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Application of *Moringa Oleifera* seed extract to treat coffee fermentation wastewater

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HIGHLIGHTS

- The use *Moringa Oleifera* Seed Extract to treat coffee wastewater is investigated.
- Coffee fermentation wastewater has high soluble COD content.
- *Moringa Oleifera* Seed Extract can remove insoluble coffee wastewater COD.
- Settling ponds are not an adequate treatment method for coffee wastewater.

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ABSTRACT

Wastewater generated from wet processing of coffee cherries degrades stream water quality downstream of processing mills and impacts human health. The widespread popularity of coffee as an export makes this a global problem, although the immediate impact is local. Approximately 40% of all coffee around the world is wet processed, producing wastewater rich in organic nutrients that can be hazardous to aquatic systems. *Moringa Oleifera* Seed Extract (MOSE) offers promise as a local and affordable "appropriate" coagulation technology for aiding in the treatment of coffee wastewater. Field research was conducted at the Kauai Coffee Company to investigate the application of MOSE to treat coffee fermentation wastewater (CFW). Coagulation tests were conducted at five pH CFW levels (3–7) and MOSE doses (0–4 g/L). After settling, TSS, COD, nitrate, nitrite, total nitrogen, and pH of supernatant from each test were measured. MOSE reduced TSS, COD, nitrate, and nitrite in CFW to varying degrees dependent on pH and dose applied. TSS removal ranged from 8% to 54%. Insoluble COD removal ranged from 26% to 100% and total COD removal ranged from 1% to 25%. Nitrate and nitrite reduction ranged from 20% to 100%.

1. Introduction

Coffee is grown in 70 countries across the globe, and is worth about $100 billion annually [19]. Two thirds of the 195 countries in the world today have GDP lower than $100 billion per year [20]. There are two primary methods for processing coffee, wet and dry, and approximately 40% of all coffee around the world is wet processed. The wet method is considered to produce superior tasting coffees, which corresponds to greater profits for farmers and cooperatives. In regions with abundant water resources, wet processing is a popular choice. However, pollution from wet processing activity is a growing environmental concern.

Traditional wet processing has two coffee wastewater (CWW) streams from milling activity (Fig. 1): coffee pulping wastewater (CPW) and coffee fermentation wastewater (CFW). First, wet processed coffee is pulped to remove the coffee fruit. After pulping, the coffee beans are submerged in large water-filled open-air tanks for the fermentative removal of the pectin layer encasing the bean. This step is an essential part of the wet process and has a significant impact on coffee quality [4]. Coffee is submerged for 24–48 h during which enzyme activity produces a significant increase in

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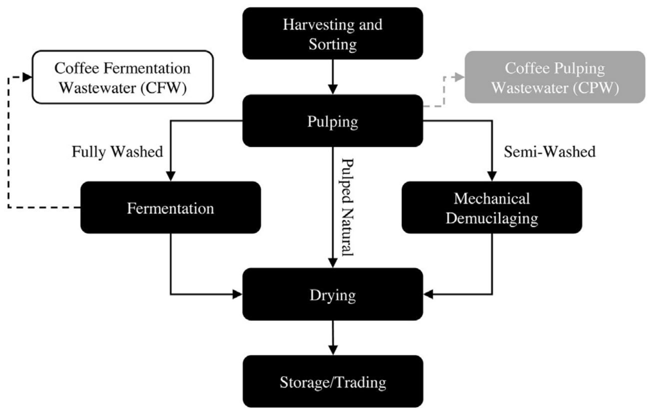

Fig. 1. Simplified wet processing flowchart for fully washed, semi-washed, and pulped natural coffees that identifies the source of CFW.

dissolved organics accompanied by a sharp decline in pH due to the dissolving of the pectin layer. Once fermentation has completed, the fermentation water is drained from the tanks, releasing CFW.

Typically, coffee processors discharge both CPW and CFW directly into surface water with minimal to no treatment. The effluent produced from wet processing is characterized by high total suspended solids (TSS), chemical oxygen demand (COD), and biochemical oxygen demand (BOD) concentrations as shown in Table 1.

In a major study on CWW involving 23 coffee mills and 18 river systems, Beyene et al. [2] concluded that wet milling caused long-term ecological impairment of the river systems monitored as a result of high organic waste being directly discharged into the waterways. Haddis and Devi [7] determined CWW has an adverse impact on human health. They found highly elevated levels of organic matter in the water bodies downstream of the wet mill studied and noted that use of this water for domestic purposes resulted in unfavorable, but nonspecific health effects such as dizziness, eye and skin irritation and breathing problems. They concluded that the WHO limits for drinking water (200 mg TSS/L, 300 mg COD/L, and 100 mg BOD/L) were being far exceeded by the wet mill due to direct discharge of untreated CWW into nearby waterways. Therefore, the authors called for innovative and eco-friendly treatment techniques. In another report by Catholic Relief Services [5], 7000 families in Nicaragua were documented to be without potable water for two weeks due to the impacts of wet coffee processing wastewater on the Matagalpa City water treatment facility. The water treatment facility itself was inoperable for two days and system cleaning took two weeks before water service was restored.

It is estimated that only 15% of coffee wet mills treat their wastewater [8]. This may be due to several factors including lack of regulation, difficult accessibility to mill sites and high cost of treatment equipment, as well as a scarcity of economic or social incentives for wastewater treatment [8]. There is a need for local, and affordable "appropriate" technology treatment options that can mitigate the impact of CWW.

Moringa Oleifera (MO) trees may be a viable option for treating CWW. These trees are cultivated across the entire equatorial region where coffee is grown [10]. MO trees have two key properties: they are highly nutritious [11] and their seeds can be used as a naturally occurring coagulant. *Moringa Oleifera* Seed Extract (MOSE) is derived from dried MO seeds and can be used to clarify turbid water. In rural areas lacking water treatment infrastructure, MOSE is used as a primitive coagulant to remove solids and improve potability. The application of MOSE for this purpose has been well studied and reported in the literature [10].

Although the application of MOSE to CFW has not been reported in the literature to date, application of MOSE to reduce turbidity in CPW has been previously studied [12]. Jar tests on CPW were conducted using five coagulants: aluminum sulfate, chlorinated ferrous sulfate, ferric chloride, and MOSE. The objective of research was to find the optimal dosing and pH for each coagulant for reducing turbidity in CPW. Wastewater pH was the largest factor in coagulant performance. The authors determined the optimal pH for MOSE was 4.27 with a coagulant concentration of 10 mL/L. This combination yielded a 90% decrease in wastewater turbidity after a settling time of 90 min.

In Kenya, the application of MOSE to reduce TSS in CPW has been previously studied [13]. The study concluded that MOSE was an ideal coagulant because it could reduce TSS in a 24-h window, which is ideal for coffee processing in Kenya. In contrast to the above study [12], MOSE required almost 24 h before a visible difference between untreated and treated wastewater was observed. Between hours 23 and 24, an almost instant formation of flocs and settling was observed. The optimum dosage in the study was reported to be between 1 and 2.5 g/L.

In addition to CPW, MOSE has been shown to reduce TSS and COD in palm oil mill effluent, human wastewater, textile effluent, and various other types of wastewater [3,10]. It has been shown to be as effective as aluminum salts, but unlike aluminum salts, MOSE does not significantly alter the effluent pH or produce toxic by-products [15]. The ability of MOSE to reduce TSS, COD, BOD, nitrate, and nitrite, in CFW is the subject of the study reported here.

Table 1
Coffee wastewater pollution loading reported in the literature.

Authors/Date	Selvamurugan et al. [18]	Adams and Ghaly [1]	Haddis and Devi [7]	Rossmann et al. [17]	Beyene et al.[a] [2]	Zayas Péerez et al. [22]
Parameters	Concentration (mg/L unless otherwise stated)					
Color (CU)	470–640					
TDS	1130–1380				170	
TSS	2390–2820		5870	1729	598	
Total solids	3520–4200					
pH	3.88–4.11		3.57	4.7	4.6–7.4	4.6
Conductivity (dSm−1)	0.96–1.20			1.8		
DO	2.0–2.6				5.2	
BOD	3800–4780	10000	10800–14200	8005	436	
COD	6420–8480	18000	15780–25600	17244		4300
BOD:COD ratio	0.56–0.59	0.56	0.55–0.68	0.46		
TOC (%)	0.36–0.48					
Nitrogen	125.8–173.2	145–248		231.6		
Nitrate			23		6.8	
Phosphorus	4.4–6.8	13-Jul	7.3	23		
Potassium	20.4–45.8	71–268				

[a] River grab samples.