*International Journal of Research in Engineering and Science (IJRES)*
*ISSN (Online): 2320-9364, ISSN (Print): 2320-9356*
*www.ijres.org Volume 2 Issue 4 ǁ April. 2014 ǁ PP.01-05*

# Characteristics of Wet Coffee Processing Waste and Its Environmental Impact in Ethiopia

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**ABSTRACT:** *This study aimed to characterize wet coffee processing waste and determine total reducing sugar potential of coffee waste (pulp juice and mucilage) in Ethiopia. The volatile solid of the waste was determined and showed that the waste (pulp juice and mucilage) has high organic component, 66.5% and 90.2%, respectively. The study showed that the waste (pulp juice and mucilage) is acidic with pH 4.75 and 3.67, respectively. The results also showed that the wastes are serious problems for environment because of their high BOD/COD values. The values are BOD of 25,600 mg/L and COD of 45,000 mg/L for pulp juice and BOD of 19,810 mg/L and COD of 33,600 mg/L for mucilage. The COD:BOD ratio is less than 5:1, which shows the wastes are bio-degradable. Generally, the study showed that the wastes are potential environmental problems and cause water pollution due to high organic component and acidic nature. The waste was hydrolyzed by dilute $H_2SO_4$ (1, 2, 3 and 4%) and distilled water. Total sugar content of the sample was determined and maximum value (85%) is obtained from hydrolysis by 3% $H_2SO_4$. The results obtained at hydrolysis of 4, 2, 1% $H_2SO_4$ and distilled water are 72.86, 76.50, 63.75 and 56.66%, respectively.*

**Keywords**- *Bio-energy, Coffee waste, Mucilage, Pulp juice, Reducing sugar*

## I. INTRODUCTION

Ethiopia is one of the largest Arabica coffee producing countries and an original home of coffee. Coffee plant was originally found and cultivated in Kaffa province of Ethiopia from which it got its name around 1000 A.D. Coffee represents an agricultural crop of significant economic importance to the coffee producing countries of the world. The global annual coffee production is estimated to 5.5 million tones of which 6.4% is produced in Ethiopia. 55, 35 and 10% of the total annual production is from the western, southern and eastern part of the country respectively. About 600,000 hectares of the country's agricultural land is planted by coffee [1].

One of the most critical problems of developing countries is improper management of vast amount of wastes generated by various anthropogenic activities. More challenging is the unsafe disposal of these wastes into the ambient environment. Water bodies especially freshwater reservoirs are the most affected. Organic pollution of inland water systems in Africa is often the result of economic and social underdevelopment. Coffee processing plants are one of the major agro-based industries which are responsible for water pollution [2]. In many coffee processing countries the wastewater is disposed from pulping, fermentation and washing of coffee beans and presents series of problem on receiving environment especially on water bodies.

Wet processed coffee is considered superior in quality than dry processed coffee. In Ethiopia at present, there are more than 400 wet coffee processing installations, all of which are located at the vicinity of rivers. The total annual wet processed coffee at these installations is estimated to be 52,000 tons. In the processes of wet coffee production, about 5-15 liters of water are required to recover 1 kg of clean green coffee beans (the actual volume of water used depends on the pulping process, fermentation intensity and coffee bean transportation volume) [1].

When no physical or biological procedures are implemented and the coffee by-products are dumped into the water, the use of the oxygen of the water by the organic residuals in the process of the coffee, cause the following problems: (i) death of the animals and of the plants due to oxygen deficiency and due to the high acidity of the water, (ii) proliferation of undesirable microorganisms, (iii) non potable and inadequacy of water for the domestic use, (iv) inadequacy of the waters for the industrial use, including for the processing of the coffee in other coffee mills, and (v) proliferation of bad odors, attraction of flies and other insects and deterioration of the landscape [3].

Water pollution is caused by the presence of organic, inorganic, biological, radiological or physical substances in the water that tend to degrade its quality. The presence of undesirable and hazardous material and pathogens beyond certain limit also cause water pollution [4].

Schematic representation of conventional wet coffee processing is shown in Fig. 1. The resultant wet coffee processing wastewater is acidic and rich in total suspended and dissolved solids which are biodegradable. If the waste water emanating from this operation is discharged into the natural water bodies without treatment, it will pollute the receiving water body [5]. Coffee byproducts of the wet processing such as pulp and mucilage constitute around 40% of the wet weight of the fresh fruit. These are commonly disposed by dumping in to the natural water systems or pilling up on to nearby agricultural or grazing land in Ethiopia. Such ways of residue disposal have been the major health challenges to coffee farmers living in the surroundings of coffee processing plants. Moreover, such unsafe way of waste disposal has greatly affected terrestrial and aquatic biota [6].

Coffee waste contains high amounts of organic substrates for bioconversion into value added bio-products. However, large-scale utilization and management of coffee wastes around the world still remains a challenge due to caffeine, free phenols and tannins (polyphenols) which are known to be very toxic to many life processes. Organic waste products, such as mucilage and pulp represent a major source of environmental pollution and their disposal is usually done in the water resources closest to the processing sites, such as rivers and lakes [7].

Coffee effluents are the main source of organic pollution in environment where intensive coffee processing is practiced without appropriate by product management systems. Environments that are exposed to the effluents generated from coffee processing plants show change in terms of their physical, biological and chemical behavior. Coffee wastewater is rich in sugars and pectin and hence it is amenable to rapid biodegradations [1]. Coffee wastewater had high concentrations of suspended solids, dissolved solids and elevated nutrient. Moreover, wet coffee processing usually has high amount of conductivity, lower dissolved oxygen and elevated amount of turbidity to nearby water bodies or receiving environment [1].

Mucilage and coffee pulp are made of different components. Mucilage is composed of water, protein, sugar, pectic acid and ash. Coffee pulp components are responsible for pollution of nearby water bodies and receiving environment. These components are ether extract, crude fiber, crude protein, ash, nitrogen fiber extract, tannin, pectic substances, reducing sugars, and caffeine. In addition to coffee pulp, mucilage also plays a great role in water pollution [8].

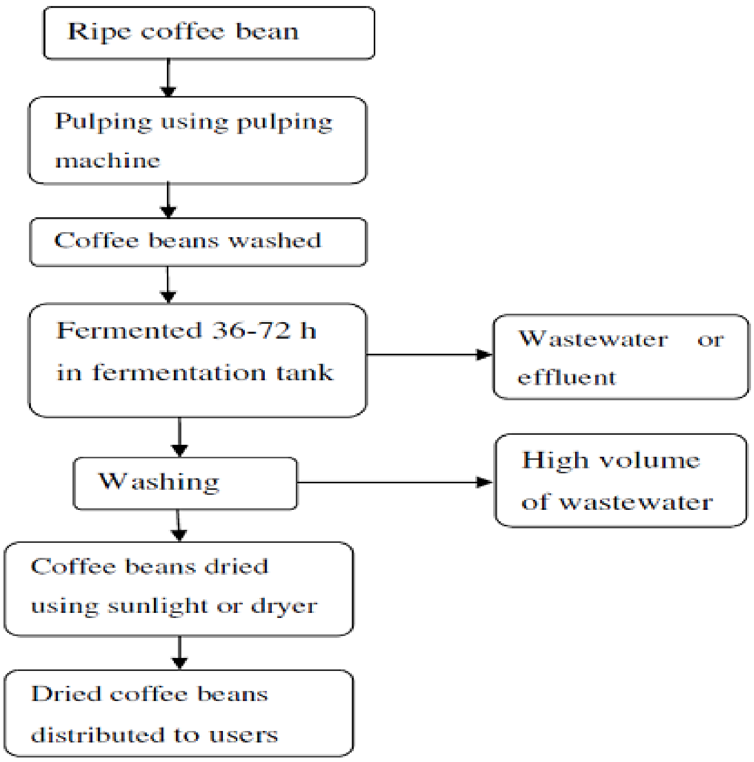

Fig.1. Schematic representation of conventional wet coffee processing.

Wastewater quality can be defined by physical, chemical, and biological characteristics. Physical parameters include color, odor, temperature, solids, turbidity, oil, and grease. Chemical parameters associated with the organic content of wastewater include the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and total oxygen demand (TOD). Inorganic chemical parameters include pH, acidity, nutrients and the like [11]. Value for biological oxygen demand (BOD) is up to 20,000 mg/L. It should be reduced to less than 200 mg/L before let into natural waterways and chemical oxygen demand (COD) make up around 50.000 mg/L and more [13].

Wastewater directly discharged to the nearby water bodies and thus causing many severe health problems, these are spinning sensation, eye, ear and skin irritation, stomach pain, nausea and breathing problem among the residents of nearby areas. In addition to effect on human health, wet coffee processing plants are posing environmental hazards due to large-scale disposal of coffee pulp, husk, and effluents from these units. This practice poses a greater threat to water and land quality around the coffee processing units. Presence of toxic compounds like phenols in these byproducts restricts their direct use in agriculture. In addition, the indiscriminate use of fresh coffee pulp also affects crop through acid formation and local heat generation in the process of its fermentation [1].

There are some studies reported in literature about the characterization of wet coffee processing waste in other countries and their potential for production of reducing sugars. However, there is no any study conducted on the characterization of Ethiopian wet coffee processing waste and its potential for the production of reducing sugars. Also its environmental impact assessment has not been studied. Therefore, the objectives of this study are: (i) to determine physico-chemical characteristics of wet coffee processing waste, (ii) to determine total reducing sugar potential of the waste, and (iii) to show the environmental impact of the waste.

## II. Materials and methods

### 2.1. Sample collection

50 L mucilage and 50 L pulp juice were collected from Bonga and Teppi, 463 km and 610 km respectively far from Addis Ababa to the south west part of Ethiopia. The samples were kept in ice box and transported to Addis Ababa Institute of Technology and kept in Environmental Engineering and Bio Innovative lab until characterization process. The study area and sample sites are selected on the basis of some stated criteria's such as the size of discharge to the rivers, the amount of water used for the process, the capacity of the processing industry, the location of coffee processing industry (whether it is located near to the society or not). The collected samples were processed in the laboratory and primary data were generated. The geographical locations of the study areas are given in Table 1.

**Table 1** Description of study area.

| Study area | Country | Region/Zone | Coordinate | Elevation above sea level | Population (2007) |
|---|---|---|---|---|---|
| Bonga | Ethiopia | SNNPR/Kaffa | 7°16′N 36°14′E / 7.267°N 36.233°E | 1,714 m | 20,858 |
| Teppi | Ethiopia | SNNPR/Sheka | 7°12′N 35°27′E / 7.200°N 35.450°E | 1,097 m | 134,519 |

### 2.2. Chemicals and equipments

Sulfuric acid (98%, sd fine-chem. limited, Mumbai, India), sodium hydroxide (Abron Chemicals, India), hydrochloric acid (Abron Chemicals, India), methylene blue, Fehling solution (A and B), filter paper, crucible, Erlenmeyer flask, round bottom flask, pH meter (3505-JENWAY, UK), balance (HCB1002-ADAM), stove (seven star, Germany), oven (202-OA), and furnace (SX-2.5-12, Box type resistance furnace, China) were used throughout the research work.

### *2.3.* Determination of moisture content

The sample was oven dried at 105 $^0$C for 24 h and the moisture content was determined using the following equation:

$$\% \text{ moisture content} = [(W_1-W_2)/W_1] \times 100$$

where, $W_1$ = weight of the sample before oven drying, $W_2$ = weight of the sample after oven drying.

### 2.4. Hydrolysis of waste

Cellulosic and hemicelluosic materials of the sample were broken down in to fermentable sugars by hydrolyzing the sample with dilute sulfuric acid at different concentrations (1, 2, 3 and 4% $H_2SO_4$) and with distilled water, allowing the hydrolysate samples to cool. The hydrolysate was filtered and determined for sugar composition by Fehling method and the pH was adjusted to pH = 5 using concentrated sulfuric acid and concentrated Sodium hydroxide.

**2.5. Determination of sugar content**

Solution 1 was prepared by: (i) dissolving 50 mL of hydrolyzed sample solution in 10 mL of distilled water, (ii) adding 2 mL of concentrated HCl to the solution and boiling, (iii) neutralizing the sample with NaOH, and (iv) making the volume of solution up to a volume of 300 mL and taking into the burette.

Solution 2 is prepared by: (i) mixing 5 mL of Fehling A and 5 ml of Fehling B with 90 mL of distilled water in 250 mL Erlenmeyer flask, (ii) adding two drops Methylene blue indicator. The sugar content of the sample is determined by: (a) titrating solution in the flask (solution 2) with the solution in the burette (solution 1) in boiling conditions until blue color disappear, (b) recording the volume at which brick red color observed, and (c) calculating the sugar content using the formula given below (14).

$$\textbf{Sugar Content}\ (\%) = \frac{300ml \times f}{V} \times \mathbf{100}$$

where: f – Fehling factor (0.051); v–volume used in the titration (titrate value) (mL).

**2.6. Determination of TS and VS**

Coffee waste → Dried at $103^0$c → Total Solid (TS) → Burnt at $550^0$c → Volatile Solids (VS) / Fixed Solids (FS)

## III. Result and Discussion

The characteristics of coffee waste (pulp juice and mucilage) obtained in this studies together with that reported in the literature are given in Table 2.

**Table 2** Physico-chemical characteristics of pulp juice and mucilage.

| Source | Sample | pH | Moisture (%) | Total solid (%) | Volatile solid (%) | Fixed solid (%) | $BOD_5$ (mg/L) | COD (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Coffee waste from Ethiopia (this study) | Pulp juice | 4.75 | 90.0 | 10.0 | 66.5 | 33.5 | 25,620 | 45,000 |
| | Mucilage | 3.67 | 96.9 | 3.1 | 90.2 | 9.8 | 19,810 | 33,600 |
| Coffee waste from India [5] | Wort (pulp juice + mucilage) | 3.58-4.21 | | | | | 3,800-4,780 | 6,420-8,480 |
| Coffee waste from Vietnam [13] | Pulp juice | ---- | 81.8 | ---- | 98.5 | 1.5 | --- | --- |
| | Mucilage | ---- | 84.2 | ---- | 99.3 | 0.7 | --- | --- |

As it can be seen from Table 2, the waste is acidic (pH = 4.75 and 3.67), therefore, discharging the waste directly to the water causes pollution. Volatile solids (organic matter or degradable components) are 66.5% and 90.2% for pulp juice and mucilage, respectively. The values showed that the wastes have high potential to pollute water bodies since the organic components are degradable. The calorific value of the organic components provides food for microbes, and potential vectors, therefore, increases potential odors and consequently increases attraction of vectors. The fixed solid (FS) is 33.5% and 9.8% for pulp juice and mucilage, respectively, and it constitute the residual inorganic compounds (N, P, K, Ca, Cu, Zn, Fe, etc.) in dissolved state.

The table also shows that $BOD_5$ of pulp juice is 25,620 and that of mucilage is 19,810 mg/L. The results showed that the waste has high oxygen-demanding biodegradable material in water. It is a useful measure for the strength of effluent and its pollution potential. The COD of pulp juice and mucilage is 45,000 and 33,600 mg/L respectively. The COD:$BOD_5$ ratio is frequently used as an indicator of biological degradability: ratios less than 5:1 indicate high digestibility. Therefore, the result showed that the ratio of COD:$BOD_5$ is less than 5:1, which indicates the biological degradability of the waste.

The data obtained during the study and presented in the above table is in agreement with the literature, i.e. the values $BOD_5$ and COD are within the interval [5] and the values of moisture content and volatile solid are in agreement with the values reported in the literature [13].

The total sugar of the waste was determined by titration method [15] and the data obtained are shown in Table 3.

**Table 3** Percentage of total sugar of the coffee waste (Wort) hydrolyzed at different concentrations of $H_2SO_4$.

| Concentration of acid used for hydrolysis | % sugar from mixture of waste | | % sugar from Bonga waste | | % sugar from Teppi waste | |
|---|---|---|---|---|---|---|
| | Pulp | Mucilage | Pulp | Mucilage | Pulp | Mucilage |
| 0 % (distilled water) | 56.66 ± 1.05 | 45.00 ± 1.32 | 58.85 ± 2.27 | 52.75 ± 0.91 | 54.64 ± 0.98 | 51.00 ± 1.70 |
| 1% | 63.75 ± 2.66 | 51.00 ± 0.85 | 66.52 ± 1.45 | 58.85 ± 2.27 | 61.20 ±2.46 | 56.66 ± 1.06 |
| 2% | 76.50 ± 1.92 | 54.64 ± 1.95 | 80.52 ± 2.12 | 63.75 ± 1.34 | 66.52 ± 1.45 | 63.75 ± 2.66 |
| 3% | 85.00 ± 2.37 | 61.20 ± 1.22 | 90.00 ± 2.65 | 69.54 ± 1.58 | 72.85 ± 1.74 | 69.54 ± 1.58 |
| 4% | 72.86 ± 1.74 | 52.75 ± 1.82 | 76.50 ± 1.92 | 61.20 ± 1.22 | 63.75 ± 1.34 | 61.20 ± 2.45 |

Table 3 showed that total reducing sugar content increases with increase in acid concentration up to 3% acid used for hydrolysis and then decreases. The maximum amount of total reducing sugar (85.00%) is obtained at 3% $H_2SO_4$ and minimum amount of total reducing sugar (56.66 %) is obtained at hydrolysis of 0% (distilled water). The increase in total reducing sugar content that resulted from the acid hydrolysis is similar to the one reported by other authors [6] for the waste but the yield decreases after optimum point. As can be seen from the table, waste from Bonga contains relatively higher sugar content than waste from Teppi, this might be because Teppi is low land and some of the sugar from the waste may be fermented.

## IV. Conclusion

Total reducing sugar in the waste increases with increase in concentration of acid used for hydrolysis and decreases after the optimum point (3% $H_2SO_4$). The discharge of effluents (coffee waste) into receiving water bodies invariably result in the presence of high concentrations of pollutant in the water. The pollutants have been shown to be present in higher enough concentrations, which is toxic to different organisms. The effluents also have considerable negative effects on the water quality of the receiving water bodies and as such, they are rendered not good for human use. It is therefore recommended that the careless disposal of the wastes without pretreatment should be discouraged.

## V. Acknowledgement

The authors are thankful to School of Chemical and Bio engineering at Addis Ababa Institute of Technology, AAU for financial, technical support and laboratory facility during research work. We also thank Ato Bilhat Leta for his valuable cooperation during sample collection and throughout laboratory activity. Asrat Gebremariam would like to appreciate Bonga College of Teacher Education for providing sponsorship for his PhD study.

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