

## Profiling the chemical and sensory properties of cascara beverages from different locations in Indonesia

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### Abstract

This study aimed to determine the chemical and sensory profiles of coffee cherry pulp (cascara) beverages from different locations in Indonesia. A total of thirteen samples were distinguished according to farming location, coffee variety, and postharvest processes. Cascara samples were brewed (3 g eq/50 mL) and used for chemical and sensory analysis. The results demonstrated presence of 3 chemical compounds at different quantities, e.g., total phenol (0.23 to 0.92 mg GAE/mL), caffeine (0.05 to 0.57 mg/mL), and 5-CQA (0.01 to 0.28 mg/mL). The antioxidant capacity of the samples was found at 0.24 – 0.95 mg of AAE/mL, and Cascara-Arabica-Kintamani showed the highest levels of 5-CQA and antioxidant activity. The quantitative descriptive analysis (QDA) method was used for sensory analysis. In general, cascara sensory properties were mostly determined by the coffee species rather than location and postharvest processing. Cascara from Arabica and Robusta coffee showed different profiles of taste and aroma. Sample with acidic taste and fruity aroma was mostly dominant in Arabica cascara samples, while bitter taste and assorted aroma (such as floral, black tea, and hay-like) dominated Robusta cascara samples.

## 1. Introduction

Coffee has been a popular beverage worldwide due to its role as an important part of the modern lifestyle and its health-promoting effects. Two coffee species, Arabica (*Coffea arabica*) and Robusta (*Coffea canephora*) are very popular since they are adaptable to various ecological conditions. Therefore, they are deemed to have tremendous economic importance. Major coffee producers in the world are Brazil, Vietnam, Indonesia, and Colombia with a total production of 103 million 60 kg bags of green bean. It was estimated that each 1 million 60 kg bags of dried coffee beans generated 218.400 tons of by-products (Dorsey and Jones, 2017).

Transformation of a coffee cherry into coffee bean requires a herculean process in terms of time-consuming and sample amount of by-products such as pulp, parchment husk, cherry husk, and silver skin (Murthy and Naidu, 2012a). However, coffee bean processing can be carried out via two methods, dry and wet (Murthy and Naidu, 2012b). In the dry process, coffee cherries are dried, followed by the de-hulling step (Heeger *et al.*,

2017). De-hulling steps gather the by-product called husks (Esquivel and Jiménez, 2012) which contain skin, pulp, mucilage, and hull parts. On the other hand, the wet process starts with the separation of unripe and ripened coffee cherries in the water. Ripened coffee cherry is processed in a pulper machine to separate the beans and the skin pulp and then fermented to remove the remaining mucilage and pulp (Magoni *et al.*, 2018). The last method generates by-products including skin, pulp, and mucilage.

Coffee by-products received serious environmental concern, regardless of the postharvest processing (Dorsey and Jones, 2017). The high content of caffeine, polyphenols, and tannins caused environmental problems, particularly in coffee-producing countries (Anal, 2017). For example, pulp and mucilage are relatively acidic, corrosive to equipment, and hard to safely dispose of. The decline in pH of the river due to such acid is potentially hazardous to fish and other water organisms. The rotten pulp left unprocessed in the landfill also causes an unpleasant odour. To deal with these problems, treatments of coffee by-products have

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been made. For instance, the coffee pulp was processed into compost (Kassa *et al.*, 2011) and bioethanol production (Choi *et al.*, 2012; Menezes *et al.*, 2013; Gurrām *et al.*, 2015). Coffee pulp was also used as feed for livestock such as pigs, chickens, rabbits, and ruminants (Murthy and Naidu, 2012b), but its application in substitution for animal feed was limited due to anti-nutritional components such as caffeine and tannin (Esquivel and Jiménez, 2012). Damat *et al.* (2019) used coffee cherry flour as an ingredient of high total dietary fibre cookies. Despite having undesirable effects, some chemical components in coffee cherry by-products showed promising benefits. The fresh cherry pulp contains high polyphenols responsible for antioxidant activity. For this reason, the development of coffee cherry tea, also popular as cascara, has increased greatly (Heeger *et al.*, 2017).

Cascara beverage has received great attention for the last 3 years. In some countries such as Indonesia and the USA, cascara-based products have been made. Its appearance is close to tea because the brew has a reddish-brown colour (Judkis, 2017). Chemically, it contains a low caffeine level but shows high antioxidant activity (Heeger *et al.*, 2017). Geremu *et al.* (2016) described that red coffee cherry pulp contained a noticeable amount of polyphenols and other antioxidative agents. Previous studies reported the presence of 4 phenolic compounds identified in cascara, namely flavan-3-ols (monomer and procyanidins), flavonols, anthocyanidins (Ramirez-Coronel *et al.*, 2004), and hydroxycinnamic acids (Cubero-Castillo *et al.*, 2017). Hydroxycinnamic acids (HAs) have been recognized as natural antioxidants. Chlorogenic acid (ChA), caffeic acid (CA), and ferulic acid (FA) belong to HAs group found in coffee pulp, while chlorogenic acid is the dominant phenolic compound. This compound can easily and

quickly donate hydrogen atoms to molecules that have already been oxidized or will be oxidized (Arellano-gonzález *et al.*, 2011). This suggests that cascara can be an ample source of antioxidants.

To develop a cascara product, health-enhancing properties and sensory profile are two key factors to consider. High variation in sensory and biochemical composition significantly dictates the sensory quality (Khapre *et al.*, 2017). In spite of numerous studies on the benefits of coffee pulp and cascara, there is a need to unveil the sensory profiles of the cascara beverage and their correlation with bioactive compounds. Therefore, this current work aimed to quantify bioactive compounds and antioxidant activity, evaluate the sensory profiles, and map the properties of cascara beverages from different varieties, origins, and postharvest treatments.

## 2. Materials and methods

### 2.1 Chemicals

All chemicals used were analytical grade. Gallic acid, 2,2-diphenyl-1-picrylhydrazyl (DPPH), ascorbic acid, chlorogenic acid 5-caffeoylquinic acid/5-CQA), and caffeine was purchased from Sigma-Aldrich (Germany). Other than those mentioned materials were bought from selected suppliers.

### 2.2 Cascara samples and brewing method

Thirteen cascara samples (Table 1) with different species, origins, and post-harvest processes were purchased from the Indonesian local market. Cascara beverage was prepared by brewing 3 g of dry matter (DM) dried coffee pulp with 50 mL of hot water at a temperature of 90°C for 6.5 mins. After that, cascara beverage was packaged in a tightly closed dark bottle

Table 1. Identity of cascara samples

District	Province	Species	Postharvest	Simplification*
Gayo	Aceh	Arabica	Dry	Gayo-Aceh-A-D
Gayo	Aceh	Arabica	Wet	Gayo-Aceh-A-W
Jambi	Jambi	Arabica	Dry	Jambi-Jambi-A-D
Pangalengan	West Java	Arabica	Wet	Pangalengan-West Java-A-W
Garut	West Java	Arabica	Dry	Garut-West Java-A-D
Temanggung	Central Java	Arabica	Wet	Temanggung-Central Java-A-W
Jember	East Java	Arabica	Dry	Jember-East Java-A-D
Bondowoso	East Java	Arabica	Dry	Bondowoso-East Java-A-D
Bondowoso	East Java	Arabica	Wet	Bondowoso-East Java-A-W
Kintamani	Bali	Arabica	Dry	Kintamani-Bali-A-D
Mamasa	West Sulawesi	Arabica	Wet	Mamasa-West Sulawesi-A-W
Padang Sidempuan	North Sumatra	Robusta	Dry	Pdgsidempuan-North Sumatra-R-D
Malang	East Java	Robusta	Dry	Malang-East Java-R-D

\*Simplification of samples code where the first word is district/origin, the second word is province, the third word is coffee species (R: Robusta and A: Arabica) and the fourth word is coffee processed (D: Dry and W: Wet).

and stored in the refrigerator until used for analysis.

### 2.3 Moisture content analysis

Moisture content was determined using the AOAC method (AOAC 2005) in triplicates and expressed as a percentage of raw material. It was used to calculate g of dry matter (DM) for each sample.

### 2.4 Value of pH and total dissolved solids analysis

The pH value measurement was obtained using the water analysis meter instrument (Starter 3100 pH Bench, OHAUS, USA). TDS Content analysis in cascara beverage was determined by refractometry technique (Sari *et al.*, 2015) which was measured by a digital refractometer (PAL-USD Cat, Atago, Japan).

### 2.5 Total phenolic content analysis

Total phenolic content (TPC) In cascara beverage was quantified according to a previous study (Vongsak *et al.*, 2013). Cascara brew (0.4 mL) was mixed with 1 mL of 10% Folin-ciocalteu reagent in deionized water and 1.6 mL of sodium bicarbonate solution (7.5% w/v), then incubated for 30 mins in 37°C with intermittent shaking. The absorbance was measured at 765 nm using a UV-VIS spectrophotometer (Thermo Scientific, Genesys, USA). Gallic acid was used as a standard with 6 concentrations between 6.25 – 200 mg/L (triplicate, LoD = 0.13 mg/mL, and  $R^2 = 0.999$ ). The result was designated as gallic acid equivalent per mL (mg GAE/mL cascara beverage).

### 2.6 5-O-Caffeoylquinic acid (5-CQA) content analysis

RP-HPLC experiment was performed to quantify 5-CQA levels (Herawati *et al.*, 2019a), without any modification. The 5-CQA levels were calculated by a standard curve of 5-CQA with 5-points concentration, ranged between 0.5 – 50 mg/L (triplicate, LoD = 0.2 mg/L, and  $R^2 = 0.999$ ). The 5-CQA levels were expressed in mg/mL of cascara beverage.

### 2.7 Caffeine content analysis

Caffeine content measurement followed Herawati *et al.* (2019b) using RP-HPLC with some modifications. Cascara beverage was filtered using 0.45 mm membrane (PTFE; Sigma-Aldrich, Germany) and 10 mL of the filtered sample was injected into HPLC MWD UV VIS detector (Agilent Technologies). The mobile phase (methanol and H<sub>2</sub>O (30:70 v/v) was set at isocratic mode at 0.8 mL/min to a Zorbax C18 (4.6×150 nm, 5 mm) column (Agilent Technologies). The caffeine component was detected at 280 nm wavelength. Five-points standard curve concentration ranged between 5-50 mg/L was used to calculate caffeine levels (triplicate, LoD = 3.0 mg/L

and  $R^2 = 0.999$ ), expressed in mg/mL cascara beverage.

### 2.8 Antioxidant activity analysis

Antioxidant analysis of the samples followed the DPPH assay (Mamilla and Mishra, 2017; Zarei *et al.*, 2019). Shortly, 0.1 mL of sample was added to 3.9 mL of 0.06 mM DPPH solution. The mixture was vortexed and incubated in the dark for 60 mins. Subsequently, absorbance was measured at 517 nm (triplicate). Antioxidant activity of the samples was determined according to a standard curve of 7-point ascorbic acid concentration ranging from 10-100 mg/L (triplicate, LoD = 8.02 mg/L and  $R^2 = 0.992$ ) and expressed in mg AAE (ascorbic acid equivalent)/mL of cascara beverage.

### 2.9 Sensory analysis

Sensory analysis was conducted for 13 samples with Quantitative Descriptive Analysis (QDA). The sample was prepared from 6 g of cascara which was brewed in 200 mL water at 90°C for 6.5 mins, then strained. Each sample was coded differently and then scored by panellists. The assessment was carried out individually under white lights and in an air-conditioned room. Specifically, the sensory evaluation is comprised of 3 main stages.

First, pre-screening was conducted by distributing questionnaires of 5-basic tastes to the panellists, aiming to evaluate their sensitivity and interest in the studied product.

Furthermore, the following stage included Focus Group Discussion (FGD) and panellist training. The eight selected panellists determined the strongest aroma and taste of 5 samples (2 sessions). This stage also aimed to expose panellists to the sample. Descriptive terms were suggested and agreed upon by the panellists since no references were available regarding the flavour attributes of cascara beverage. Assessment of the attribute intensity followed a 5-scale level (0 “does not exist”, 1 “very low”, 2 “low”, 3 “medium”, 4 “rather high”, 5 “high”). Panellists' training was designed to confirm the sensitivity, ability and consistency of panellists in assessing the appearance, mouthfeel, taste, and aroma of the samples. Actual standard attributes and cascara beverages were consistently prepared throughout training.

Lastly, the sample testing was divided into three sessions (4-5 samples for each session). Each sample was served in a standard cupping bowl, given a special code and presented randomly. Water and plain cracker were used as palate cleansers. The attributes for the QDA test (Table 2) were selected from the supreme attributes according to FGD.

Table 2. Dominant sensory attribute of cascara beverage used for quantitative descriptive analysis (QDA)

Attribute group	Attribute	Attribute group	Attribute
Appearance	Clarity	Mouthfeel	Longevity
	Brown		Watery
	Shine		Body fullness
Taste	Bitter	Aroma	Dried fruit
	Citric acid		Raisin
	Astringent		Peach
	Tamarind		Tamarind
	Lime		Floral
	Black tea		Black tea
	Herb-like		Hay-like
	Roasted		Hibiscus
	Hibiscus		

### 2.10 Statistical analysis

XLSTAT software version 2021.1 (Addinsoft, Paris, France) was employed for statistical analysis. Each parameter data was analysed using multivariate ANOVA followed by the Duncan test for multiple comparisons ( $P < 0.05$ ). Chemical and sensory profiling was analysed by Principal Component Analysis (PCA).

## 3. Results and discussion

### 3.1 Chemical properties of cascara beverages

Table 3 presents the level of bioactive compounds and antioxidant capacity of cascara beverage. In this study, the content of TPC in the samples from different species, origin, and postharvest processes differed significantly ( $p \leq 0.05$ ), ranging from 0.23 to 0.92 mg/mL (230 – 920 mg/L). Compared to a previous study (Saura-Calixto and Goñi, 2006), the quantity of phenolic compounds in a certain sample was comparable with those in black tea (763 mg/L) but much lower than those in the coffee brew (3430 mg/L). Cascara Arabica-Bondowoso-East Java beverage showed the highest level of TPC in the sample prepared with either wet or dry processing. Both of them originated from the same area and were processed by the same farmers. In this case, Heeger *et al.* (2017) confirmed that the content of TPC in coffee could be variable due to geographical conditions, despite similar variety and process. Intriguingly, as presented in Table 3, TPC in cascara Arabica-Gayo-Aceh beverage prepared by the dry process was significantly different from that prepared by the wet process. In the dry process, some parts of the coffee cherry, e.g. silver skin, may still exist, which contributes to the increment of TPC (Murthy and Naidu, 2012b). In addition, the discrepancy of TPC between two cascara samples was caused by a difference in locations and farmers. It is noteworthy that the difference in

phenolic compounds in a plant results from numerous factors such as postharvest processes, growing conditions (altitude, climate, soil, and planting practices), and harvesting time (Heeger *et al.*, 2017).

Regarding caffeine, it also varied between samples tested, ranging from 0.05 to 0.57 mg/mL (50 – 570 mg/L). Furthermore, regardless of the types of process, the caffeine content in the cascara Arabica-Bondowoso-East Java beverage (from one location) was not significantly different, even though coffee cherries were washed in the wet process. Caffeine is an alkaloid and dissolved easily in organic solvents such as alcohol and chloroform, as well as in hot water but not in cold water (Bibra, 1995). This provides a clear reason for the comparability of caffeine content in cascara from the same origin but prepared differently.

Additionally, temperature and drying time are also key factors controlling caffeine content. As presented in Table 3, Malang-East Java-Robusta-dry Cascara showed the lowest total dissolved solids (TDS) value, meaning that caffeine, as a water-soluble compound, was low. This finding may also result from the low water content of the sample, thus reducing the extractability of the caffeine. According to another study (Heeger *et al.*, 2017), the caffeine level in cascara beverage was 226.4 mg/L, which is lower than the caffeine level in the coffee brew (174-5400 mg/L), green tea (1357.38 mg/L), and black tea (1030.39 mg/L) (Kim *et al.*, 2011). In general, cascara has low caffeine content than coffee and tea.

Afterwards, 5-caffeoylquinic acid (5-CQA) content in cascara beverage ranged from 0.01 to 0.28 mg/mL (10 -28 mg/L cascara beverage). Former experiments exhibited different results, including 69.9 mg/L 5-CQA (Heeger *et al.*, 2017) and 6.93 – 9.33% depending on the water temperature (Mangiwa *et al.*, 2015). CGA in foods exists in various forms, called isomer. The main isomer found in coffee is 5-caffeoylquinic acid (5-CQA) (Cheng *et al.*, 2016), considerably dictating the quality, taste, and aroma of coffee (Mangiwa *et al.*, 2015). Chlorogenic acid has the highest concentration at a certain altitude. According to Figueiredo *et al.* (2013), the highest level of 5-CQA is when coffee plants are grown at medium heights. However, it can also be influenced by other factors such as climate and environmental temperature. Scholz *et al.* (2018) also describe similar results that the highest levels of chlorogenic acid are found in coffee plants that have a medium altitude (620 -730 masl) in Brazil. For this reason, the 5-CQA level in the Robusta cascara beverage was relatively lower (0.01 mg/mL) compared to that in the Arabica cascara beverage (0.105 mg/mL). Robusta species are usually cultivated at lower altitudes (<600

Table 3. Chemical properties of cascara beverage

Cascara Samples*	Moisture content (g/100 g)	pH	TDS (g/100 mL)	TPC (mg GAE/mL)	Caffeine (mg/mL)	5-CQA (mg/mL)	DPPH AOA (mg AAE/mL)
Gayo-Aceh-A-D	17.80±0.14 <sup>c</sup>	3.93±0.01 <sup>h</sup>	2.45±0.64 <sup>a</sup>	0.47±0.01 <sup>d</sup>	0.37±0.01 <sup>e</sup>	0.03±0.00 <sup>ef</sup>	0.36±0.01 <sup>h</sup>
Gayo-Aceh-A-W	17.89±0.43 <sup>c</sup>	4.92±0.09 <sup>a</sup>	1.35±0.49 <sup>abc</sup>	0.31±0.03 <sup>efg</sup>	0.32±0.04 <sup>f</sup>	0.03±0.00 <sup>fg</sup>	0.24±0.01 <sup>i</sup>
Jambi-Jambi-A-D	15.40±0.07 <sup>g</sup>	4.49±0.19 <sup>c</sup>	0.80±0.00 <sup>c</sup>	0.34±0.02 <sup>ef</sup>	0.40±0.02 <sup>de</sup>	0.04±0.00 <sup>de</sup>	0.49±0.03 <sup>f</sup>
Pangalengan-West Java-A-W	23.70±0.41 <sup>a</sup>	4.11±0.03 <sup>fg</sup>	2.65±0.07 <sup>a</sup>	0.37±0.02 <sup>c</sup>	0.50±0.03 <sup>b</sup>	0.26±0.03 <sup>a</sup>	0.63±0.01 <sup>d</sup>
Garut-West Java-A-D	19.92±0.46 <sup>d</sup>	4.19±0.03 <sup>ef</sup>	2.15±0.07 <sup>abc</sup>	0.23±0.01 <sup>h</sup>	0.42±0.02 <sup>cd</sup>	0.01±0.01 <sup>fg</sup>	0.30±0.01 <sup>i</sup>
Temanggung-Central Java-A-W	20.72±0.65 <sup>c</sup>	4.00±0.07 <sup>gh</sup>	2.30±0.42 <sup>ab</sup>	0.84±0.12 <sup>b</sup>	0.28±0.01 <sup>g</sup>	0.10±0.02 <sup>c</sup>	0.91±0.01 <sup>ab</sup>
Jember-East Java-A-D	22.52±0.59 <sup>b</sup>	4.24±0.02 <sup>c</sup>	1.75±0.92 <sup>abc</sup>	0.30±0.02 <sup>fgh</sup>	0.44±0.02 <sup>c</sup>	0.14±0.01 <sup>b</sup>	0.35±0.00 <sup>h</sup>
Bondowoso-East Java-A-D	19.79±0.45 <sup>d</sup>	4.19±0.03 <sup>ef</sup>	0.85±0.78 <sup>c</sup>	0.92±0.03 <sup>a</sup>	0.24±0.00 <sup>h</sup>	0.12±0.00 <sup>b</sup>	0.88±0.03 <sup>b</sup>
Bondowoso-East Java-A-W	16.94±0.49 <sup>f</sup>	4.10±0.04 <sup>fg</sup>	1.45±0.21 <sup>abc</sup>	0.92±0.03 <sup>a</sup>	0.27±0.01 <sup>gh</sup>	0.09±0.01 <sup>c</sup>	0.83±0.02 <sup>c</sup>
Kintamani-Bali-A-D	16.83±0.46 <sup>f</sup>	4.36±0.02 <sup>d</sup>	1.40±0.57 <sup>abc</sup>	0.49±0.02 <sup>d</sup>	0.57±0.03 <sup>a</sup>	0.28±0.01 <sup>a</sup>	0.95±0.04 <sup>a</sup>
Mamasa-West Sulawesi-A-W	17.93±0.39 <sup>e</sup>	3.96±0.01 <sup>h</sup>	1.60±0.28 <sup>abc</sup>	0.70±0.04 <sup>c</sup>	0.29±0.02 <sup>g</sup>	0.05±0.00 <sup>d</sup>	0.74±0.10 <sup>d</sup>
Pdgsidimpuan-North Sumatra-R-D	13.30±0.37 <sup>h</sup>	4.35±0.09 <sup>d</sup>	0.85±0.07 <sup>c</sup>	0.26±0.01 <sup>gh</sup>	0.41±0.03 <sup>cde</sup>	0.01±0.00 <sup>fg</sup>	0.43±0.02 <sup>g</sup>
Malang-East Java-R-D	6.65±0.16 <sup>i</sup>	4.80±0.03 <sup>b</sup>	1.00±1.13 <sup>bc</sup>	0.24±0.01 <sup>gh</sup>	0.05±0.01 <sup>i</sup>	0.01±0.00 <sup>g</sup>	0.26±0.01 <sup>i</sup>

Values are presented as mean±SD (n = 3). Values with different superscripts within the same column are significantly different ( $p < 0.05$ ). Moisture content measured is the moisture content of dry cascara. TDS: total dissolve solid, TPC: total phenolic compound, 5-CQA: 5-Caffeoylquinic Acid, DPPH AOA: anti-oxidant activity are the values for cascara brew (3 g eq/50 mL).

\*Simplification samples code where the first word is district, second word is province, third word is coffee species (R: Robusta and A: Arabica) and fourth word are coffee processed (D: Dry and W: Wet).

m), while Arabica species are often found in altitudes of 600 – 1800 m (Ky *et al.*, 2001).

Antioxidant activity of cascara beverage analyzed with the DPPH method varies greatly, ranging from 0.24 to 0.95 mg AAE/mL. It was found that the lowest and highest antioxidant activity was attributed to cascara Robusta-Malang-East Java and cascara Arabica-Kintamani-Bali, respectively. Variations of the antioxidant properties between samples resulted from various secondary metabolites produced by plants especially phenolic compounds and caffeine (Samsonowicz *et al.*, 2018; Herawati *et al.*, 2019a). The difference in antioxidant activity of each cascara beverage is influenced by the total dissolved solids in each sample. Samples with low TDS tend to have low levels of bioactive compounds.

The correlation between cascara samples and chemical characteristics is depicted in Figure 1. A very strong correlation is found between total phenolic and antioxidant activity. This is clear since phenolic compounds as famous secondary metabolites have been evidenced to exert antioxidant activity (Coomes and Allen, 2007). In essence, the quantity of the phenolic content in a food positively correlates with antioxidant activity. Wu and Wei (2009) and Samsonowicz *et al.* (2018) state that derivatives containing polyphenols have potential antioxidant activity both *in vitro* and *in vivo*.

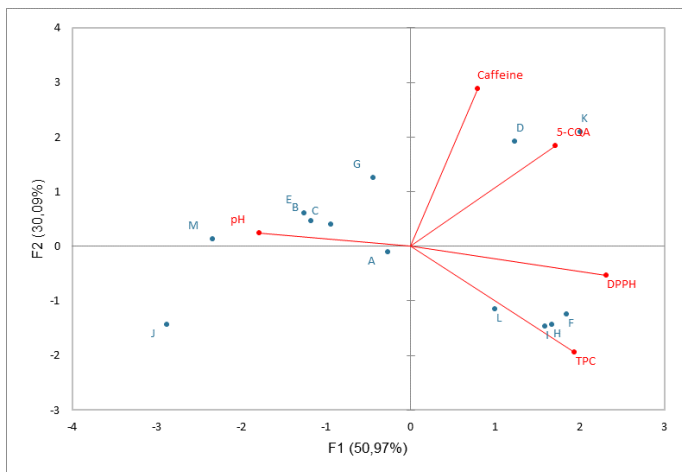


Figure 1. PCA plot of cascara samples and chemical characteristics. (A: Gayo-Aceh-Arabica-dry, B: Pdgsidimpuan-North Sumatra-Robusta-dry, C: Jambi-Jambi-Arabica-dry, D: Pangalengan-West Java-Arabica-wet, E: Garut-West Java-Arabica-dry, F: Temanggung-Central Java-Arabica-wet, G: Jember-East Java-Arabica-dry, H: Bondowoso-East Java-Arabica-dry, I: Bondowoso-East Java-Arabica-wet, J: Malang-East Java-Robusta-dry, K: Kintamani-Bali-Arabica-dry, L: Mamasa-West Sulawesi-Arabica-wet, and M: Gayo-Aceh-Arabica-wet)

Furthermore, the interaction between chlorogenic acid and total phenolic composition is considerable since they exist in different quadrants. This is because the

constituent of phenolic compounds found in cascara beverages is not only chlorogenic acid (5-CQA). Chlorogenic acid is only one of the many types of phenolic compounds that exist in cascara. According to Hečimović *et al.* (2011) coffee is a phenolic source that is mostly derived from phenolic compounds from the hydroxycinnamic acid group (caffeic, chlorogenic, and ferulic acid). In addition, chlorogenic acid in coffee brew has several isomer subgroups such as caffeoylquinic acid, dicaffeoylquinic acid, and feruloylquinic acid (Yen *et al.*, 2005). As described in Figure 1, some samples (H, I, F, and L) possessed similar characteristics showing greater antioxidant activity and phenolic compound in comparison with others. Sample K and D exhibited equal characteristics, i.e. high levels of caffeine and chlorogenic acid. Meanwhile, samples A, B, C, E, G, and M form their groups with J.

Samples B and J are cascara Robusta, while others are cascara Arabica. In this regard, cascara Robusta tends to be on the left side of the quadrant with a high pH value while cascara Arabica tends to be on the right side with a higher level of bioactive compounds.

From another point of view, there are differences in the content of bioactive compounds, especially TPC, Caffeine, and 5-CQA in the cascara beverage of Robusta and Arabica. The two types of coffee have different fruit compositions and different growing areas. Arabica has thicker flesh and grows in the highlands while Robusta has thinner flesh and grows in lower areas. The pulp and mucilage of coffee have high nutrients which can determine the content of bioactive compounds. This high nutrient content also allows the presence of metabolites and organic acids produced by microorganisms during the fermentation process that occurs during the drying process which will also affect the content of metabolite compounds such as TPC, caffeine, and 5-CQA (Haile and Kang, 2019).

This difference causes the levels of bioactive compounds in Arabica higher than that of Robusta. Haile and Kang (2019) also explained that the post-harvest process determines the degree of fermentation. The wet process tends to take a shorter time where the coffee pulp fermentation can already occur. While the dry process takes a longer drying time ranging from 10 days - 3 weeks. This long drying process increases the risk of second fermentation, depletion of organic acids present in the coffee pulp, as well as the growth of unwanted fungi and bacteria. This explains why cascara obtained from the post-harvest process of wet coffee tends to have a higher TPC, 5-CQA, and antioxidant activity.

Growing environmental conditions and farming techniques for coffee farmers greatly affect the

composition contained in coffee (Scholz *et al.*, 2018). TPC, caffeine, and 5-CQA are secondary metabolites produced by plants as a form of adaptation to the environment. Factors that can affect it are not only because of differences in plant cultivars, but also altitude (Cheng *et al.*, 2016), latitude, longitude, altitude, and annual average temperature (Scholz *et al.*, 2018). It also explains why there are differences in the levels of TPC, Caffeine, and 5-CQA among Arabica which grows in different areas. Scholz *et al.* (2018) compared the differences in the content of bioactive substances in Arabica in Brazil, where terroir grows at different heights. The results showed that coffee with a lower growing area had the lowest content of CGA, TPC, 5-CQA, and caffeine. Meanwhile, coffee grown at high altitudes tends to have high bioactive compounds. This is supported by the research of Cheng *et al.* (2016) who said that the higher the altitude, the higher the CGA and caffeine content due to lower air temperature changes and a decrease in the intensity of sunlight which can slow down the fruit ripening process (Borem *et al.*, 2019). The most chlorogenic acid content is found in coffee cherries that are not yet fully ripe (Milkjkovik *et al.*, 2010).

### 3.2 Sensory properties of cascara beverages

Sensory analysis was performed with 18 trained panellists. They never tasted cascara beverage before and like to drink coffee and tea. Sample preparation tightly followed protocol enabling decline variations between samples. The soluble solid was determined then followed by cascara-to-water ratio, water temperature, and the length of infusion (Heeger *et al.*, 2017; Nafisah and Widyaningsih, 2018).

A total of 51 sensory attributes collected during FGD were screened and grouped according to intensity. The distribution of 25 selected attributes (Table 2) was presented in the PCA plot (Figure 2). The Figure demonstrates whether correlations exist between each attribute (Koch *et al.*, 2012). As a result, cascara beverage has a dominant citric acid and black tea taste with a strong tamarind aroma.

The dominant attributes of appearance and mouthfeel of the cascara sample included shine, watery, body fullness, longevity, clarity, and brown colour. Adjacent samples showed a similar profile, while samples in opposite quadrants displayed numerous profile dissimilarities. Samples A, E, and K demonstrated similar appearance and mouthfeel descriptions, i.e. clear/clarity, shine, and watery. Samples possessing attributes of body fullness, as found in samples B and M, tend to have a longevity of taste and brown appearance; conversely, samples having watery

attributes had clarity and a shiny appearance.

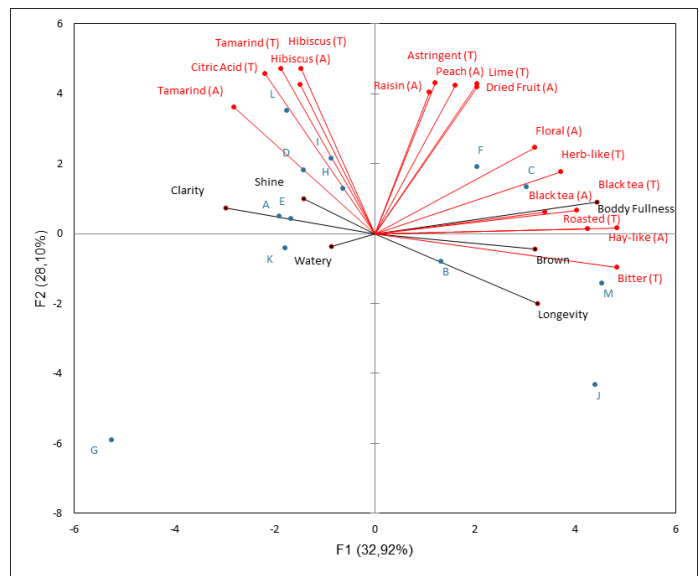


Figure 2. Plot mapping of dominant attributes of cascara beverage. T: Taste attribute; A: Aroma attributes. Red marks for the attributes of taste and aroma, and black marks for the appearance and mouthfeel attributes. Blue letters are sample code. (A: Gayo-Aceh-Arabica-dry, B: Pdgsidimpuan-North Sumatra-Robusta-dry, C: Jambi-Jambi-Arabica-dry, D: Pangalengan-West Java-Arabica-wet, E: Garut-West Java-Arabica-dry, F: Temanggung-Central Java-Arabica-wet, G: Jember-East Java-Arabica-dry, H: Bondowoso-East Java-Arabica-dry, I: Bondowoso-East Java-Arabica-wet, J: Malang-East Java-Robusta-dry, K: Kintamani-Bali-Arabica-dry, L: Mamasa-West Sulawesi-Arabica-wet, and M: Gayo-Aceh-Arabica-wet)

In terms of aroma, each quadrant shows unique aroma profiles, i.e. hibiscus and tamarind aroma found in quadrant 1, raisin, peach, dried fruit, floral, black tea and hay-like found in quadrant 2. Attributes existing within a similar quadrant had a positive correlation. Samples F and C showed prominent floral and black tea aroma; B and M had a similar aroma with black tea and hay-like aroma. D, H, I, and L samples had prominent hibiscus and tamarind aromas. Samples A and E possessed prominent tamarind scent characteristics. Meanwhile, G and J had their characteristics.

Most Arabica cascara appeared in the upper quadrants, except for samples K and M, while Robusta cascara appeared in the left quadrant. Therefore, this is clear that Arabica cascara beverage tends to have a fruit-like aroma namely tamarind, hibiscus, peach, dried fruit, raisin and floral, while Robusta cascara beverage tends to have floral, black tea and Hay-like scents. The cascara sample has a strong black tea aroma. Thearubigin is a compound responsible for the fragrance of tea. This compound is formed during the drying process, i.e. the oxidation of gallic acid to the thearubigin compound. Cascara contained a certain amount of gallic acid (Heeger *et al.*, 2017) which was oxidized to produce

thearubigin.

Moreover, taste attributes in cascara samples included tamarind, citric acid, and hibiscus (quadrant 1); lime, astringent, herb-like, black tea, and roasted (quadrant 2); and bitter (quadrant 4). The sour taste described by citric acid attribute in cascara beverage occurred due to the presence of organic acids. Like tea, cascara beverage also had astringent characteristics, linked to catechins and tannin. Coffee pulp contained a significant amount of tannins (Esquivel and Jiménez, 2012). Based on Figure 2, samples B and J belong to quadrant 4, suggesting that they have a prominent characteristic. Cascara Robusta samples namely B (Robusta-Padangsidimpuan-North Sumatra) and J (Robusta-Malang-East Java) tend to have a roasted and bitter taste whereas Arabica cascara beverages have acidic and fresh taste characteristics such as fruits. These characteristics are comparable with the flavour characteristics of coffee brew. In this sense, Arabica coffee has a more complex taste including sour taste, while Robusta coffee brew is dominated by a strong bitter taste (Perrois *et al.*, 2014).

### 3.3 Profiling of chemical and sensory properties of cascara beverages

The correlation between taste and chemical components of cascara beverages can be seen in Figure 3. Chemical parameters and taste attributes existing in one quadrant showed a positive correlation; on the contrary, those in the opposite quadrant displayed a negative correlation. The level of 5-CQA (chlorogenic acid) and caffeine did not affect the dominant taste attribute in cascara beverage.

Surprisingly, as presented in Figure 3, caffeine and bitter taste showed no significant correlation. According to Variyar *et al.* (2003), there is a relationship between bitter taste and caffeine content in coffee but caffeine only affects 10% of the bitter taste in coffee. However, other studies explained that bitter taste was not also determined by caffeine but also by other compounds such as caffeic acid, ferulic acid, trigonelline, and flavonols demonstrating a strong association with a bitter taste (Lesschaeve and Noble, 2005; Laukaleja and Kruma, 2019). The interactions between caffeine, chlorogenic acid, and trigonelline determined the bitter taste in a coffee brew. This could explain why the bitter taste of cascara did not relate to caffeine. The pH value and the taste attribute of citric acid (acid-base taste) seem to have a negative correlation because they are in the separated quadrant. Explanation of this finding can be linked to the relationship between pH and acidic conditions. A higher level of pH indicates a less acidic system, which enables to decline of sour taste intensity.

As depicted in Figure 3, a cascara beverage at low pH produces a stronger taste of citric acid (acid/sour-based taste). Besides citric acid, astringent is a pH-dependent sensory attribute, in which the intensity of the taste perception increases with decreasing pH (Neta *et al.*, 2007). Phenolic compound level positively contributed to several taste attributes (Figure 3), such as astringent and tamarind, followed by lime, hibiscus, and citric acid. It was reported in other studies that phenolic compounds positively correlated with a few taste attributes such as astringency, bitter, and floral notes in coffee and tea brew (Lesschaeve and Noble, 2005; Laukaleja and Kruma, 2019).

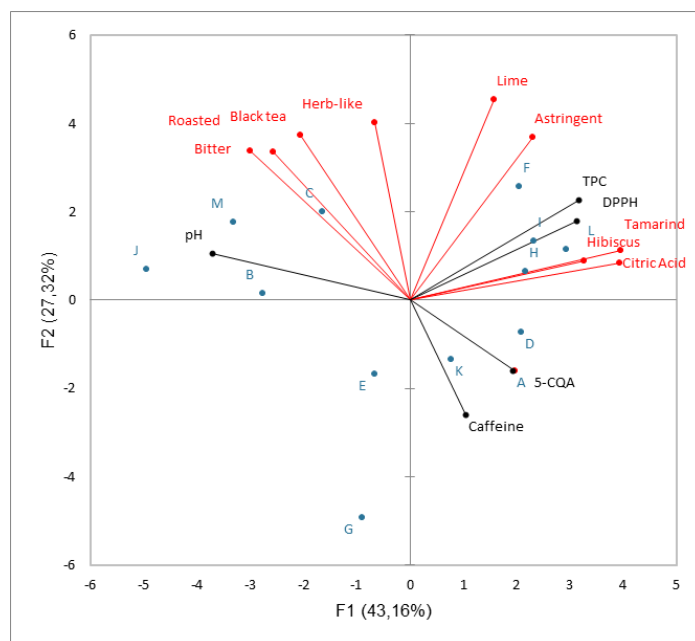


Figure 3. PCA plot correlation between taste attributes and chemical characteristics of cascara beverage. T: Taste. Red marks for the attributes and black marks for the chemical properties. Blue letters are sample code. (A: Gayo-Aceh-Arabica-dry, B: Pdgsidimpuan-North Sumatra-Robusta-dry, C: Jambi-Jambi-Arabica-dry, D: Pangalengan-West Java-Arabica-wet, E: Garut-West Java-Arabica-dry, F: Temanggung-Central Java-Arabica-wet, G: Jember-East Java-Arabica-dry, H: Bondowoso-East Java-Arabica-dry, I: Bondowoso-East Java-Arabica-wet, J: Malang-East Java-Robusta-dry, K: Kintamani-Bali-Arabica-dry, L: Mamasa-West Sulawesi-Arabica-wet, and M: Gayo-Aceh-Arabica-wet)

## 4. Conclusion

Cascara beverages contained some functional components at various levels, including phenolic compounds (0.23 - 0.92 mg/mL), caffeine (0.05 - 0.57 mg/mL), and chlorogenic acid (0.01 - 0.28 mg/mL). The antioxidant activity of the tested samples ranged from 0.24 to 0.95 mg AAE/mL. Furthermore, Cascara-Kintamani-Bali (sample K) demonstrated the best potential product in terms of antioxidant performance since it had the highest level of chlorogenic acid (5-CQA) and antioxidant activity. Our experiment also



noted that the postharvest process could affect the characteristics of chemical compounds in cascara beverages. In this case, the dry process of the cascara beverage resulted in a high caffeine and TDS value, while the wet process produced higher total phenolic compounds and antioxidant activity. Additionally, coffee species was also the determinant factor of the flavour profile of cascara beverages. For Arabica cascara products, the general taste profile was acidic and astringent like lime, tamarind, and hibiscus, while their aroma was peach, dried fruit, raisin, hibiscus, and tamarind. For Robusta cascara products, the taste profile included herb-like, bitter, roasted, and black tea, while the aroma was floral, black tea, and hay-like.

### Conflict of interest

This work has no conflict of interest that influence the work reported in this paper.

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### References

- Anal, A.K. (Ed.) (2017). Food processing by-products and their utilization. United Kingdom: Wiley-Blackwell. <https://doi.org/10.1002/9781118432921>
- Arellano-gonzález, M.A., Ramírez-coronel, M.A., Torres-mancera, M.T., Pérez-morales, G.G. and Saucedo-castañeda, G. (2011). Antioxidant activity of fermented and nonfermented coffee (*Coffea arabica*) pulp extracts. *Food Technology. Biotechnology*, 49 (3), 374–378.
- Bibra, B.E.V. (1995). Plant Intoxicants: A Classic Text on the Use of Mind-Altering Plants. Rochester, Vermont, USA: Healing Arts Press.
- Borem, F.M., Cirillo, M.A., Alves A.P.C., Santos C.M., Liska, G.R., Ramos, M.F. and Lima, R.R. (2019). Coffee sensory quality study based on spatial distribution in the Mantiqueira mountain region of Brazil. *Journal of Sensory Studies*, 35(2), E12552. <https://doi.org/10.1111/joss.12552>
- Cheng, B., Furtado, A., Smyth, H.E. and Henry, R.J. (2016). Influence of genotype and environment on coffee quality. *Trends in Food Science and Technology*, 57(Part A), 20–30. <https://doi.org/10.1016/j.tifs.2016.09.003>
- Choi, I.S., Wi, S.G., Kim, S.B. and Bae, H.J. (2012). Conversion of coffee residue waste into bioethanol with using popping pretreatment. *Bioresource Technology*, 125, 132–137. <https://doi.org/10.1016/j.biortech.2012.08.080>
- Coomes, D.A. and Allen, R.B. (2007). Effects of size, competition and altitude on tree growth. *Journal of Ecology*, 95(5), 1084–1097. <https://doi.org/10.1111/j.1365-2745.2007.01280.x>
- Cubero-Castillo, E., Bonilla-Leiva, A.R. and García-Velasques, E. (2017). Coffee berry processing by-product valorization: coffee parchment as a potential fiber source to enrich bakery good. *Journal of Food, Nutrition and Population Health*, 1(2), 1–7.
- Damat, D., Anggraini, R., Setyobudi, R.H. and Soni, P. (2019). Dietary fiber and antioxidant activity of gluten-free cookies with coffee cherry flour addition. *Coffee Science, Lavras*, 14(4), 493–500. <https://doi.org/10.25186/cs.v14i4.1625>
- Dorsey, B.M. and Jones, M.A. (2017). Chapter 2 - Healthy components of coffee processing by-products. In Galanakis, C.M. (Ed.) Handbook of Coffee Processing By-Products. Sustainable Applications. USA: Academic Press. <https://doi.org/10.1016/B978-0-12-811290-8.00002-5>
- Esquivel, P. and Jiménez, V.M. (2012). Functional properties of coffee and coffee by-products. *Food Research International*, 46(2), 488–495. <https://doi.org/10.1016/j.foodres.2011.05.028>
- Figueiredo L.P., Borem F.M., Cirillo M.A., Ribeiro F.C., Giomo G.S. and Dalva T.J.G. (2013). The potential for high quality of Bourbon coffees from different environments. *Journal of Agricultural Sciences*, 5, 87-98. <https://doi.org/10.5539/jas.v5n10p87>
- Geremu, M., Tola, Y.B. and Sualeh, 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(1), 1–6. <https://doi.org/10.1186/s40538-016-0077-1>
- Gurram, R., Samuel, M.A., Tapas, K., Das, T., Singasaas, E. and Alkasrawi, M. (2015). Technical possibilities of bioethanol production from coffee pulp: a renewable feedstock. *Clean Technologies and Environmental Policy*, 18(1), 1–10. <https://doi.org/10.1007/s10098-015-1015-9>
- Haile, M., Kang, W.E.N. (2019). The Harvest and Post-Harvest Management Practices Impact on Coffee Quality. In Castanheira, D.T. (Ed.), Coffee - Production and Research. InTech Open E-Book. <https://doi.org/10.5772/intechopen.89224>
- Hećimović, I., Belščak-Cvitanović, A., Horžić, D. and Komes, D. (2011). Comparative study of polyphenols and caffeine in different coffee varieties

- affected by the degree of roasting. *Food Chemistry*, 129(3), 991–1000. <https://doi.org/10.1016/j.foodchem.2011.05.059>
- Heeger, A., Kosińska-Cagnazzo, A., Cantergiani, E. and Andlauer, W. (2017). Bioactives of coffee cherry pulp and its utilisation for production of Cascara beverage. *Food Chemistry*, 221, 969–975. <https://doi.org/10.1016/j.foodchem.2016.11.067>
- Herawati, D., Giriwono, P.E., Dewi, F.N.A., Kashiwagi, T. and Andarwulan, N. (2019a). Critical roasting level determines bioactive content and antioxidant activity of Robusta coffee beans. *Food Science and Biotechnology*, 28(1), 7–14. <https://doi.org/10.1007/s10068-018-0442-x>
- Herawati, D., Giriwono, P.E., Dewi, F.N.A., Kashiwagi, T. and Andarwulan, N. (2019b). Three major compounds showing significant antioxidative,  $\alpha$  - glucosidase inhibition, and antiglycation activities in Robusta coffee brew. *International Journal of Food Properties*, 22(1), 994–1010. <https://doi.org/10.1080/10942912.2019.1622562>
- Judkis, M. (2017). Cascara — a soda made from coffee cherries — could be this summer's 'it' drink. Retrieved on October 29, 2019, from Washington Post website: <https://www.washingtonpost.com/news/food/wp/2017/05/10/cascara-a-soda-made-from-coffee-cherries-could-be-this-summer-it-drink/?noredirect>
- Kassa H., Suliman H. and Workayew T. (2011). Evaluation of composting process and quality of compost from coffee by-products (coffee Husk and pulp). *Ethiopian Journal of Environmental Studies and Management*, 4(4), 8–13. <https://doi.org/10.4314/ejesm.v4i4.2>
- Khapre, Y., Kyamuhangire, W., Kihara Njoroge, E. and Kathurima, C.W. (2017). Analysis of the diversity of Some Arabica and Robusta Coffee from Kenya and Uganda by sensory and biochemical components and their correlation to taste. *IOSR Journal of Environmental Science*, 11(10), 39–43.
- Kim, Y., Goodner, K.L., Park, J., Choi, J. and Talcott, S.T. (2011). Changes in antioxidant phytochemicals and volatile composition of *Camellia sinensis* by oxidation during tea fermentation. *Food Chemistry*, 129(4), 1331–1342. <https://doi.org/10.1016/j.foodchem.2011.05.012>
- Koch, I.S., Muller, M., Joubert, E., Rijst, M.V.D. and Næs, T. (2012). Sensory characterization of rooibos tea and the development of a rooibos sensory wheel and lexicon. *Food Research International*, 46(1), 217–228. <https://doi.org/10.1016/j.foodres.2011.11.028>
- Ky, C., Louarn, J., Dussert, S., Guyot, B., Hamon, S. and Noirot, M. (2001). Caffeine, trigonelline, chlorogenic acids and sucrose diversity in wild *Coffea arabica* L. and *C. canephora* P. accessions. *Food Chemistry*, 75(2), 223–230. [https://doi.org/10.1016/S0308-8146\(01\)00204-7](https://doi.org/10.1016/S0308-8146(01)00204-7)
- Laukaleja, I. and Kruma, Z. (2019). Phenolic and volatile compound composition influence to specialty coffee cup quality. *Agronomy Research*, 17(S2), 1367–1379.
- Lesschaeve, I. and Noble, A.C. (2005). Polyphenols: factors influencing their sensory properties and their effects on food and beverage preferences. *The American Journal of Clinical Nutrition*, 81(Suppl. 1), 330–335. <https://doi.org/10.1093/ajcn/81.1.330S>
- Magoni, C., Bruni, I., Guzzetti, L., Dell'Agli, M., Sangiovanni, E., Piazza, S., Regonesi, M.E., Maldini, M., Spezzano, R., Caruso, D. and Labra, M. (2018). Valorizing coffee pulp by-products as anti-inflammatory ingredient of food supplements acting on IL-8 release. *Food Research International*, 112, 129–135. <https://doi.org/10.1016/j.foodres.2018.06.026>
- Mamilla, R.K. and Mishra, V.K. (2017). Effect of germination on antioxidant and ACE inhibitory activities of legumes. *LWT - Food Science and Technology*, 75, 51–58. <https://doi.org/10.1016/j.lwt.2016.08.036>
- Mangiwa, S., Futwembun, A. and Awak, P.M. (2015). Kadar asam klorogenat (CGA) dalam biji kopi arabika (*Coffea arabica*) asal wamena, papua. *Jurnal Ilmiah Pendidikan Kimia "Hydrogen,"* 3(2), 313–317. <https://doi.org/10.33394/hjkk.v3i2.690> [In Bahasa Indonesia].
- Menezes, E.G.T., Do Carmo, J.R., Menezes, A.G.T., Alves, J.G.L.F., Pimenta, C.J. and Queiroz, F. (2013). Use of different extracts of coffee pulp for the production of bioethanol. *Applied Biochemistry and Biotechnology*, 169(2), 673–687. <https://doi.org/10.1007/s12010-012-0030-0>
- Murthy, P.S. and Naidu, M.M. (2012a). Production and application of Xylanase from *Penicillium* sp. utilizing coffee by-products. *Food Bioprocess Technology*, 5(2), 657–664. <https://doi.org/10.1007/s11947-010-0331-7>
- Murthy, P.S. and Naidu, M.M. (2012b). Sustainable management of coffee industry by-products and value addition — A review. *Resources, Conservation and Recycling*, 66, 45–58. <https://doi.org/10.1016/j.resconrec.2012.06.005>
- Nafisah, D. and Widyaningsih T.D. (2018). Kajian metode pengeringan dan rasio penyeduhan pada proses pembuatan teh cascara kopi arabika (*Coffea arabica* L.). *Jurnal Pangan dan Agroindustri*, 6, 37–

47. <https://doi.org/10.21776/ub.jpa.2018.006.03.5> [In Bahasa Indonesia].
- Neta, E.R.D.C., Johanningsmeier, S.D. and McFeeters, R.F. (2007). The chemistry and physiology of sour taste - A review. *Journal of Food Science*, 72(2), 33–38. <https://doi.org/10.1111/j.1750-3841.2007.00282.x>
- Perrois, C., Strickler, S.R., Mathieu, G., Lepelley, M., Bedon, L., Michaux, S., Husson, J., Mueller, L. and Privat, I. (2014). Differential regulation of caffeine metabolism in *Coffea arabica* (Arabica) and *Coffea canephora* (Robusta). *Planta Medica International Open*, 241(1), 179–191. <https://doi.org/10.1007/s00425-014-2170-7>
- Ramirez-Coronel, M.A., Marnet, N., Kolli, V.S.K., Roussos, S., Guyot, S. and Augur, C. (2004). Characterization and estimation of proanthocyanidins and other phenolics in coffee pulp (*Coffea arabica*) by Thiolysis – High-Performance Liquid Chromatography. *Journal Agricultural and Food Chemistry*, 52(2), 1344–1349. <https://doi.org/10.1021/jf035208t>
- Samsonowicz, M., Regulska, E., Karpowicz, D. and Le, B. (2018). Antioxidant properties of coffee substitutes rich in polyphenols and minerals. *Food Chemistry*, 278, 101–109. <https://doi.org/10.1016/j.foodchem.2018.11.057>
- Sari, H.P., Purwanto, Y.A. and Budiastira, I.W. (2015). Prediksi padatan tidak terlarut dan chilling injury mangga CV. Gedong gincu selama penyimpanan dingin secara non destruktif menggunakan Near Infrared Spectroscopy (NIRS). Bogor, Indonesia: Bogor Agricultural University, Thesis. [In Bahasa Indonesia].
- Saura-Calixto, F. and Goñi, I. (2006). Antioxidant capacity of the Spanish Mediterranean diet. *Food Chemistry*, 94(3), 442–447. <https://doi.org/10.1016/j.foodchem.2004.11.033>
- Scholz, M.B.S., Kitzberger, C.S.G., Prudencio, S.H. and Silva, R.S.S.F. (2018). The typicity of coffees from different terroirs determined by groups of T Physico-chemical and sensory variables and multiple factor analysis. *Food Research International*, 114, 72-80. <https://doi.org/10.1016/j.foodres.2018.07.058>
- Variyar, P.S., Ahmad, R., Bhat, R., Niyas, Z. and Sharma, A. (2003). Flavouring components of raw monsooned Arabica coffee and their changes during radiation processing. *Journal of Agricultural and Food Chemistry*, 51(27), 7945–7950. <https://doi.org/10.1021/jf030408q>
- Vongsak, B., Sithisarn, P. and Mangmool, S. (2013). Maximizing total phenolics, total flavonoids contents and antioxidant activity of *Moringa oleifera* leaf extract by the appropriate extraction method. *Industrial Crops and Products*, 44, 566–571. <https://doi.org/10.1016/j.indcrop.2012.09.021>
- Wu, C.D. and Wei, G. (2009). Tea as a functional food for oral health. *Food Constituents and Oral Health: Current Status and Future Prospects*, 9007(2), 396–417. <https://doi.org/10.1533/9781845696290.2.396>
- Yen, W.J., Wang, B.S., Chang, L.W. and Duh, P.D. (2005). Antioxidant properties of roasted coffee residues. *Journal of Agricultural and Food Chemistry*, 53(7), 2658–2663. <https://doi.org/10.1021/jf0402429>
- Zarei, M., Fazlara, A. and Tulabifard, N. (2019). Effect of thermal treatment on physicochemical and antioxidant properties of honey. *Heliyon*, 5(6), e01894. <https://doi.org/10.1016/j.heliyon.2019.e01894>