are accompanied by a corresponding reduction in total inputs, otherwise losses after field application will increase. Integrated assessment tools are needed which can evaluate all internal flows of nutrients, imports and exports, energy use, hygienic risks and contaminants, as well as costs, at the farm-scale and beyond. It is important to consider pollution control strategies for a farm in the framework of local and regional pollution control planning.

KEYWORDS: recycling, livestock, manure, whole, farm, pollution, nutrient, management

I. INTRODUCTION

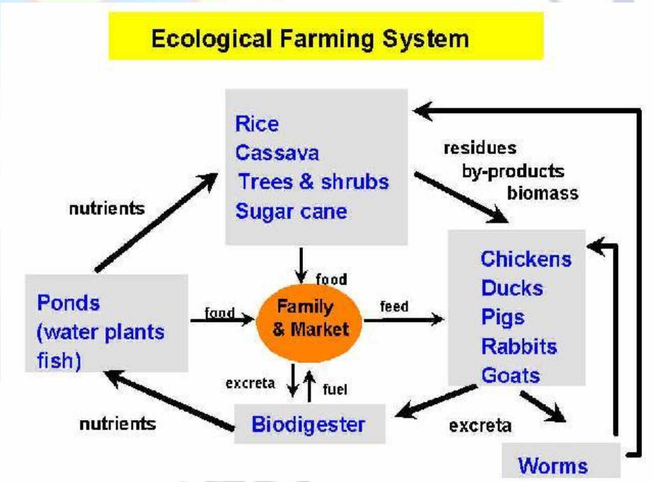
Worldwide agricultural production is increasing dramatically, and it tends to become concentrated on larger production units in order to increase the profitability of the enterprise. Agriculture manages large volumes of animal manure, as well as crop residues and imported wastes. This biomass is both a source of valuable plant nutrients and a threat to the environment. The whole-farm perspective of agricultural waste treatment and management has been selected as a central theme many conferences. The ultimate goal of the work presented in the many contributions is to ensure a rational recycling of nutrients while controlling environmental hazards such as odour, ammonia (NH3) and greenhouse gas (GHG) emissions, nutrient leaching, and dissemination of pathogens, heavy metals or organic micro-pollutants in the environment. Research activities typically focus on an individual production factor or environmental effect, e.g., reducing the N surplus of pig diets or increasing the energy yield from organic waste materials in digesters. [1,2]



But with a strong focus on one factor there is a potential that important side effects or interactions are overlooked or disregarded because they occur "downstream" in the manure management chain. The best evaluation of a change in practice is obtained using a holistic approach linking feeding, housing, treatment processes, storage conditions and field application practices. Finding practical methods or models to address the whole-farm perspective, however, is a great challenge. Firstly, agricultural production systems are extremely diverse, and secondly the various indicators of sustainability are not always easy to compare. Recycling of livestock manure to partially substitute synthetic fertilizer nitrogen (N) input is recommended to alleviate the environmental degradation associated with synthetic N fertilization, which may also affect food security and soil greenhouse gas (GHG) emissions. However, how substituting livestock manure for synthetic N fertilizer affects crop productivity (crop yield; crop N uptake; N use efficiency), reactive N (Nr) losses (ammonia (NH3) emission, N leaching and runoff), GHG (methane, CH4; and nitrous oxide, N2O; carbon dioxide) emissions and soil organic carbon (SOC) sequestration is also possible. Substituting livestock manure for synthetic N fertilizer (with equivalent N rate) significantly increased crop yield by 4.4% and significantly decreased Nr losses via NH3 emission by 26.8%, N leaching by 28.9% and N runoff by 26.2%. Moreover, annual SOC sequestration was significantly increased by 699.6 and 401.4 kg C ha–1 yr–1 in upland and paddy fields, respectively; CH4 emission from paddy field was significantly increased by 41.2%, but no significant change of that was observed from upland field; N2O emission was not significantly affected by manure substitution in upland or paddy fields. In terms of net soil carbon balance, substituting manure for fertilizer increased carbon sink in upland field, but increased carbon source in paddy field. This suggests that recycling of livestock manure improves crop productivity, reduces Nr pollution and increases SOC storage. [3,4]

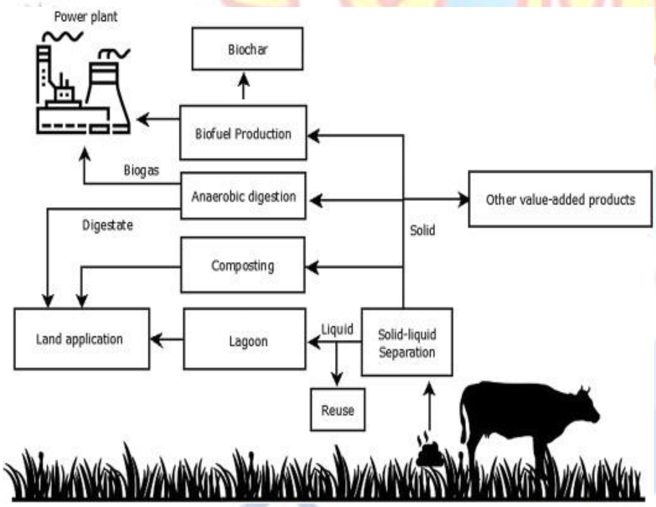
Observations

Vermicomposting is a mesophilic biooxidation and stabilisation process of organic materials that involve the joint action of earthworm and microorganism. This increases the rate of the decomposition process by accelerating the stabilisation of organic matter and greatly modifying its physical and biochemical properties. [5,6]



Microorganisms produce the enzymes that cause biochemical decomposition of organic matter, but earthworms are the crucial drivers as they stimulate and increase biological activity by fragmentation and ingestion of organic matter and this will increase the surface area to be exposed to microorganism . Earthworms act as mechanical blenders and by comminuting the organic matter they modify its physical and chemical status by gradually reducing the C : N ratio and increasing the surface area exposed to microorganism . They also serve as agent of turning and aeration .[7,8]

A Vermicomposting process has two distinguished phases and is (i) an active phase, where the earthworms process the biomass, modifying its physical state and microbial composition. The effect of earthworm on the decomposition of organic matter during vermicomposting processes is due to gut associated processes (GAPs), and it includes the modification that organic waste and microbes undergo during their passage through the gut of earthworm. (ii) A maturation like phase, also known as cast associated processes (CAPs), is marked by the displacement of the earthworm towards fresher layers of undigested waste, where the microbes take over in the decomposition of waste and the effects of earthworm are mainly indirect and derived from GAPs . Vermicompost is a finely divided, peat-like material with a low C : N ratio, excellent structure, porosity, aeration, drainage, and moisture-holding capacity, and it supplies a suitable mineral balance, improves plant nutrient availability, and could act as complex-nutrient-source granules [9].



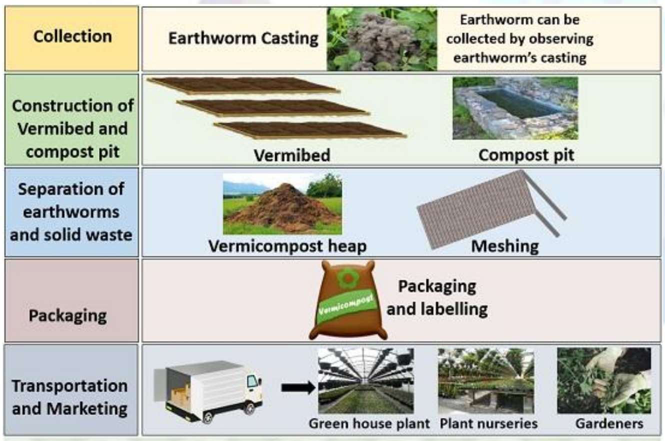
Earthworm plays a significant role in processing ruminant manure as it reduces the moisture content, pH, and electrical conductivity compared with composting . These might be attributed to high rate of mineralisation, this can be up to 60% , and it brings accumulation of organic acids from microbial metabolism and enhances production of fulvic and humic acids during decomposition. Carbon dioxide evolution decreases rapidly (44%) one week after the introduction of earthworms, and continued at a lower rate throughout the 17 weeks, 51% reduction as compared to 22% without earthworms, indicating increasing organic matter stability. [10,11]

Vermicomposting enhanced nitrogen mineralisation and increase the rates of conversion of ammonium-nitrogen into nitrate. This will increase the concentration of nitrate-nitrogen to 28% after 17 weeks, while in compost the nitrate-nitrogen concentration will increase by 3%. This suggests that earthworms produced conditions in the manure that favoured nitrification, resulting in rapid conversion of ammonium-nitrogen into nitrates .

Comparison of compost and vermicompost showed that vermicompost had significantly lower C : N ratios, and this was due to loss of carbon as CO_2 during bioxidation and production of mucus and nitrogen excrements increase the level of nitrogen which lower the C : N ratio With regard to lignolysis, at the beginning of vermicomposting, lignolysis was more efficient compared with composting; however, at the end fraction identified as cellulose increased particularly in the vermicompost, apparently the rate of cellulolysis and lignolysis was slightly faster in the compost. [20] Vermicomposting increases the ash content and accelerates the rate of mineralisation which is essential to make the nutrients available to plant . Ruminant manure vermicompost was found to have the highest total phosphorous compared to other livestock manure vermicomposts .Among the effects of different microorganisms and enzymes contributing to such increased availability of phosphorus, major emphasis may be given to the presence of very high concentration of phosphate-solubilising bacteria in the vermicast. Addition of vermicompost to the soil adds to its mineralogical nutrients and contributes to its biological fertility by adding beneficial microbes to the soil. It favourably affects soil pH, microbial population, and enzyme activities. It also reduces the proportion of water soluble chemicals, which causes possible environmental contamination. All these help in increased production of healthier crops .[12]

II. Discussion

The major problems associated with traditional thermophilic composting are the long duration of the process, the frequency of turning of the material, loss of nutrients during the prolonged composting process, and the heterogeneous nature of the product. The major drawback in the vermicomposting process is that it must be maintained at temperatures below 35 °C which does not remove all the pathogens.[13]

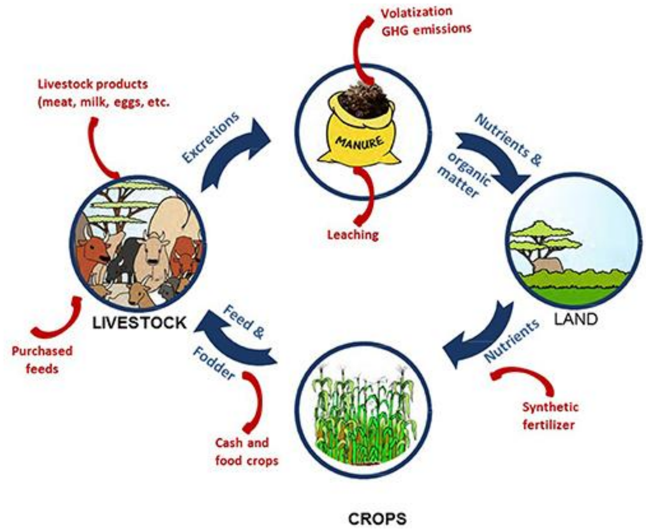


Process of Vermicomposting

Thus, an integrated system approach that harvests advantages from both processes would be necessary to provide a product free of pathogens, and a product with desirable characteristics at a faster rate than either of the individual processes. If vermicomposting is used in combination with the traditional composting, the required temperature for ensuring adequate pathogen kill would be achieved. Above said approach was tried using vermicomposting process for 30 and composting for 28 days in sequences[19] . Combining the two systems resulted in a superior product with more stability and homogeneity. Another trial of this combination of both processes has been successfully conducted . The chemical properties of the substrates processed by different treatments at experiment conducted . The quality parameters like pH and EC increased after composting and decreased after vermicomposting and the combined treatment . The lowered C:N ratio is a good indicator of quality organic fertilizer and it was significantly lower in the treatments involving vermicomposting suggesting that it was more intensely decomposited. The concentration of mineral N (mainly NO−3NO3-) was significantly higher in all treatments than raw cattle manure, indicating an important degree of mineralization. Hence, earthworms change the degrading property of the manure. This was reflected by the lower EC, C to N ratio and pH in the substrates produced after vermicomposting.[14]

III. Results

Based on the field interviews, multiple case studies were employed to investigate the characteristics of livestock and identify the reasons for emergence, success factors, risk factors, operation mechanism, scalability, key elements, and environmental effects of alternative manure management systems. The conclusions are drawn as follows.



First, compost-based systems, product-based systems, substrate-based systems, and biogas-based systems were identified as the four main types of manure management systems, each possessing its success factors and risk factors. The adoption of a system was driven by various factors, including farmer's endowment of main resource elements, local weather conditions, regional economic development, and environmental regulations and policies.

Second, a market-oriented operation was the dominant operation mechanism of all the manure management systems. The key behind the mechanism was to build and maintain a smooth industrial chain of manure recycling, including the supply of raw materials before production, the implementation of technology during production, and the sales of products after production. Third, compared to manure's direct application to croplands, all four manure management systems could reduce nitrogen loadings from livestock farms and lower their environmental effects. Among the systems, biogas-based systems could reduce nitrogen loadings to the greatest extent, followed by product-based systems and substrate-based systems, and then by compost-based systems. [18]

Lastly, with the ongoing trend of intensification and consolidation of livestock farming, integrated management of manure with mixed recycling systems is imperative for reducing its environmental effects, which can benefit from the increasing role of third-party entities in manure recycling.

The study contributes to ongoing policy discussions in three ways. [15]

First, given the positive externalities of these sustainable manure management systems in reducing nitrogen loadings and improving the rural living environment, incentive-based policies such as subsidies, tax reductions, and low-interest loans should be used to encourage livestock farmers as well as third-party entities to adopt these systems.

Second, policy support from the government to streamline certain land use approval procedures and to facilitate land transfer between farmers can help remove barriers for livestock farms to adopt manure management systems that require large amounts of land, such as substrate-based systems.

Finally, technical assistance would benefit livestock farmers who adopt technology-intensive manure management systems, such as biogas-based systems. Government promotion policies such as subsidies for research and development of manure recycling technologies would also be desirable.[16,17]

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