The potential use of tropical silage for livestock production with special reference to smallholders

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Summary

This paper considers the range of possible raw materials that can be used by smallholders in the tropics and the various ways in which they might be preserved and used as animal feeds following ensilation. It concludes that for the systems to be applied they must be uncomplicated, safe, repeatable, have a low investment cost, use locally sourced equipment and consumables and give a rapid and significant return on any investment. The greatest potential exists where a fermentation system is used to preserve materials. It also suggests that the use of forage silages by gestating sows and growing – finishing pigs might be an effective and economically viable system of feeding for smallholders.

1. Introduction

Forages have been preserved using acids for many years and the process is referred to as ensilation. This term has also been adopted to describe the preservation and storage of protein-rich materials such as fish and animal products to be used as animal feeds. More recently this process has been used to preserve carbohydrate rich materials, either alone or on fermentation with other materials.

The essential feature of this means of preserving organic materials is the use of acids. These can either be mineral or organic, which can be provided by direct addition or produced by fermentation. Clearly the choice of acid will affect the composition and use of the ensiled product as well as having financial implications for the economic viability of its use.

For such a system to be suitable for smallholders in the tropics it must: -

- Have low investment costs.
- Be reliable and repeatable.
- Use uncomplicated technology.
- Use locally sourced equipment and consumables.
- Be safe.
- Give rapid and significant returns on investments.

This paper will therefore consider the various alternative silage production systems in the context of the above requirements.

Furthermore, since the large-scale ensilation of forage crops is well established world wide, this paper will focus on the use of wastes and by-products that otherwise would be un- on under-utilised as well as the non- conventional use of forage silage by other species than ruminants.

2. Conventional processing of perishable wastes and by-products

Traditionally, most wastes used as animal feeds are heat-treated to sterilise the materials and if the heat-treated product cannot be utilised locally or in a short time the product would then be dehydrated to facilitate storage and transport. Such processing is generally carried out where waste materials are available in large quantities on a regular basis and where the final product is of medium to high value. Such circumstances are unlikely to apply to smallholders.

Whilst cooking of perishable materials is commonly and successfully carried out by smallholders for materials that are to be used within a short time, the dehydration process is less commonly and successfully practised. The exception to this is where local fish meals are manufactured using sun drying. This type of processing is generally carried out in unhygienic conditions with the meals frequently becoming contaminated with bacteria.

Smallholders are likely to have only small to medium quantities of materials available for processing, which are likely to be used for local consumption.

In such circumstances, and where materials cannot be used immediately, the use of ensilation for the processing and storage of small to medium quantities of organic material could be a useful system.

3. Materials that could be suitable for ensilation by smallholders

Almost all organic materials could be suitable substrates for ensilation in one form or another. The decision on the approach and technique to apply will depend upon:

- The composition of the material including dry matter content.
- The type and degree of pathogenic and fermentative bacteria contamination.
- The buffering capacity of components of the material.
- The presence of potential autolysing enzymes in the main substrate or naturally present bacteria.
- The availability of other materials, such as acids, fermentable substrates and fermentative bacteria to assist inensilation.
- The cost of preservation using the technique in the prevailing circumstances.

Considering these criteria it is clear that the range of possible ensilation processes consist of the following:

- Ensilation using acids produced by the fermentation of carbohydrates within the material by naturally present bacteria or cultures of added bacteria.
- Ensilation using acids produced by the fermentation of carbohydrate rich materials added to the substrate to be preserved using fermentative bacteria as in 1.
- Ensilation using added inorganic acids such as hydrochloric or sulphuric acids or mixtures of such acids.
- Ensilation using organic acids such as formic, propionic or acetic acids or mixtures of such acids.

4. Ensilation using naturally present bacteria

This type of ensilage is typical of that carried out with plant materials having a low buffering capacity, a dry matter content higher than 20%, a fermentable carbohydrate concentration of between 5 and 20% and with naturally occurring lactic acid fermentative micro-organisms present.

This traditional silage making process has been extensively reviewed and the present paper will only consider the possible use of this type of material for animal species not traditionally fed such materials.

4. 1. The use of ensiled forages for non-ruminant animals

Whilst ensiled forages have commonly been fed to ruminants in all parts of the world, such materials have rarely been fed to monogastric animals, such as pigs, in commercial situations.

Currently, there is considerable interest in the possibility of feeding forages, including those preserved by ensilation, to pregnant sows in order to improve their reproductive performance through improved welfare. (Lee and Close 1987). In this situation it is agreed that most pregnant sows suffer stress through being fed relatively small quantities of compound feeds (approx.2.2 kg) when their appetite would be for two or three times that amount.

The main objective is to prevent such animals becoming over-fat, which is associated with breeding problems. It is proposed that by feeding such animals on low nutrient dense feeds to appetite they would be less stressed, stay within targeted weights, which could result in improved reproductive performance, longer reproductive life and lower feed costs.

Ensiled forages would be ideal materials for use in such circumstances, since pigs would be able to digest all enzymically digestible components in the upper gut and then through fermentation in their lower gut digest fibrous materials and absorb the associated products.

Similarly, work with such materials has been carried out with growing pigs. It has been demonstrated that the guts of commercial type pigs (large white, landrace, etc) are able to use such materials from about 50 kg liveweight (Machin 1990). However, where such a feeding system is practised the rate of gain has been correspondingly less than where commercial feeds were used. Nevertheless, such low cost feeds might well be financially attractive in circumstances where compound feeds are expensive and where through lower labour and housing costs a better margin can be obtained using such an approach.

The use of ensiled forages could offer considerable benefit for smallholder pig farmers in the feeding of gestating sows and growing/fattening pigs. However, due to the high nutrient demands of lactating animals this system would not be recommended for lactating sows.

The remainder of this paper will concentrate on the application of the ensilation process to store and preserve non-forage, nutrient rich, perishable materials.

5. Non-forage materials for silage production

The materials that have been preserved by ensiling can be divided into those that produce acids through anaerobic fermentation which preserve the unfermented remainder of the substrate and those that are preserved by acids added directly or produced by the fermentation of materials mixed with them. Many of these materials also undergo autolysis of the substrate using naturally containing autolytic enzymes as a secondary phase of preservation.

5.1. Fermentable substrates

These materials contain carbohydrate that can be fermented to produce acids such as lactic or acetic acid. Clearly, such a process requires the presence and action of micro-organisms. These may be naturally occurring or may be added as a separate culture (Martin and Bozoglu 1996). Similarly, some substrates may contain insoluble carbohydrates that are not readily fermentable and require enzymes to break them down into simple soluble carbohydrates that can be fermented. These can then generate acids to preserve the remainder of the material or mixture.

Examples of materials that have been used as fermentable substrates

Sugar Industry by-products	**References**
Molasses – Sugar Cane.	(Evers and Carroll 1998,)
Molasses – Beet.	(Fagbenro and Jauncey, 1998)
Sugar Cane Wastes	Alimon et al, 1994,)
Fruit Wastes	
Bananas.	(Ash and Elliott, 1991,)
Papayas.	(Bello and Fernandez, 1995,)
Pineapple.	(Bello and Fernandez, 1995, ,)
Citrus.	(Megias et al, 1998)
Apple Pomace.	(Nikolic and Jovanovic, 1986,)
Kiwi Fruit.	(Ciruzzi et al, 1996)
Grape Waste.	(Nou et al, 1981,)
Other Agro-industrial Wastes	
Brewery and distillery wastes	Pelz and Hoffman, 1997
Vegetable processing wastes	Ashbell *et al.* 1995
Milk by- products	Sander *et al.*1995
Flower wastes (carnations)	Ceron *et al* 1996)
Taro roots	Ash and Elliott 1991
Cassava root wastes	Fagbenro and Bello 1997
Bakery by-products	Bastian 1990
Olive waste	Hadjipanayiotou and Koumas 1996
Tofu wake	Niwa and Nakanisi 1995
Sisal waste	Rodriguez *et al.* 1985
Oil palm fronds	Abu Hassan *et al.* 1996

To the other extent materials rich in soluble carbohydrates, e.g., fruits, sugar cane or beet products etc. are capable of preserving materials at relatively low dry matter levels through osmotic effects alone without the need for acid fermentation.

The preceding list of materials that have been successfully ensiled demonstrate the broad range of products that can be preserved in this way. However, only those with high levels of soluble carbohydrate, such as sugar and fruit products are likely to be able to produce sufficiently high levels of acid by fermentation to assist in the storage of non-fermentable materials.

Clearly, ensilation could be a useful means of preserving a wide range of perishable materials that would otherwise be unused as animal feeds.

Examples of non-fermentable materials that have been preserved by ensilation

Slaughter house wastes	**References**
Poultry carcass waste.	Machin *et al*. 1984
Poultry viscera.	Fagbenro and Fasakin
Hatchery waste.	Deshmukh and Patterson
Feather meal.	England *et al*. 1991
Large animal carcass waste.	Machin 1986
Blood.	Le-Van-Lien *et al*. 1996
Fishery Wastes	
Waste whole fish	Machin *et al*. 1990
Shrimp by-catch	Ames and Ward
Salmon viscera	Dong *et al*. 1993
Scallop viscera	Myer *et al*. 1990
Prawn and shrimp heads	Le-Van-Lien *et al*. 1996; Evers and Carroll 1998
Crab waste	Evers and Carroll 1996
Fish viscera	Ahmed *et al*. 1996

Many of the above materials are available to smallholders in small to medium quantities in a variety of locations around the world. A simple low capital process such as ensilation could be an attractive way of preserving such materials. Quite clearly, matching the availability of suitable supplies of fermentable materials to mix with these types of materials could cause logistical difficulties. In such circumstances the use of low cost by-products such as fruit wastes would be the first choice with more expensive sugar by-products used as back up materials.

However, the main problem with such an approach for smallholders would be the higher degree of technical knowledge required to be able to change systems to meet variations in raw material availability. Unless fermentable and non fermentable proteinacious material supplies are available at the same time it might be best to place most emphasis on the use of storable fermentable materials such as molasses for this type of processing for smallholders.

6. The use of directly added acids in ensilation

Considerable research has been carried out on the preservation of perishable proteinacious wastes using added acids.(Machin 1986; Perez1995). Initial studies focussed on the use of mineral acids such as hydrochloric, sulphuric or phosphoric acids, but these alone were shown to be poor preservers ofsilages (Disney *et al.* 1977) Silages have, however, successfully been made using mixtures of organic (formic, propionic, citric, etc.) acids and mineral acids or organic acids alone (Perez 1995). Nevertheless, the use of direct addition of organic and /or mineral acids is very unlikely to be a means by which smallholders could process feed materials due to the cost and danger of handling strong acids in low technology situations.

For this reason it would appear that the most appropriate way that smallholders will be able to use the acid ensilage process will be through a natural fermentation system.

7. The use of fermentation silage

In recent years most researchers in this field have focussed on this approach to processing small to medium quantities of perishable organic materials. Although some researchers have been able to get successful fermentation using sources of fermentable carbohydrates alone mixed with non fermentable materials (Raa and Gildberg 1982) most have used lactic acid bacterial cultures to stimulate fermentation. Some of the most successful bacteria that have been used include;- *Lactobacillus plantarum*, *Streptococcus faecium* and *Pediococcus acidilactici* (Deshmukh and Patterson 1997)

However, the use of bacterial cultures would obviously be a deterrent for low technology processing by smallholders. It is therefore interesting to note that although raw materials low in lactic acid bacteria content generally benefit from the use of suitable inoculants it is not always essential that they be included (Martin *et al*.1995).

There are also reports that if the raw material already has a high concentration of lactic acid bacteria, inoculants do not improve the process (Desmulch and Patterson 1997)

It would therefore appear that smallholders could well be able to produce fermented silages without the need to produce or purchase starter cultures provided that appropriate mixtures of fermentable and non-fermentable materials are selected. To the other extent, where mixtures not capable of generating a rapid fermentation and sufficiently low pH have been tried, successful silage production has not been achieved (Urlings *et al*.1993).

In this context it is interesting to note that non-fermentable materials, which have been preserved by mixing them with fermentable carbohydrates, include poultry slaughter house wastes, hatchery waste, large animal slaughter house waste, whole waste fish (fish viscera, shrimp by-catch), shrimp and prawn heads and crab waste.

8. Health implications of feeding silage

There is considerable concern about the presence of pathogenic bacteria in food materials fed to farm animals. Unfortunately, many of the materials listed above as possible substrates for preservation through ensilage could well be contaminated with such bacteria. The acid ensilage process has been shown to be an effective means of reducing or eliminating pathogens and indicator organisms in materials such as poultry slaughter house wastes, hatchery waste and fishery waste. Many other researchers reviewed in Machin (1986) showed a range of silages to be free from coliformes, *Salmonella* spp, *Clostridia* spp, *Staphylococcus* spp, and faecal *Streptococcus* and to have a very low bacteria count or to be bacteria free. This concept is supported by Frazier and Westhoff (1978) who showed that all common bacteria which cause food-borne infections are inhibited at pH values below 4 and in the case of *Clostridium botulinum* toxication is prevented below pH 4.5.

In particular, fermentation of such inedible wastes has been shown to decrease the numbers of Gram-negative pathogens (Talkington *et al.* 1981) and viruses (Wooley *et al.* 1981).

The means by which this occurs relates to the effect of low pH, the presence of antibiotic substances produced by lactic acid bacteria and the ability of organic acids to pass over the cell membranes of micro-organisms by dissociation and lower the organisms internal pH to destructive levels (Raa and Gildberg 1982). Lactic acid bacteria also produce antibiotics and bacteriocins which are often bacteriostatic against other bacterial species (Urlings *et al.* 1993). Mineral acids do not have the same dissociating ability as organic acids and so are much less effective in silage production.

Many wastes of animal and fish origin contain autolytic enzymes, which at low pH, are able to break down large organic molecules so exposing any micro-organisms present in the waste to anti-microbial action (Backhoff 1976).

9. The use of ensiled wastes

Following ensilation most animal wastes have been successfully processed and fed to a wide range of domestic animals without problem. Perez (1995) noted that fish silages were suitable for feeding to pigs, poultry, ducks, ruminants and camels. Other researchers have successfully fed fish silages to farmed fish. Many others have shown that materials such as poultry slaughter house and hatchery waste as well as ruminant offal silage could be successfully fed to pigs, poultry, mink, fish (catfish – *Clarias gariepinus*, the common carp – *Cyprinus carpio*) compared with control feeds.

10. Conclusion

It is clear that the ensilation of waste materials could offer a simple and inexpensive means by which smallholders in certain circumstances might be able to process and preserve a wide range of materials for use in animal feeding. However, there are likely to be many situations where the correct balance of materials and knowledge are not in place and so this approach should not be applied. In particular, most benefit is likely to occur using fermentation not requiring the use of prepared bacterial innoculants.

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