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REVIEW PAPER

Study on Coffee Cherry its Chemical Characteristics, Processing and its By-product Utilization in Food: A Review

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ABSTRACT

Globally, coffee is the second most traded good after oil, and it is among the most commonly consumed drinks. From fruit to brewed coffee, a lot of byproducts are created during coffee production. On the basis of different processing methods used, various waste products are produced, such as husks, pulp, mucilage, leftover coffee grounds, and silver skin which only has a few uses, such as compost, livestock feed, fertilizer, and other similar things. Various value-added products are produced in the pharmaceutical, cosmetic, and food industries via pretreatments and recovery procedures (antioxidants, vitamins, enzymes, cellulose, starch, lipids, proteins, and pigments. Since the coffee industry generates enormous amounts of coffee by-products, which are abundant sources of nutrients and thriving nutrient resources, there is an urgent need to use and apply them in industrial settings to offset the large amount of crop production that will occur in the coming years. This review discusses methods for adding value to coffee byproducts, which can be achieved through a valorizing strategy, integrating bioengineering principles into food processing and waste management, as well as environmental conservation and disposal problems that accelerate both economic and ecological resources.

Keywords: Coffee cherry, By-products, Biotechnological, Value-added products, Economic resources

Globally, coffee (*Coffea* sp.) is an important crop (Arpi *et al.* 2021). As a perennial plant, coffee trees belong to the *Rubiaceae* family. Fully mature coffee fruits or berries have a bright red epicarp surrounding highly pectic mucilage (mesocarps). the coffee bean's final spermoderm layer and a thin endocarp layer made of parchment (Arya *et al.* 2022). The two main coffee species grown for commercial production around the world are mainly Coffea Robusta and Coffea arabica (Nigam & Singh, 2014). Approximately 75% of global coffee production is Arabica coffee, while less than 25% is Robusta coffee, according to Arpi *et al.* 2021. Historically, coffee has been grown either next to other valuable food, fuel, and fodder crops like leguminous pod trees, citrus, or tall forest trees, or beneath their canopy (Nigam & Singh, 2014). Globally, coffee is the second most traded good after oil, and has a significant economic impact on the economies of its major producing countries, including Brazil, Vietnam, Indonesia, Colombia, Ethiopia, India, and Mexico. Brazil ranks second in terms of consumption and are the world's leading coffee producer and exporter (Oliveira & Franca, 2015). Fig. 1 represents the world's total production of coffee from 2018-2023 Dec.

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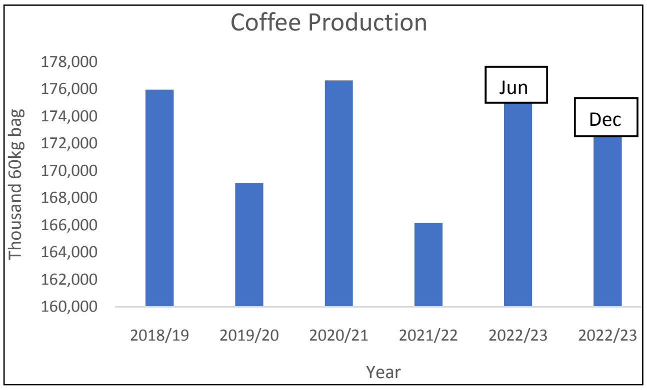

Fig. 1: Coffee production (Robusta & Producer, 2022)

Characteristics of coffee

Acidity, aroma, and taste are three of coffee's key distinguishing characteristics. Coffee's acidity is due to the dryness of the back of the tongue and palate edges. Before smelling the aroma, people inhale the vapor that rises from the coffee cup. A good coffee drinker, like a wine taster, inhales the aroma before letting his or her lips touch the coffee. Coffee has a variety of distinct flavors that interact with acidity, aroma, and body to produce flavors like caramel, chocolatey, fragrant, fruity, ripe, sweet, almondy, delicate, and piquant (Padmapriya *et al.* 2019).

Chemical constituent

Fresh coffee beans have a protein content of about 9%, but dried coffee beans have a protein content that ranges from 11 to 15%. Due to their interactions with sugars during the roasting process, these proteins may not be suitable for commercial extraction processes and result in low-quality protein. (Bekedam *et al*. 2008). As an integral component of the Maillard reaction, proteins contribute to the development of coffee flavor by releasing volatile secondary compounds including pyridines, furans and pyrazines (Farah, 2012).

After water extraction, coffee grounds are primarily composed of hydrophobic materials such as oils, lipids, triglycerides, fatty acids, and insoluble carbohydrates like cellulose and various indigestible sugars. In addition, coffee contains protective phenolics, wonderful aroma-producing essential oils, and structural lignin (Padmapriya *et al.* 2019). On a dry weight basis, the green bean contains up to 8.2% chlorogenic acids. A number of pre-processing steps can reduce the amount of soluble chlorogenic acids by up to 7% before roasting; however, after roasting, as a result of numerous reactions, this content may drop to as low as 4.5%, mainly due to the release of caffeic and quinic acids, respectively (Arya *et al.* 2022).

Caffeine

(Toschi *et al.* 2014) Caffeine is the main ingredient in coffee, and it has a mild stimulant effect that helps to maintain cognitive function and reduces central fatigue (Kalmar and Cafarelli, 2004). In Fisone *et al.* (2004), caffeine was reported to act as an adenosine receptor antagonist due to its chemical similarity to adenosine. Caffeine inhibits adenosine function when it binds to the adenosine receptor, promoting sleep (Basheer *et al.* 2004). According to (Hino *et al.* 2007), humans benefit from caffeine consumption by having a lower risk of type 2 diabetes, and obesity and also minimization in Parkinson's symptoms (Trevitt *et al.* 2009) and as per (Carman *et al.* 2014) delayed onset of age-related cognitive decline and Alzheimer's disease. A study by Janissen & Huynh (2018) found caffeine concentrations of (1.5, 1.2, 1.4 and 0.4) percent in coffee pulp, husk and silver skin.

Tannins

According to the Nicola *et al*. (2007), Tannins are mainly found in developing nations and are traditionally connected to the leather tanning industry. The most common sources of these compounds are vascular plants' bark and leaves, flowers, fruits and seeds (Osman, 2012). Tannins are widely considered antinutritional compounds, limiting their use in animal feed (Pandey *et al.* 2000). According to (Janissen & Huynh, 2018), tannins have beneficial effects on human health, including applications against cardiovascular diseases and anti-bacterial, anti-microbial, anti-inflammatory, and anti-allergy properties. However, different chemical structures and tannin polymerization into oligomers could have an impact on the beneficial properties of tannins. Coffee husk, pulp, silver skin, and used coffee grounds all contained between 1.8 and 9.6, 4.5 and 9.3, and 0.02 percent tannin respectively.

Processing of coffee

Coffee cherries must undergo several processing steps after harvesting to remove their outer layers, such as their skin (exocarp), the pulp (mesocarp), mucilage, and endocarpal parchment (Calvert *et al.* 2014). In Dry and semi-dry postharvest processing separates seeds from skin and pulp mechanically after washing and drying, while wet postharvest processing releases seeds by fermenting or enzymatically digesting the skin and pulp (DePaula *et al.* 2022). The coffee pulp alone accounts for approximately 28% of the coffee fruit by dry weight, the skin for about 12%, and the seeds for about 50–55% (Heuze and Tran, 2022). Fig. 2 illustrate the parts of coffee cherry.

Fig. 2: Coffee cherry and its parts

A hot air dryer or the sun is used to dry red coffee cherries to a moisture content of 10% to 12% during the dry processing method. The dry skin and pulp are then scraped off of the cleaned and dried coffee fruit. The complex steps of the wet coffee processing method include mechanically removing the coffee's skin and pulp, fermenting the mucus layer, air-drying, and hulling to remove the parchment skin. Combined dry and wet methods of coffee processing, semi-dry (semi-wet) coffee production is achieved during mechanical processing of the cherries, followed by drying without removing the mucilage of coffee. After drying, the coffee is stored and ready for roasting (Muzaifa *et al.* 2021). Roasting causes the beans to undergo different stages of heating, causing chemical changes that have an impact on the beans' color, flavor, and aroma. In the first step, water is removed from the bean while the temperature is 180°C and the humidity is 2.5%. Then, the temperature is increased to 200–300 °C, where physicochemical transformation results in flavor development. The final step is cooling using water or cold air jets (Calvert *et al.* 2014). The processing method of coffee by dry and wet method represent below Fig. 3 as per (Kleinwächter *et al.* 2015).

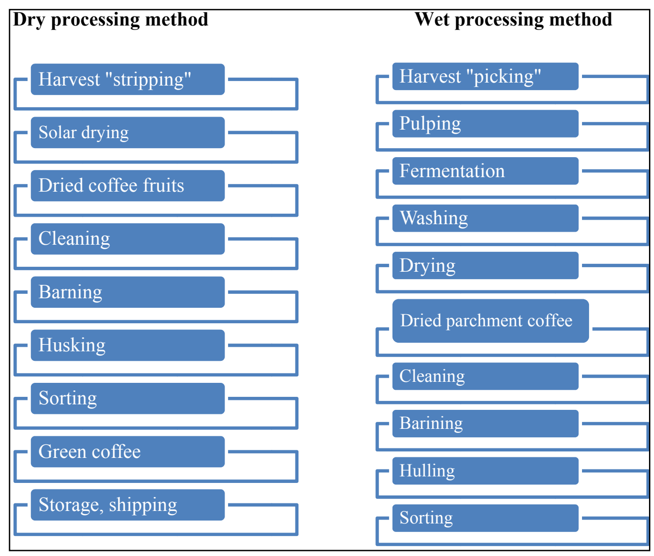

Fig. 3: Processing flow chart of coffee cherry (Kleinwächter *et al.* 2015)

Coffee by-products

Globally, coffee is the second most traded good, and the process of making coffee produces a significant amount of residue and by-products (Nabais *et al.* 2008; Mussatto *et al.* 2011; Murthy & Madhava Naidu, 2012)which have limited applications such as fertilizer, livestock feed, compost and such others. Biotechnological applications in the field of industrial residues management promote sustainable development of country's economy. The objectives pertaining to food processing by-products, waste and effluents include the recovery of fine chemicals and production of precious metabolites via chemical and biotechnological processes. Pre-treatments, followed by recovery procedures endow value-added products (natural antioxidants, vitamins, enzymes, cellulose, starch, lipids, proteins, pigments. Processing of coffee production generates; massive amounts of coffee by-products are produced. These byproducts have an environmental impact in countries where they are grown and processed (Muzaifa *et al.* 2021). Coffee husks, peels, and pulp, which contain nearly 45% cherry, are the most important byproducts of the coffee industry. Because they are nutrient-rich, they are used for a variety of purposes, such as the extraction of caffeine and polyphenols (Murthy & Madhava Naidu, 2012). The table 1 provides the information about chemical characteristics of coffee-by products.

Coffee pulp

A study given by Murthy and Madhava Naidu (2012), during wet or semi-dry processing, coffee pulp makes up about 29% of the dry weight of the whole cherry. For every two tons of green coffee produced, one ton of coffee pulp is produced. The mesocarp and exocarp (outer skin) of coffee pulp are both present (fleshy portion). It primarily contains significant amounts of minerals (9%), proteins (5-15%), carbohydrates (21-32%), and fats (2-7%) as well as moderate levels of tannins, polyphenols, and caffeine (Blinová *et al.* 2017). Tannin content ranges between 1.8 and 8.56%, total pectin substances are 6.5%, reducing sugars are 12.4%, non-reducing sugars are 2%, caffeine is 1.3%, chlorogenic acid is 2.6%, and total caffeic acid is 1.6%. In addition, coffee pulp contains anthocyanins, which can be used as natural food coloring. Coffee flour can be used to make beverages, breads, muffins, pastas, bars, cookies and brownies (Muzaifa *et al.* 2021).

Coffee husk

Coffee cherry husks are produced during the dry processing of coffee berries. About 12% of the total coffee cherry is made up of the industrial byproduct known as coffee husk (dry weight). For a single ton of fresh coffee, 0.18 tons of coffee husk are generated. Husks are abundant in proteins, minerals, and carbohydrates, but Additionally, they include organic components like chlorogenic acid, caffeine, and tannins (Janissen & Huynh, 2018). In coffee husks, 72.3% of the mass is carbohydrates, 15.0% moisture, 5.4% ash, 7.0% protein, and 0.3% fats (Gouvea *et al.* 2009). Coffee husk is made up of 6.2% ash, 24.5% cellulose, 29.7% hemicelluloses, and 23.7% lignin. (Murthy & Madhava Naidu, 2012). Coffee husks contain a variety of compounds, including

Table 1: Chemical characteristics of coffee-byproducts

Parameters %	Pulp	Husk	Silver skin	Spent
Carbohydrate	44.0-50.0	57.8	44.0	82.0
Protein	11.5 ±2.0	8.0 ±5.0	18.6 ±4.0	13.6 ±3.8
Fat	2.0 ±2.6	0.5±5.0	2.2±1.9	6.0
Ash	8.9	6.0	4.7-7.0	1.6
Total Fiber	60.5±2.9	24±5.9	62.4±2.5	60.5
Cellulose	63.0±2.5	43.0±8.0	17.8±6.0	8.6±1.8
Hemicellulose	2.3±1.0	7.0±3.0	13.1±9.0	36.7±3.8
Total sugar	14.4±09	58.0±20.0	6.65±10.0	8.5±1.2
Tannin	3.0±5.0	5.0±2.0	0.02±0.1	0.02±0.1
Chlorogenic acid	2.4±1.0	2.5±0.6	3.0±0.5	2.3±1.0
Caffeine	1.5±1.0/ 10.7	1.0±0.5/12.59	0.03±0.6/15.82	0.02±0.1/11.45

Franca et al. 2009; Murthy and Madhava Naidu 2010; Mussatto et al. 2011a; Mussatto et al. 2011b; Murthy & Madhava Naidu, 2012); Hachicha et al. 2012; Ballesteros et al. 2014; Regazzoni; Shemekite et al. 2014; Kang et al. 2017; Janissen & Huynh, 2018.

caffeine, tannins, and polyphenols. They are also rich in organic matter and nutrients. These residues are toxic due to the latter compounds present, which limits their use as animal feed and worsens the issue of environmental pollution (Oliveira & Franca, 2015).

Coffee silver skin

Roasting of coffee results in the production of the silver coffee skin, a thin layer of the outer layer of coffee beans that accounts for 4.2% (w/w) of its weight. Obtained by-product contains several phenolic compounds, including chlorogenic acid, along with additional phytochemicals and bioactive substances that help to increase the component's high antioxidant capacity (Muzaifa *et al.* 2021; Iriondo *et al.* 2017). Furthermore, coffee silver skin may be used as a support and nutrient source during the production of fructooligosaccharides and -furctofuranosidase by Aspergillus japonicus under solid-state fermentation conditions, which is then used as a raw material to produce fuel bioethanol (Blinová *et al.* 2017). Cruz, (2014); Janissen and Huynh (2018) also stated that it contains a high amount of total dietary fiber (62.4 g per 100 g), with cellulose and hemicellulose being the main constituents, and that it may be useful as an additive for the food industry. It has also been shown that magnetically modified coffee silver skin can be used to remove xenobiotics from wastewater (methylene blue) (40) or that coffee silver skin aqueous extract may be used for antiaging cosmetics and dermaceutics because of its powerful antioxidant activity (Blinová *et al.* 2017).

Spent ground coffee

For the preparation of soluble coffee, nearly half of the coffee that is produced worldwide is processed. One ton of green coffee yields approximately 650 kg of spent coffee, and for every kg of soluble coffee yielded, approximately 2 kg of wet spent coffee is obtained. Mannose and galactose-containing sugars, as well as a sizable portion of proteins, are more abundant in Spent coffee (Murthy & Madhava Naidu, 2012). The average amount of cellulose in coffee grounds is 12.4%. The average amount of hemicellulose is 39.1% (3.6% arabinose, 19.07% mannose, and 16.43% galactose). The average amount of lignin is 23.9%. In addition, the average amount of fat is 2.29%. As a result, they become intriguing sources of raw materials for various products (Blinová *et al.* 2017). Additionally, according to Bonilla-Hermosa *et al.* (2014), spent coffee contains a variety of minerals, including phosphorus (1475.1), potassium (3549.0), calcium (777.4), iron (118.7), magnesium (1293.3), manganese (40.1), copper (32.3), and zinc (15.1). Additionally used coffee grounds have been promoted as a natural source of prebiotics, carbohydrates, dietary fiber, and antioxidants (Muzaifa *et al.* 2021).

Utilization of pulp and husk of coffee cherry

According to Arpi *et al*. (2021), Caffeine, tannins, and polyphenols found in coffee cherry pulp are harmful to the environment if discarded, but they can be useful in functional drinks like cascara for providing antioxidants and phenolic compounds. The following six processing methods were used in this method: P1 is a delayed-pulped cherry pulp, P2 is a water-soaked cherry pulp, P3 is a water-soaked cherry pulp, and P4 is a dry process coffee pulp and husk, P5 is a wet process coffee pulp and husk, and P6 is a wine process coffee pulp and husk. As a result, all treatments reduced tannin content from 86 mg/L to around 35 mg/L, regardless of the treatments used. The antioxidant activity of cascara beverages ranged from 53 to 78% inhibition of DPPH. Caffeine levels in cascara beverages were low in the P1, P2, and P3 treatments, hovering around 0.20%, and were roughly double that in the P4–P6 treatments.

Another attempt has been made by (Heeger *et al.* 2017) to create the refreshing beverage Cascara. Six dried coffee pulp samples were collected and analyzed, along with a Cascara beverage made in Switzerland using one of the samples. Coffee pulps' total polyphenol content was found to range between 4.9 and 9.2 mg gallic acid equivalents (GAE)/g DM after aqueous extraction. The assay with ABTS radical revealed that the antioxidant capacity ranged between 51 and 92 lmol Trolox equivalents (TE)/g DM. Congo's Bourbon variety and the maragogype variety had the highest caffeine contents at 6.5 and 6.8

mg/g DM, respectively. A total of 226 mg of caffeine and 283 mg GAE/L of total polyphenols were found in the sample Cascara, with an antioxidant capacity of 8.9 mmol TE/L.

Manasa *et al*. (2021) investigated how to recover pectin and polyphenols rapidly from coffee pulp because of its high pectin and polyphenol content. Several chemicals were evaluated for their effectiveness in precipitating pectin from coffee pulp, including ethanol, sulfuric acid, hydrochloric acid, nitric acid, and ammonium oxalate. Based on the results, metal salts and ethanol with 6.0% and 6.7%, respectively, produced the highest pectin extractions. Commercial pectin and crude pectin had methoxyl contents of 9.3 and 5.6%, respectively. It was found that the polyphenol fraction had good antioxidative abilities against phosphomolybdate, FRAP, and DPPH radicals.

Muzaifa *et al*. (2021), Kombucha from cascara has also been researched and is likely to become a viable product. Tea leaves are fermented by acetic acid bacteria and yeast to create kombucha, a traditional ferment of sweetened tea. The benefits of kombucha include immune system stimulation, increased cancer resistance, better digestion, decreased inflammation, and other advantages. Currently, kombucha is among the most well-liked health beverages in America. According to the findings, cascara kombucha and traditional kombucha are nearly identical. Cascara kombucha ferments for eight days, producing better chemical results, but the final product tastes better after twelve days.

The coffee cherry husk, which is made up of dried skin, pulp, and parchment, is the main by-product of the dry method (also known as "unwashed") (Cruuz, 2014; Bondesson, 2015. Several approaches have been investigated for re-utilizing coffee cherry husks as a biogas substrate (Cruz, 2014; Ulsido *et al*. 2016; Akinbomi *et al*. 2014), production of alcohol (Gouvea *et al*. 2009; Sahu, 2014), biosorbents for cyanide (Gebresemati *et al*. 2017.), Heavy metal removal from aqueous solutions using biosorbents or extracted in order to recover bioactive substances (Oliveira *et al*. 2008). Further, coffee husks were demonstrated to be suitable substrates for growing edible mushrooms (Alemu, 2015; Leifa *et al*. 2000). Additionally, coffee husks are used as a potential functional ingredient in the preparation of food (using the ground husk as a food supplement for use in juices, granola, and smoothies). The coffee husk contains high concentrations of caffeine and tannins, which are negative for the environment, but can be extracted to produce energy drinks. Since coffee husk is naturally gluten-free, it could also be marketed as allergy-friendly. In addition, Coffee husks are useful substrates for the production of molds, yeasts, and enzymes, due to their high fermentable sugar content (Blinová *et al*. 2017).

CONCLUSION

The cultivation, processing, trading, transportation, and marketing of coffee, one of the world's most important products, promotes employment and represents an important industry around the world. Coffee processing, from fruit to ready-to-drink coffee, generates a large amount of by-product. Various by-products are produced depending on the method used to process the coffee, including pulp, husk, mucilage, silver skin, and leftover coffee grounds. Coffee pulp, which makes up half of the entire coffee cherry, is the most important byproduct of wet coffee processing. Researchers have looked into the potential of coffee byproducts as sources of prebiotics, dietary fiber, antioxidants, and natural food colorants and flavorings. In addition, they are also used in some pharmaceutical products along with food supplements and foodstuffs. Coffee pulp can be converted into functional drinks such as cascara and cascara kombucha using a simple and promising process. For this reason, it is imperative to properly utilize and use coffee by-products in industrial applications.

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