

Full Length Research Paper

Enhancing benefits from biomass wastes within small-medium scale coffee processing factories in Kiambu County, Kenya

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Coffee processing is associated with various sustainability challenges largely due to high water and energy demand, biomass waste generation and lately low returns to farmers. The number of farmers actively involved in coffee production in Kenya is declining. Despite this trend, this paper reports on the potential of maximising benefits to coffee farmers by using coffee processing wastes (pulp and husks) in energy and agricultural services. A survey research design targeting six small to medium scale factories selected based on common criteria and 252 respondents was used. Results showed that about 210 tons of unprocessed coffee was received cumulatively in all the six factories surveyed per year. Processing generated approximately 51% biomass waste from the total input. Direct disposal of this waste to land contributes to direct environmental pollution. Accumulation of coffee husks and pulp was attributed to low awareness of the various uses these wastes have been successfully put elsewhere in the world. Opportunities for increasing benefits to farmers and reduced environmental loads exist in the conversion of coffee husks into branded briquettes for domestic energy supply, and pulp into fortified organic fertilizer for increased land productivity. Kiambu County government needs to invest in these two options through technological innovations and commodity specific extension service that is aligned to global sustainable production and consumption patterns.

Key words: Coffee processing biomass wastes, sustainability benefits.

INTRODUCTION

Coffee production in Kenya has been on the decline since 2009, a trend attributed to among others factors erratic weather, conversion of coffee land to real estates and high costs of inputs (Republic of Kenya, 2013a).

However, estimates from the International Coffee Organization (2010) indicate that the total production of coffee from exporting countries increased in years 2000 and 2010 from 112, 991,000 and 133,065,000 bags,

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respectively with Kenya exporting 51,000 metric tons of coffee beans in 2010 alone. In Kenya, more production is being witnessed in smallholder systems as large plantations, especially those in proximity to the city Nairobi, give way to real estate development. Despite this trend, projections indicate that Kenya's coffee production in 2016/2017 will increase to 700,000 bags up from 600,000 bags in 2015/2016 (USDA-FAS, 2016). Fluctuations in global market prices have nevertheless often been detrimental to small-scale farmers. In addition, organic waste generated from coffee processing and other crop specific postharvest processes are challenges that need to be addressed in-line with environmental sustainability concerns (Republic of Kenya, 2013b), hence the gist of this paper.

The main sustainability concerns in coffee processing are as a result of intensive use of pesticides and poor disposal of waste products. About 99% of the biomass waste produced, mainly untreated pulp and husks is discarded on land. Further coffee processing consumes high quantities of water and energy. According to Shitanda (2006), over 200,000 tonnes of pulp at 77% moisture content and 2,300,000 litres of polluted water are released into the environment everyday in Kenya. This is equivalent to pollution caused by 1.2 million people per day. On average 45.5 kg of green coffee requires between 1000-2000 L of water, 12.5 kWh of electricity and 0.07 cum of firewood for processing (Instituto del Caf  de Costa Rica -ICAFE, 2006). A survey of rivers between Nairobi and Thika towns in Kenya showed that they were all polluted with coffee waste with Biological Oxygen Demand (BOD) levels of more than 100 mg/l. The unpolluted rivers had BOD of 4 mg/l (Wrigley, 1988). Although a river of 10 mg/l is considered significantly polluted, the maximum allowable limit of effluent discharge into the environment is 30 mg/l (BOD 5days at 20°C) according to Kenya's National Environment Management Authority (NEMA) Standards (Republic of Kenya, 2006). In pursuit of sustainable goals 6 and 12 (<https://sustainabledevelopment.un.org>) such large volume of water can be treated and reclaimed for other uses particularly in a water scarcity nation like Kenya

(<http://www.unep.org/dewa/vitalwater/article83.html>), this waste water can be treated and reclaimed for other uses. Establishing facilities capable of improving the overall efficiency of coffee processing with focus on waste reduction is costly and may not be affordable to majority small-scale farmers. Opportunities for bulking raw material lies with factory level operations. Studies elsewhere indicate that coffee husk and pulp can be used as organic fertilizer, domestic fuel, and for biogas generation (Ulloa et al., 2003; Pandey et al., 2000; Kaliyan, 2009; Sanchez et al., 1999; Sorby, 2002), thus reducing the burden of waste disposal.

Although coffee processing has significant

sustainability challenges, major coffee producing nations such as Brazil have made significant efforts to treat coffee waste water and utilize solid biomass waste, thus contributing to reduced environmental pollution and burden on virgin resources (Cofie et al., 2005; Padmapriya et al., 2013). Further, since the middle of this century, efforts have been made to develop methods for coffee waste treatment and management, and also its utilization as a raw material for the production of vinegar, biogas, caffeine, pectin, peptic enzyme, protein, compost and feed for producing polysaccharides and mono-saccharide. While multiple benefits from using and adding value to agricultural wastes are appreciated in densely populated nations like India (Sindhu and Shehrawat, 2015), a key adoption limitation in most developing countries is lack of awareness and lack of detailed regulations on crop specific agricultural wastes management for environmental protection (Khanh and Thanh, 2010). Kenya lags behind in this regard, which translates into missed opportunities towards increased environmental and socio-economic benefits to farmers. Availability of this knowledge implies that new extension approaches that address the entire crop value chains with farmers owning key aspects thereof like is the case in soil improvement demonstration plots by the Alliance for a Green Revolution in Africa (AGRA) and International Institute of Rural Reconstruction (IIRR) (2014) may benefit coffee systems. Milling sites can be converted into extension service demonstration sites (plots) for maximized benefits from coffee wastes. For instance, the Gusii Coffee Farmers Co-operative Union is among progressive millers in Kenya who have embarked on processing of coffee husks into branded charcoal briquettes (Gusii Coffee Charcoal Briquettes - 100% Organic) as part of its efforts to protect the environment from the menace of dumping husks at the Union's coffee milling site (Oroko, 2015). Here-in is an initiative that the Ministry of Agriculture and the National Environment Management Authority (NEMA) could isolate for upgrading into a demonstration centre in order to scale-out and scale-up environmental and economic benefits from coffee wastes across all millers and supply farmers in the country.

Already this prospect of energy from coffee wastes has attracted entrepreneurs dealing with different products along the coffee value-chain, such as production of briquetting machines improved cookstoves for using such briquettes and product distribution and consultancy services (Youth Agro-environmental Initiative, 2015). Although the by-products of coffee processing include mucilage, which is part of waste water, the focus of this study was the potential of using pulp and husks in agricultural and energy services at the farm level. Suffice is to indicate that mucilage which is removed through the fermentation process makes waste water have serious environmental problems due to the high acidity generated

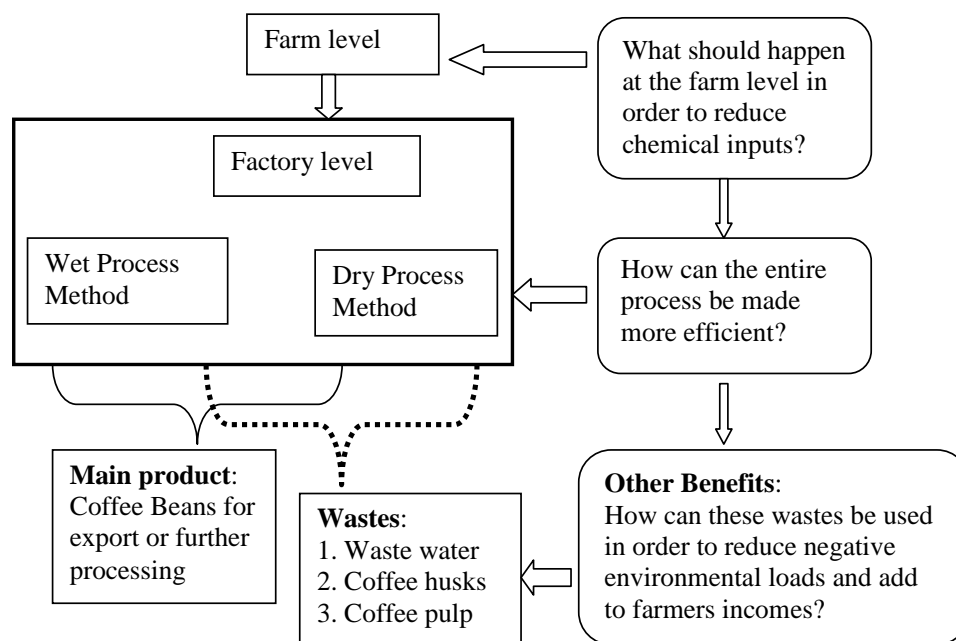


Figure 1. A life cycle management framework in coffee processing.

and also Biological Oxygen Demand (BOG) and chemical oxygen demand (COD) (<http://www.coffeeresearch.org/agriculture/processing.htm>; http://www.saiplatform.org/uploads/Library/6Coffee_Waste_Water_treatmentV4.pdf). For this paper, the focus was how to maximise benefits from coffee husks and pulp in the context of sustainability thinking.

METHODOLOGY

This study was done in Kiambu County, located within Central Kenya highlands. Its socio-economic activities are greatly influenced by its dense population, rich agricultural potential and proximity to Nairobi, the capital of Kenya. This County was selected because of its fame as a coffee growing and processing region, and increasing popularity of commercial peri-urban agriculture, which could tap into coffee biomass wastes as unique inputs. Since the main goal of this study was to assess general trends in the flow of pulp and husks, a survey design was adopted. Data was collected using interviews, questionnaires and environmental check lists. Primary data was obtained from a random sample of 252 respondents including 240 farmers and 12 factory operators obtained from the six study factories, namely *Karia, Gititu, Riabai, Gatei, Ndarugo and Ndumberi*. These factories were selected for being in the category of small to medium processing status (that is, capable of handling 500-3000 tons of coffee per year), and for having been operational with accurate records since 2008.

Quantities of coffee husk and pulp in each factory were calculated as percentages of the total amount produced per year. Variance at factory level with respect to the amounts of coffee solid waste and demand was also determined across the factories. The research plan used is summarised in Figure 1. Observation

checklists were used to document status of coffee processing infrastructure, various uses of coffee husks in the factories and the surrounding area, and critical environmental changes associated with coffee processing. Data was analyzed mainly by use of descriptive statistics since the main goal was to determine general trends in the key variables under investigation.

RESULTS AND DISCUSSION

Sustainability concerns

At the farm level, the study revealed that instability of coffee prices leads to low income generation from coffee growing. This translates into poor investment in farm inputs such as agro-chemicals and protective gear, as attested to by about 68% of the farmers interviewed (Table 1). On farm occupational health and safety standards remain items of concern. Since coffee farming requires high chemical input to regulate pests and diseases, farmers are at high risks of serious health concerns from exposure to toxic substances.

High demand for water in coffee processing is not a new challenge. The concern among millers in Kiambu County is the lack financial capacity for technological solutions to decrease and or treat the volume of waste water as well as turn solid biomass waste into other products such as fertilizer. Overall coffee farmers viewed sustainability concerns from a financial and economic perspective only, when negative environmental effects are likely to be most significant. In terms of marketing,

Table 1. Sustainability concerns for coffee processing life cycle.

Life cycle stage and activities	Sustainability Concerns (Economic, Social and Ecological)
Farm level	<ul style="list-style-type: none"> - Expensive agro-chemicals - Health risks due to minimum use of protective gear - Soil pollution due to copper-based agrochemicals - Water pollution from agro-chemical carried in sediment
Factory level	<ul style="list-style-type: none"> - Inadequate support infrastructure - Health and safety standards of coffee workers - High energy and hence threat to tree cover - High water demand amidst other competing uses - Odour from accumulating coffee pulp - Water pollution from disposed waste water
Marketing	<ul style="list-style-type: none"> - Declining and volatile coffee prices
Waste management	<ul style="list-style-type: none"> - Lack of a robust management framework - Inadequate protective gear - Poor disposal of waste water, pulp and husk - Negative environmental load particularly due to accumulating pulp

global fluctuations in prices and existence of multiple brokers in the marketing chain translates into diminished net returns to farmers.

Inventory analysis indicated that more than 8,000 tons of husks and pulp are generated every year in Kiambu County from using both wet and dry processing methods at factory level. All factories processed coffee using the wet method except *Ndarugo* and *Riabai*. As a result the amount of coffee husks generated in the two factories was significantly higher than other factories (Table 2). The husk generated in *Ndumberi*, *Gititu*, *Karia* and *Gatei* accounts for approximately half of the unprocessed coffee received. *Ndarugo* and *Riabai* husk generation is higher accounting for 57% of unprocessed coffee beans. On average the amount of husk and pulp generated in all factories in 2010 was 122.76 tons. With such availability of raw material, benefits along the coffee processing value-chain can be extended.

All the six factories recorded high wastage rates producing very little fine coffee in comparison to the unprocessed coffee received. Factory records showed that more than 8,000 tons of husks and pulp are generated every year in the County from using both wet and dry processing methods. The amount of coffee husks generated at *Ndarugo* and *Riabai* factories was significantly higher than other factories because the two used dry processing method. All factories except *Gatei* registered a general decline in raw coffee production from 2008-2010. This is indicative of changing land use in peri-urban areas in Kenya in favour of real estates. Overall about 56% of husk and pulp was generated, which translated into avoidable environmental burden were mechanisms of turning such waste into useful products

available.

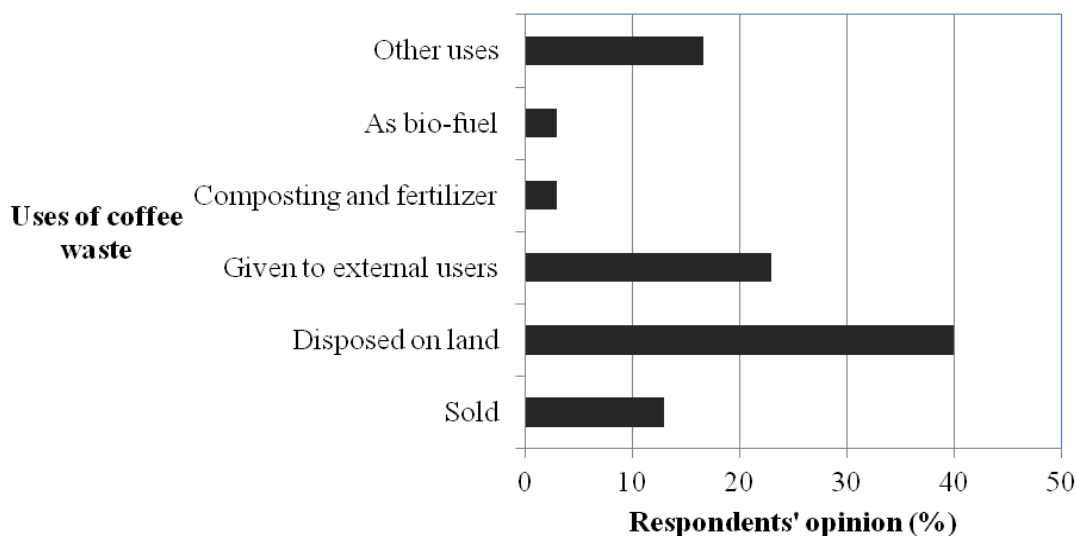
Relative importance and uses of coffee husks and pulp in Kiambu County

The utilization of coffee husk generated varied from one factory to another. Only 3% of the solid biomass was directly used as biomass fuel within the factories. About 13% of solid biomass waste was sold to external users, who used it in poultry farming. Up to 40% of the pulp and husk was disposed to the land, signifying lack of awareness on extra value or recycling technology for these resources (Figure 2). In addition to direct disposal of waste on land, limited knowledge on other ways of composting could account for the widespread use of open-pile approach, which reduced the pulp and husks to low grade organic fertilizer. Comparative assessment showed that more husk and pulp were used in agricultural services than in energy services (Table 3).

This is attributed to the high cost implications when it comes to biogas production and briquetting technologies. In addition the practice of using agricultural residues for manure and compost has been practised for a long time in Kiambu and thus become an acceptable culture unlike the use of agricultural residues for energy production at factory and household levels. This is indicative of the need for innovation and capacity building towards increasing benefits of coffee waste in energy service provision and other possibilities along coffee value chain. Compared to factory level, more solid biomass was used for composting as reported by about 47% of the respondents (Figure 3).

Table 2. Factory records of quantities of raw coffee and generated husks and pulp (tons).

Name of Factory	Year	Raw coffee received (tons)	Processed coffee (Tons)	Husk/Pulp generated (tons)	Husk/Pulp as % of raw coffee
Ndumberi	2010	94.70	24.00	36.75	38.80
	2009	100.13	48.60	56.07	56.00
	2008	102.90	43.20	57.62	56.00
Gititu	2010	45.00	18.50	25.20	56.00
	2009	51.70	21.70	28.99	56.10
	2008	53.00	20.50	29.70	56.00
Karia	2010	19.00	7.90	10.64	56.00
	2009	22.00	10.10	12.32	56.00
	2008	--	--	--	--
Ndarugo	2010	19.60	7.90	10.97	55.95
	2009	24.30	11.30	13.61	56.01
	2008	22.80	9.40	12.76	55.96
Riabai	2010	15.00	7.30	8.40	56.00
	2009	19.00	9.40	10.64	56.00
	2008	21.50	10.10	12.04	56.00
Gatei	2010	36.00	18.60	20.16	56.00
	2009	27.50	13.80	15.40	56.00

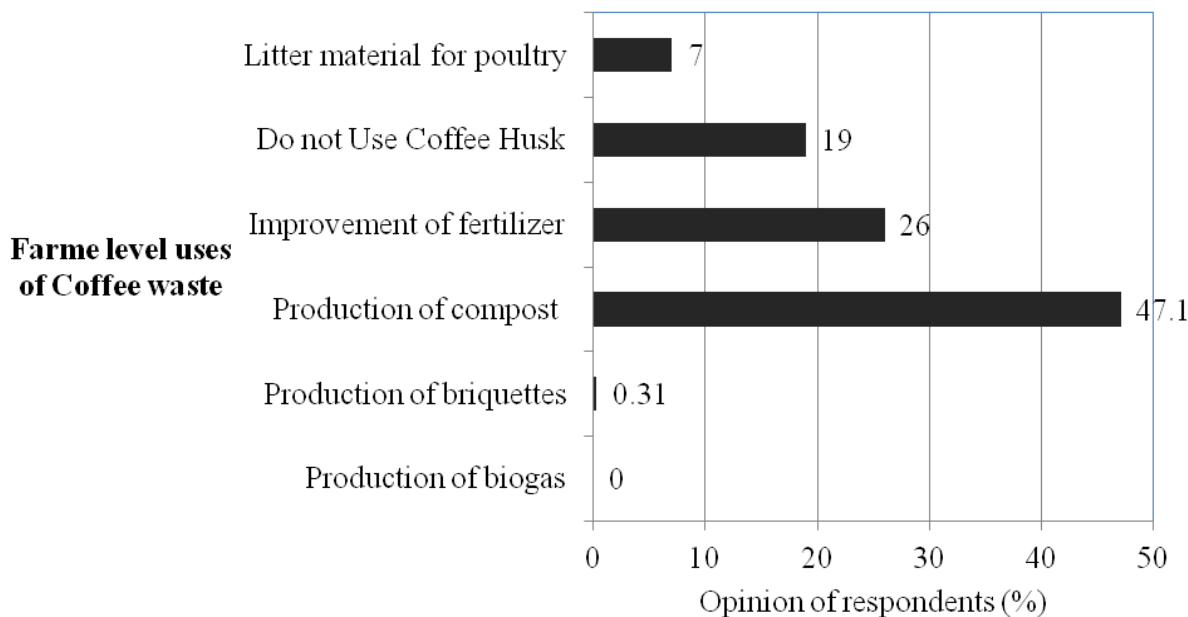
**Figure 2.** Relative importance of the uses of coffee husks and pulp at factory level.

Ndumberi Youth Group was the only respondents' category using coffee pulp for briquette production, accounting for only 0.3% of the respondents. This statistics is expected given the industrial nature of

briquette production and commensurate skills required which ordinary farmers do not have. Lack of knowledge of other forms of composting technologies could account for the widespread use of open pile system approach.

Table 3. Comparative use of coffee husk/pulp in agriculture and energy services (%).

Agricultural Services		Energy Services	
a. Organic fertiliser	27.10	a. Direct Biomass	13.70
b. Animal Feed	5.50	b. Biogas	4.50
c. Direct disposal on land	33.10	c. Briquettes	12.20
Total	65.70	Total	30.40

**Figure 3.** Comparative use of coffee husk/pulp among farming households and business users.

Increasing awareness and enhancing capacity on available technologies for using biomass waste for energy and agricultural services can contribute to husk and pulp management at household level.

Unlike Kenya, studies conducted in Costa Rica and Vietnam show that coffee pulp and husk are used in many more applications such as biogas production, mushroom growing, mulch, and animal feed among other uses (Pandey et al., 2000). With such readily available raw material, Kenya is missing out on other eco-based business opportunities with potential to impact farmers and their environment positively. This calls research and capacity building around multiple uses of coffee wastes along the value chain.

Challenges of using coffee husks and pulp in agricultural ecosystem

The outstanding challenges facing the use of coffee husk and pulp in the six factories were limited financial

resources for investment in waste management, lack of requisite equipment in material management, low demand of husks, and lack of trained personnel in overall agricultural waste management (Figure 4). Use of pulp and husks in energy services provision was constrained by lack technical knowledge and availability of other sources of cooking energy like kerosene, Liquefied Petroleum Gas (LPG) and wood fuel. Faced with challenges of climate change and declining availability of wood fuel, investing in biogas systems is one approach where the potential of pulp and husk could yield more economic and environmental benefits.

In Vietnam, biogas from pulp and parchment generation is used to produce both electricity and heat (Ali, 2004). However, respondents indicated that pulp and husks from coffee processing cannot be compared to other solid waste materials such as metals, paper, and some plastics, which have high demand from recycling traders within Kiambu. Further, coffee husks and pulp are also bulky and thus cumbersome and difficult during handling, transportation and storage. Respondents also

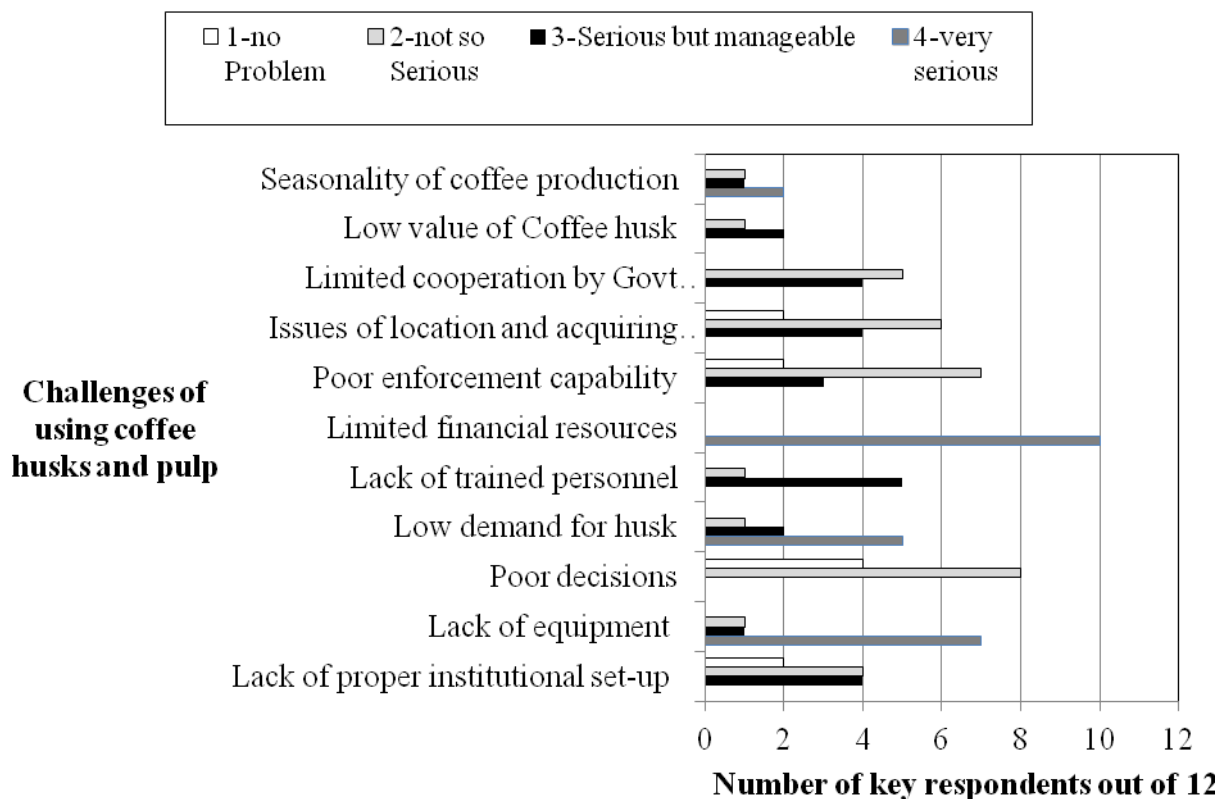


Figure 4. Factory operators' opinions on the challenges of using coffee husk and pulp.

blamed the low use of coffee husks and pulp in agriculture to risk of contamination from caffeine and tannins. More than 80% of respondents were also not aware of companies that use waste or persons who could collect the waste, hence the apparent accumulation of this waste. More than 60% of the respondents were not aware of biomass alternative devices and did not know what happened to collected wastes. About 55% did not think that coffee wastes could be a source of good income, but interestingly, more than 70% of the respondents were willing to pay for waste management services (Figure 5). This opinion could be informed by their perhaps higher understanding and concern for environmental quality and human health.

It seems that with good capacity and competence building, farmers and factories could invest in recycling and or re-use of coffee wastes as sources of extra income and in the interest of environmental health. The coffee factories relied on limited financial resources and therefore lacked the ability to manage the amount of coffee husk and pulp produced. On average 45.5 kg of green coffee requires between 1,000-2,000 L of water, 12.5 kWh of electricity and 0.07 cu. m of firewood for processing (Instituto del Café de Costa Rica - ICAFE, 2006). This is exacerbated by lack of equipment

and infrastructure in the factories. Incorporating waste management as an integral part in coffee processing can establish innovative and feasible approaches which have potential to maximize use of pulp and husk in Kiambu. Mobilizing resources for biogas development at selected factories has merit in the context of clean production mechanisms as envisaged in sustainable development goals.

In terms of the use of coffee solid wastes, the survey revealed that planning and economic factors were the most limiting constraints and in particular lack of awareness about alternative uses of wastes and lack of modern equipment in waste management (Figure 6).

About 20% of farming households raised concerns about using urban composts for fear of contamination and hence risk to consumers of produced crops. In addition, about 70% of the farmers had a positive attitude towards compost but were not willing to pay for the product as opposed to chemical fertilizers. Further 87% of respondents were not aware of alternative energy devices for domestic cooking and heating that is available, despite many agreeing that biomass solid coffee waste can be profitably utilized. Combined efforts by the public extension, environmental agencies, research and training organisation is needed to raise awareness in

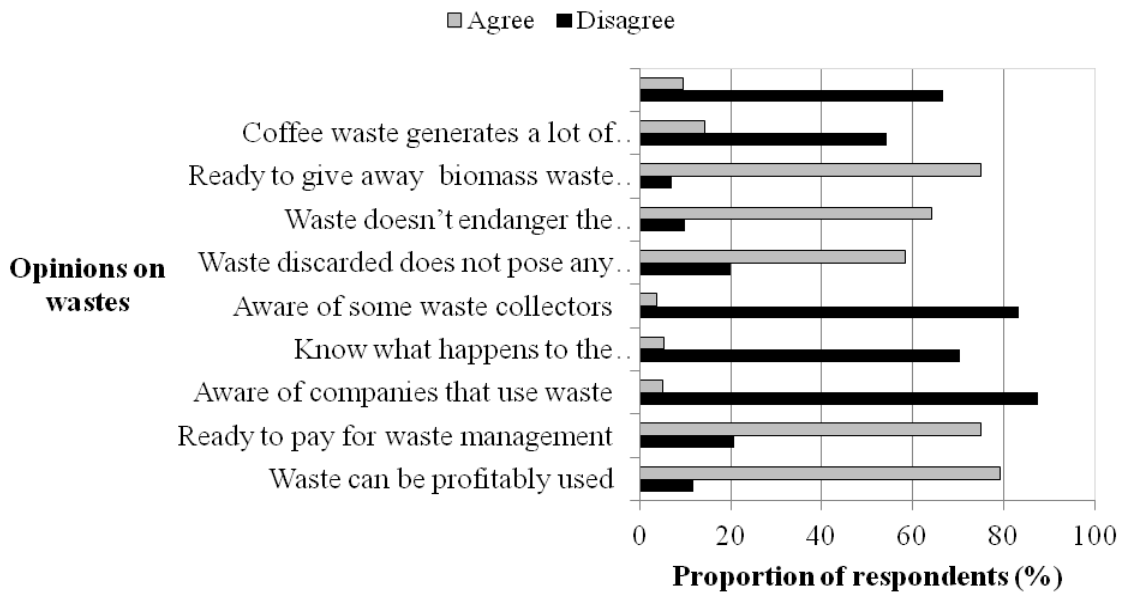


Figure 5. Respondents' opinions on various aspects of biomass coffee waste (%).

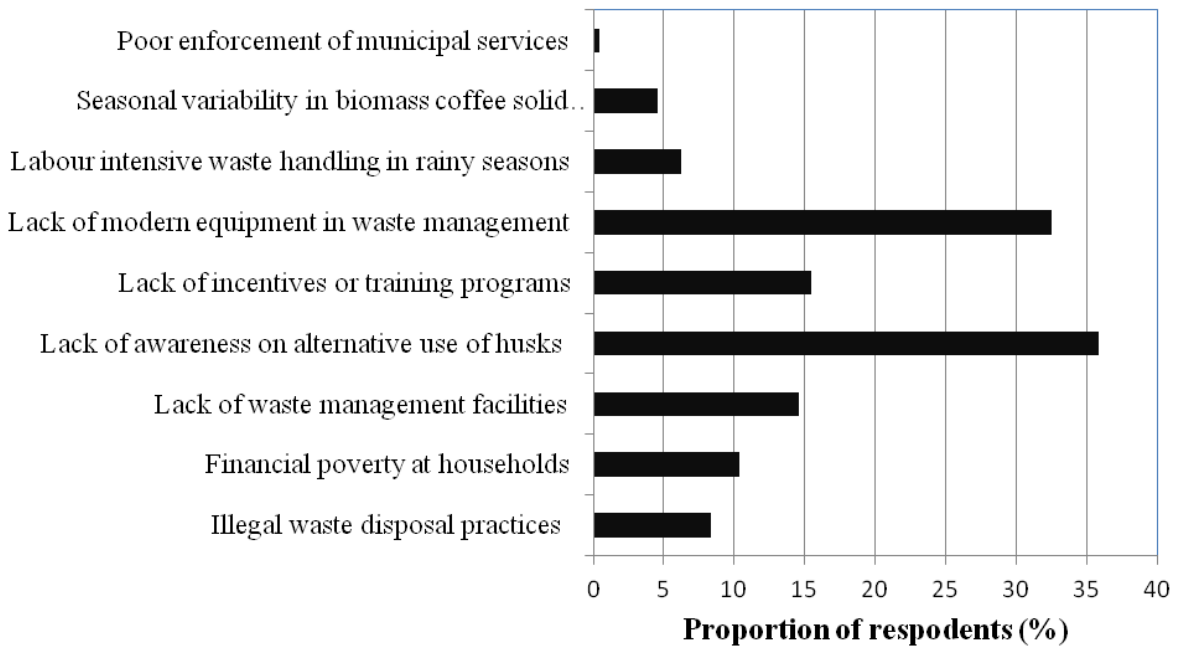


Figure 6. Factors influencing use of coffee solid wastes.

the potential of coffee wastes in environmental enhancement and income generation.

CONCLUSIONS AND RECOMMENDATIONS

Solid biomass wastes from coffee processing constituted

about 51% of the total raw input. About 40% of this waste is routinely disposed directly to the land hence contributing to avoidable pollution. Success stories elsewhere indicate that with proper planning and investment, these amounts of coffee wastes can be used in particular compost, briquettes and biogas at selected factories, being inherent bulking centres. Accordingly

some factories can be strategically selected, re-organised and re-designed to include in-situ compost and biogas production systems. While compost can be sold to farmers or distributed to them based on corporate social responsibility principles, the biogas can be distributed to homesteads in proximity to the design factories to ease their reliance on wood fuel.

For not being bulky, coffee husks can also be used for mass production of branded briquettes in-situ or elsewhere and marketed as an alternative source of clean domestic energy. The contribution to global effort against reliance on wood fuel, increasing tree cover and mitigation of climate change effects cannot be overemphasised. Similarly, waste water that is conventionally discharged into water bodies can be sufficiently treated and used for irrigation in crop farming. All these under-utilised agri-business innovations call for commodity specific extension service, which should be deliberately aligned to sustainable development goals focussing on sustainable production and consumption agenda.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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