RECYCLING LIVESTOCK EXCRETA IN INTEGRATED FARMING SYSTEMS

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Summary

Loss of soil fertility and species biodiversity, and environmental pollution, are negative consequences of modern agricultural practices in the industrialized countries where, on most farms, high-yield intensive systems of production have resulted in the physical separation of livestock and crop production. One outcome of this policy is that the disposal of manure from livestock units concentrated in a small area, often with no land attachment, has become a major problem.

In SE Asia, the integration of crops and livestock, and the use of manure as fertilizer, are traditional practices and are the basis of farming systems, especially at small-holder level. This article describes ways in which these systems can be made more efficient, more productive and more environmentally friendly, by applying simple, low-cost technologies for recycling the manure through biodigesters, duckweed ponds and earthworms.

1. Introduction

The deterioration of soil fertility through loss of nutrients and organic matter, erosion and salinity, and the pollution of the environment-of air, soil and water-are negative consequences of modern agricultural practices in the industrialized countries where the divorce of livestock and crop production has become the norm. Traditionally, livestock were a balanced-indeed an essential-component of farming systems, but the development of the chemical industry in the nineteenth century and the major impetus received from the discovery of oil, created opportunities for the low-cost supply of plant nutrients in inorganic form and led to the rapid displacement of organic manures derived from livestock excreta.

The increasing global awareness that resources are finite, and that the livelihood of future generations depends upon the maintenance of renewable natural resources, is now a major stimulus for initiatives that will lead to the more efficient use of these same resources. In industry, recycling of processed goods at the end of their useful life is now seen as a means of lowering costs of production and reducing the pollution caused by accumulation of these materials in the environment.

This article describes recent developments in the same recycling strategy as it can be applied to livestock.

2. Livestock Excreta as Livestock Feed

The accumulation of livestock excreta, chiefly from poultry kept in deep litter, was seen by some scientists as an opportunity to recycle this material as a feed for ruminant livestock, and there were even attempts to do likewise with the excreta from intensively-fed pigs and cattle. However, in all these cases the nutritional value of the manure is mainly a reflection of the spillage of feed which is almost inevitable when intensive systems of self-feeding are practiced. The high risk of disease from recycling wastes through livestock, highlighted by the recent outbreaks of Bovine Spongiform Encephalopathy (BSE), is now seen as a major deterrent to these practices. They will therefore not be considered further in this document.

3. Potential Benefits from the Recycling of Livestock Excreta

The potential benefits from the recycling of livestock excreta can be summarized as follows:

- A source of nutrients for growth of plants
- Control of pollution
- A renewable source of energy (biogas)
- Added value to the end-product as being of “organic”origin

The relative contribution that livestock excreta can make to the achievement of the above goals is a function of:

- The processing applied to the excreta after it leaves the animal
- The species of livestock in view of the differences in the anatomy and physiological characteristics of their digestive system
- The chemical and physical characteristics of the feeds that are given to the livestock
- The management system (especially the housing) applied to the livestock
- The ecosystem in which the farming system must function (temperate or tropical; arid or humid)

These features are often determined by economic issues, (for example the species and genotype of the livestock, and the feeding and management systems that are applied). Most of them are inter-dependent (i.e. the most appropriate way of processing the excreta depends on its physical characteristics, which in turn is determined by the livestock species, and by the systems of housing). However, decisions in all of these areas are increasingly seen to be affected by the role of livestock within the immediate ecosystem. In other words, the advantages that may accrue from an appropriate system of recycling of the excreta become a stimulus for decision-making in the selection of both the livestock species and the genotype within the species, and of the system of feeding and management. It follows that research on methods of recycling livestock excreta, and the development of appropriate technologies for this purpose, should be given high priority, as these eventually become important determinants of the farming systems that are selected in a given ecosystem.

4. Methods of Processing (Recycling) of Livestock Excreta

In order of priority these are considered to be:

- Anaerobic biodigestion (biodigesters)
- Vermiculture
- Aerobic biodigestion (composting)
- Direct application as fertilizer in fish ponds
- Direct application in or on soils for crop growth

Irrespective of the processing method that is applied, the concept of recycling implies an ecological and holistic approach to the use of natural resources in which livestock play an intrinsic role (Figure 1). It may not always be possible, or convenient, to incorporate all of the sub-systems in the overall process.

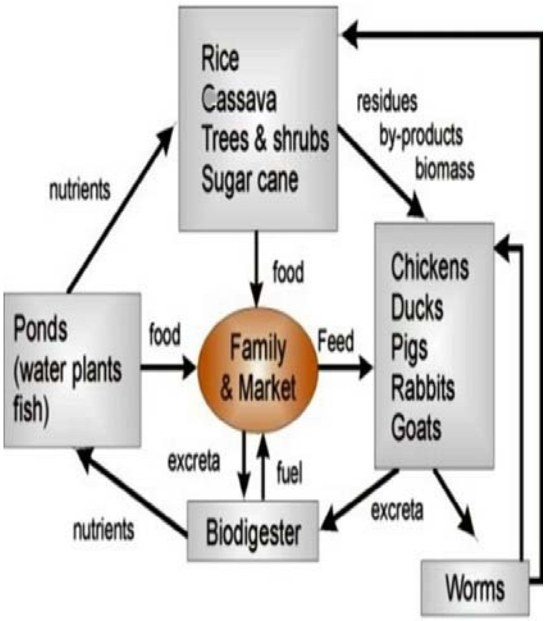

Figure 1. The integrated farming system.

Neither the biodigester sub-system, nor the pond, are essential for ensuring that plant nutrients are retained, as the essential cycle is between the crops and the livestock. Nevertheless, biodigesters and ponds are components in the system which:

- Increase the efficiency of uptake of plant nutrients derived from livestock wastes,
- Reduce the health hazards that might arise when livestock excreta is applied directly to the soil
- Reduce the release to the environment of greenhouse gases such as methane, nitrous oxides and carbon dioxide
- Give rise to products (biogas) and water plants which respectively contribute to family well-being (a clean fuel in the kitchen) and food security

This article describes a holistic approach to recycling of livestock excreta based on experiences gained in ecological farms in Colombia, Vietnam and Cambodia. The aim is to show the way to optimize the process, selecting the pathways that are most suitable for the different kinds of excreta likely to be produced in a small-scale family farm. An example of this approach is shown in Figure 2.

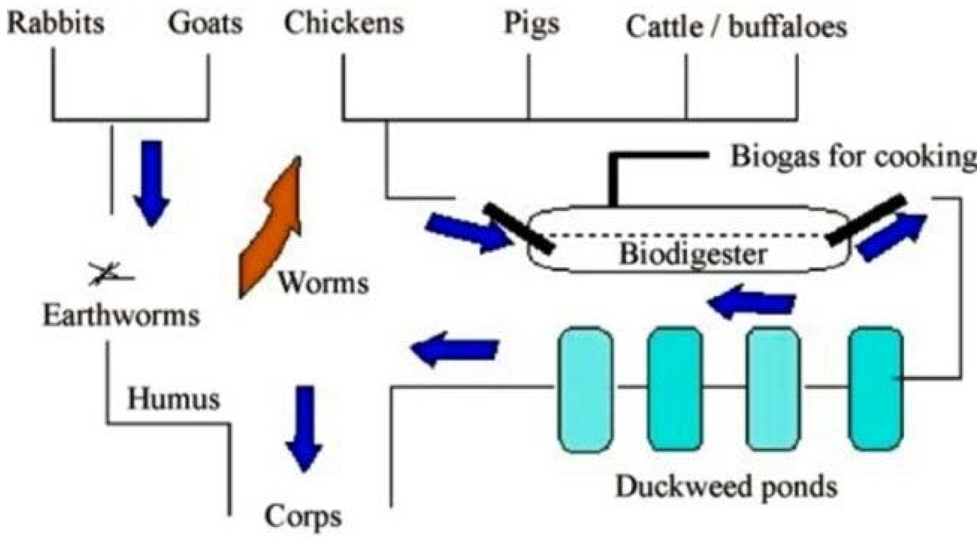

Figure 2. Optimum pathways for recycling of excreta in a small-scale farm.

5. The Biodigester Sub-system

5.1 Types of Biodigester

The biodigester is a closed medium in which livestock and human excreta (and/or other organic wastes) are fermented anaerobically giving rise to a gas (biogas) and a residue (the effluent) (see *Renewable Energy from Organic Waste*). Biogas is a mixture of methane and carbon dioxide the volume ratio of which is about 65:35 (substrates rich in lipids produce biogas with higher proportions of methane). The effluent contains all the original mineral elements that give rise to nutrients needed for plant growth, but the reducing anaerobic medium improves the efficiency with which they can be assimilated (e.g. the conversion of part of the organic nitrogenous compounds into ionic ammonia).

There are three main types of biodigester which originated respectively in India (floating canopy), in China (the fixed dome-dual compartment system) and in Taiwan (the plastic red mud tubular plug flow model). The Taiwan model has since been modified into a simpler form using tubular polyethylene film, standard PVC sanitary fittings and discarded motorcycle inner tubes. The Indian and Chinese models are undoubtedly the most robust and the most efficient. They are also the most expensive in terms of materials, the need for skilled artisans, and time taken for construction.

The materials required for the tubular plastic biodigester are low cost (from US$10.00 to US$50.00 for small-scale farm family units), the required materials can usually be found in the markets of major cities throughout the developing world, and they can be assembled and installed with unskilled labor. This article is concerned only with the low-cost tubular polyethylene model, in view of its cost-effectiveness as demonstrated by high rates of adoption by farmers in Vietnam without the need for subsidies.

5.2 Factors Influencing the Cost and Performance of Plastic Biodigesters

5.2.1 The Plastic Tube

Two types of plastic have been used for the tubular biodigester: poly-vinyl-chloride (PVC) and polyethylene. PVC film is manufactured by a rolling process, which results in sheets that must be welded with heat into a tube. By contrast, polyethylene is produced by blowing air vertically (forming a large bubble) through the molten plastic encased in a mould the diameter of which determines the diameter of the tube. The thickness of the plastic film is controlled by the rate at which the air is introduced into the process.

Making a tube by welding together PVC sheets is a skilled operation and not always successful. The facilities for the welding are rarely found except for in major cities. By contrast, tubular polyethylene needs no further processing and is ready to be used immediately it leaves the factory. The raw material is also cheaper than PVC.

Tubular polyethylene is therefore the material of choice. The cost is usually in the range of US$1.00 to US$1.50/kg, depending on whether it is purchased direct from the factory or from re-sellers. A tube of 80 cm diameter and thickness of film of 200 microns (the most common dimensions) weighs 500g per meter of length. For a biodigester that is 6 m long the need is for 15 m of tube (two tubes are used one inside the other) and 75 cm is required at each end for fixing the tube to the inlet and outlet pipes. This will weigh 7.5 kg and cost between 7.00 and 11.00 US$.

5.2.2 The Inlet and Outlet Pipes

Alternative types of inlet and outlet pipes are made from “fired” clay (ceramic), concrete and PVC. The relative advantages of each are indicated in Table 1.

Material	Preference	Cost	Weight	Ease of use
Ceramic	1	Low	Medium	High
Concrete	2	Medium	High	Low
PVC	3	High	Low	High

Table 1. Relative advantages of different types of inlet and outlet pipes.

5.2.3 Connecting the Tubular Film with the Inlet and Outlet Pipes

The tubular polyethylene is attached to the inlet and outlet pipes using rubber strips (5 cm diameter) made from rejected inner tubes from the wheels of vehicles. The relative advantages of the different sources are indicated in Table 2.

Preference	Source	Strength	Ease of use
1	Motor cycle	Good	High
2	Bicycle	Medium	High
3	Motor car	High	Medium
4	Truck	Very high	Low

Table 2. Relative advantages of different sources of rubber bands to secure the tubular polyethylene to the inlet and outlet pipes.

5.2.4 The Gas Line

There are only two choices: rigid PVC tube (id: 13mm) or flexible garden hose. The latter is cheaper but the former is preferable as there will be fewer maintenance problems, especially blockages in the pipe.

5.2.5 The Reservoir

The gas pressure in tubular plastic biodigesters is low: between 1 and 1.5 cm water column. If the cooking stove is situated more than 10 m away from the biodigester, the flow rate of the gas will be too low for efficient burning. The solution is to situate a reservoir as close as possible to the kitchen.

The reservoir is made from the same tubular polyethylene as the biodigester and usually it is 2–3 m long. It is closed at one end and the other is connected to the gas pipeline. A string is placed around the middle of the reservoir and can be tightened manually whenever a higher gas pressure is required (Photo 1).

Glossary

Biodigester:	A closed air–tight container in which manure (or other organic material) is fermented anaerobically
BSE:	Bovine Spongiform Encephalopathy
DM:	Dry matter
USD:	US dollars
VS:	Volatile solids
KW:	Kilowatt
N:	Nitrogen
PVC:	Polyethylene Vinyl Chloride
SE:	South–East
TS:	Total solids
Water column:	Pressure exerted by a column of water

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Biographical Sketch

Dr T. R. Preston was raised on a small family farm in the Lake District of NW England where he gained his first experience of the need to develop solutions to problems by making maximum use of local resources. He studied Agricultural Chemistry and Animal Nutrition at Newcastle University where he was awarded the degree of Ph.D. in 1955 and D.Sc. in 1972. His professional career began at the Rowett Research Institute, Aberdeen, Scotland where he developed novel systems of early weaning of calves and intensive (barley–beef) cattle fattening.

His first introduction to the tropics was in Cuba, where`he designed and then directed the Institute of Animal Science from 1965 to 1971. A major output of research there was the development of livestock feeding systems based on molasses. In Mexico and the Dominican Republic, he developed livestock feeding systems based on sugar cane. It was in the latter country, in 1976, that he became convinced of the need to recycle livestock manure through biodigesters. A floating dome "Indian"model was followed by the twin compartment, liquid displacement "Chinese" model. But dissatisfied with the cost and complexity of these constructions he quickly replaced them with the "red mud" PVC "plug–flow"model developed in Taiwan. The cost and difficulties of working with PVC film which needed to be welded into a tube was again the stimulus to search for a simpler solution. This he found by using polyethylene film, which is moulded in tubular form in the manufacturing process. The first working model, which was constructed on a small family farm on the outskirts of Addis Ababa in Ethiopia in 1981, has since been refined to the point where it can be installed in almost any country, as it uses material which can be purchased in almost all local markets. Over 8000 units have been installed in South Vietnam, the majority paid for and built by the farmers themselves.