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RESEARCH ARTICLE

WET COFFEE PROCESSING WASTE MANAGEMENT PRACTICE IN ETHIOPIA

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ABSTRACT

Coffee is one of the most important agriculture commodities in the world. Ethiopia had been the origin of coffee because coffee plant was initially found and cultivated in the Kaffa province. Due to the great demand of coffee, large amounts of residues are generated in the coffee industry, which are toxic and represent serious environmental problems. 100 kg of fresh berry gives about 40 kg of wet waste pulp. Coffee pulp contains caffeine, tannins, polyphenols and organic solid residues. It shows toxic nature and thus not been utilized beneficially. This effluent is being directly discharged to the nearby water bodies causing severe ailments like overexcitement, skin irritation, stomach pain, nausea and breathing problem. Severeness of this waste causes a serious environmental problem among the residents of nearby area. For this reason, efforts have been made to develop methods for coffee waste treatment and management, also its utilization as a raw material for the production of bio energy is emerging as a new technology. Recently, some attempts have been made to use these residues for energy or value-added compounds production as strategies to reduce their toxicity levels. The present article provides an overview regarding coffee and its main industrial residues. Based on the data, it was concluded that coffee may be considered as one of the most valuable primary products in world trade, crucial to the economies and politics of many developing countries since its cultivation, processing, trading, transportation, and marketing provide employment for millions of people. As a consequence of this big market, the reuse of the main coffee industry residues is of significant importance from environmental and economical viewpoints.

INTRODUCTION

Coffee is one of the most important agricultural export commodities in the world economy, next to oils and it is the most important and strategic commodity on which Ethiopia's economy depends on. It has always been the most important cash crop and largest export commodity, which account 90% of exports and 80% of total employment in Ethiopia (Addis Ababa, 2008). Ethiopia had been the origin of coffee since coffee plant was initially found and cultivated in the Kaffa province (Bonga, Makira) of Ethiopia (UNCTAD/WTO, 2002). Coffee in Ethiopia contributes 41% of the country's total foreign exchange earnings and about 10% of the gross domestic product. Over 25% of the populations of Ethiopia are dependent on coffee for their livelihoods. There are four types of coffee production system in Ethiopia: forest coffee (10%), semi-forest coffee (35%), garden coffee (35%), and plantation coffee (20%) (5% government, 15% private) (Addis Ababa, 2008). Coffee contains over 1500 chemical substances, 850 volatile and 700 soluble, and when prepared correctly involves 13 independent chemical and physical variables. When coffee is extracted in water, most of the hydrophobic compounds, including oils, lipids, triglycerides, and fatty acids remain in the grounds, as do insoluble carbohydrates like cellulose and various indigestible sugars. Structural lignin, protective phenolics and the wonderful aroma-producing essential oils are also present in coffee. Coffee is a major plantation crop grown worldwide and is one of the most popular beverages consumed throughout the world. There are three common species of coffee: robusta, arabica and liberica. 75-80% of the coffee produced worldwide is Arabica and 20% is Robusta.

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Residues Generated in the Coffee Industry

The agro-industrial and the food sectors produce large quantities of waste, both liquid and solid. Due to the great demand of coffee, coffee industries are responsible for the generation of large amount of residues, which are toxic and represent serious environmental problems (Solange *et al*., 2011).

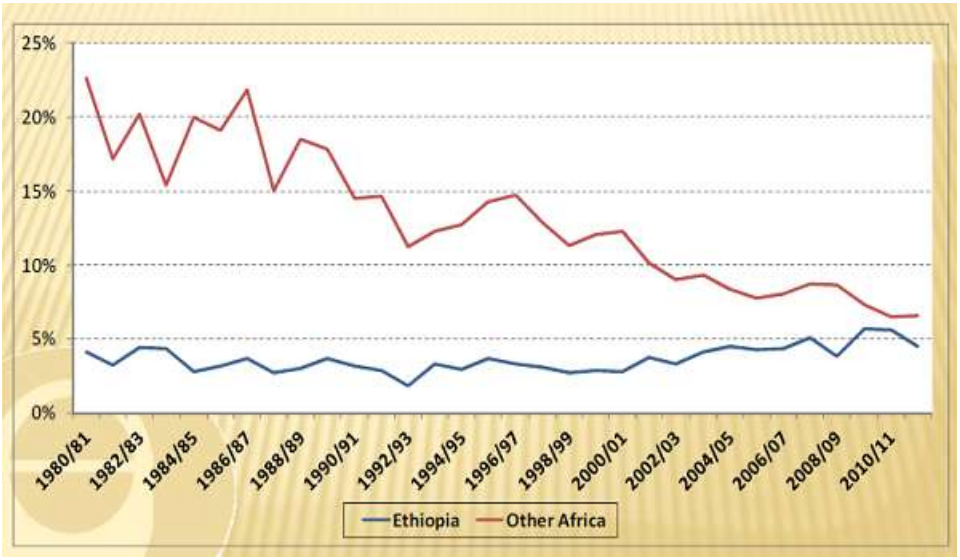
Table 1. Africa: Coffee production (Average in thousand bags of 60 kg each)

Year	1980 - 89	1990 - 99	2000 - 09	2010 -12
Total Africa	19888	16078	15372	15712
Ethiopia	3128	2973	4904	6450
Uganda	2724	2811	2924	3002
Cote d'ivoire	4338	3448	2692	1291
Cameroon	1771	1022	821	845
Tanzania	875	779	796	686
Congo, D.R.	1610	1019	383	681
Kenya	1726	1377	766	669
Madagascar	1092	780	490	566
Others	2625	1868	1597	1522

nature, without any treatment, causes severe environmental pollution due to putrefaction of organic matter.

Coffee Industry Residues Applications

Nowadays, there is great political and social pressure to reduce the pollution arising from industrial activities. Almost all developed and underdeveloped countries are trying to adapt to this reality by modifying their processes so that their residues can be recycled. Consequently, most major companies no longer consider residues as waste, but as a raw material for other processes (Mussatto *et al*., 2006).



Source: (International Coffee Organization, 2014)

Fig. 1. Percent (%) share of Africa and Ethiopia in World coffee production (International Coffee Organization, 2014)

Fig. 2. Harvesting coffee for wet processing

The wastewater generated from coffee processing plant contains organic matter like pectin, proteins, and sugars (Bello-Mendoza and Castillo-Rivera, 1998). Coffee pulp, one of the principal by-products of wet processed coffee constitutes almost 40% of the wet weight of the coffee berry, is rich in carbohydrates, proteins, amino acids, poly-phenols, minerals, and appreciable quantities of tannins, caffeine and potassium. The poly-phenols and caffeine are reported to be the anti-physiological factors on animal feed. Hence, coffee pulp has to follow a preliminary treatment before it is used (Sebastianos *et al*., 1998). Coffee pulp is generated to the extent of 40% in the fermentation of coffee berries poses many problems in the coffee producing countries. Its disposal in The presence of organic material and its demand of great quantities of oxygen to degrade confer a toxic nature. Despite the negative characteristic and the large amounts that they are generated, there are few studies focusing on their use in different and profitable applications. Besides to add value to these unused materials, finding alternative forms to use them would be useful to decrease their impact to the environment (Solange *et al*., 2011).

Processing of Coffee

There are two ways by which coffee can be processed: wet (fermented and washed) and dry (natural) processing. In most

cases, wet processing is regarded as producing a higher quality product.

Wet Method

Approximately half of the world coffee harvest is processed by the wet method in which the coffee berry is subjected to mechanical and biological operation in order to separate the bean or seed from the exocarp (skin), mesocarp (mucilagenous pulp) and the endocarp (parchment) (Clark, 1985). Pulp represents about 40% of the weight of the fresh fruit and presently is underutilized, causing serious pollution problems. In wet method, the de-pulping involves the removal of the outer red skin (exocarp) and the white fleshy pulp (mesocarp) and the separation of the pulp and beans. Immature cherries are hard and green and very difficult to de-pulp. If the coffee is to be wet processed, correct harvesting is essential. For small-scale units, the cherries can be de-pulped in a pestle and mortar, and is very labor intensive.

Dry Method

In dry method, the coffee cherries are dried immediately after harvest. This is usually sun drying on a clean dry floor or on mats. The bed depth is less than 40 mm and the cherries are raked frequently to prevent fermentation or discoloration. However, there are problems associated with this method. The most serious problem is dust and dirt blown onto the product. Another problem is rainstorms often appear (even in the dry season) with very little or no warning. This can soak the product very quickly. Labor has to be employed to prevent damage or theft. Sun drying is therefore not recommended. The dried cherry is then hulled to remove the pericarp. This can be done by hand using a pestle and mortar or in a mechanical huller. The mechanical hullers usually consist of a steel screw, the pitch of which increases as it approaches the outlet so removing the pericarp.

Fig. 3. Sun drying of coffee for dry process

Problems of Coffee Waste

Agro-industrial residues/wastes are generated in large quantities throughout the world. Their non-utilization results in loss of valuable nutrients and environmental pollution.

Fig. 4. Waste disposal

The better utilization by biotechnological means assumes social, economic and industrial importance. The wastewater from agro industries has high concentration of organic pollutants. So it's very harmful for surrounding water bodies, human health and aquatic life if discharged directly into the surface waters. People residing in the vicinity of agro industries utilizing the stream water for domestic purposes suffer from severe health problems (Alemayehu and Rani, 2008). The seriousness of the situation is shown in Table 2. From this it is obvious that some people were suffering from one problem while others were having cumulative health effects. Agricultural practices such as use of organic herbicides, inorganic and synthetic pesticides, efficiency of the uses of inorganic fertilizers, etc., determines the environmental issues arising from them. For instance, the use of agricultural pesticides significantly changes the toxic characteristics of the wastewater (Chanakya and Dealwis, 2004).

Table 2. Health problems reported by the population living nearby industries (Alemayehu and Rani, 2008)

Health problems	% of population affected
Spinning sensation (feeling drunk)	89
Eye irritation (burning inside)	32
Skin irritation	85
Stomach problem	42
Breathing problem	75
Nausea	25

Coffee pulp/husk contains some amount of caffeine and tannins, which makes it toxic resulting in disposal problem. However, it is rich in organic matters, which makes it an ideal substrate for microbial processes for the production of value-added products. Several solutions and alternative uses of the coffee pulp and husk have been attempted. These include fertilizers, livestock feed, compost, etc.

Management of Coffee Waste

Having known the problems of coffee waste, several attempts have been made to manage. Coffee pulp solid waste is being converted into compost, which was used by the suppliers in fertilizing their coffee farms. Waste water management techniques used by the coffee pulping operators are based on the use of lagoons.

Table 3. Characteristics of effluent wastewater from conventional wet coffee processing plants

Parameter	Mean ± SD	discharge standard (Ethiopia EPA)
pH	4.13 ± 0.23	6-9
BOD_5 mg/L	1697 ± 391	80
COD mg/L	5683± 304	250
NH_3 mg/L	4.51 ± 1.62	5
NO_3N mg/L	3.39 ± 0.65	20
PO_4^{3-} mg/L	3.32 ± 0.5	5
TSS mg/L	1975 ± 322	100
TDS mg/L	1801 ± 245	3000
DO mg/L	2.14 ± 0.72	-

Source: (Tsigereda *et al*., 2013)

Environmental Issues

The coffee process has been causing environmental problems at the local level not only due to the consumption of water, but more due to the discharge of effluents with large volumes of organic waste. Pollutants in coffee wastewater emerge from the organic matter set free during pulping, especially due to the difficulty in degrading the mucilage layer surrounding the beans. The organic and acetic acids from the fermentation of the sugars make the wastewater very acidic (with pH as low as 3.8), a condition in which higher plants and animals can hardly survive. Moreover, the total suspended solids in the effluents are high; in particular, the digested mucilage, when precipitated out of the solution, builds a crust on the surface, clogging up waterways and further contributing to the anaerobic conditions.

Table 4. Composition of coffee waste

Pulp		Mucilllage	
Contents	Proportion (%)	Contents	Proportion (%)
Ether extract	0.48	Water	84.2
Crude fiber	21.4	Protein	8.00
Crude protein	10.1	Reducing sugar	2.50
Ash	1.50	Non-reducing sugar	1.60
Nitrogen free extract	31.3	Pectin	1.00
Tannins	7.80	Ash	0.70
Pectic substances	6.50		
Non-reducing sugars	2.00		
Reducing sugars	12.4		
Chlorogenic acid	2.60		
Caffeine	2.30		
Total caffeic acid	1.60		

In addition, the presence of some toxic chemicals – alkaloids, tannins, and poly-phenolics makes the environment for biological degradation of organic material in the wastewater more difficult. The main ecological effect of organic pollution in a water course (into which effluents have been discharged) is the decrease in oxygen content. The organic substances diluted in the wastewater break down very slowly by microbiological processes, using up oxygen from the water. Due to the decrease in oxygen content, the demand for oxygen to break down organic material in the wastewater exceeds the supply, dissolved in the water, thus creating anaerobic conditions.

The amount of oxygen needed to biologically break down organic wastes diluted in water (BOD) could be as high as 15,000 mg/l, while the amount of dissolved oxygen required to combine with chemicals in the wastewater (COD), could be between 15,000 and 25,000 mg/l. The resulting anaerobic conditions can be fatal to aquatic creatures and also cause bad odour; moreover, the bacteria cause health problems if the wastewater seeps into a source of potable water. Another environmental problem is the high requirement of water for coffee processing; as much as 15,000 litres per tonne of cherries (coffee fruit) can be used, if there is no recycling and reuse (UNCTAD/WTO, 2002). In Ethiopia at present, there are more than 1026 wet coffee processing installations processing 1000 tons of coffee cherry daily on average and a number of industries under construction. About 15 liters of water is required to recover 1 kg of clean green coffee beans. The effluents from the processing industries are directly discharged to the river streams. Waste water from pulping, fermentation and washing of coffee beans presents series problem on receiving environment especially on water bodies.

Conclusion

In coffee producing countries, coffee waste constitutes a source of severe contamination and serious environmental problems. For this reason, since the middle of the last century, efforts have been made to develop methods for coffee waste treatment and management, also its utilization as a raw material for the production of feed, beverages, vinegar, biogas, caffeine, pectin, peptic enzyme, protein, and compost. Hence, there is a need to curb these problems through innovative and eco-friendly techniques. So, this documentation may be an eye opening for the area. Presently, coffee waste management systems in Ethiopia are not operating. They could reduce on their losses if they employ qualified staff and adopt modern management techniques. Therefore, unless they improve their profitability, they will consider demands to take an additional investments, e.g. for environment as a burden. Many by-products from wet coffee processing offer additional sources of revenue, employment and new enterprises. It is therefore high time that coffee waste started to put a price.

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