Coffee waste management-An overview
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Abstract

Coffee is one of the most important agriculture commodities in the world. *Coffea arabica* and *Coffea robusta* are the two principal varieties of the genus cultivated all over the world. 1000 kg of fresh berry gives about 400 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 giddiness, skin irritation, stomach pain, nausea and breathing problem. Severe of this waste courses and 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 feeds, beverages, vinegar, biogas, caffeine, pectin, pectic enzymes, protein and compost. Coffee waste is emerging as a new feed for producing polysaccharides and monosaccharide.

Keywords: coffee effluent, *Coffea arabica*, *Coffea robusta*, by products

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Introduction

Coffee (*Coffea* sp.) is one of the most important agricultural commodities in the world (ICO, 1998). Ethiopia had been the origin of coffee because coffee plant was initially found and cultivated by Oromo people in the Kafa province (ITC, 2002). Coffee is concerned with only two/three coffee species like *Coffea arabica*, *Coffea robusta*, *Coffea liberica* and *C. canephora*. It belongs to the family Rubiaceae, which produce seeds that are used for coffee preparation. Coffee is a brewed beverage with a distinct aroma and flavor, prepared from the roasted seeds of the *Coffea* plant. It is dark in colour and the roasted round bean is used around the world to prepare an aromatic, stimulating beverage.

Coffee is derived from 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 (Central Coffee Research Institute, 2000).
Jimma zone is one of the areas in Ethiopia where coffee producing plants are cultivated in large numbers (ITC, 2002). Angola, Benin, Bolivia, Brazil, Burundi, Cameroon, Central African Republic, Cote d’Ivoire, Colombia, Republic of Congo, Democratic Republic of Costa Rica, Cuba, Dominican Republic Ecuador, El Salvador, Equatorial Guinea, Ethiopia, Gabon, Ghana, Guatemala, Guinea, Haiti, Honduras, India, Indonesia, Jamaica, Kenya, Liberia, Madagascar, Malawi, Mexico, Nicaragua, Nigeria, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Rwanda, Sierra Leone, Sri Lanka, Tanzania, Thailand, Togo, Trinidad and, Tobago, Uganda, Vietnam, Zambia, Zimbabwe are the countries that produced coffee in the world. India has 4.5% share of the global coffee market. Coffee production in India is dominated in the hill tracts of South Indian states, with the state of Karnataka accounting 53% followed by Kerala 28% and Tamil Nadu 11% of production of 8,200 tones. There are 250,000 coffee growers in India. In Tamil Nadu, Nilgiris District, Yercaud and Kodaikanal are the areas in which coffee is produced (Yeboah, Salomey, 2010). The production rate of coffee in Karnataka is about 2,27,205 tones, with 78,705 tones of arabica and 1,48,500 tones of robusta.

The coffee varieties arabica and robusta production rate falls on 2,075, 61,750 and 17,750 tones in the region of Kerala and Tamil Nadu respectively. There are many different robusta (Coffea canephora) varieties. In general, they can thrive in hotter lowland areas (i.e.) below 900 m above sea level and over 20°C. Robusta coffee is preferred for instant coffee production due to high soluble solid extraction. Liberica (Coffea liberica) is a larger tree with large leaves and berries. It can tolerate hot and wet conditions. The coffee produced is bitter. This is preferred in Malaysia and West Asia. Robusta is a high-yielding plant, resistant to disease, growing at lower elevation, characterized by ‘harsh’ flavours, containing about 2% caffeine and yielding 1-1.5 kg green coffee per plant per year. It is used in lower grade coffee, generally not found in specialty shops, and is often used to make soluble (instant) coffee and popular commercial blends.

Arabica (Coffea arabica) is a glossy leafed shrub or small tree. The leaves are relatively small and the flowers are fragrant and white. Arabica coffee usually receives a premium for its superior flavour and aroma. Arabica is more suited to higher, cooler climates like 600-2000 m above sea level and 15-20°C. The species arabica grows best at altitudes of 3000-6500 feet, has a refined flavor, contains about 1% caffeine and yields 0.5-0.8 kg per plant per year. It is a coffee that specialty roasters search for and accounts for about 75% of world production. Arabica is susceptible to disease and poor climatic conditions such as frost and drought (Chanakya, 2004). The wastewater generated from coffee processing plant contains organic matter like pectin, proteins, and sugars (Bello-Mendoza, 1998).

Coffee pulp, one of the principal byproducts of wet processed coffee (Coffea arabica. L.) which constitutes almost 40% of the wet weight of the coffee berry, is rich in carbohydrates, proteins, minerals, and appreciable quantities of tannins, caffeine and potassium (Bresanni, 1979). Coffee pulp is the main byproduct on coffee exploitation industry. Two tons of green coffee produces one ton of coffee pulp (dry matter). Its production on world scale raised 2.400.000 tons in the harvest cycle from 1986 to 1987. Coffee pulp is essentially composed of carbohydrates, proteins, amino acids, mineral salts, tannins, poly phenols, and caffeine. The polyphenols 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 Roussos, 1998). Coffee pulp is generated to the extent of 40% in the fermentation of coffee berries (Zuluaga, 1989), poses many problems in the coffee producing tropical countries. Its disposal in nature, without any treatment, causes severe environmental pollution, due to putrefaction of organic matter (Zuluaga, 1989). Hence, it is essential to treat and manage preferably by organic means.

**Characteristics of coffee**

The three main characteristic features of coffee are acidity, aroma and taste. Acidity is related to the dryness caused by coffee on the edges of the tongue and the back part of the palate. Without sufficient acidity, the coffee is frequently flat. To feel the aroma of coffee, people first inhale the vapor that rises from the cup. Just like a wine taster, a good coffee drinker, inhales the aroma before allowing his/her lips to touch the coffee. The relation between acidity, aroma, and body gives coffee its taste like caramel, chocolaty, fragrant, fruity, ripe, sweet, almondy, delicate, piquant etc.

**Processing of coffee**

There are two ways by which coffee can be processed and are dry (natural) processing and wet (fermented and washed) processing. In most cases, wet processing is regarded as producing a higher quality product. However, some areas prefer dry processed coffee for its fuller flavor. The areas in which coffee processing are being done by wet and dry methods are given below:

Dry processing areas are Angola, Benin, Brazil, Central African Republic, Congo, Congo Democratic Republic, Côte d’Ivoire, Gabon, Ghana, Guinea, Haiti, Madagascar, Nigeria, Paraguay, Philippines, Sri Lanka, Thailand and Togo (Chellamuthu et al., 2000).

**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). Adams and Dougan (1981) reported that the skin and most of the pulp is separated in the pulpers. This fraction represents about 40% of the weight of the fresh fruit and presently is underutilized, causing serious pollution problems. In wet method, the 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 pulp. If the coffee is to be wet processed, correct harvesting is essential. For small-scale units, the cherries can be pulped in a pestle and mortar, and is very labour intensive. There are the two most common pulpers and most suitable for small-scale units. They are the drum and the disc pulpers.

**Drum pulpers**

This involves a rotating drum with a punched sheet surface and adjustable breast plate between which the coffee cherries are pulped and the pulp and the beans separated. The distance between the drum and the breast plate has to be adjusted so that the pulp is removed without
the beans being damaged. These can be manually operated or attached to a treadle or bicycle. For larger scale units, motorized drum pulpers are available.

**Disc pulpers**

The concept used in drum pulper is involved with the disc pulper also. The only difference is that rather than the cherries being squeezed between a breast plate and a drum, a disc with a roughened surface is used in disc pulper. Adams (1981) investigated that the industrial processing of coffee cherries is done to isolate coffee powder by removing shell and mucilaginous part from the cherries.

**Dry method**

In dry method, the coffee cherries are dried immediately after harvest. This is usually sun drying on clean dry floor or on mats. The bed depth is less than 40mm 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 produce. Another problem is rainstorms often appear (even in the dry season) with very little warning. This can soak the produce very quickly. Finally, labour has to be employed to prevent damage or theft. Sun drying is therefore not recommended. Alternatively solar drying is done where the solar cabinet drier and the exell solar drier are used. In this way the coffee is placed in the trays in the solar drier. The layer of the crop is deeper than one inch (3 cm) and the whole tray area is covered. The drier will be made ready as early in the day as possible so that all possible sunlight hours are used. The coffee is stirred regularly so that a uniform colouration is formed. At night, the crop should be placed in a cool dry room. In the wet season solar drying of produce is difficult. Rain is very unpredictable and frequent. Solar driers will prevent the coffee getting wet. However, due to the low level of sunlight, solar drying can take a long time. This can lead to mould growth. Hence, an alternative drier is used.

**Hulling**

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.

**Cleaning**

The hulled coffee is cleaned by winnowing.

**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 (Zuluaga, 1989). The better utilization by biotechnological means assumes social, economic and industrial importance. Considering these facts, centre of ORSTOM participated into a scientific collaboration with Universidad Autonoma Metropolitana (UAM), Mexico for the development of biotechnological processes for better utilization of agro-industrial byproducts/wastes, especially the coffee pulp (Viniegra et al., 1991; Chapman, 1996, Deepa, 2002). The wastewater from such type of 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. Alemayehu Haddis (2008) reported that the people residing in the vicinity of this plant utilizing this stream water for domestic purposes suffer from severe health problems. The seriousness of the situation is shown in Table 1. 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, 2004).

Table 1. Health problems reported by the population living nearby industries (Alemayehu Haddis, 2008)

<table>
<thead>
<tr>
<th>Health problems</th>
<th>% of population affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinning sensation (feeling drunk)</td>
<td>89</td>
</tr>
<tr>
<td>Eye irritation (burning inside)</td>
<td>32</td>
</tr>
<tr>
<td>Skin irritation</td>
<td>85</td>
</tr>
<tr>
<td>Stomach problem</td>
<td>42</td>
</tr>
<tr>
<td>Breathing problem</td>
<td>75</td>
</tr>
<tr>
<td>Nausea</td>
<td>25</td>
</tr>
</tbody>
</table>

Coffee pulp/husk contains some amount of caffeine and tannins, which makes it toxic resulting 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. However, for these applications only a fraction of available quantity is utilized and is not technically very efficient. Attempts have been made to detoxify it for improved application as feed, and to produce several products such as enzymes, organic acids, flavour and aroma from coffee pulp/husk. Solid state fermentation has been mostly employed for bioconversion processes. Factorial design experiments offer useful information for the process optimization. Pandey (2000) reported the developments on processes and products developed for the value-addition of coffee pulp/husk through the biotechnological means.

Management of coffee pulp

Having known the problems of coffee waste several attempts have been made to manage the same. An aerobic lake system (meaning aerobic lagoons) was reported by San Luis Beneficio a production facility in Brazil. This method facilitated recycling of wastewater back into production plants. Coffee pulp solid waste was converted into compost, which was used by the suppliers in fertilizing their coffee farms (www.cetr.br). Waste water management techniques used by the coffee pulping operators in India are based on the use of lagoons. Anaerobic digestion has been applied with different degrees of success, to the treatment of liquid and solid wastes from the coffee processing units (Kostenberg, 1993). Under appropriate operational conditions, anaerobic reactor will remove the organic and suspended solids loads with an efficiency of 70-80%. However, in many cases the produced effluent will require a post-treatment step to produce a final effluent quality that is compatible with the standards set by the environmental control authorities (Sousa et al., 2001). They made an attempt to increase the nutritional value of CoP for monogastric animals by the following methods: (a) NaOH treatment; (b) pre-treatment with HCl followed by NaOH, and (c) pre-treatment with NaOH followed by ensilage. Rojas, (2002) analyzed the response of CoP to these treatments by measuring changes in the chemical composition of treated and untreated CoP samples. Selvamurugan (2010) made an attempt to ensure that an effluent quality that complies with the Indian Standards for the effluent discharge, different combination of treatments like biomethanation, aeration and constructed wetland technology were adopted as an integrated system for the treatment of coffee processing waste water.
Adsorption-based technique (Devi et al. 2002; Devi and Dahiya 2006) developed with low-cost carbonaceous materials showed good potential. Such adsorption approach can offer an easy and economic solution to these environmental challenges. Moreover, activated carbon is considered very effective in reduction of color, absorbable organic halides and non-biodegradable pollutants present in such waste water but this process also has some additional costs associated with the production of activated carbon. The high rate reactor, most widely used for the treatment of several types of wastewaters is upflow anaerobic sludge blanket (UASB) reactor which was developed by Lettinga, (2001). The upflow anaerobic hybrid reactor (UAHR) configuration has combined the advantages of both UASB and upflow anaerobic filter (UAF) while minimizing their limitations and the reactor was efficient in the treatment of dilute to high strength waste water at high organic loading rates (OLRs) and short hydraulic retention time (HRT).

The current anaerobic-aerobic lagoon system was evolved around 1978. The National Environmental Engineering and Research Institute (NEERI), Nagpur, produced a waste water processing solution based on the existing water usage pattern of 16,000-23,000 litre water per ton of fruit processed. The treatment process is based on the use of anaerobic (21 days) and aerobic (7 days) lagoons after an initial chemical pre-treatment (neutralization). The Indian Coffee Board has suggested this process with a total 29 days hydraulic retention time (HRT) (CCRI, 2000). A number of research efforts are in progress. Mohammed et al. (1998); Wang et al. (2005) developed such types of waste water treatment technologies. Various low-cost adsorbents like chitin, chitosan, corn stalks, peat, rice husk, and wood have been used for removal of organic matter from industrial effluents (Poots et al., 1976; Mckay et al., 1980; Sharma and Sharma, 1994). Discarded material based low-cost adsorbents of different origins like industrial waste material, bagasse, fly ash, and jute processing waste can also be used for removal of organic matter from waste water (Patnaik et al., 1996; Pala and Tokat, 2002; Srivastava et al., 2005; Wang and Wu, 2006; Bhatnagar, 2007).

By products

It is understood from the literature that many byproducts have been prepared from coffee waste. Some of them are as follows:

(i) Organic manure

Coffee pulp is a source of nutrients: 0.5% of composted pulp is nitrogen, 0.15% is phosphorus, and 0.5% is potassium. Therefore, pulp was treated and used as organic fertilizer. The pulp left in piles, for 3 to 12 months, turns into rich, black humus that can be used for composting. Another way of composting is to mix coffee husk with cattle manure, leaving the mixture in pits or heaps. The use of organic fertilizer helps to improve soil properties thus increasing yield as shown through investigations in Columbia. Using organic fertilizers also helps to reduce the need to buy inorganic fertilizers, hence saving the farmers money.

(ii) Role in Mushroom production

Coffee pulp is used as planting soil for mushroom production. After having fermented for two days, the pulp is pasteurized with hot water, drained, dried, and mixed with mushroom spores. Then, they are put in plastic bags. After 3 - 4 weeks, the mushrooms grow out of the holes in the bags and are collected. One bag allows 2-3 mushroom-harvests. The mushroom can be eaten or dried and sold in
the market. Considering the large amount of coffee pulp generated every harvesting season, the income from mushroom growing is significant for farmers.

(iii) Animal feed

As the coffee pulp is rich in nutrients. It can be dried and used in animal feeds. Further application, the pulp needs to be treated as soon as possible to prevent the development of fungi. The pulp can be treated with Ca(OH)₂ and dried under pressure. Alternatively, the pulp can be mixed with sugar cane molasses, or urea and other inorganic substances and put in silos. The silage can be used after 3 weeks, and can be stored up to 18 months. However, using coffee pulp as animal feeds is of limited value, since the cost for drying the pulp sometimes exceeds the gain. Besides, the effects of caffeine, tannin and the high level of potassium on the animal’s health are unknown (http://library.thinkquest.org/04oct/01639/lighten/sustainability/processinb/products).

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 present 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 society.

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