Silage from by-products for smallholders

Kayouli Chedly[1] and Stephen Lee[2]

[1] Institut National Agronomique de Tunisie,
43 Ave Charles Nicole 1082 Tunis, Tunisia
Tel: 002161892785 ; Fax: 002161799391 and
E Mail: chedly.kayouli@gnet.tn

[2] Brooklyn Valley, Rd 3 Motueka, New Zealand.
Tel: 00643 528 0476; Fax: 00643 5288967 and
E Mail: SteveLee@ts.co.nz

Summary

The paper summarises some of the practical experiences of the authors in formulating and making silages with and for smallholder farmers in North Africa and the South Pacific.

Livestock are an important part of the farming system in developing countries, particularly for subsistence and semi-commercial farmers. There is good potential to improve food security and family incomes by improving livestock production. This applies particularly to milk production by rural and peri-urban farmers. However, a shortage of affordable feeds of adequate quality and quantity, particularly during the dry season is a major obstacle to improving production.

Many agricultural, agro-industrial and fishery by-products have potential as animal feeds. Many of these products currently are completely unused or are largely wasted due to the inability of farmers to use them before they spoil, as a result of seasonal production peaks and troughs. Consequently these by-products often become pollutants.

Ensiling by-products is a simple and low-cost option, which can preserve feeds that are seasonally abundant for later feeding during periods of feed shortage. Ensiling can also render some previously unpalatable products useful to livestock by changing the chemical nature of the feed. Silage is a very versatile product and can be used as a basal diet or as a concentrate type supplement to other feeds such as forage. Preparations suitable for monogastrics such as pigs or ruminants can be tailored to the needs and digestive ability of the target livestock.

Information is given on the nutritive value, physical nature, and availability of a range of common by-products. Clear descriptions of how these by-products are used in silage making allow the reader to easily apply the message of this paper. Also included are practical examples of successful silage combinations, and feeding regimes including silage for different classes of livestock and desired production levels.

1. Introduction

The livestock sector plays a significant economic role in most developing countries and is essential for the food security of their rural population. It is contributing to poverty alleviation and provides elements that are essential to the national economy, such as: traction power, transport, manure as fertiliser and fuel, food, fibre, leather, savings bank, and by generating significant household cash income through sales of live animals or livestock products.

However, among the major constraints limiting the development of livestock production in many developing countries, inadequacy of animal feed resources is most often the crucial factor. Feed shortages, both quantitatively and qualitatively, are limiting livestock productivity. During ploughing of crop fields these shortages seriously affect working ability of oxen and they also depress the production of dairy and meat units managed by small-scale commercial farmers.

In many tropical countries, such as those in Africa and the South Pacific Islands, the bulk of livestock feed resources comes from grazing mainly poor quality annual and perennial grasses from natural pastures often at a late stage of maturity. In other countries, such as those in Southeast Asia, livestock farming is increasingly being limited by the restriction of grazing lands. During the long dry season (at least 6-7 months per year) animals are on poor quality feeds characterised by low palatability, low intake and low nitrogen concentration. However, crop residues (straw and stover from sorghum, millet, wheat, barley, rice, maize) play a key role in animal feeding mainly in Asia and Africa.

As there is an incipient urban market demand for milk around the largest cities in most developing countries, there is an increasing development of small-scale peri-urban dairy units mainly from pure Friesian cows. However, the smallholder dairy producers are often facing low milk yields from these exotic cattle due to the poor feeding management (lack of rations with balanced nutritive content) and/or high-producing costs because their feeding system is primarily based on purchased feeds and concentrates.

It is recognised in developed countries that the production of silage of high quality cultivated forage can be a valuable component for the development of a high-performing and low-cost system of animal production, using a relatively low level of purchased concentrates. However, this appears inappropriate for smallholders in tropical countries primarily for the following reasons:

- lack (and/or high cost) of equipment for harvesting and conservation
- production of cultivated forage is often limited due to lack of available land. Most farmers in developing countries rely for their food security on the cultivation of cereals, root crops and high value crops such as fruits and vegetables, which understandably take priority in the allocation of land.

Fruit, vegetables and root crops are increasingly integrated in the farming system and play a key role as staples in the human diet in most developing countries. Consequently, there is a wide range of valuable by-products and residues resulting from food crops cropping systems and food processing which are often inefficiently or totally under-utilised and wasted.

The ensiling of by-products is a simple and appropriate method of conservation. It is the most-effective way to improve animal feed resources through the rational use of locally available agricultural and industrial-by products likely to be available to small-scale farmers at village level. In developed countries herbage ensiling is now accepted as the major method of forage conservation and much research has been undertaken in that field (Mc Donald 1983; Thomas 1985). However very few research and extension activities are related to the various aspects of silage production from by-products.

The paper is aimed at examining some of the practical aspects of making and utilising silage from by-products by small-scale farmers. There are very large amounts of various by-products in tropical countries and it is not possible to provide a global review on this topic. Our contribution is therefore restricted to our experience in North Africa (from the first author) and experience in two projects financed by the Technical Co-operation Programme of FAO, first in Samoa, repeated subsequently in Tonga, managed by both authors.

2. Advantages of silage making from local crop residues and by-products

The problem usually encountered with agro by-products is seasonality of supply, which is often accentuated by their high moisture content. High-moisture agro-industrial by-products are often of high nutritional value. In industrial countries there are well-developed technologies for recovering by-products and converting them into protein-rich meals and/or energy-rich concentrates. However, such facilities are rarely found in tropical less-developed countries, especially at the level of small villages where by-products often become contaminating wastes: they quickly go sour, mouldy and lose considerable quantities of soluble nutrients in the effluent. Dehydration increases cost, about 250 - 300 litres of fuel and 200 kWh of electricity are required to produce one ton of dry product (88 - 90% DM). Research has shown that the ensiling of by-products is the most suitable method of conservation for long period (Lien *et al.* 1994; Bouqué and Fiems 1988; Hadjipanayiotou 1993; 1994; Kayouli 1989; Kayouli *et al.* 1993; Kayouli and Lee 1998). The main advantages of silage are:

1. it can be efficiently used for strategic off-season feeding
2. it is a means of increasing feed resource availability and form of insurance, especially for calving dairy cows

3. it can be fed to reduce pressure on pasture when required

4. it can be an efficient supplement to grazing cattle during the dry season

5. it is an inexpensive home-made feed resulting in the production of milk and beef at lower cost

6. it improves palatability, reduces significantly toxic substances present in some fresh vegetables to safe level concentrations (such as cyanogenic glucosides in fresh cassava leaves) and destroys harmful micro-organisms possibly present in poultry litter or fish wastes

7. it can provide a major diet source, as basal ration as well as a feed supplement for grazing animals.

3. By-products widely available in tropical and sub-tropical countries potentially suitable to silage making

In tropical and sub-tropical countries there is a wide range of by-products and residues from food crops and food processing that are potentially valuable feed supplements, without considering residues from cereal grain. The most common by-products from various root and tuber crops, fruit crops, agro-industry and animal industries are the following:

3.1. Brewer's spent grains

The extracted malt, or spent grain, contains 75 - 80% water when filtered off. Wet spent grain spoils rather quickly and should be used fresh or stored out of contact with air. It can be stored up to two weeks quite successfully by heaping it, treading it well and covering with sacs or plastic sheets. For longer storage, it may be ensiled in an airtight trench silo with drainage. Ensiling in tightly tied plastic bags is also an effective storage method (this method will be described in details later). Wet spent grain can be ensiled alone or in association with other ingredients, for example, with 2 - 3% molasses (to ensure proper fermentation), chopped banana by-products (trunk, pseudostems, fruit, peel) or chopped cassava. The latter has the advantage to absorb the juice from spent grain and consequently to limit losses during fermentation. The quantities to be incorporated depend on availability. However, in any case the dry matter content in ensiled mass, should not exceed 45%, in order to ensure proper fermentation.

Brewer's spent grain is a valuable potential supplementary feed for livestock. It is a safe feed when it is used fresh or properly stored. It is a relatively bulky feed but a good source of energy and protein (Table 1). It can be used to feed beef cattle (10 - 15 kg daily) and calves (2 - 4 kg daily), however it is far more suitable in rations for dairy cows. Spent grain is a balanced feed for dairy cows and has a strong reputation for stimulating milk production. Milk yield response is very rapid and production significantly increases when lactating cows are fed spent grain supplement. Wet grain can be given in large amounts to dairy cows, up to 15 kg per day. In order to avoid off-flavours, it is recommended that spent grain be fed to cows after rather than before milking. When it is eaten in large quantities (15 - 20 kg per day), distribution of 100 - 150 g of sodium bicarbonate given twice daily is recommended in order to prevent rumen acidosis disorder.

Table 1: Nutritive value of tropical by-products potentially to be ensiled and inclusion rate in dairy cow diets.

		Per kg Dry Matter			***Per kg Fresh Matter***			
Feed Stuffs	Dry Matter	Metabo Energy	Crude Protein	Crude Fibre	Metabo Energy	Crude Protein	Crude Fibre	Inclusion Rate
	%	MJ/kg	g/kg	g/kg	MJ/kg	g/kg	g/kg	Fresh, kg/day
Spent Grain	22.0	8.2	260	130	1.8	57.2	28.6	5 - 20
Banana Stems	9.5	5.5	20	210	0.52	1.9	20.0	5 - 10
Banana skin (ripe)	15.0	6.7	42	77	1.0	6.3	11.6	2 - 5
Rejected Banana (ripe)	30.0	11.5	54	22	3.5	16.2	6.6	2 - 5
Cassava Leaves	16.0	6.7	235	190	1.1	37.6	30.4	3 - 6
Cassava Roots	28.5	12.5	16	52	3.6	4.6	14.8	5 - 15
Molasses	78.0	11.5	15	0.00	9.0	11.7	0	0.5 - 2
Breadfruit (ripe fruit)	29.8	10.8	57	49	3.2	17.0	14.6	4 - 8
Taro Leaves	16.0	6.2	223	114	1.0	35.7	18.2	1 - 2
Taro Roots	25.0	13.2	45	20	3.3	11.25	5	2 - 5
Sweet Potato (leaves)	12.0	5.8	200	145	0.7	24.0	17.4	10 - 20
Sweet potato (tubers)	30.0	13.5	70	25	4.1	21.0	7.5	5 - 10
Yams (leaves)	24.0	7.3	120	250	1.8	28.8	60	2 - 5
Yams (roots)	34.0	13.5	80	25	4.6	27.2	8.5	2 - 5
Poultry Litter	82	8.2	265	145	6.7	217.3	119.0	0.5 - 2

Table 1bis: Nutritive value of sub-tropical by-products potentially to be ensiled and inclusion rate in dairy cow diets.

		Per kg Dry Matter			***Per kg Fresh Matter***			
Feed Stuffs	Dry Matter	Metabo Energy	Crude Protein	Crude Fibre (ADF)	Metabo Energy	Crude Protein	Crude Fibre (ADF)	Inclusion Rate
	%	MJ/kg	g/kg	g/kg	MJ/kg	g/kg	g/kg	kg fresh/day
Olive cakes	45.5	3.8	40	465	1.7	18.2	211.6	2 - 4
Olive leaves	56.8	5.7	105	300	3.2	59.6	170.4	3 - 6
Grape marc	37.1	4.9	138	410	1.8	51.2	152.1	1 - 3
Sugar beet pulp	19.5	9.8	91	316	1.9	17.4	61.6	up to 20
Tomato Pulp	22.5	8.0	215	350	1.8	48.4	78.8	up to 15
Wheat Bran	89.1	8.1	160	137	7.3	142.6	122.1	1 - 3
Date palm fruit	87.6	12.0	32	50	10.5	28.0	43.8	0.5 - 1
Citrus pulp	23	10.3	75	200	2.4	17.3	46	up to 15

3.2. Banana by-products

Bananas are grown in almost all–farms in the humid tropics and constitute one of the staple foods for human consumption. Banana plant waste is of considerable importance in feeding ruminants. The by-products are the followings:

3.2.1. Rejected banana: Rejected bananas both green, immature and ripe, are a good source of energy supplement to grazing or penned animals. Dairy cows relish them and can consume them in fairly large amounts. But bananas have a low content of fibre, protein (Table 1) and minerals and should therefore be fed together with grass or other source of roughage (in order to avoid rumen disturbance) as well as with protein and mineral supplements. When the rejected bananas are widely available, a good silage can be made from chopped bananas mixed with one or several rich-protein feeds, such as poultry litter, dry spent grain, fish wastes and cassava leaves.

3.2.2. Banana leaves and pseudostems (trunks): Banana pseudostems (trunks) and leaves are useful sources of roughage in many tropical countries, mainly during the dry season. They can be chopped and fed fresh or ensiled. As pseudostems are low in protein and minerals, they are more efficiently used when supplemented with rich-protein ingredients, such as copra meal, multi-nutrient feed blocks, cassava leaves, poultry manure and spent grain.

The use of chopped and ensiled pseudostems is particularly recommended when the bunch has been harvested and plants are cut down; the large quantity of trunks available at harvest time can be safely preserved through a well planned silage operation. The silage is of good quality when chopped pseudostems are properly mixed with an easily fermentable carbohydrate (such as molasses, sliced root vegetables) and protein-rich feeds (such as poultry litter, wet spent grain).

3.3. Root crops

The major root crops that are potentially available for animal feeding in tropical countries are mostly cassava, taro, sweet potato and yams.

3.3.1. Cassava by-products: Both the roots and the leaves are valuable feed resources for dairy cattle.

3.3.1.1. Cassava roots: Fresh and sun-dried cassava roots are consumed by ruminants in different forms (sliced, chopped, ground) and used as a substitute for cereal grains in many countries. Cassava roots are a good energy source for dairy cattle, because they are high in carbohydrate, which is an important and readily available energy source for rumen microbes. However, they are low in protein (Table 1). They are particularly efficiently used by high producing cows and at the first stage of lactation. Cassava roots can be given in large quantities: up to 25% of total dry matter intake. However, protein and mineral supplements must be fed in order to balance the ration. As cassava roots are rich in easily fermentable carbohydrates, they constitute an excellent energetic additive when they are chopped and ensiled with other feed resources, such as fish waste, cassava leaves, banana pseudostems, spent grain, poultry litter, etc.

3.3.1.2. Cassava leaves: The cassava leaves are also a potential and valuable protein feed resource for ruminants (Table 1). It is estimated that when leaves are harvested at the same time as the roots, yields are in the range of 1 to 4 tonnes dry matter/ha. Fresh cassava leaves have been successfully fed to cattle, including dairy cows, in many countries.

Fresh raw cassava contains cyanogenic glucosides (HCN compounds) which are toxic to monogastrics. But, leaves can be fed fresh to ruminants, as rumen micro-organisms appear to be able to detoxify the HCN. However, this is easily removed during processing by sun drying or ensiling. Ensiling cassava leaves is the simplest method, not only to reduce significantly HCN concentrations to safe levels for monogastrics, but also to preserve the nutritive value of harvested cassava leaves for efficient use for off-season feeding of dairy cows. The freshly harvested leaves are first chopped and can be ensiled alone or mixed with rich-energy feeds, such as banana wastes, root vegetables, wet spent grain. The whole cassava plant (including root and aerial parts) can also be chopped and ensiled in the same way. The silage is fairly balanced for dairy cows.

3.3.2. Taro: Taro is the staple food of the population in many tropical countries. Taro by-products include roots, trimmings, leaves and stems that are all potentially valuable feed supplements. Taro roots are out-standing as a feed, particularly rich in energy. Raw taro contains substances that irritate the tongue and palate of animals, so that it must be cooked to improve their nutritional usefulness, mainly for monogastrics. The leaves are rich in protein (Table2) and are relished by cattle. Taro by-products can be chopped and ensiled in association with aforementioned feed resources. Silage making reduces considerably undesirable substances in taro by-products, which thus become more appetising.

3.3.3. Sweet Potato: Sweet potato is another root crop grown by farmers in many tropical countries. The by-products are roots, offcuts, leaves and vines. Roots have low protein, fat and fibre concentrations (Table1), but they are high in carbohydrates, whilst foliage has a lower carbohydrate concentration but higher fibre and protein concentrations (Table1). The vines, which are usually wasted, can serve as a nutritive and relished green supplement for cattle. A mixture of waste bananas, cassava roots and sweet potato tubers and leaves can be ensiled effectively without the need for additives.

3.3.4. Yams: Yams are also widely grown in many tropical countries. Their nutritional value is limited by their bitter alkaloid concentration, as well as of tannins and saponins. Yams must be cooked to improve their nutritional usefulness, when they are fed to monogastrics or calves. The by-products include roots, offcuts, leaves and vines. Vines are a valuable cattle feed and can be successfully ensiled mixed with other feed ingredients above indicated.

3.4. Wet pulps from fruit and vegetables (citrus and pineapple pulps and leaves)

Many fruits are grown in tropical countries: mango, papaya, pineapple, citrus, etc. Fruit wastes and leaves are some other potential feed resources. The most suitable method for conserving these materials is to ensile them with the aforementioned ingredients, so that they ensure a good fermentation and enhance the silage quality due to their high sugar concentration.

Almost all Mediterranean Countries produce large amounts of citrus for local consumption and export. Citrus pulp is the residue remaining after the extraction of citrus juice, it represents approximately half of the fruit and has a mean DM of 20% (Boucqué and Fiems 1988). Citrus pulp is an energy-rich feed resource with high metabolisable energy content (Table1). The ensiling of the citrus pulp, damaged fruits and leftovers, in combination with other by-products with high protein concentration, such as poultry litter and wheat bran, is a simple and appropriate method of conservation which can make a significant contribution to the feeding requirements of ruminants, mainly for high-yielding cows in early stage of lactation. In addition, ensiling citrus wastes has advantages over traditional drying, in that less energy is used, cost of processing is much reduced and there is improvement of palatability.

3.5. Fish by-products

Fish by-products are usually obtained from inedible whole fish or from waste in fish processing industries. This is an excellent source of protein and minerals for livestock, mainly for cows that have recently calved and for high-yielding cows. The ensiling of the by-products, using molasses and other easily available feeds rich in fermentable carbohydrates, such as molasses, sweet potatoes, cassava roots, is a simple and appropriate method of conservation which has been successfully applied recently in some countries. In all cases, the maximum amount of fish wastes that can be included in the silage should be 50% with a dry source of carbohydrates and much lower, about 10%, with fresh sources.

3.6. Poultry litter

Another potential feed resource is poultry litter that is available in some intensive poultry farms in developing countries. Poultry litter and manure contain about 25% crude protein on a dry matter basis, about half of which derives from uric acid that can be efficiently used by rumen microbes for protein production, poultry litter is also rich in minerals. The results of many experiments in the world indicate that dried or ensiled poultry litter can be successfully included in the feed of ruminants as a protein supplement. The ensiling of the poultry litter is a simple and appropriate method of conservation. It has proved to be an excellent ingredient for cattle feeding, and the process significantly destroys harmful micro-organisms possibly present in poultry litter. Silage made from poultry litter, chopped root crops and bananas by-products provides a balanced diet for dairy cows.

3.7. Tomato pulp

Tomato is the most popular vegetable crop grown in Mediterranean countries where there are numerous tomato-processing plants. Tomato processing residues called tomato pulp (a mixture of peel and seed) accounts for about one fifth of fresh weight and has a high nutritional value, it is a particularly protein-rich feed resource (Table 1). Fresh tomato pulp becomes sour and mouldy rapidly because it is traditionally processed during summer time and has a high moisture content, approximately 80-84 %. Consequently, it is advisable to ensile tomato pulp in alternative layers with dry by-products, such as chopped straw, wheat bran and poultry litter, so that the liquid effluent is absorbed and fed. Good-quality silages made from those combinations are successfully used to feed dairy cows and fattening steers by small farmers in Tunisia (Kayouli 1989).

3.8. Pressed olive cakes

The production of olive oil is basically confined in the Mediterranean basin. Large amounts of crude olive cakes, a residue of kernels and pulp left after oil extraction, are produced yearly. Despite its low nutritive value (Table1), this by-product is a potential feed resource mainly during feed shortage. Usually, crude olive cake stored in heaps next to the processing plant deteriorates quickly because of it is high lipid concentration between 10 and 14%. The voluntary intake of such cake decreases with storage duration. Ensiling fresh olive cake either alone or with high-quality by-products, such as wheat bran, poultry litter and tomato pulp, improves storage quality and gives a well-preserved palatable feedstuff. This technique was tried ten years ago in Tunisia (Kayouli *et al.* 1993) then successfully adopted by many smallholders in the vicinity of olive oil processing plants.

3.9. Grape marc

After pressing 100 kg of grapes, there is production of 5 - 10 kg of grape marc (seed and pulp) with about 50% DM and relatively low nutritive value (Table1). Ensiling fresh grape marc either alone or with high-quality by-products, such as wheat bran, poultry litter and tomato pulp, improves storage quality and gives a well-preserved palatable feedstuff (Hadjipanayioutou 1987).

4. Silage - making from by-products

Ensiling may be used as a general term to describe any procedure involving the storage of materials in silos or pits. However, the term is commonly used to specifically describe the storage of green fodder under anaerobic conditions that allow naturally occurring microbes to ferment plant carbohydrates to organic acids, reducing the pH in the silo, inhibiting further fermentation and preserving the crop as silage. These basic principles of silage making from grass are the same for silage-making from by-products, so attention must be paid first to ensure anaerobic conditions, i.e. the by-products must be stored air-tight at all times, and secondly, there must be sufficient natural acid in the silage to restrict the activities of undesirable bacteria (for this the ensiled material must be rich enough in carbohydrates).

In order to achieve a successful ensiling of by-products, the following points should be rigorously respected:

1. Moisture content: ensiled material should contain more than 50% moisture so that it is easy to compress it tightly in order to get better compacting and to eliminate air. However, excessive moisture, more than 75% can also be harmful, leading to an undesirable fermentation in later phases and produces sour silage, which reduces palatability and intake. Water can be added and/or wet and dry feeds can be mixed to get such moisture,

2. Length of chopping: The finer the chopping, the better the compaction and therefore storage will be more successful, due to the effective exclusion of air. Chopping in small pieces can be done by hand or with a stationary forage chopper.

3. The time it takes to fill a silo: The rapidity of filling and sealing the silo is of high priority. Because of slow filling or delayed covering can easily increase feed losses due to extended aerobic fermentation.

4. Presence of enough easily fermentable energy (naturally present or added): The major objective in silage fermentation is to achieve a stable low pH at which biological activity virtually ceases. In this way preservation is obtained whilst minimising nutrient losses and avoiding adverse changes in the chemical composition of the material. The final pH of the ensiled by-

products depends largely on the carbohydrate contents in the original materials. For this reason, protein-rich feeds with low content of energy are very difficult to ensile successfully and should be mixed with easily fermentable energy-rich products, such as molasses, rejected bananas and root crops.

The technique of silage making from by-products is extensively described by Kayouli and Lee (1998). The silage can be stored in stacked layers, packed in succession on the soil that has been covered beforehand with a plastic sheet or banana leaves. This heap, once finished, is then tightly covered with banana leaves or plastic sheets, pressed down by some heavy objects which are placed on its top. Packed silage in plastic bags that are tightly closed is also an effective storage method. This storage method is easy to handle and has the potential to produce high quality silage with less waste in a well-sealed bag. However, it is not recommended for coarse materials, such as banana trunk and cassava leaves, which can puncture the bag and render the contents useless.

After approximately 6 weeks, the farmer can open the silo and start to feed silage to animals. Silage can be suitably preserved for as long as air is kept away from the ensiled material; it is therefore possible to store air-tight silage for more than 6 months. Once the silo is open, care must be taken to cover again the ensiled material after each opening that is made to feed the animals.

5. Practical examples of successful silage combinations

Crop residues and by-products vary in their composition and physical structure. Within this paper it is impossible to provide a review of all combinations possible in silage making and therefore it will be restricted to those which have been successfully applied. However, in order to succeed in silage making, the following guidelines must be respected:

1. Carbohydrate or energy-rich feeds: such as crop roots, rejected bananas, and fruit wastes, can be successfully ensiled alone.

2. Energy/protein-rich by-products: such as spent grain, tomato pulp can be successfully ensiled alone.

3. Fibre-rich feeds with low energy and protein concentrations, such as banana pseudostems, olive cake, grape marc are better utilised when ensiled in combination with energy-rich by-products.

4. Protein-rich feeds with low energy-content, such as cassava leaves, fish wastes and poultry litter should not be ensiled alone. However, this type of feed can be successfully ensiled when mixed with one or several energy-rich products such as crop roots, rejected bananas, spent grain and molasses. This type of silage is highly recommended because it provides a balanced diet.

5. Incorporation of molasses to silage is optional; nevertheless, this is an excellent additive to ensure a good conservation and enhance high silage quality of any ensiled feed resource.

Incorporation rate of the different ingredients to be ensiled is function of:

- Available amount of by-products

- Animal categories to be fed. For example a high-quality silage, containing increased proportions of energy-rich ingredients such as spent grain and crop roots, should be prepared for high producing dairy cows. Whereas high proportions of cassava leaves and banana pseudostems can be used when there is seasonal feed shortage and therefore when silage would compose the bulk diet, during off-season feeding.

Several silage combinations from various by-products and crop residues have been successfully developed in two projects funded by the Technical Co-operation Programme of FAO, first in Samoa: (FAO-TCP/SAM/6611): Milk Production Areas and Small Milk Processing Units, repeated subsequently in Tonga: (FAO-TCP/TON/8821): Smallholder Forage Based Dairy Production and expanded to a South Pacific Sub-Regional basis in: GCP/SAM/007/FRA: Dairy Production and Processing Units.

As an example the following silage combination (on % weight basis):

- chopped cassava leaves (15),
- chopped cassava roots (25);
- chopped banana pseudostems (10),
- spent grain (30),
- poultry litter (10) and
- molasses (10)

was efficiently preserved, with a good smell and low pH (between 3.5 and 4.5); the silage when fed as a supplement to grazing dairy cows caused a big increase in milk production in those South Pacific Islands. The impact has been excellent; smallholders were particularly impressed by the ease with which they could use locally available materials to quickly and cheaply increase milk production. The improved performance due to supplementary feeding with silage has been manifested by fast and very significant increases of milk production. As most of project co-operating farmers are selling milk, this positive production effect of feeding silage has been directly translated into immediately increased financial returns.

Two suitable dairy rations are hereafter presented, where basal diet is grazing improved pasture under coconut plantations or cut-and-carry elephant grass.

Case 1: Basal diet while grazing improved pasture under coconut plantations:

Feed Supplements Kg/day (fresh basis)	**Milk Yield, kg/day**				
	5	**10**	**15**	**20**	**25**
Copra meal	1	2	3	3	3
Spent grain			5	10	10
Silage* (30% DM)		10-15	15-20	20-25	20-25

(*) as presented in the above paragraph

Case 2: Basal diet is chopped Elephant grass (cut-and-carry system)

Feed Supplements Kg/day (fresh basis)	**Milk Yield, kg/day**				
	5	**10**	**15**	**20**	**25**
Chopped Elephant grass	40	40	40	50	50
Copra meal	1	2	3	3	3
Spent grain		10	15	20	25
Silage (30%DM) (*)		10	15	25	25

(*) as presented in the above paragraph

Large amounts of agro-industrial by-products and crop residues produced in the Mediterranean basin (citrus pulp, grape marc, tomato pulp, olive cake, wheat bran, etc.) have been successfully ensiled in different ways as sole ingredients or in different associations. Such silage making practices are extensively practised by numerous farmers and replace conventional feedstuffs, including imported concentrates (Kayouli *et al.* 1993; Kayouli 1989; Hadjipanayioutou 1987; 1993).

Table 2: Feed intake and performance of growing lambs fed an ensiled poultry diet or concentrate diet (12 animals per treatment ; 66 days trial) (Kayouli *et al.* 1993)

	Ensiled poultry litter diet[1]	Concentrate diet
In vivo OM digestibility (%)	61.4	74.9
Retained nitrogen (g/day)	33.0	37.2
Feed intake (g DM/day)	1520.0	1098.0
Daily gain (g/day)	252.8	221.2
Feed conversion (kg DM/day)	6.1	5.4
Carcass yield (%)	47.5	45.1
Feed cost (U.S.$/kg gain)	0.4	0.8

(1): Poultry litter was ensiled with olive cakes and wheat bran in the following proportion on a dry matter basis: 45:45:10 w/w/w for the three ingredients respectively. Water was added to obtain 50 % DM in the silage, based on DM contents of the ingredients.

Screened poultry litter has been successfully ensiled with olive cakes and wheat bran (45:45:10% w/w/w, dry matter basis). After 6 weeks, results indicated that the ensiling technique is efficient for conservation of poultry litter at low cost and to eliminate health hazards. The litter silage was substituted for commercial concentrate and soybean meal and fed to lambs in a growing trial during 66 days (Kayouli *et al.* 1993). Results in Table3 show that daily gain and feed intake registered with the experimental diet were higher than those on the concentrate diet; meanwhile feed cost was lowered by 50% with the poultry litter silage group.

In another trial on beef fattening (Kayouli 1989) an experimental diet containing ensiled sugar beet pulp and poultry litter was compared to control diet (sugar beet pulp and concentrate with high content of soybean meal) fed to fattening beef during 150 days period. Animal performances (growth rate, feed conversion and carcass quality) were similar while feeding cost was reduced by 20% with the experimental diet.

6. Conclusion

In order to increase farm incomes from livestock in developing countries, an adequate low-cost feeding system must be developed.

Making silage from agricultural, agro-industrial and fishery by-products is a proven system, which offers considerable potential to improve farm incomes and profits.

Agriculture Ministries should survey the types, qualities, quantities and seasonal availability of by-products produced in their country. The current levels of utilisation should also be assessed.

Whilst farmers will tend to opt for utilising by-products they can easily identify and acquire locally, Government officers can improve by-product utilisation by assessing the "whole picture" of by-product availability and advising farmers accordingly.

Practical programmes of research and extension are recommended in each country. These should create and demonstrate a range of model feeding systems based on ensiled by-products [in addition to other available feeds]. These feeding systems would have formulations based on regional/national by-product availability, feeding requirements and critical annual periods of feed shortage.

Development of by-product silage production can yield continuity of quality feed availability even in times of drought, at low cost. Small farmers easily make these feeds with simple technology.

Different types of silage can be made by altering the formula [the choice and mix of by-products]. In this way the individual needs of different classes of livestock can be met.

Wider adoption of these technologies will benefit low-income rural communities through improved income and food security and also the wider community via the better availability of reasonably priced animal products and by a decrease in pollution formerly caused by wasted by-products.

7. References

Bouqué, C.V. and Fiems, L.0. 1988. Vegetable by-products of agro-industrial origin. *Livestock Production Science* 19, 97 - 135.

Hadjipanayiotou, M. 1987. Experience in the Near East with the utilization of non-conventional feedstuffs and the various systems of feeding. *Animal Production and Health Paper no. 54*; FAO, Rome, pp 185 - 210.

Hadjipanayiotou, M. 1993. Voluntary intake of citrus pulp-poultry litter silage by growing female Friesian calves, chios lambs and Damascus kids. *Technical Bulletin 155*. Agricultural Research Institute, Nicosia.

Hadjipanayiotou, M. 1994. Voluntary intake and performance of ruminant animals offered poultry litter olive cake silage. *Livestock Research for Rural Development* **6**:10.

Kayouli C., 1989: A strategy for animal nutrition in the dry subtropics. *International Symposium on the Constraints and possibilities of ruminant Production in the Sub-Tropics* (MOA of Egypt, ESAP, EAAP, FAO, ICAMS, WAAP), Cairo, Egypt, November 1988. Pudoc Wageningen, pp 201 - 206.

Kayouli C., Demeyer D. and Accacha M., 1993: Evaluation of poultry litter and olive cakes as an alternative feed for ruminant production in Tunisia. *Proceedings of the International Conference on Increasing Livestock Production through Utilisation of Local Resources* October 18-22, 1993 Beijing, China. pp 420 - 440

Kayouli, C. and Lee, S. 1998: Supplementary feeding for dairy smallholders in Pacific Island Countries: Fiji, Samoa, Vanuatu, Cook Islands, Solomon Islands and Tonga. In: Manual of Smallholder Milk Production in the South Pacific, (Eds. Stephen Lee, Roderick Kennard and Chedly Kayouli), FAO Sub-Regional Office for the Pacific, Apia, Samoa, pp.: 67 - 101.

Lien, L.V., Sansoucy, R. and Thien, N. 1994. Preserving shrimp heads and animal blood with molasses and feeding them with a supplement for pigs. In: Proceedings of National Seminar-Workshop "Sustainable Livestock Production On Local Feed Resources" (Eds. T.R. Preston, B. Ogle, Le Viet Ly and Lu Trong Hieu), Ho Chi Minh City, November 22 - 27, 1993. pp. 59 - 62.

Mc Donald, P. 1983: *Hannah Research Institute Annual Report* pp 59 - 67.

Thomas, C. 1985: In: Recent Advances in Animal Nutrition,. (Eds. W; Haresign and D.J.A Cole). London: Butterworths, pp 223 - 256.