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Review Article

Coffee Processing Methods, Coffee Quality and Related Environmental Issues

Misgana Banti[1], Eba Abraham[2]

[1]Food Science and Nutrition Research, Kulumsa Agricultural Research Center, Assella, Ethiopia

[2]Department of Plant Science and Horticulture, Hebrew University, Jerusalem, Israel

Email address:
misganabanti2013@gmail.com (M. Banti)

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Abstract: Coffee is among the most valuable agricultural products throughout world. There are over 80 countries that produce and export coffee around the world. Increasing and maintaining coffee quality are of utmost importance due to the fact that the volume of sales depended upon coffee quality. The quality of coffee can be defined as its organoleptic and, physical quality and chemical composition such as sugars, caffeine, volatile and non-volatile phenol contents of a green bean produced. To the coffee industry, quality is of paramount importance. There are various factors affecting coffee quality among which processing methods is one. There are three ways to process coffee: washed, semi-washed and sun-dried. The 60% of coffee quality is determined by this primary and secondary coffee processing. Therefore, to produce coffee of good quality and to remain competitive on the world market, proper processing of coffee is required from both a quality and environmental standpoint in addition to breeding and other pre-harvest activities. However, selection coffee processing methods is not only determined by coffee quality; but also the environmental impact of processing method and accessibility of the methods as well. In this review, the effect of processing methods on coffee quality, environmental issues related to coffee processing, especially wet processing were discussed to identify major research gaps that should be addressed in future research and management practices.

Keywords: BOD, COD, Coffee Processing, Coffee Quality, Semi-washed, Natural, Washed Coffee

1. Introduction

Coffee is one of the most important agricultural produces in the world both in terms of economic contribution and consumption. As a food commodity, over 500 billion cups of coffee are consumed every year across the world [1]. Worldwide consumption of coffee in 2020/21 is estimated at 167.26 million bags which is an increase by 1.9% as compared to 164.13 million bags recorded in 2019/20 [2]. Coffee is also among the most traded commodities in the world. It is the second most important export commodity on which several national economies depend preceded only by crude oil. Moreover, coffee is produced and exported by more than 80 countries in the world. Coffee (in its different forms) exported in 2020/21 was estimated to 118.96 million bags which is an increase by 1.9% compared as compared with 116.77 million bags in the 2019/20 coffee year [2]. This is an indication that coffee production, trade and consumption is increasing.

Arabica Coffee is originated in Ethiopia [3]. Besides, coffee is foundation in the Ethiopian export economy and supports directly or indirectly the income of millions [4]. The improvement of coffee quality could provide the coffee chain with a new impetus [5]. As its volume of sales depends on coffee quality, much attention is paid to quality improvement and/or maintenance. The quality of coffee can be defined as its organoleptic cup-quality, physical quality and inherent chemical constituents such as sugars, caffeine, volatile and non-volatile phenolic contents of a green bean produced. Therefore, coffee quality is of critical importance to the coffee industry.

Production and supply of coffee with excellent quality appear more crucial than ever before for coffee exporting countries owing to increasing competition in the field and consumer demand. Quality coffee is a product that has

desirable characteristics such as clean raw and roasted appearance, attractive aroma, and good cup taste [6]. Coffee quality encompasses beans flavor in fragrance, aroma, sweetness, acidity or overall taste felt by consumers after a drink as well as physical characteristics such as length, width, thickness or weights, shape and color of coffee beans [7]. There are different factors affecting coffee quality among which processing methods is one. Among these, ways coffee is processed, sun-dried (natural), washed (washed) and semi-washed are the most common. Primary and secondary coffee processing determines 60% of coffee quality [8]. Primary and secondary processing is therefore essential for maintaining the inherent quality and value of coffee.

The influence of coffee processing is not only limited to coffee quality. Most pollutants found in coffee wastewater are derived from organic matter during pulping due to the difficulty of degrading the mucilage layer surrounding the beans. Wastewater generated from coffee processing plants is acidic and plants and animals hardily survive when exposed to it. The sugars contained in the mucilage undergo a fermentation process. The organic and acetic acids from the fermentation of sugars make the wastewater very acidic. As a result of digested mucilage in wastewater, a crust forms on the surface, clogging up waterways and contributing to anaerobic conditions. Mucilage and coffee pulp have different components. Mucilage is composed of water, protein, sugar, pectic acid and ash [9]. Components in the coffee pulp can pollute local water bodies and the receiving environment. Moreover, coffee husk from drying coffee beans in case of dry processing has also its own impact on the environment as indicated in literature [10-12].

The processing of coffee is therefore very important from various perspectives. It has to do with bean quality and therefore, the price of coffee, as well as environmental management. Ethiopia only has limited and fragmented work related to environmental management related to coffee processing and further relationships between coffee processing methods and quality. In light of this concept, it is very important to review the available literature in the country and across the globe in order to identify what has been done so far in the country and identify research gaps.

2. Overview of Coffee Production

Latin America and the Caribbean are the world's largest producers of coffee. In 2018, Brazil is the largest producer covering almost one-third of all Worlds' coffee production and the third-largest consumer as well [13]. In the same year, other countries in Asia such as Vietnam, Indonesia and India together with Ethiopia contribute a significant amount to World coffee production. Ethiopia ranks fifth coffee producer in the world and leading in Africa [14]. Moreover, Ethiopian coffee is also known to be unique in terms of its quality characteristics including aroma and flavor. As the birthplace of Arabica coffee, there exists wide variability of Arabica coffee in relation to quality [15]. However, there are various factors responsible for coffee quality apart from genetic variability. Among these factors, processing methods receive a significant portion.

3. Coffee Processing Methods

There are three dominant coffee processing methods that are widely applied in our country and the world at large. The coffee produced by the three methods differs in its quality profile [16]. The three processing methods might also have differences in terms of impact on nearby processing environments especially water bodies. Therefore, it is important to review the literature and comparatively evaluate these methods from the quality and environmental effect perspectives.

3.1. Dry Processing

Among the various methods of processing coffee, dry processing is the simplest and least expensive [17]. Typically, it produces natural-tasting coffees, and it is widely used in western Africa and Brazil. The berries are sorted or cleaned manually to remove dirt, leaves, and twigs. Afterward, the berries are spread in the sun and regularly raked to prevent fermentation [18]. As a whole, the coffee beans were dried along with their pulp and mucilage in the cherry state. Dry processing is slow and can lead to translocation of chemical constituents from pulp to the inner bean as well as the chemical transformation that depends on ambient conditions and thus can have a considerable effect on final bean and cup quality [19].

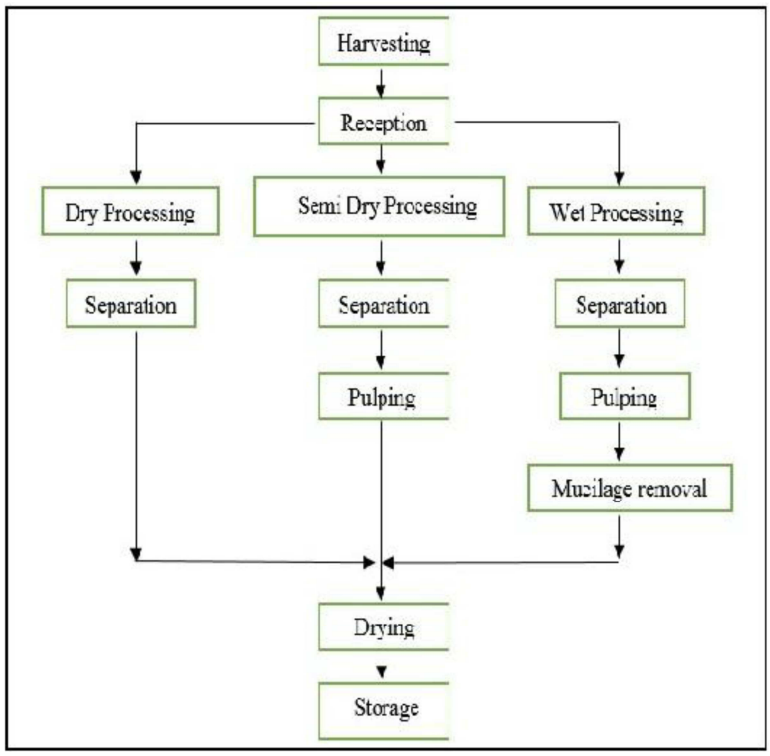
3.2. Wet Processing

In the wet coffee processing method, coffee beans are pulped, fruit and skins are separated and mucilaginous mesocarp is removed in fermentation. In the wet coffee processing methods fermentation occurs in water at controlled temperatures which produce lower levels of undesirable flavors. That is why the washed coffee is often associated with better cup quality. The quality of green and roasted coffee, measured by aroma was better after conventional fermentation than after mechanical mucilage removal [20]. However, this method is more favorable in places where there are plentiful supplies of freshwater [21]. Moreover, the know-how required and the huge amount of waste water generated for this method is presented as major shortcoming [22].

3.3. Semi-washed Processing

In semi-washed coffee processing, fresh cherry skin is physically removed with the addition of water by a pulper machine. A demucilager is then used to remove the mucilage immediately after pulping. As the mucilage is mechanically scraped by a demucilager, there is no fermentation of the mucilage in this process [23]. Clean parchment is ready for drying after demucilaging once the bean inside reaches 12% moisture or lower. Therefore, in this method, pulped coffee beans are not placed in fermentation tanks rather set out to dry directly resulting in parchment coffee called semi-washed coffee. Here wet and dry processing of coffee is the two common coffee

processing in our country, Ethiopia. However, the third method of coffee processing (semi-washed) are emerging in Ethiopia in response to the adoption of the technologies from other parts of the world [8].



Source: [24]

Figure 1. *Simplified diagram of coffee processing methods.*

4. Processing Methods and Coffee Quality

4.1. Dry Processing and Coffee Quality

The dry-processed coffee represents more than 60% of Ethiopian Arabica coffee [25]. The processing methods and moisture reduction are very important postharvest operations that determine the final coffee bean and cup quality. As literature implied so far, it is hardly possible to produce high-quality coffee by using the dry process method on a regular basis due to the variability of climatic conditions which resulted in the inconsistency of drying. That is why some literature recommends a wet process to dry for the production of good quality coffee. Studies on the impact of processing treatments on coffee acidity at a well-known coffee research station in Ethiopia, Awada found that dry-processed coffee scored the highest acidity [26]. The highest medium-full body was also reported in the literature above when the coffee was sun-dried. Contrary to wet-processed Arabica coffee, dry-processed coffee has less aromatic but a greater body [27].

In the dry method of processing, the coffee cherries are collected at different levels of ripening which may be another factor affecting the final quality of dry-processed coffee. Nearly all coffee producers will tout the virtues of the processing method they use. Guatemala, for example, considers dry processing a bad word and with good reason. Due to their high humidity, a dry-processed coffee will almost definitely be fermented, which is why only their lowest grade coffees are dried without pulping. Nevertheless, in Brazil, dry processing yields a sweet, complex, and heavy-bodied coffee that is almost essential for any good espresso blend. The only conclusion that one can be made is, therefore, that every region has its own proper processing methods and that the processing technique should help attain the flavor profile that is desired by the producer and consumer [28, 29]. In terms of defect, another factor that determines coffee quality, literature reports higher in dry-processed coffee beans than the others [30].

The fungal and mycotoxins contamination is also one of the most important factors affecting the quality of coffee. There are various factors responsible for this contamination. However, literature indicated that Ochratoxin A (OTA) contamination is more related to drying materials used and swept coffee from the ground than the processing methods [31]. Moreover, fruit contact with the soil facilitated contamination by fungi and should be avoided. Additionally, there is literature suggesting that fungal contamination and OTA are dependent on geological regions and processing methods, explaining the high OTA risk in east Africa where Arabica coffee is mainly processed dry method [6, 32]. Therefore, drying on the ground can facilitate the contamination by this toxin while drying on appropriate materials can produce coffee with the intended bean quality. From this, it is possible to understand that OTA is dependent on contact with soil in one or

the other ways than the actual processing methods. Therefore, well managed dry processing methods can produce coffee with the good quality requirement.

Studies have reported the presence of OTA in raw coffee. In an experiment carried out in Thailand, OTA has been found to form in the pericarp of a Robusta coffee plant during sun drying [33]. Arabica coffee samples collected from three localities in southwest Ethiopia showed a high incidence of aspergillus ochraceus on unwashed coffee dried on the bare floor than washed coffee on drying beds [1]. Literature has identification and reported six fungal species belonging to the genera aspergillums and penicillium associated with Ethiopian dried cherries [34]. Ochratoxin A is formed in raw coffee beans after harvest mostly attributed to the way of drying whether it is on the ground or appropriate drying bed [35].

4.2. Wet Processing and Quality

The wet coffee processing method involves more handling steps than the dry method [36]. Moreover, the quality of coffee produced by the method is also superior to that in dry process counterparts. The use of wet-processed Arabica can result in the best aromatic with fine and pointed acidity [37]. It is agreed that wet-processed coffee gives much better quality than dry one mostly attributed to handling and management practices [38]. The fermentation of coffee parchment is the most important stage for maintaining the quality of coffee. When the fermentation time is long, the microbial inhibition takes place and hence pungent flavor and stinker beans develop and this ultimately affects coffee cup quality [39, 36, and 40]. Coffee beverages prepared from coffee beans obtained from wet processing (often described as washed Arabica) are characterized by their full aroma and pleasant acidity [41].

In the wet method of processing, the fruit is harvested by selective picking because the cherries entered to the machines are only the red cherries and the use of underwater fermentation as opposed to 'dry' emphasizes the formation of acids. The fermentation breaks the cellulose of the mucilage converting the bean and increasing the acidity of the coffee [42]**.** The wet-processed Arabica is aromatic with fine acidity and some level of astringency [37]. In washed coffee processing, fermentation is a very decisive process as it produces organic acids and volatile compounds by the action of yeasts and hence determines the final quality of coffee [43, 44].

It has been confirmed that under-water soaking following 'dry' fermentation, i.e., two-stage fermentation enhances the appearance of both raw and roast coffees compared to 'dry' fermentation only [6]. These authors elaborated that soaking for 24 hours after fermentation produced a better raw and roast appearance.

Natural fermentation of coffee is the function of many parameters, such as environmental, PH, temperature, microflora and level of pollution in the water used and difference in the ripe cherries, geographical location and cultural origin, harvesting method and variations in the processing method [6]. Furthermore, it is reported in the above literature that coffee fermented under shade takes more time. Shaded fermentation tanks help to achieve a uniform fermentation process and better quality coffee. Moreover, storage of coffee where high relative humidity is there for longer time in warm conditions increases bean moisture content and subsequently reduces quality of raw coffee, roasted coffee and liquor [45]. Defects, the other important attribute to determine coffee quality are fewer in wet-processed coffee as compared to the dry counterpart [30].

Table 1. *Steps, factors reducing quality and positional problems of wet processing method.*

Process step	Factors reducing quality	Potential problem
Harvesting cherry	Harvest green cherry	Green or grassy flavour
	Harvest over-ripe cherry	Fermented or fruity flavour
	Pick fallen old cherry from the ground	Fermented, Mould contamination producing mouldy or musty flavour
	Hold fresh cherry for long periods before pulping	Fermented or fruity flavour
Pulping cherry	Poor quality pulping equipment	Nipped beans causing stinker beans
Fermentation	Over-fermentation	Fermented, fruity, sour or onion flavour
	Poor hygiene in fermentation tanks	Stinker beans producing foul flavour
Washing	Poor washing leaving	Mould growth (mouldy flavour)
Drying of parchment	Contaminated by drying on the ground or dirty drying surfaces	Earthy flavour. Mould contamination producing mouldy or musty flavour
	Stored partially dry for long periods or rewet during drying	Mould growth producing mouldy or musty flavour
	Machine drying too fast, too hot, or uneven	Poor, mottled or faded colour, dull or bland flavour
	Coffee is over-dried	Poor, faded bean colour. Damages easily during hulling
Storing dried parchment	Stored dried parchment too wet	Mould growth producing mouldy or musty flavour
	Stored near fuels or chemicals	Contaminated with foul odour
Hulling dry parchment	Incorrect huller setting	Bean damage
	Coffee too dry	Bean damage
Storing hulled green bean	Storing too wet	Mould growth (mouldy or musty)
	Stored near fuels or chemicals	Contaminate with foul odour
	Stored in jute bags made on machinery lubricated by petroleum oils	Contaminated with baggy or oily taints
	Stored in hot humid condition for long periods	Mould growth producing mouldy or musty flavour. Surface oxidation of beans causing woody flavour faded bean colour
Transport	Rewetting of coffee due to leaky tarpaulins or containers	Mould growth producing mouldy or musty flavour
	Stored near fuels or, chemicals	Contaminated with foul odour during storage

Source: [47].

When fermentation is complete, the beans should be washed thoroughly of the decayed mucilage immediately. However, many producers ferment the beans for longer periods of time, up to several days. In such cases, the undesirable taste of over fermentation developed and negatively affects quality of coffee. The harvested green, unripe fruit is too firm to pass through the depulper without damaging it, so it is sorted out and stored. When the skin of coffee bean ripe and turns yellow, the fruit can be pass through a depulper. In wet processing methods, the coffee pulp is removed early during pulping and drying is also on the appropriate drying bed. Moreover, storage conditions are also better for such kinds of processing methods. Due to the combination of these factors and more, there is low contamination of coffee by fungi as compared to dry processing [46].

4.3. Semi Washed and Coffee Quality

The pulper/demucilager units are a cost-efficient and effective way to consistently produce high-quality coffee without the need for fermentation and washing. It use only 0.5 L of water per kg of fresh cherry, moderate the risk of over-fermentation and quality problems in the final coffee product. There is no doubt that the initial capital cost to purchase the pulper and demucialger units is high. However, there is no need for fermentation tanks and washing systems in this processing method. Pulper/demucilager is suggested for semi-washed wet coffee processing in Lao [48].

The report in literature indicated that the acidity of semi-wet processed coffee is in medium pointed range [26]. In this type of processing, the separation of defective beans and the rapid dehydration of the beans in suitable drying places hinder the action of endogenous fungi and bacteria and create a better environment for coffee quality preservation [49]. Moreover, under semi-washed processing, different coffee varieties showed a medium to full body as reported in literature [26]. In general, in this newer processing (semi-washed) coffee bean is less in defects count, homogeneous appearance, better roasting quality, and a better acceptance by consumers [49]. Color and aroma of green coffee beans also indicated a good result of processing which is bluish-green color and pleasant aroma of fresh grass and sweet sugar cane aroma. Literature reported that semi-washed coffee had more triage and defect points than fully washed, which could be improved by more controlled processing steps or sorting of ready-to-store green beans [50].

There is also honey coffee processing more or less similar to semi-washed coffee with some deference. It is a newer method of handling coffee that is gaining popularity in Brazil, Panama, and many other countries but Costa Rica may be the country that's run the farthest with this ball. The Central American nation has different color-coded categories for how much mucilage is left on in the process and has truly popularized the method to great success. There is some distinction between honey processing and semi-washed coffee. In honey-processing, the husk and some of the mucilage only are removed from the bean. Therefore, there is a certain amount of mucilage remaining on the bean which determines the color and character profile of the coffee bean [51]. The perceptions of smallholder farmers in Banyuwangi Regency of Indonesia are in the range of doubt and agree (ranging between 2.43 and 4.21) with the advantageousness of honey processing technology. This implies that the usefulness of the honey process is at a medium level. However, honey process technology is generally considered advantageous by these farmers [52].

5. Processing Methods and Environment

5.1. Dry Processing and Environment

The dry processing method of coffee involves washing solely for separation of impurities and hulling. This is not source of water pollution as a case in wet method though it can cause dust problem affecting plant worker health [53]**.** In dry processing, the water used to wash out impurities and facilitate the drying process ranges from 1.4-141 per kg of processed coffee depend up on the sophisticated of washing equipment. The chief residue of dry processing is the hulls themselves which constitute as high as 50% of harvested weight [54].

In dry processing industries, the work environment is commonly filled with dust and endotoxin that is released during handling of raw bean [55]. This dust contain allergenic compound (chiefly chlorogenic acid) that result in developing asthma, rhinitis or dermatitis to the exposed worker. The dry processing also generates the solid waste (coffee husk) which piled up in the field and cause serious environmental problems [56]. According to this report, estimated annual generation of solid wastes are 430,920 tons per year for husk and 72, 960 tons per year, for coffee pulp which is huge resources.

There are huge potentials of this coffee husk to be used as fertilizers. Despite this, coffee hull are rarely used as fertilizers as it is low in nutrient composition and difficulties in installing hulling equipment at farm level. It is also uneconomical to transport the hull from local processor which in turn limits their use as fertilizer [57].

5.2. Wet Processing and Environment

It has been confirmed that there are potentially detrimental effects caused by liquid and solid by products of wet processing methods; hence finding simple, economical and suitable ways to overcome these problems have no alternatives. The organic and acetic acids from the fermentation of the sugars in the mucilage make the wastewater very acid (pH down to 3.8). Under these acid conditions, higher plants and animals will hardly survive [58].

Source: [59]

Figure 2. *Schematic reprisentation of wet coffee processing.*

After the first fermentation of sugars in the waste water, the organic substances diluted in the waste water break down only very slowly. This is by the action of micro- biological processes using up oxygen from the water and demand oxygen to break down organic material in the wastewater exceeds oxygen supply dissolved in the water. This creates anaerobic conditions. Therefore, the values for Biological Oxygen Demand (BOD) indicating the amount of oxygen needed to break down organic matter in coffee waste water are high (up to 150 g/l for effluents from demucilators [60].

Apart from degradable organic matter in waste water, there are also resistant organic materials which can only be broken down using chemical means which indicated by the Chemical Oxygen Demand (COD). These make up around 80% of the pollution load and are reaching 40 g/l and more [61]. Fortunately, most of this material can be taken out of the water stream as precipitated mucilage solids and made into compost. The high values of COD and BOD cause anaerobic conditions ("rotting") to set in quickly and cause bad smells and speed up the death of aquatic life due to the quick use up of oxygen dissolved in the water [60]. Bacteria living in anaerobic conditions can also cause health problems for humans when found in drinking water. In addition to the bad smell, coffee waste water will turn dark green to black after a while. This discoloration is caused by the chemical components of the red color of the coffee cherry (flavonoids) and is also known in other food processing industries, like the wine and olive industries. These fruit color is actually the precursors of the brown humus color of swamp water, which is completely harmless to aquatic species. So, although they do not look nice, the intermediate black colors by themselves do not do any harm to the environment nor add much to the BOD or COD. Summarizing, the combination of high acidity, and high BOD, depleting life supporting oxygen from the water, is causing the problems in coffee waste water treatment and need to be overcome [8].

In Jimma, there are significant reports on river water quality deterioration as a result of disposing untreated coffee waste into running water courses [58]. Furthermore, during coffee-processing (wet) season, the highest organic load (1,900 mg/l), measured as biochemical oxygen demand, depleted dissolved oxygen (DO) to a level less than 0.01 mg/l, and thus curtailed nitrification. During off season, oxygen started to recuperate and augmented nitrification. Macro invertebrate diversity was significantly reduced in impacted sites during the wet season contrary to the off season. As it is partied in the conceptual model, oxygen is removed from the river water as organic materials are oxidized by chemical processes (COD) and biological activities of aquatic organisms (BOD).

In Ethiopia coffee is processed either using dry or wet methods of processing. When properly done wet processing of coffee ensure that intrinsic qualities of coffee are better preserved, producing green coffee which is homogeneous and have few defective beans. Hence coffee processed by this method is usually regarded as being of better quality and commands higher prices. The production of wet processing Arabica coffee is sharply increased following the establishment of numerous coffees washing station in the south and south western part of the county. This rise in the number of wet processing plants has therefore resulted in the generation of huge amount of processing by products which have high potential of polluting the environment as long as safe and efficient waste management practice are not followed. Coffee processing by products generated from these wet coffee processing stations is usually damped into nearby river or to the place where subsequent seepage of the effluent to the river is highly likely [62].

Table 2. *Average values of the characteristics of nearby water bodies (river) before and after receiving coffee processing plant effluent, Jimma Zone, Ethiopia.*

Parameter	Water characteristics	
	Before	After
Temperature (°C)	15	18
PH	6.5	5.15
BOD (mg/ L)	120	7800
COD (mg/ L)	176	9780
TSS	520	2880
Nitrate (mg/ L)	2.3	4.1
Phosphate (mg/ L)	4	7.5

Source: [63]
Except pH.

5.3. Semi Washed Processing and Environment

Similar to washed coffee processing, the organic matter and then toxicity in semi-washed methods are also high. This high toxicity of waste water on the other hand can lead to degradation of the level of oxygen in water and then kill off nearly all aquatic life in the water [22]. However, depending on the processing method, quantities of coffee waste water is varying for the two washed and semi-washed coffee processing. The mechanical coffee mucilage removal machines used in semi-washed coffee production minimize the use of fresh water to about 1 m^3 per ton of fresh cherry from 20 m^3 per ton cherry in traditional fully washed technique [64]. Although the amount of waste water generated from semi washed coffee processing is lower than that of washed coffee, still significant amounts of coffee pulp and wastewater is generated [65].

The solid materials in coffee waste will ferment, acidified, hydrolyzed and degraded by natural fermentation. During fermentation and acidification, long chain pectin is break down into shorter chain pectin and oligosaccharides. The resultant pectin oligosaccharides then get out of solution and float on the surface of the waste water leaving highly resistant materials, acids and flavanoid color compounds from coffee cherries in the effluent water [61].

The Biological Oxygen Demand (BOD), amount of oxygen needed to break down organic matter are high in coffee waste water. It can be as high as 20.000 mg/l for effluents from pulpers and 8.000 mg/l from fermentation tanks [61]. Moreover, there are also resistant materials which can only be broken down by chemical process COD as it is in wet processing. These are 80% of the pollution load and are reaching 50.000 mg/l. This is why pretreatment, minimization of the amount of waste water and utilization is very important.

6. Conclusion

Coffee, one of the most essential agricultural produces is traded by many countries across the world. Coffee quality is a very important attribute that determines the trade and price of its exchange. Factors responsible for coffee quality on the other hand are multifaceted among which processing methods share a significant portion. There are various coffee processing methods among which three categories are the most commonly practiced methods in the world. Each processing method, therefore, is influencing the quality of coffee and the processing environment differently. Washed coffee for example is preferable in terms of coffee quality by different consumers. However, still, there are some concerns with the methods including lack of practicability in water scares areas, high wastewater disposal and the like. Semi-washed coffee is also better in quality even as compared to wet-processed coffee beans. Still, the issue of environment and cost of demucilager is high until installation. Dry processed coffee on the other hand is easy, simple and cost-effective coffee processing method. Polluting waste from this method is not as high as the prior methods. However, the quality of coffee may not similar to wet methods if not proper management from harvesting methods through drying conditions is practiced. There is also literature implying that coffee processing methods are environment-specific. In some environmental conditions, the dry method is recommended while the wet method in others. All in all, the selection of appropriate methods with better quality standards, less environmental effect is mandatory. Moreover, recovering possible waste utilization is very important as there are no materials to be called waste as such but by-products in this world.

7. Recommendation

Taking the increasing trends in coffee trade and consumption and related requirement in the quality of coffee into account, plenty of works need to be done in different fields. Among these, coffee processing research and related environmental impact are still very important. Moreover, the impacts of the existing and recently emerging and growing coffee processing methods need to be explored in detail. There are different works performed in various coffee growing countries liked soaking under different organic acids and reported to improve the quality of coffee. These and similar methods need to be investigated in context of our country.

There is the newly introduced processing method, underwater soaking following dry fermentation. Additional investigation is also very important to see the effect of such methods on the coffee quality. It is also important if the stage at which the developments of ochratoxin occur will be investigated in the near future. The enzymatic activation of fermentation speed should also be considered as future research agenda. New coffee waste management options should be researched and possible utilization options need to be investigated.

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