Pelita Perkebunan 36 (3) 2020, 226–235
DOI: 10.22302/iccri.jur.pelitaperkebunan.v36i3.452

ISSN: 0215-0212 / e-ISSN: 2406-9574

Fermentation of Arabica Coffee Beans Using Ohmic Heating Technology in Producing Specialty Coffee

Reta[1*)], Salengke[2)], Mursalim[2)], Junaedi Muhidong[2)], Arnida Mustafa[1)], Syamsia[3)], Ophirtus Sumule[4)], and Zaimar[1)]

[1)]Department of Agroindustry, Pangkep State Polytechnic of Agriculture, South Sulawesi, Indonesia
[2)]Department of Agriculture Engineering and Food Technology, Hasanuddin University, Makassar, Indonesia
3)Department of Agribusiness, Muhammadiyah University, Makassar, Indonesia
4)Department of Fisheries and Marine Science, Hasanuddin University, Makassar, Indonesia
[*)]Corresponding author: etariskinapolitani@gmail.com
Received: 13 March 2020 / Accepted: 28 June 2020

Abstract

Coffee is one of the most important agricultural commodities in global market. Therefore, the quality of coffee beans is certainly an important factor which notables in considering taste of coffee, especially on flavor profile. Coffee beans produced by farmers in Indonesia are generally “inferior quality of coffee”, as mentioned unsorted or ungraded coffee/*kopi asalan* with defect score more than 225. It is caused by improper processing that is affecting coffee flavor become stink and fermented. Improvement of post-harvest aspects are needed to upgrade coffee quality. This research examine a processing system using Ohmic-based fermentation technology to produce specialty coffee. This research was conducted by setting the temperature (30, 35 and 40°C) and fermentation time (2, 6, 12, and 18 hours). The results showed that this treatments could gain cupping score ranging from 81.81 to 85.25 with an average cupping score of 84.03. In this study, the application of 12 hours fermentation time and 35°C temperature generated the highest cupping score of 85.25. The best coffee flavor by applying 30°C temperature was mouthfeel or body with cupping score of 7.81, whereas flavor, aroma and balance were the best characteristic coffee profile by applying 35°C temperature on the fermentation process. On the other hand, fermentation temperature of 40°C generated high preference score of balance, that was 7.84. In term of fermentation time, the best characteristics of 2 hours and 12 hours fermentation were flavor and aroma, respectively. Enrekang Arabica coffee has 21 flavor profiles.

Keywords: Arabica coffee, fermentation, Ohmic technology, specialty coffee

INTRODUCTION

Coffee is cultivated by almost 50 countries around the world, including Indonesia and traded globally (Afriliana *et al*., 2018). According to FAO (2019), total annual coffee exports in last five year was around 7 million tons. Total production of world coffee increased from 8.945 million tons in 2014 to 9.580 million tons in 2017 (Salengke *et al*., 2019). ICO (2019) revealed that Indonesia had 4th position after Brazil, Vietnam, and Colombia for coffee production, where most widely cultivated types of coffee are Arabica and Robusta types. According to Directorate General of Estate Crops (2016-2017), Indonesia coffee area reached 1,227,787 ha with total production of 637,539 tons per year. Area of Arabica coffee in Indonesia is about 207,474 ha with 173,681 tons production.

Based on the Directorate General of Estate Crops data (2017), the production of Arabica coffee from plantations owned by smallhoders was around 92.74%. The coffee beans produced by coffee growers in Indonesia were usually classified as "inferior quality of coffee" because it generally has lower in quality with defect score more than 225 (Afriliana *et al.*, 2018; Misnawi & Sulistyowati, 2006). Characteristics of the coffee quality is influenced by various factors such as soil and climate conditions (Bertrand *et al.*, 2006), origin of growth (Leroy *et al*., 2006), coffee varieties, growth conditions (Vaast *et al*., 2006), daily temperature (Teketay, 1999; Decazy *et al*., 2003) and processing methods that would contribute to the aromatic compounds and the unique characteristic of any type or origin of coffee (green beans) (Selmar *et al*., 2006; Bailly *et al*., 1992).

To obtain coffee beans with excellent coffee flavor, coffee growers should pay much attention in the determination of varieties and origin of coffee as well as the application of harvest and post-harvest technologies (Salengke *et al*., 2019**).** According to Salengke *et al*. (2019), improvement of coffee quality have been carried out by developing many processing methods which processes coffee cherries into green bean. These activities are included in natural fermentation processes (Avallone *et al*., 2001; Evangelista *et al*., 2015), fermentation using enzymes inoculated with yeast and bacteria (Murthy & Naidu, 2011; De Melo Pereira *et al*., 2014; Bressani *et al*., 2018), and the most popular as the world's most expensive coffee is fermentation using mongoose by feeding coffee cherries to mongoose or civet (Towaha & Rubiyo, 2016; Hadipernata & Nugraha, 2017; Marcone, 2004; Muzaifa *et al*., 2018). Another study is the application of coffee processing technology with Ohmic heating technology (Reta *et al*., 2017a) which is also one way to improve coffee quality to be classified as specialty coffee. This technology generates heat internally so that the heating process is going on quickly and uniformly (Salengke & Sastry, 2007), and it is easily controlled accurately by Ohmic heating. Heating by applying its system is re-considered because the availability and quality of electrode material is increased. Limitations of conventional heating treatment are well known in the food industry. It impacts on inappropriate quality of product with customer's preference and being related to the sensitivity of food products on heat. Thus, this Ohmic system is applied by carrying out heat from the outside into inside using a hot surface, Ohmic heating delivers heat throughout food masses uniformly (Muchtadi *et al*, 2010; Anderson, 2008).

The Ohmic heating technology could be applied to the liquid products and products consisting of a mixture of liquid-solid (Delgado *et al*., 2012). The application of Ohmic heating in the coffee fermentation has never been done before, so this research is aimed to identifying the use of Ohmic heating in controlled fermentation process of coffee beans.

To improve the quality of coffee flavor, development of coffee fermentation technology can be conducted by using a controlled fermentation system including temperature, pH and the availability of oxygen. By controlling of those parameters, the purpose of this study is to produce specialty coffee using Ohmic heating technology in the fermentation process.

The results of fermentation of Arabica coffee beans using the Ohmic heating technology is expected to produce specialty Arabica coffee. Specialty coffee is coffee which has cup-test sensory score of more than 80 regarding SCAA standards (Saragih, 2016). According to Saragih (2016), specialty coffee is coffee that different from coffee in general as indicated by the final score of the cup-test (SCAA, 2015).

MATERIALS AND METHODS

Sample Preparation

Cherries of Arabica coffee variety of S 795 were used in this study which obtained from Enrekang regency at altitude of 1,800 m above sea level (asl.) and processed using pulper machine to peel the skin and pulp of coffee. Furthermore, coffee was fermented by the Ohmic heating technology. Ohmic fermentation reactor made from PVC pipe (diameter of 10.25 cm and length of 100 cm). Electric flow was supplied to the Ohmic heating space through electrodes tied to the end of the pipe and its temperature could be controlled in bucket, it used an electrical heating system with Ohmic tube capacity of 5 liters of water. Various temperature and fermentation times were applied in this research. The applied temperatures were 30°C, 35°C, and 40°C, while fermentation times were 2 hours, 6 hours, 12 hours and 18 hours. Those various treatments obtained were 12 combinations.

The Ohmic fermented coffee was washed thoroughly, then dried on the drying facilities to obtain the water content of less than 12%. Further, the parchment beans was processed to produce green bean coffee.

Roasted Preparation

Coffee samples were prepared in accordance with SCAA standards (2012). Coffee was weighed 150 g, and then roasted using a BR22 type of Probat roaster machine. The roasted temperature was 150°C during 25 minutes (Baggenstoss *et al*., 2008; Illy &Viani, 2005; Owen, 2009; Schenker *et al*., 2002; Sivetz & Desrosier, 1979; Yeretzian *et al*., 2002; Reta *et al*., 2017a). Then, the roasted coffee was ground with Latina grinder machine using a mesh size of 7.8 within 10 seconds for the test sample. The samples were tested immediately and the testing time not exceed 30 minutes to ensure the freshness of the sample (Sivetz & Desrosier, 1979; Reta *et al*., 2017a).

Sensory Test Analysis Procedures (SCAA Method)

The sensory analysis was conducted according to SCAA standard (2009). Roasted coffee samples were stored for 24 hours before being ground. In this cup-test, the water used was clean, odorless and having dissolved solids of 125 to 175 ppm. The coffee samples of 10 g were brewed using ceramic bowl with 150 mL hot water. The water was boiled at 95-99°C and poured directly on the ground coffee samples in bowls. Nine panelists (3 women and 6 men, age range about 37 to 55 years) from Sensory Laboratory of Indonesian Coffee and Cocoa Research Institute, did this sensory test. The samples were taken randomly with 3 times replication of 9 descriptors 1. The quality of brewed coffee was evaluated its flavor profiles such as aroma, acidity, after test, body, flavor, clean cups, mouthfeel and overall flavor profiles. Other method the quality and intensity of overall flavor profiles were evaluated simultaneously using score scale from 1 to 5 according to Ribeiro *et al*. (2011). The scores of flavor profiles were divided into 4 categories including Average (5.00-5.75), Good (6.00-6.75), Very good (7.00-7.75), Excellent (8.00-8.75), and Outstanding (9.00-9.75), according to SCAA (2009).

Data analysis

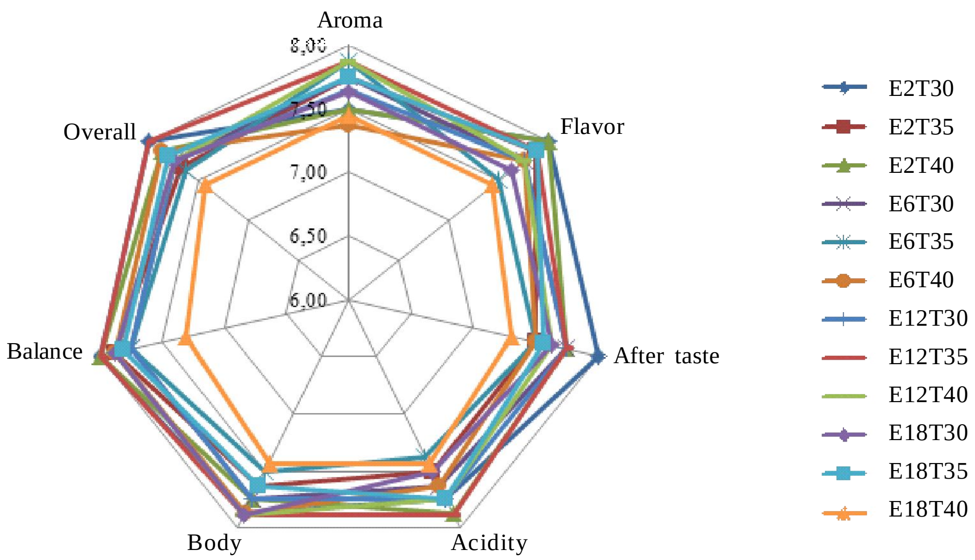
The data were collected using computer software of Compusense data collection. Data were analyzed by using analysis of variance (ANOVA), particularly Duncan test for diagnostic checking the significance of data. ANOVA analysis was performed by using SPSS at 5% significant level. Sensory analysis was used to evaluate the relationship between temperature, fermentation time and description of flavor profiles. In this research, spiderweb was used in interpreting panelists' perception regarding score results of coffee flavor profiles of all coffee samples.

RESULTS AND DISCUSSION

Based on the criteria of specialty Arabica coffee, the coffee quality was indicated by the value obtained from the sensory cup-test of SCAA standard which includes aroma, flavor, acidity and body (Widyotomo & Yusianto, 2013). Cupping scores of all coffee samples could be seen in Figure 1 which reflected flavor profiles of Enrekang Arabica coffee that was fermented using Ohmic technology.

The results of sensory analysis showed that all of coffee samples in various treatments had scores ranging from 7.23 to 10. It indicated that the flavor quality of Arabica coffee was excellent (7.00 to 9.00). Widyotomo & Yusianto (2013) mentioned that aroma of brewed coffee would emerge as a result of the evaporation of volatile compounds which are captured by the human sense of taste and smell. Based on the research results, the treatment of 12-hours fermentation at temperatures of 35^{o}C and 40^{o}C had the highest flavor score of 7.88, compared with the other treatments.

Yusianto (2008) revealed that the best flavor of coffee could be produced in fermentation process for 12 hours. It is also an advantage of coffee flavor produced by the Ohmic fermentation process which applied controlled temperature and fermentation time, so that the heat generated by the Ohmic fermentation spread well on all surfaces of fermented materials compared with the fermentation that occurs naturally in mongoose animals that produced Luwak coffee (Gonzalez-Rios *et al*., 2007), and fermentation using controlled fermenters had empty spaces that lead to metal sheet had the potential heat propagation would lose heat into ambient in the fermentation chamber, so that the heat was not utilized maximally (Widyotomo & Yusianto, 2013).



Notes: E = name village Enrekang
2, 6, 12, and 18 = time of fermentation (h)
30, 35, 40 = temperature (^{o}C)

Figure 1. Flavor profile of Arabica coffee originating from Enrekang processed by Ohmic Fermentation Technology

The flavor profile is a combination of scents, acidity and aftertaste captured by the human sense of smell and is felt when drinking (Afriliana *et al*., 2018). Based on Figure 1, the highest score of sensory analysis was found in the treatment of 2 h fermentation time and 30°C fermentation temperature and 2 h fermentation time and 40°C fermentation temperature. It is in accordance with Yusianto (1999) research which mentioned that the flavor produced from decaffeinated Arabica coffee would decrease as the length of the dissolution process and the higher of the extraction temperature, so that the fermentation at 30°C and 40°C obtained the highest score of coffee flavor. The trigonellin in the coffee beans should be more than 1% to obtain optimum flavor.

Aftertaste or known as persistence of a sensation of coffee flavor was any taste which remains in the mouth (palate or oral cavity) after the coffee has been swallowed (Widyotomo & Yusianto, 2013; Afriliana *et al*., 2018). Based on Figure 1, the highest aftertaste score was gained in treatment 2 h fermentation time and 30°C fermentation temperature. According to UCDA (2010), a low aftertaste score indicates that coffee has a lacked of aftertaste as a result of strong/high acidity.

Good acidity was felt on the coffee with a good quality, fresh sweet like fresh fruit that could be perceived directly when coffee was taken a sip from the cup (Afriliana *et al*., 2018). The 12 h fermentation time and fermentation temperature of 35°C had an acidity level of 7.88. It was due to good control of temperature and fermentation time could change the acid in coffee pulp into simple sugars (monosaccharides) and subsequently into lactic acid, which causes the freshness of coffee flavor can be felt (Bressani *et al*., 2018; De Melo Pereira *et al*., 2015). It was in accordance with the research results of Reta *et al*. (2017b) which stated that acidity score of 1.8% could be reduced to 0.18%.

Clean cup is an uniformity in each cup. Clean cup obtained in the sensory analysis does not decrease the score into negative from the beginning of taste to aftertaste (as the final score). The sensory analysis reflected that clean cup was uniform and clean for all samples with a score of 10, so it could be stated that all of treatments had uniformity and had no affect toward coffee flavor. It was balance on the coffee flavor profiles including aroma, aftertaste, acidity, sweetness, and body. The highest score was the 12 h fermentation time and 40°C fermentation temperature. Finally, it described overall taste of the coffee sample which was evaluated by the panelists. The 2 h fermentation time and 50°C fermentation temperature and 2 h fermentation temperature and 35°C fermentation temperature treatments had the highest score with a score of 8.

Based on the results of sensory analysis, it indicated that all of treatments were categorized as specialty coffee with an average score above 8.00 in which coffee was categorized as specialty or excellent if it had flavor score ranging from 8.00 to 9.00. The results of this study were also in line with the research results of Widyotomo & Yusianto (2013) and Yusianto (2008), which revealed that fermentation of Arabica coffee beans for 12 hours would improve the flavor and fermentation of Arabica coffee beans which applied temperature from 30 to 40°C and no effect on the change of coffee beans.

Fermentation Temperature Effect

Figure 2 reflected that the Arabica coffee which originating from Enrekang at an altitude growth of 1,800 m above sea level had the highest score of body (7.81) based on the results of cup-test applying the best temperature of 30°C, whereas flavor, aftertaste and the overall preference had score of 7.78. Application of 35°C temperature resulted the best coffee flavor on aroma and balance; while the application of 40°C temperature delivered the highest score of coffee flavor on balance (7.84) and body (7.81). Barlaman *et al.* (2013) stated that the temperature used is generally about 30°C, if the temperature is less than 30°C causing the growth of acid-producing microorganisms will be slow so the product growth can occur.

Application of improper fermentation process would produce coffee beans with a low defect of coffee flavor (Reta *et al.*, 2017b; Widyotomo & Yusianto, 2013). Taint flavor such as fermented or stinker are severe defects in the aroma of coffee. Various fermentation defects can be avoided by carrying out the fermentation process properly and correctly, so that the combination treatment of fermentation time and temperature ranging from 35-40°C would deliver an average score of 84-85 where the score is categorized as excellent or specialty coffee based on SCAA Standards (2009).

Fermentation Time Effect

Figure 3 showed that Arabica coffee originating from Enrekang at an altitude of 1,800 m had the highest score of flavor, aftertaste and balance in the Ohmic fermentation treatment for 2 hours. Whereas, the highest score of aroma, body and acidity were obtained in the Ohmic fermentation for 12 hours. In general, fermentation for 12 hours delivers the best aroma and coffee flavor. It is in line with the research results of Yusianto (2008).

Figure 4 described that Arabica coffee originating from Enrekang has 21 flavor notes (related to coffee flavor) based on panelists' perception, wherein the percentage of flavor notes description according to perception of panelists in ICCRI were strong fragrance (100%), flowery (77%), heavy body and nutty (66%), and rather winey (55%).

Marshall & Mejia (2011) stated that fermentation carried out by controlled fer-

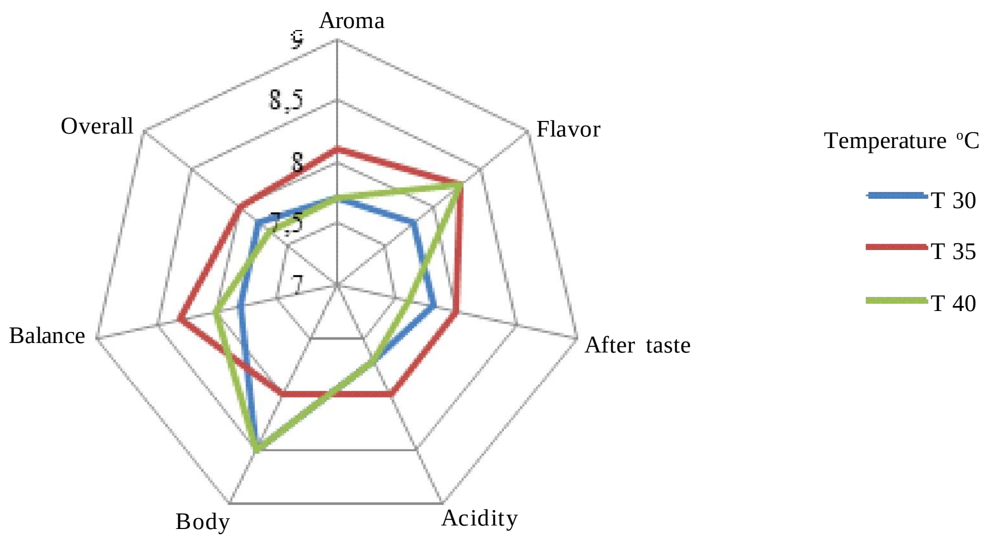


Figure 2. Flavor profile of Arabica coffee originating from Enrekang processed using Ohmic heating technology at various temperature

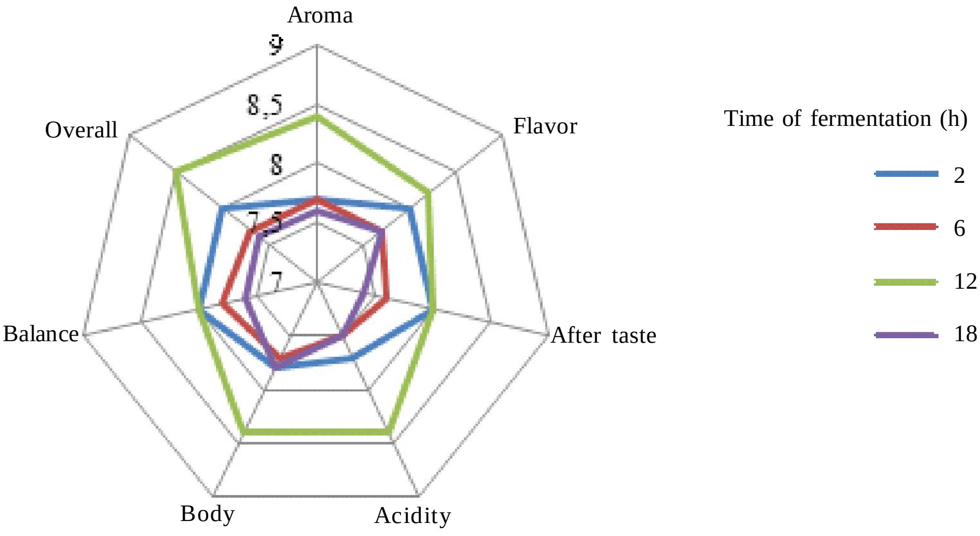


Figure 3. Flavor profile of Arabica coffee originating from Enrekang processed using Ohmic heating technology at various fermentation time

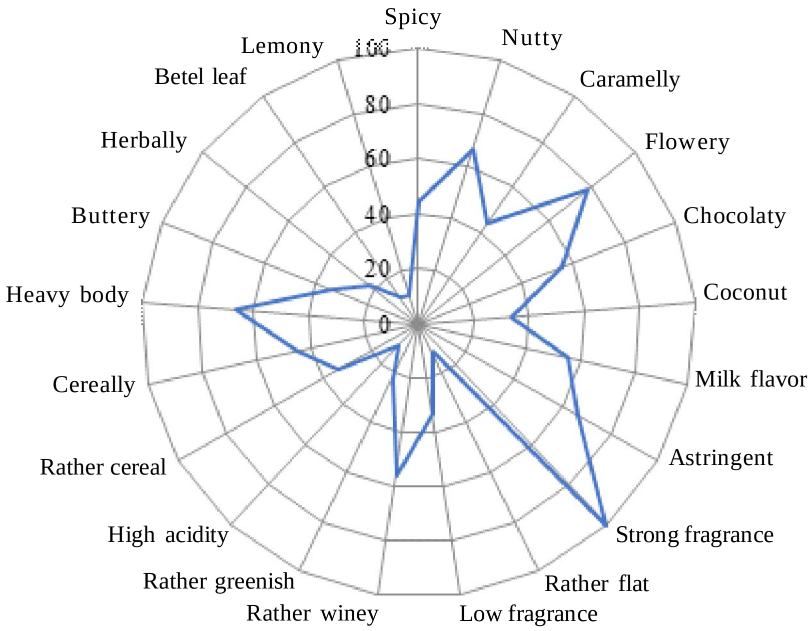


Figure 4. Preception profile flavor coffee from Enrekang processed with Ohmic heating technology

mentation will deliver good aroma of coffee and will lead to the diversification of flavors in brewed coffee. Thus, the other taste of coffee which were noted in this research such as lemony, betel leaf, herbal, chocolate, nutty, winey, and another flavor.

CONCLUSIONS

Fermented Arabica coffee beans originating from Enrekang at an altitude of 1,800 meters above sea level using Ohmic fermentation technology had high score with 85.25 in the fermentation time of 12 hours and temperature of 35°C. Meanwhile, the fermentation process at 30°C had the best coffee flavor profiles on the body with a score of 7.81. The fermentation process at 35°C appeared the best flavor profiles on the flavor, aroma and balance, while fermentation at 40°C emerged high score on the balance with a score of 7.84. The application of fermentation time for 2 hours delivered good flavor, whereas fermentation time for 12 hours generated good aroma. Arabica coffee originating from Enrekang has 21 flavor notes (related to coffee flavor) based on panelists' perception. Based on the sensory analysis of all treatments, it stated that Arabica coffee which applied all treatments could produce specialty coffee with an average score above 80 therefore it was classified as specialty coffee.

ACKNOWLEDGMENT

The Author would like to thank the Director of Higher Education, Ministry of Research, Technology and Higher Education for funding the research activities through Research Grand Competition in 2019.

ORCID

https://orcid.org/0000-0002-8407-8272

REFERENCES

Afriliana, A.; H. Harada; P.Q. Khotijah; Jayus & Giyarto (2018). Fermented technology of Robusta coffee beans (*Coffee canephora*) with kefir milk to produce specialty coffee. *Proceedings of the International Confrerence on Food, Agriculture and Natural Resources (FANRes 2018).* (172):302-309. Advances in Engineering Research. Atlantis Press.

Aklimawati, L.; Yusianto & S. Mawardi (2014). Characteristics of quality profile and agribusiness of Robusta coffee in Tambora Mountain side, Sumbawa. *Pelita Perkebunan,* 30, 159-180.

Anderson, D.R. (2008). *Ohmic Heating as an Alternative Food Processing Technology*. Kansas State University, Kansas.

Avallone, S.; B. Guyot; J.M. Brillouet; E. Olguin & J.P. Guiraud (2001). Microbiological and biochemical study of coffee fermentation. *Current Microbiology International Jurnal*, 42, 252-256.

Baggenstoss, J.; L. Poisson; R. Kaegi; R. Perren & F. Escher (2008). Coffee roasting and aroma formation: Application of different time and temperature conditions. *Journal of Agricultural and Food Chemistry*, 56, 5836-5846.

Bailly, H.S.B. & S. Graci'a-Graci'a (1992). Proyecto de tratamiento de aguas de benefi'cioshu'medosresiduals. *Cafe' Cacao, The XXXVI,* 129-136.

Barlaman, M.F.B.; S. Suwasono & Djumartin (2013). Physical characteristics and appearance Arabica coffee beans processing results semi wet and variation type and old containers fermentation (A case study in the village of carts and Sukosawah Bondowoso). *Agrointek*, 7, 108-121.

Bertrand, B.; P. Vaast; E. Alpizar; H. Etienne; F. Davrieux & P. Charmetant (2006). Comparison of bean biochemical composition and beverage quality of arabica hybrids involving Sudanese-Ethiopian origins with traditional varieties at various elevations in Central America. *Tree Physiology*, 26, 1239-1248.

Bressani, A.P.P.; S.J. Martinez; S.R. Evangelista; D.R. Dias & R.F. Schwan (2018). Characteristics of fermented coffee inoculated with yeast starter cultures using different inoculation methods. *LWT Food Science and Technology*, 92, 212-219.

Decazy, F.; J. Avelino; B. Guyot; J.J. Perriot; C. Pineda & C. Cilas (2003). Quality of different honduran coffees in relation to several environments. *Journal of Food Science*, 68, 2356–2361.

Delgado, A.; L. Kulisiewicz; C. Rauh & A. Wierschem (2012). Fluid dynamics in novel thermal and non-thermal processes p. 7–33. ***In***: *Novel Thermal and Non-Thermal Technologies for Fluid Foods. Foods*, Chapter 2. Academic Press, New York.

De Melo Pereira, G.V.; E. Neto; V.T. Soccol; A.B.P. Medeiros; A.L.Woiciechowski & C.R.Soccol (2015). Conducting starter culture controlled fermentations of coffee beans on during on-farm wet processing: Growth, metabolic analyzes and sensorial effects. *Food Research International*, 75, 348–356.

De Melo Pereira, G.V.; V.T. Soccol; A. Pandey; A.B.P. Medeiros; J.M.R.A. Lara: A.L. Gollo & C.R. Soccol (2014). Isolation, selection and evaluation of yeast for use in fermentation of coffee beans by the wet process. *International Journal of Food Microbiology*, 188, 60-66.

Ditjenbun (2017). *Statistik*. *Perkebunan Kopi 2015-2017*. Direktorat Jenderal Perkebunan. Kementerian Pertanian. Jakarta.

Evangelista, S.R.; M.G.D.C.P. Miguel; C.F. Silva; A.C.M. Pinheiro & R.F. Schwan (2015). Microbiological diversity associated with the spontaneous wet method of coffee fermentation. *International Journal of Food Microbiology*, 210, 102–112.

FAO (2019). *Food and Agriculture Data*. Rome, Italy.

Gonzalez-Rios, O.; M.L. Suarez-Quiros; R. Boulanger; M. Barel.; B. Guyot; J.P. Guiraud & S. Schorr-Galindo (2007). Impact of "Ecological"post-harvest processing on the volatile fraction of coffee beans: I. Green coffee. *Journal of Food Composition and Analysis*, 20, 289–296.

Hadipernata, M. & S. Nugraha (2017). Processing technology of luwak coffee through bioreactor utilization, p. 1–6. ***In:*** *Proceedings of IOP Conf (Series: Earth and Environmental Science 102)* doi: 10.1088/1755-1315/102/1/012092.

ICO (2017). *Coffee Statistics. Trade Statistics of Total Production of Exporting Countries.* International Coffee Organization Statistics. London, UK.

Illy, A. & R. Viani (2005). *Espresso Coffee*: *The Science of Quality* (2nd ed.). London, UK: Elsevier Academic Press.

Leroy, T.; F. Ribeyre; B. Bertrad; P. Charmetant; M. Dufour;C. Montagnon; P. Maraccini & D. Pot (2006). Genetics of coffee quality. *Brazilian Journal of Plant Physiology*, 18, 229–242.

Marcone, M.F. (2004). Composition and properties of Indonesian civet coffee (Kopi Luwak) and Ethiopian civet coffee. *Food Research International*, 37, 901–912.

Marshall, E. & D. Mejia (2011). *Traditional Fermented Food and Beverage for Improved likelihood.* Diversity Booklet Number 21, Food and Agriculture Organization of the United Nations, Rome.

Misnawi & Sulistyowati (2006). Mutu kopi Indonesia dan peluang peningkatan daya saingnya. *Warta Pusat Penelitian Kopi dan Kakao Indonesia*, 22, 127-132.

Muchtadi, T.R.; Sugiyono; Ayustaningwarno & Fitriyono (2010). *Teknologi Proses Pengolahan Pangan*. Alfabeta, Bandung

Murthy, P.S. & M.M. Naidu (2011). Improvement of Robusta coffee fermentation with microbial enzymes. *European Journal of Applied Sciences*, 3, 130–139.

Muzaifa, M.; D. Hasni; A. Patria; Febriani & A. Abubakar (2018). Sensory and microbial characteristics of civet coffee. *International Journal on Advanced Science Engineering Information Technology*, 8, 2088–5334.

Owen, T. (2009). *An Updated Pictorial Guide to the Roast Process*. Sweet Maria's Coffee Library. Oakland, Canada.

Reta; Mursalim; J. Muhidong & Salengke (2017a). Characteristic flavor of robusta coffee from South Sulawesi after fermentation by Ohmic technology. *International Journal of Current in Biosciences and Plant Biology*, 4, 33–38.

Reta; Salengke; Mursalim; J. Muhidong; Mariati & P. Sopade (2017b). Reducing the acidity of arabica coffee beans by Ohmic fermentation technology. *Food Research*, 1, 157–160.

Ribeiro, F.C.; F.M. Borem; G.S. Giomo; R.R. De Lima; M.R. Malta & L.P. Figueiredo (2011). Storage of green coffee in hermetic packaging injected with CO2. *Journal of Stored Products Research*, 47, 341–348.

Salengke, S.; A. Hasizah; Reta & A.A. Mochtar (2019). Technology innovation for production of specialty coffee, p. 1–5. ***In:*** *IOP Conf. Series: Earth and Environmental Science* 355 (2019) 012105 doi:10.1088/1755-1315/355/1/012105. IOP. Publishing.

Salengke, S. & S.K. Sastry (2007). Models for Ohmic heating of solid-liquid mixtures heating under worst-case scenarios. *Journal of Food Engineering*, 83, 337–355.

Saragih, J.R. (2016). *Arabica Coffee Production Specialties of North Sumatra: Socio-Economic Analysis, Ecology and Policy of Local Government*. https://www.google.com/ [Retrieved on March 28, 2016].

SCAA (2009). *SCAA Protocols - Cupping for specialty coffee*. Specialty Coffee Association of America.

SCAA (2012). *Coffee Terms & Definitions from the Specialty Coffee Association of America*. The Specialty Coffee Event 24th. Oregon Convention Center, Portland, Oregon.

SCAA (2015). *SCAA Protocols: Cupping Specialty Coffee*. The Specialty Coffee Association of America, US.

Schenker, S.; C. Heinemann; H. Huber; R. Pompizzi; R. Perren & F. Escher (2002). Impact of roasting conditions on the formation of aroma compounds in coffee beans. *Journal of Food Science*, 67, 60–66.

Selmar, D.; G. Bytof; S.E. Knopp & B. Breitenstein (2006). Germination of coffee seeds and its significance for coffee quality. *Plant Biology*, 8, 260–264.

Sivetz, M. & N.W. Desrosier (1979). *Coffee Technology*. AVI, Westport, CT.

Teketay, D. (1999). History botany and ecological requirements of coffee walia. *Journal Ethiopian Wildlife*, 20, 28–50.

Towaha, J. & Rubiyo (2016). Mutu fisik biji dan citarasa kopi Arabika hasil fermentasi mikroba probiotik asal pencernaan luwak. *Jurnal Tanaman Industri dan Pertanian*, 3, 61–70.

UCDA (2010). *Making Uganda a distinguished producer of high value coffee*. Uganda Coffee Trade Development Autority. ***In***: *Annual Report 2010-2011*. 1–77.

Vaast, P.; B. Bertrand; J.J. Perriot; B. Guyot & M. Genard (2006). Fruit thining and shade improve bean characteristics and beverage quality of coffee (*Coffea arabica* L.) under optimal conditions. *Journal of the Science of Food and Agriculture*, 86, 197–204.

Widyotomo, S. & Yusianto (2013).Optimasi proses fermentasi biji kopi Arabika dalam fermentasi terkendali. *Pelita Perkebunan*, 29, 53–68.

Yeretzian, C.; A. Jordan; R. Badoud & W. Lindiger (2002). From the green bean to the cup of coffee: Investigating coffee roasting by on-line monitoring of volatiles. *Europe Food Research Technology*, 214, 92–104.

Yusianto (1999). Komposisi kimia biji kopi dan pengaruhnya terhadap citarasa seduhan. *Warta Pusat Penelitian Kopi dan Kakao*, 15, 190–202.

Yusianto (2008). Panen dan penanganan pasca panen. p. 109–160. ***In:*** *Panduan Budidaya dan Pengolahan Kopi Arabika Gayo*. S. Mawardi; R. Hulupi; A. Wibawa; S. Wiryadiputra & Yusianto, Eds. Pusat Penelitian Kopi dan Kakao Indonesia, Jember, Indonesia. ICCRI, Jember.

0