Utilization of Coffee By-Products as Profitable Foods - A Mini Review

M Muzaifa* 1  F Rahmi2 and Syarifudin3

1 Agricultural Product Technology Department, Universitas Syiah Kuala Banda Aceh 23111 Indonesia
2 Agrotechnology Department, Universitas Gajah Putih Blang Bebangka Aceh Tengah 24552 Indonesia
3 Economic Department, Universitas Gajah Putih Blang Bebangka Aceh Tengah 24552 Indonesia

*E-mail: murnamuzaifa@unsyiah.ac.id

Abstract. Indonesia is one of the largest coffee producer and exporter countries in the world. The current significant environmental problem challenge being faced by Indonesian farmer is the absence of utilization of coffee by-products. Coffee processing from fruit to brewing coffee that is ready to drink produces a large amount of by-product. Depending on the processing method chosen, the waste produced also differs consisting of pulp, husk, musilage, silver skin and residual coffee grounds. This review aims to provide an overview on coffee by-products characteristic and their potential utilization as profitable products. For this purpose, we have collected and reviewed some literature on chemical properties of coffee by-products and the history of these by-products consumption in some countries. The coffee pulp is the largest by-product acquired during wet coffee processing, so the primary attention has given to the by-product. The by-products have been studied from the coffee pulp including juice, cascara and kombucha. Cascara is a tea made from dried coffee pulp. Cascara has a long history of consumption in Yemen, Ethiopia and South America with different name. Other products are still being studied as products with great potential for further development. With the high crop production projected in the future, the utilization of coffee by-products as useful products should be realized. It is hoped that the results of this review can provide insight to all stakeholders.

1. Introduction

Coffee (Coffea sp.) is the most important drinks in the world after tea. Many people consume coffee every day. The existence of coffee as one of the most favorite drink in the world is inseparable from its delicious taste and stimulating effect. Not only because of consumer enjoyment of coffee drinkers but also because of the economic value for countries that produce and export coffee beans. Brazil, Vietnam, Colombia, Indonesia and India are top five coffee producing countries in the world [1].

In 2017, Indonesia is the 4th biggest coffee producer in the world. Position occupied first by Brazil. Coffee production in Brazil is more modern, they make use of machines in the process plant maintenance and harvest. In addition, the average land use for coffee plantations it is around 2.3 million ha, with productivity levels ranging between 1,020-1,380 kg/ha. Productivity and average area of coffee in Indonesia is still very far away in comparison with Brazil. Coffee productivity level Indonesia is 707
kilograms kg/ha. Most of it, namely 95% of coffee plantations, is a people's plantation land, with the average land ownership is less than 1 ha. The low productivity of coffee in Indonesia at which is caused by plants that have old, broken and unproductive.

The local coffee commodity has an important role for the country's foreign exchange and a stage for coffee farmers in Indonesia. Coffee commodities and their types vary in each region, so that coffee can be used as a national identity. There are two types of coffee at most grown in Indonesia, namely Robusta and Arabica. Robusta is a type of coffee that is more resistant to hot climates, so it can be planted in the lower plains, in contrast to Arabica coffee which demands more plain high, the temperature at the planting site should be ranges from 14-24 degrees Celsius [2]. The first coffee commodity cultivated in Indonesia was Arabica coffee originating from Africa. Currently, some of the coffee cultivated in Indonesia is robusta coffee, which is about 90% and the rest is arabica coffee. Although initially Arabica coffee was cultivated in Indonesia, for several reasons the number of Arabica coffee cultivation decreased and was replaced by robusta coffee [3]. As mention above, coffee has an important role in Indonesia's economic structure, especially in terms of exports. Most of the coffee are exported to various countries in world. America and Japan are the biggest importer of Indonesian coffee [4].

2. **Coffee Processing Method**

The coffee quality is influenced by many factors i.e coffee type, harvest quality, coffee growth location, agronomic system, coffee processing method, drying and storage condition [5,6,7,8,9]. The quality of coffee is complex interactions results between the plant genetics, environment and management plantation [10,11]. The coffees that are traded are the dry coffee beans that have been released from the other parts of coffee cherry (outer skin, pulp, parchment, silver), which are called coffee beans. The coffee cherry cross-section can be seen in Figure 1.

![Figure 1. The coffee cherry cross-section](image)

Coffee bean comes from coffee cherries that have undergone several stages of processing. Based on how it works, in general there are two ways of processing coffee cherries, namely the wet process of coffee and the dry process. The difference between the two methods lies in the use of water in the peeling of the coffee skin and fermentation [12,13,14]. However, in practice, semi-wet processing which is a combination of the two types of processing, is also widely used [15,16]. Flow chart of coffee processing method can be seen at Figure 2.
In dry coffee processing, red coffee cherry is dried in the sun or dried in hot air machine to a moisture content of about 10% - 12%. After drying, the coffee fruit is cleaned and the next process is to remove the dry skin and pulp. Contrast to dry processing method, wet coffee processing involves complex stages, including the mechanical removal of the coffee skin and coffee pulp, mucilage layer fermentation, sun drying and hulling to remove the parchment skin. Semi-dry (semi-wet) coffee processing combine the stages of the dry and wet coffee processing methods, in which the coffee cherries are mechanically processed and the drying process is carried out without removing coffee mucilage. The dry coffee processing method is commonly applied for robusta coffee. The coffee processing for robusta coffee is technologically simpler comparing with wet coffee processing which is generally applied for Arabica coffee. In wet coffee processing, pulp and husk are removed while the coffee cherry is still fresh [16].

3. **Coffee by-product**

Enormous amounts of coffee by-products are generated during the coffee industrial processing. These by-products cause an environmental impact in countries dedicated to its cultivation and processing. Different by-products may be produced such as pulp, husk, silver skin and spent coffee grounds, depending on the method chosen for coffee processing (Figure 3 and 4). The coffee processing method that is carried out is usually adapted to the conditions of coffee plantation location and the customs of the local society. In particular from coffee cherries to green bean, approximately 40-45% of by-product is formed [17,18,19,20].
3.1. **Pulp**

Coffee pulp is the main by-product in the wet coffee processing, represents a half of the whole coffee cherry. Coffee pulp obtained during the wet coffee processing is common deposited directly into huge waste disposal sites or river stream without undergoing any treatment [21,22]. Coffee pulp is left alone to rot and cause foul odor pollution. Several studies have shown that coffee pulp has been used to produce bioethanol, biogas, compost, mushrooms substrate and animal feed. Coffee pulp is composed of proteins (10-12%), carbohydrates (44-50%), and fibers (18-21%). Coffee pulp also contains caffeine (1.3%) and appreciable amounts of bioactive compound, polyphenols (1.48%). Polyphenols can prevent or decrease the peroxidation of fatty acids, reduce oxidative stress in animals at critical physiological stages and increase the shelf life of animal meat when it is includes in their diets [23, 24, 25, 26, 27]. Other bioactive compound in coffee pulp is anthocyanins that have potential applications as natural food colorants [22]. Coffee pulp flour with a high fiber (times more fiber than whole grain wheat flour) and mineral content has been developed by Ramirez [28]. The coffee flour has proposed for use in different food formulations such as cookies, breads, muffins, squares, brownies, pastas, sauces and beverages.

3.2. **Husk**

Coffee husk, which is consisted of outer skin, pulp and parchment is the main residues obtained in dry coffee cherry processing. It has a high content in proteins (5-11%), carbohydrates (35-85%), minerals
(3-11%) and soluble fibers (30.8%). Dietary fibers in coffee husk containing 24.5% cellulose, 29.7% hemicellulose and 23.7% lignin. Coffee husk also rich in phytochemicals such as cyanidins (20%) and tannins (5-9%) for industry of food and pharmacy [22,29,30]. In food industry, one of the first applications of coffee husks was the production of citric acid [31]. Coffee husk has been also described as an important source of natural aroma compounds [32, 33].

3.3. Silver skin
The silver coffee skin is a thin layer of the outer layer coffee beans and represent about 4.2% (w / w). The silver coffee skin is the only by-product produced during the coffee roasting process. This component consists of phenolic compounds, especially chlorogenic acid (CGA), as well as other phytochemical and bioactive compounds that contribute to high antioxidant capacity [34]. CGA have shown good bioavailability and present several functions such as antibacterial, antifungal, anti-inflammatory, antioxidant, anti-glycative, anti-carcinogenic and neuroprotective functions. The bioactive content of silver coffee skin has been investigated by extracting its natural bioactive components which are used in the fields of food supplements, foodstuffs and some pharmaceutical products [35].

3.4. Spent coffee
Spent coffee is fine particulate by-product generated after brewing roasted coffee grounds. It is calculated that for each kilogram of brewed coffee, 0.65 kg of dried spent coffee or 2 kg of wet spent coffee is produced [36]. The most important components of spent coffee grounds are polysaccharides whose thermal hydrolysis may produce manooligosaccarides (MOS). MOS from spent coffee show prebiotic effect since they resist digestion and promote bifidobacteria growth that are thougt to promote intestinal health. MOS also show other health effect in decreasing blood pressure, reducing body fat and help protecting against oxidative stress-related diseases such as cancer. Spent coffee has been advanced as natural source of several ingridients such as prebiotics, carbohydrates, dietary fiber and antioxidants [37,38,39].

4. Coffee Pulp Utilization as Profitable Foods (Functional Drink)
As mention above, several research results indicate that coffee pulp contains a number of important chemical components, if processed properly it can be used in food production. Coffee pulp is rich in nutrients and acts as a source of phytochemicals such as caffeine, chlorogenic acid, procyanidin and other polyphenolic compounds. In addition, it also contains high fiber and antioxidants [19, 40]. With this content, coffee pulp can act as a functional drink. Functional drinks are foods that are naturally or have been processed containing one or more compounds that are beneficial to health. Functional drinks have characteristics such as drinks or foods that have sensory characteristics such as appearance, texture, color and taste that are acceptable to consumers [41].

Coffee pulp actually can be processed into special beverage products with a very simple process and promising economic potential. Coffee pulp can be processed into special delicious and healthy drink products. With a very simple processing process that has very promising economic potential, several beverage products have been obtained from coffee pulp, including coffee pulp juice [42] cascara [43,44] and kombucha cascara [45,46].

Cascara is a tea made from dried coffee pulp. Cascara is considered as a new drink in the United States and Indonesia [47] even though this drink has long been known by the people of Yemen as “quishr” before the tea. Cascara can be drunk without sugar due to the natural sweetness and fresh sour taste found in the coffee pulp. Ethiopians and Yenmis also mix spices such as ginger, nutmeg, and cinnamon known as “hashara”. In South America especially El Salvador and Bolivia, it turns out that cascara has been an export commodity for a long time [44, 48]. Currently cascara ready to drink commercially available. Peloton is a beverage company that sells this product (Figure 5). Cascara collect from a small co-op farm in Honduras and process it in New Jersey and Pennsylvania. Peloton offers four flavors: original lightly sweetened, peach ginger, cranberry lime, and apple pomegranate [49].
Another product that has been researched and has the potential to be developed is kombucha from cascara. Kombucha is a traditional fermentation of sweetened tea obtained from infusion of tea leaves by the fermentation of a symbiotic association of acetic acid bacteria and yeast [50,51]. Kombucha is known to boost the immune system, increase resistance to cancer, improve digestive function, reduce inflammation and other benefits. Currently kombucha is one of the most popular health drinks in the United States [52,53]. Muzaifa [46] has developed kombucha made from cascara by varying the fermentation time. The resulting cascara kombucha is relatively the same as the original kombucha. The results of 8 days of cascara kombucha fermentation are better chemically, but in terms of taste, 12 days of fermented kombucha is preferred. The kombucha uses raw materials from cascara Gayo arabica coffee and is commercialized as Gayo kombucha (Figure 6).

5. Conclusion
Coffee processing from fruit to brewing coffee that is ready to drink produces a large amount of by-product. Depending on the coffee processing method chosen, the by-products produced also differs consisting of pulp, husk, musilage, silver skin and residual coffee grounds. The coffee pulp is the largest by-product obtained during wet coffee processing, represents a halp of the whole coffee cherry. The coffee by-products have studied their potential as source of several ingredients such as natural food colorant, natural aroma compounds, prebiotics, carbohydrates, dietary fiber and antioxidants. They used in food supplements, foodstuffs and some pharmaceutical products. Coffee pulp can be processed into special beverage products with a very simple and promising process, cascara and cascara kombucha which are functional drinks. With the high crop production projected in the future, the utilization of coffee by-products as useful products should be realized. It is hoped that the results of this review can provide insight to all stakeholders.

References
[1] International Coffee Organization 2019 Historical data on The Global Coffee Trade accessed January 5 2019 from ICO website: //www.ico.org/ new_historical.asp
[2] Warta Ekspor 2018 Tajuk Utama Kopi Indonesia http://dipen.kemendag.go.id/app_frontend/admin/docs/publication/9321548126511.pdf accessed
[3] Rahardjo P 2013 *Kopi Panduan Budidaya dan Pengolahan Kopi Arabika dan Robusta* (Bogor: Penebar Swadaya)

[4] Pusat Data dan Sistem Informasi Pertanian 2017 *Outlook Kopi* (Komoditas Pertanian Sub Sektor Perkebunan) Jakarta

[5] Baggenstoss J 2008 *Coffee Roasting and Quecnching Technology – Formation and Stability of Aroma Compounds*. Dissertation, Eidgenossische Technische Hochshule Zuerich (ETH) - Switzerland.

[6] Clemente J M et al 2015 Effects of nitrogen and potassium on the chemical composition of coffee beans and on beverage quality *Acta Scientiarum Agronomy* 37 297-305

[7] Yusianto and Widjoyotomo S 2018 Panen dan pengolahan produk hulu kopi in Misnawi and Widjoyotomo S penanganan pasca panen, pengolahan, alat mesin dan diversifikasi limbah kopi, Jember, Jawa Timur, Indonesia: *Puslit Kopi dan Kakao Indonesia* 1-78

[8] Salla M H 2009 Influence of genotype, location and processing methods on the quality of coffee (Coffea arabica L.). *Msc. Thesis*. Hawassa University, Hawassa.

[9] Towaha J, Purwanto, E H and Aunillah A 2014 Peranan pengolahan terhadap pembentukan citarasa kopi. *Bunga Rampai Inovasi Teknologi Tanaman Kopi untuk Perkebunan Rakyat* 157-167

[10] Alvarado R A and Linnemann A R 2010 The predictive value of a small consumer panel for coffee-cupper judgment *British Food Journal* 112 1023–1032

[11] Sunarharum W B, Williams D J and Smyth H E 2014 Complexity of coffee flavor: A compositional and sensory perspective *Food Research International* 62 315-325.

[12] Gardjito M and Rahadian D R 2011. *Kopi* (Jakarta: Kanisius)

[13] Chalfoun S M, Pereira M C, Carvalho G R, Pereira A V, Savian T V and Botelho D M S 2013 Characteristics of coffee (Coffea arabica L.) varieties in the alto paranaiba region *Coffee Science Lavras* 1 43-52

[14] Figueiredo L P, Borém F M, Cirillo M Â, Ribeiro F C, Giomo G S and Salva, T D J G 2012 The potential for high quality bourbon coffees from different environments *Journal of Agricultural Science* 10 87–98

[15] Pereira G V et al 2018 Exploring the impacts of postharvest processing on the aroma formation of coffee beans – A review *Food Chemistry* 272 441–452

[16] Karim M A, Wijayanti F and Sudaryanto A 2019 Comparative studies of coffee processing methods for decision making in appropriate technology implementation *AIP Conference Proceedings* 2114, 020015

[17] Nabais J M V, Nunes P, Carrott P J, Carrott M M L R, García A M and Díaz-Díez M A 2008 Production of activated carbons from coffee endocarp by CO2 and steam activation. *Fuel Processing Technology* 89 262-268.

[18] Mussatto S I., Carneiro L M, Silva J P, Roberto I C and Teixeira J A 2011 A study on chemical constituents and sugars extraction from spent coffee grounds *Carbohydrate Polymers* 83 368-374

[19] Esquivel P and Jiménez V M 2012 Functional properties of coffee and coffee by-products. *Food Research International* 46 488–495

[20] Cruz R 2014 *Coffee by-products: Sustainable Agro-Industrial Recovery and Impact on Vegetables Quality*: Dissertation thesis. Universidade de Porto.

[21] Geremu M, Bekele T Y, Sualed A 2016 Extraction and determination of total polyphenols and antioxidant capacity of red coffee (Coffea Arabica L.) pulp of wet processing plants. *Chemical and Biological Technologies in Agriculture* 3 25-30

[22] Murthy P S, Naidu M M 2012 Sustainable management of coffee industry by-products and value addition - A review *Resources Conservation and Recycling* 66 45-48

[23] Menezes E G et al 2014 Optimization of alkaline pretreatment of coffee pulp for production of bioethanol *Biotechnology Progress* 30 451-462

[24] Corro G et al 2013 Generation of biogas from coffee-pulp and cow-dung co-digestion: Infrared
studies of postcombustion emissions. *Energy Conversion and Management* **74** 471- 481

[25] Bernas S M 2011 Effect of coffee pulp compost and terrace on erosion, run off and nutrients loss from coffee plantation in Lahat Regency, South Sumatra *Journal of Tropical Soils* **16** 161-167

[26] Salomones D, Mata G, Waliszewski K N 2005 Comparative culturing of Pleurotus spp. on coffee pulp and wheat straw: Biomass production and substrate biodegradation *Bioresource Technology* **96** 537-544

[27] Salinas-Rios T et al 2014 Carcass characteristics, physiochemical changes and oxidative stress indicators of meat from sheep fed diets with coffee pulp *Arquivo Brasileiro de Medicina Veterinaria e Zootecnica* **66** 1901-1908

[28] Velez A R and Lopez J C R Pat EP3278672A1, 2011.

[29] Pandey A, Soccol C R, Nigam P, Brand D, Mohan R and Roussos S 2000 Biotechnology potential of coffee pulp and coffee husk for bioprocess *Biochem. Eng. J.* **6** 153-162

[30] Prata E R B A and Oliveira L S 2007 Fresh coffee husks as potential sources of anthocyanins *LWT - Food Sci. Technol.* **40** 1555-1560

[31] Shankaranand V S and Lonsane B K 1994 Coffee husk: An inexpensive substrate for production of citric acid by *Aspergillus niger* *World J. Microbiol. Biotechnol.* **10** 165-168

[32] Soares M, Christen P, Pandey A and Soccol C R 2000 Fruit flavour production by Ceratocystis fimbriata grown on coffee husk in solid-state fermentation process *Biochem. Eng.* **35** 857-861

[33] Soares M, Christen P, Pandey A, Raimbault M and Soccol C R 2000 A novel approach for the production of natural aroma compounds using agro-industrial residue *Bioprocess Eng* **23** 695-699

[34] Iriondo-DeHond A, Fernandez-Gomez B, Martinez-Saez N, Martirosyan D M, Garcia M D M and Castillo M D 2017 Coffee Silverskin: A Low-Cost substrate for bioproduction of high-value health promoting products *Ann Nutr Food Sci.* **1** 1005

[35] Dai J and Mumper R J 2010 Plant phenolics: extraction, analysis and their antioxidant and anticancer properties *Molecules* **15** 7313-52

[36] Dias D R et al., 2015 in Schwan R F and Fleet G H *Cocoa and Coffee Fermentations* (Florida: CRC Press)

[37] Asano I et al Pat 036208, 2006.

[38] Bravo J, Monente C, Juaniz I, De Peña M P and Cid C 2013 Influence of extraction process on antioxidant capacity of spent coffee *Food Res. Int.* **50** 610-616

[39] Voiz R K, McGhie T K and Kumar S 2014 Variation and genetic parameters of fruit colour and polyphenol composition in an apple seedling population segregating for red leaf *Tree Genet. Gen.* **10** 953-964

[40] Winarti C and Nurdjanah N 2005 Peluang tanaman rempah dan obat sebagai sumber pangan fungsional *Jurnal Litbang Pertanian* **24** 47-55

[41] Zuhra N H, Hasni D and Muzaifa M 2018 Pengolahan pulp kopi menjadi minuman sari buah dengan penambahan buah terong belanda dan konsentrasi gula yang berbeda *Jurnal Teknologi dan Industri Pangan* **31** 38-49

[42] Muzaifa M, Abubakar Y, Andini R 2020 Pengembangan produk komersial berbasis kulit kopi sebagai minuman sehat dan ekslusif. Laporan PKMBP. LPPM Universitas Syiah Kuala.

[43] Voiz R K, McGhie T K and Kumar S 2014 Variation and genetic parameters of fruit colour and polyphenol composition in an apple seedling population segregating for red leaf *Tree Genet. Gen.* **10** 953-964

[44] Heeger A, Cagnazzo A K, Ennio C, Wilfried A 2016 Bioactives of coffee cherry pulp and its utilisation for production of Casaca beverage *Siencece Research* **3** 120-127

[45] Nurhayati, Yuwanti S and Urbahillah A 2020 Karakteristik fisikokimia dan sensori kambucha casaca (kulit kopi ranum) *J. Teknol. dan Industri Pangan* **31** 38-49

[46] Zuhra N H, Hasni D and Muzaifa M 2018 Pengolahan pulp kopi menjadi minuman sari buah dengan penambahan buah terong belanda dan konsentrasi gula yang berbeda *Jurnal Teknologi Pertanian Andalas* **22** 157-164

[47] Yuliandri M 2016 Teh dari Ceri Kopi https://travel.kompas.com/read/2016/10/27 accessed August, 27th 2020

[48] Umanzor C 2017 Sensory characterization and analysis of tea infusions from dry coffee cherry
pulp “cascara” from washed and natural processed coffee. *Thesis*. Universitas Studiorom Utinensis, Honduras.

[49] Peloton Drink. What is Cascara accessed August 20th 2020 from https://www.drinkpeloton.com/

[50] Lobo R O, Dias F O and Shenoy C K 2017 Kombucha for healthy living: Evaluation of antioxidant potential and bioactive compounds *International Food Research Journal* **24** 541-546

[51] Jayabalan R, Malbasa R V, Loncar E S, Vitas J S and Sathishkumar M 2014 A review on kombucha tea—microbiology, composition, fermentation, beneficial effects, toxicity, and tea fungus *Comprehensive Reviews in Food Science and Food Safety* **13** 538-550

[52] Dufresne C and Farnworth E 2000 Tea, kombucha, and health: A review. *Food Res. Int.* **33** 409-421

[53] Kapp J M and Sumner W 2019 Kombucha: A systematic review of the empirical evidence of human health benefit *Ann. Epidemiol* **30** 66-70