Re-use of processing residues can create additional income

Arabica coffee processors have to deal with residues of processing in both liquid and solid form. These need to be stored and treated in order not to threaten the environment and pose smell nuisance to people living nearby the processing plant.

So far, residues are mainly dealt with as "waste" rather than seen as a source of energy and additional income. However, there are many applications which can turn processing residues into new products as well as create an extra revenue for processors.

Characteristics of coffee pulp

Coffee pulp is next to processing waste water one of the main by-products. Approximately 2,5 tons of coffee cherry result in 1 ton of wet coffee pulp taking up the space of almost 1 m^3. The bulk of coffee pulp is water, remaining organic components are quickly fermenting sugars and small amounts of caffeine and other polyphenolics. In the presence of oxygen and fermenting bacteria, sugars in the pulp are converted into acids making the leakage from coffee pulp smelly and highly acid – these effluents should not be lead into rivers.

Making compost from coffee pulp

The easiest form to turn pulp into a useful product is composting. However, in order to create value for the plants as soil improver or organic fertiliser, coffee pulp needs to be chemically stabilised before applied to the field. If not done so, raw coffee pulp will continuously develop organic acids through a "silage" reaction which will damage the roots of coffee trees. In addition, pathogens and insect larvae present in coffee pulp need to be eliminated before composted pulp can applied to the field. If not done so, coffee pulp will give a good breeding ground for pests and diseases endangering the coffee crop.

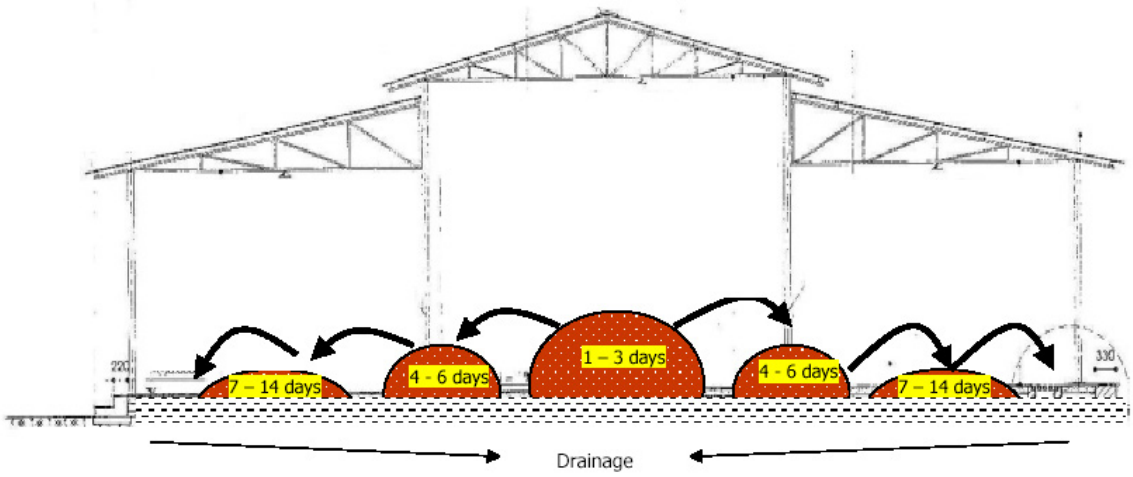
During the first days when pulp is left in heaps, temperatures inside the pulp heap can increases up to 75 degrees Celsius. This temperature increase acts like a "pasteurisation"

Coffee Pulp Compost – a source of nutrients

Macro Nutrients	Content Fresh Pulp	Content Composted Pulp
Nitrogen (N)	2,5%	0,5%
Phosphorus (P_2O_5)	0,15%	0,15 %
Potassium (K_2O)	3%	0,5%

Source: Manual de Caficultura, ANACAFE, Guatemala

Post Harvest Processing
Arabica Coffee



Industrial scale coffee pulp composting shed in under simple roof construction with open sides and roof ventilation

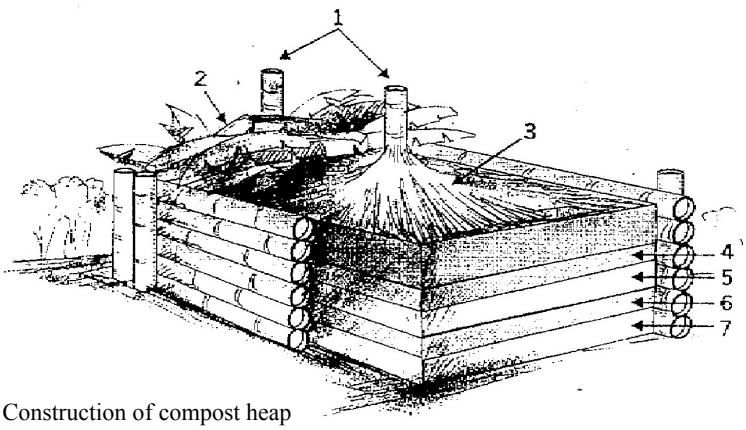
process in which pathogens are eliminated. In later stages, pulp needs to be in contact with oxygen to create good conditions for decomposing bacteria turning pulp into humus.

In right conditions, coffee pulp turns black within 2 to 3 weeks. After this, only little water will leak out and the smell is reduced considerably, provided compost is protected against rainwater. For turning pulp into rich, black humus, another 3 to 12 months are needed.

During composting phase, heaps need to be turned regularly to allow oxygen to enter and mix micro organisms in the compost evenly. In industrial scale for the reason of speed of turnover, pulp can be stored in long rows of around 1.5 metre width and 10 metre long. The first turning can be done already after around 1 to 3 days. When moving large quantities of pulp, processors might decide to use machines like tractors to move pulp.

Composting areas should be in good distance from parchment coffee storage or green beans to avoid mould spores from raw pulp being carried to coffee and cause infections such as moulds and fungus, possibly leading to Ochratoxin A (OTA).

For small scale processors and farmers, heaps should be allowed to rest around 2 weeks before the first turn. Pulp should heaped up in the back garden as close to the plantation as possible to easily re-apply ready compost. Coffee pulp based compost should be combined with other household residues, for example chicken manure, ash from cookers, rice straw in an organised compost heap. It is important that the compost heaps are always protected against rain and direct sunshine in order to minimise losses of nutrients.



Construction of compost heap

1 Hollow bamboo for oxygen supply
2 Banana leaves as coverage
3 Black soil
4 Ash from stoves (wood)
5 Coffee Pulp
6 Manure (chicken, cattle, …)
7 Rice straw, husk

A simple cover of banana leaves is sufficient to protect the compost.

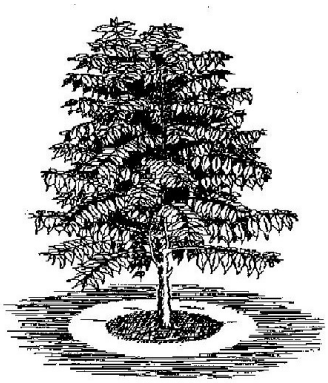
Content of compost

In order to guarantee quick decomposition, the right content in compost needs to be provided. Coffee pulp is rich in carbon. In order to balance this high amount of carbon, nitrogen rich material needs to be added, for example chicken manure, green, fresh leave cuttings or handfuls of urea. The addition of nitrogen rich material will greatly speed up the decomposition process. Sources of minerals also need to be provided, which is ideally done by soil and/or ash from wood. It has also been shown that pulp decomposition can be speeded up when worms (e.g. *Eisenia foetida, Lombricus rubellus*) are added to the compost which help digesting coffee pulp and therefore reducing composting time.

Application of compost

The main benefit a farmer can expect form applying coffee pulp compost in his field is the improvement of soil characteristics. Water holding capacity and absorption and storage of nutrients will be improved which will greatly support the health and growth of the coffee tree. Also, the acidity of the soil can be corrected up to pH 6 where nutrient uptake from the soil to the plant is improved. When enriched with either household wastes or compound fertilisers, chemical and physical properties of the compost assist in an even release of nutrients to the soil and plant.

The final product of compost from coffee pulp is a rich source of Potassium and should be incorporated



Compost application under the tree in a circle

into the soil around the coffee tree. In terms of quantity, the rule of thumb of compost application should be around 2 to 3 kg in normal coffee soils and up to 6 kg in poor soils per tree. Investigations from Columbia showed that through the application of enriched compost from coffee pulp soil properties are improved and by this, coffee yields can be significantly increased.

Mushroom production

Due to its physical and chemical properties, coffee pulp from wet processing can also be used as substrate for mushroom production of species like Shiitake, Pleurotus ostreatus or Linh Chi. However, before using coffee pulp as substrate, sugars need to be fermented into acids. The fermentation of sugars is relatively quick depending on the environmental conditions. If sufficiently aerated and spread thinly, sugars will be turned into acids in less than 2 days. When left in piles, the fermented pulp can be easily identified in the inner parts of the pile by the typical pink colour and the sour smell. Fermentation must be fully achieved before used for mushrooms production .

Pleurotus spp. mushrooms on coffee pulp

Post Harvest Processing
Arabica Coffee

After fermentation, pathogens need to be killed through pasteurisation in hot water. For this purpose, fermented pulp is put into a mesh wire basket which is dipped into a large drum filled with water of about 70 to 80 degrees Celcius and left for at least 30 minutes. During this time, pathogens will be killed off and the water will wash out the acids attached to the pulp.

After taking out of the hot water, the pulp needs to be thoroughly drained to leave the pulp at less than 70% moisture. It must be taken care that the pulp is not in contact with dirt to avoid infection with other mould spores and bacteria.

When pulp is readily drained and cooled down, it is mixed with lumps of mushroom spores and tightly pressed into transparent PE bags. For the production of Shiitake and Linh Chi, an additional part of parchment husk should be added (10-15%) to the mix.

After 3 to 4 weeks stored in dark conditions, fine, white cotton like structures will establish inside the plastic bags indicating that the mushrooms are ready for fruiting. Now, small holes are to be punched into the plastic bags which will supply oxygen to start the fruiting process. Within short time, mushrooms will start growing out of the holes and can be harvested. One bag can sustain around 2 to 3 harvests.

Mushrooms can be readily eaten or dried and sold on the local market.

Other uses

There is a wide range of material present for other uses of coffee pulp like aninmal feed stuff, fish feed, etc. However, none of these have been tested out in Vietnam so far.

Energy 1: Parchment Husk for burners

Coffee parchment husks are a good source of energy when used in burners for heat exchangers of coffee driers. It is recommended to have export processing (i.e. hulling) close to the drying facilities so that parchment does not have to be transported over long distances. Parchment husk is very bulky and therefore transport over long distances bears large costs in terms of volume.

In order to use parchment husks in burners, a blower needs to be installed which continuously blows the husks into the oven. Parchment burns best and develops most heat when it is burnt while blown into the chamber rather than just put in. VINACAFE engineering has special equipment available.

Energy 2: Biogas

Biogas can be generated from wet processing waste waters. The investments needed are between 6.000 and 10.000 USD and make only economical sense for larger scale operations of at least 80 tons fresh cherry input per day. In a multi step approach, water needs to be treated before Methane (MH4) is generated by a special strain of bacteria. The gas can be used for several purposes, however, the most financial beneficial seems to be the generation of electricity.

One cubic metre of concentrated and neutralised waste water can generate up around 1 cubic metre of Methane. One cubic metre of Methane has a theoretical

<u>Raw effluents</u> – simplified sugar to alcohol reaction of sugars from pulp/mucilage:

(1) $C_6H_{12}O_6 = 2\ CH_3CH_2OH + 2\ CO_2$
Sugar = 2 Ethanol + 2 Carbon dioxide

<u>Raw effluents</u> – simplified alcohol to acid reaction:

(2) $2\ CH_3CH_2OH + O_2 = 2\ CH_3COOH$
2 Ethanol + Oxygen = 2 Acetic acid

<u>Neutralisation</u> of acidified waste water:

(3) $2CH_3COOH + CaCO_3 = Ca(CH_3CO_2)_2 + CO_2 + H_2O$
Acetic Acid + Limestone = Calcium Acetate + Carb. Diox. + Water

<u>Biogas</u> Reaction

(4) $Ca(CH_3COO)_2 + H_2O = 2\ CH_4 + CO_2 + CaCO_3$
Calcium acetate + water = 2 Methane + carbon dioxide + limestone

Chemical reactions of processing waste water from sugar to methane

net caloric value of around 7 kWh. Calculating on 100 cubic metre waste water treated and digested in a reactor per day, a substitution of 700 kWh could be achieved in one day, potentially replacing electricity costs of around 500.000 VND (at an assumed electricity price of 900 VND/kWh) making a biogas operation investment profitable after 3 to 4 years operation.