MJSIR
Mountain Journal of Science and Interdisciplinary Research
PRINT ISSN: 2619-7855
ONLINE ISSN: 2651-7744
July-December 2022 • 82 (2) :152-162

Effects of Roast Levels on the Physical Properties, Microbial Contaminants, and Cup Quality of Arabica Coffee

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ARTICLE INFO

Date Received: 11-11-2021
Date Last Revised: 04-18-2022
Date Accepted: 08-23-2022

KEYWORDS

Arabica coffee
roast levels
cup quality

Abstract

Turning raw green coffee beans into roasted coffee beans and other products cannot be completed without the roasting process. However, information on the influence of roast levels on the essential qualities of Arabica coffee is scant. This study was conducted to determine the effects of roast levels on the physical properties, microbial contaminants, and cup quality of Arabica coffee. Wet processed BSU-Red Bourbon Arabica coffee green coffee beans were roasted in a 250g-capacity drum-type roaster at three roast levels: light, medium, and dark. The changes in physical properties such as roasted bean dimensions and volume, roast volume, weight loss, and bulk density were observed and analyzed. Results indicated that dark roasted coffee had the highest change in bean size and volume, roast volume, weight loss, and lowest bulk density. Fungal species *Saccharomyces cerevisiae* and *Penicillium* sp. were found in the green coffee beans before roasting but were not detected in the roasted coffee beans. Arabica coffee roasted in the three roast levels were all classified as specialty although medium roast scored better than light and dark roasts. The result can be used as a guide in enhancing the development of roasted coffee products towards satisfaction in the consumption of quality Arabica coffee.

Introduction

Coffee is still the most widely consumed beverage worldwide. Its appreciation was thought to have undergone three waves. Dincer et al., (2016) opined that coffee consumption habits and consumer preferences have changed due to globalization and improvement in communication technologies which led to the third wave of consumption trend. The first wave is known as commodity coffee or low-quality coffee which is characterized by very dark and bitter coffee. The second wave is described as the rise of coffee brands that offer higher quality coffee but are spiced with sweet flavorful syrups and other ingredients. Slight attention is given to the country's origin of coffee while more emphasis is on creative drinks or flavored drinks. On the other hand, the third wave that originated in the 1980s gave much focus to coffee beans. The term "third wave" was coined in 1999 and rapidly became a growing trend. It focuses on the art of brewing and the source of coffee beans, transparency in the production of the coffee, and lighter roast profiles. We are presently at this wave where coffee appreciation is shown through industry trade shows, quality competitions, manual brewing, or self-made coffee drinks (Oksnevad, 2019). This current trend demands quality coffee.

The definition of quality varies and differs depending on a stakeholder's point of view. The International Trade Center (2002) defined coffee quality as a combination of the botanical variety, topographical conditions, weather conditions, and the care taken during growing, harvesting, storage, export preparation, and transport. Therefore, assessing coffee quality involves determining the journey of the coffee bean from production postharvest processing methods. Postharvest processing could be classified into primary and secondary processing. Primary processing usually happens at the field level and starts with the fresh coffee berries undergoing depulping, fermentation (for wet method), drying, dehulling, sorting, and grading to obtain green coffee beans. Meanwhile, secondary processing details the process where raw green coffee beans into various products, normally as a coffee beverage from roasted coffee beans. The secondary process involves further green coffee bean sorting, roasting, grinding, packaging and labeling. In 2016, about 28 processors and 200 micro-processors in the Cordillera Administrative Region (CAR) were into roasted coffee processing. The end products, either whole or ground coffee, are sold to local households, hotels and restaurants, and market outlets, and go beyond the region (Department of Agriculture-Cordillera Administtrative Region [DA-CAR], 2016). The DA-CAR also reported that roasting was done using coffee roasting machines but only a few use roasting machines as the traditional way of manual roasting is still practiced.

With the use of roasting machines, there is still a dearth of information in the locality on the influence of roasting on Arabica coffee in terms of determining the level of roast, changes in physical and chemical properties, and its effect on the presence of microbial contaminants. Moreover, the question of whether Arabica coffee retains or diminishes its cup quality when subjected to different roast levels needs to be answered.

The roasting process brings out the desired aroma and flavor of coffee because the beans undergo a series of reactions leading to changes in physical properties and chemical composition (Illy & Viani, 2005). The roasting process is highly complex because the amount of heat and roast duration are crucial in producing the specific level of roast. A number of studies were done to evaluate the degree of coffee roast in terms of physical properties and chemical composition. However, those techniques could not be done in real-time and have their own limitations (Noor-Aliah et al., 2015). Locally, coffee processors do not have modern or state-of-the-art equipment such as roast color analyzer or kits to aid in determining the desired roast and often rely on roasted bean color as the basis of determining roast degree. Thus, understanding the changes in physical properties of coffee beans during roasting is essential as this would shed light on establishing a common standard for roast levels.

Meanwhile, fungal contamination of green coffee beans is known to happen worldwide. In the Philippines, Alvindia and Acda (2010) reported high fungal diversity in green coffee and roasted beans from Benguet, Davao, and Cavite with 26 species from 14 genera of mycobiota. However, studies on the diversity of fungi in freshly roasted coffee beans are scant. The determination of the degree of fungi contamination in roasted coffee beans is important because according to Culiao and Barcelo (2015), the presence of fungal isolates does not necessarily imply the presence of mycotoxins. It is also necessary to assess if the roast levels play a role in the reduction of microbial contaminants.

Coffee quality is greatly affected by pre and postharvest practices. These practices are considered the most crucial as they could ultimately bring out the best or ruin the coffee quality. Various authors stated that the growing appreciation of coffee in recent years led to the quest for knowledge regarding the physical quality of roasted coffee as the quality of the coffee beverage is closely related to the physical appearance of the roasted beans. Moreover, the coffee quality serves as a scale for determining the price of a particular coffee. DA-CAR (2016) reported higher coffee farmgate prices in CAR than in other coffee-producing regions due to the perceived taste difference of coffee produced in the region which it attributed to its unique agro-climatic characteristics. This is affirmed by the results of national coffee cupping competitions where most of the top finalist entries came from CAR. In the 2017 First Kape Pilipino Green Coffee Quality Grading Competition, six out of the top 10 Arabica coffee came from CAR with Benguet State University's Arabica coffee entry placing second (Philippine Coffee Board, 2017). The following year, Arabica coffee from CAR also dominated in the Philippine Coffee Quality Competition (PCQC) landing seven out of the top 12 where the champion came from Atok, Benguet (PCQC, 2018; Philippine Information Agency-Cordillera Administrative Region, 2018). Investigating whether the roast levels affect the quality of Arabica coffee would provide a guide to Arabica coffee producers and processors to develop coffee products to suit consumers' tastes or preferences. In addition, the results of the study may provide baseline information on roasting to researchers, students, and other stakeholders in the coffee industry. Thus, this study aimed to document the roasting duration and temperature of three roast levels, and determine the effects of roast levels on the physical properties, microbial contaminants, and cup quality of Arabica coffee using a small batch drum-type roaster.

Materials and Methods

This study was conducted at the Benguet State University-Institute of Highland Farming Systems and Agroforestry (BSU-IHFSA) Pine-based Arabica coffee farm, Puguis, La Trinidad, Benguet from January 2020 to May 2020.

Green Coffee Bean Preparation

Ripe Arabica coffee berries variety BSU-Red Bourbon harvested within the day were processed through the wet method. Sun drying of the parchment coffee was done on elevated beds inside a greenhouse-type dryer until the green coffee beans (GCB) attained 11-12% moisture content. Afterward, the parchment coffee was dehulled using a dehulling machine to extract the GCB. These were sorted to size using improvised handheld sieves with openings of 6.35mm and defects were removed. These were measured in their dimensions, and then samples for roasting were weighed at 250g.

Coffee Roasting

Sorted Arabica GCB were subjected to different roast levels using a small batch, 250g-capacity drum-type coffee roaster. The pre-heating requirement largely depends on the type of coffee roasters, capacity, configuration, and manufacturer's recommendation. Most drum-type coffee roasters require 180ºC to 200ºC for pre-heating. This is to ensure the consistency of the roasted coffee beans and prolong the life span of the roaster. In this study, the manufacturer's recommendation was followed, wherein the coffee roaster was pre-heated at 160ºC. Then, 250g of GCB was dropped into the roaster cylinder. Roasting was monitored through the viewing window and visual inspection by bringing out coffee beans using the sample spoon of the roaster. After attaining the desired roast level, the roasted coffee beans (RCB) were allowed to cool using a cooling tray with a fan underneath to suck the hot air off the beans. After pouring the RCB, the roaster temperature was again allowed to reach 160ºC before dropping the next batch of GCB. The levels of roast were light, medium, and dark which were determined based on the color of the RCB. These were compared to the samples of RCB of the respective roast level provided by local coffee processors and traders who sought roasting services at the Coffee Postharvest and Processing Center of BSU-IHFSA.

Data Gathered

Roasting Duration or Time to Attain Roast Level

This was recorded using a digital timer from the moment the GCB was dropped into the roaster cylinder until the minute the desired roast level was attained. There were four trials for each roast level.

Coffee Bean and Roaster Temperature

Prior to roasting, the temperature of the GCB was recorded. A minute after the GCB were dropped into the roaster cylinder, a sample of the beans being roasted was obtained by pulling out the sample spoon attached to the roaster cylinder, temperature of the beans was immediately measured then the sample spoon was inserted back. Likewise, the temperature inside the roaster cylinder was monitored every minute along with the roasting duration of the GCB. The temperatures were measured using an infrared thermometer (Cason).

Bean Volume

A caliper was used to determine the dimensions of the individual coffee beans before and after roasting. Ten RCB samples per trial were obtained and their length, width, and thickness were measured. By approximating the coffee bean shape to a semi-ellipsoid (Figure 1), bean volume was calculated using the Bustos-Vanegas (2018) equation:

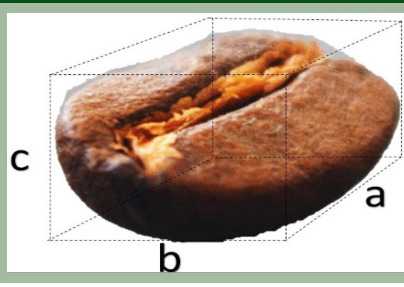
$$V=\pi abc/6 \quad \text{(Equation 1)}$$

Where:

V = bean volume in mm^3; a = bean length; b = bean width; and c = bean thickness

Figure 1

Semi-ellipsoid Approximation for a Coffee Bean



Roast weight loss, Roast volume change, and Bulk density. Before and after roasting, the weight and volume of coffee beans were measured using a sensitive balance and a 100ml graduated cylinder, respectively. Then, using the equations developed by Sualeh et al., (2014), percent roast weight loss and bulk density of roasted coffee bean were calculated as follows:

Roast weight loss:

$$RWL=\frac{(GBW-RBW)}{GBW} \times 100 \quad \text{(Equation 2)}$$

Where: RWL=percent weight loss; GBW=Green bean weight; RBW=Roast bean weight

Roast volume change:

$$RVC=\frac{(RBV-GBV)}{GBV} \times 100 \quad \text{(Equation 3)}$$

Where RVC= roast volume change; RBV=roast bean volume; GBV=green bean volume

Bulk density of roasted bean:

$$BDRB=RBW/RBV \quad \text{(Equation 4)}$$

Where BDRB=bulk density of roasted bean; RBW= roast bean weight; RBV=roast bean volume

Determination of Fungal Contaminants

Coffee samples taken from each treatment were brought to the BSU-Plant Health Clinic for the isolation of microorganisms into the culture media. The isolated microorganism was observed from 2 to 7 days of incubation. Microbial growth or structures were sampled and observed under a compound microscope and were subcultured separately into pure culture for identification. Potato Dextrose Agar was used as media for filamentous fungal isolates, while Malt Extract Agar for yeast, a unicellular fungus.

Identification of Associated Fungi

The isolated fungi were identified to the genus and species level based on the cultural and morphological characteristics as described by the following authors: Penicillium spp. by Frisvad and Samson (2004), Pitt (2000), Raper and Thom (1949), Thom (1930); while the works of Kurtzman et al., (2011), Martini and Martini (1993), Kreger-Van-Rij (1984) for yeast.

Cup Quality Evaluation

The coffee cup quality evaluation or referred to as coffee cupping was performed following the established cupping protocols of the Specialty Coffee Association (SCA). The protocols recommend standards and a set of guidelines to accurately evaluate the quality of coffee. It contains the recommended necessary equipment, forms, and other paperwork, cupping environment conditions, preparation of coffee samples, sample evaluation, and description of procedures. Further, it provides a guide on assigning individual scores of positive attributes namely; Fragrance/Aroma, Flavor, Aftertaste, Acidity, Body, Balance, Sweetness, Uniformity, Cleanliness, and Overall using a quality scale: Good (6.0-6.75); Very Good (7.0 – 7.75); Fine (8.0-8.75); and, Outstanding (9.0-9.75). The final score is calculated by summing the individual scores given for each attribute and then subtracting any defects to arrive at a final score. The final score and its quality classification are as follows: <80 and below

= below specialty (not specialty); 80 to 84.99 = very good (specialty); 85 to 99.99 = excellent (specialty); 90 to 100 = outstanding (specialty).

A panel of three (3) Q-graders conducted the cupping evaluation. Their individual cupping reports were tallied and the average final cupping score was computed.

Design and Data analysis

The experiment was arranged following a completely randomized design with four replications. Quantitative data of bean volume, roast weight loss, roast volume change, and bulk density were subjected to analysis of variance (ANOVA) and significant means were separated by Fisher's protected LSD at 5% probability using Gen Stat 15th Edition software.

Results and Discussion

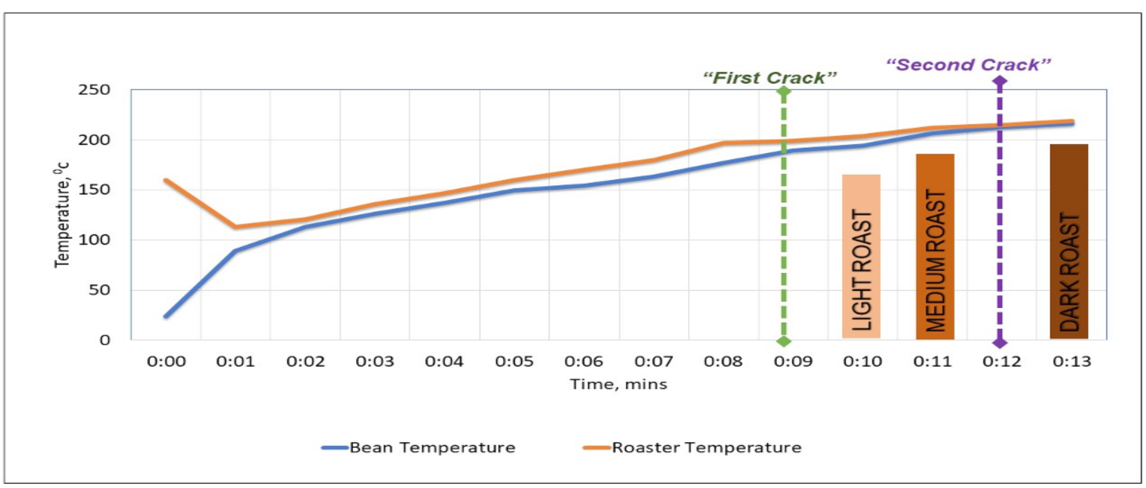
Mean Roast Duration and Temperature

Figure 2 shows the mean time and final temperature of the roaster and RCB at each roast level. In each trial, the GCB temperature of 24°C rose to 88.89°C after a minute in the roaster cylinder. The light roast was done after 10 minutes with a roaster temperature of 204°C and RCB temperature of 193.83°C. The medium roast was completed in 11 minutes with the roaster and RCB temperature of 212°C and 206.67°C, respectively. Meanwhile, the dark roast was finished after 13 minutes, roaster temperature of 219°C and RCB temperature of 216.0°C. Dutra et al. (2001) performed a 12-minute roast of 300g of green coffee beans using a lab-scale coffee roaster and reached the optimum degree of roast in 9 minutes. These observations were similar to the findings of Mendes et al. (2001) that in the conventional roasting process, the temperature ranges from 200°C to 230°C while the processing time ranges from 12-20 minutes. The roasting process could vary greatly depending on the degree of roast required, the type of roaster used, and also on the variety, age, and moisture content of the coffee beans.

In this study, the "first crack" or the popping sound of the bean during roasting occurred at the 9th minute while the "second crack" was noted at the 12th minute. Light roasts are often finished during or immediately after the first crack. Meanwhile, medium roasts were in between the first crack and just before the second crack. On the other hand, dark roasts are often classified into two: medium-dark and dark roasts. Both of these roast levels occur past the second crack. RCB of dark roast is dark brown to almost black with some oil on the surface. Common roast names under the light roast category include "cinnamon roast, light city, half city, and New England roast" and "Light Brown". Beans under this roast are light

Figure 2

Roast Duration, Temperature, and Levels of Roasting



brown with no oil on the surface. Medium roast is known as "Medium Brown", "regular, brown, American roast, city roast, and breakfast roast" and appears medium brown and has no oil on the bean surface. For dark roasts, medium-dark roasted coffee is commonly called "full city, Vienna roast, light espresso, after dinner" while the dark roast is known as "Very Dark Brown, French roast, Italian roast, espresso roast, continental, New Orleans roast, and Spanish roast" (Lokker, 2020; Coffee Review, n.d.).

The change in bean dimension and volume of RCB due to roasting is shown in Table 1. The effect of roast levels on the change in bean dimensions was found highly significant (P<0.001). The dark roasted beans had the highest increase in length (11.56mm), width (8.23mm), thickness (4.27mm), and bean volume change with 263.6mm³. Similarly, the roast volume change was significantly high in dark roasted coffee with 96.78%, followed by medium roast with 69.74% and light roast with 54.78% (Figure 3). This finding shows that as the roast duration increases the size of coffee beans and volume expands. This is similar to results obtained by Rodrigues et al. (2002), which revealed that a significant increase in volume was observed after 12 minutes of roasting while Dutra et al. (2001) reported a 100% increase in bean volume at 9 minutes of roasting. In addition, the roast volume change of medium roast found in this study is in range with the findings of Ameyu (2016) for wet processed Arabica coffee with 67.97%. According to Clarke (1985), physical changes in coffee beans during roasting leads to considerable expansion of beans while Mekonen

Table 1

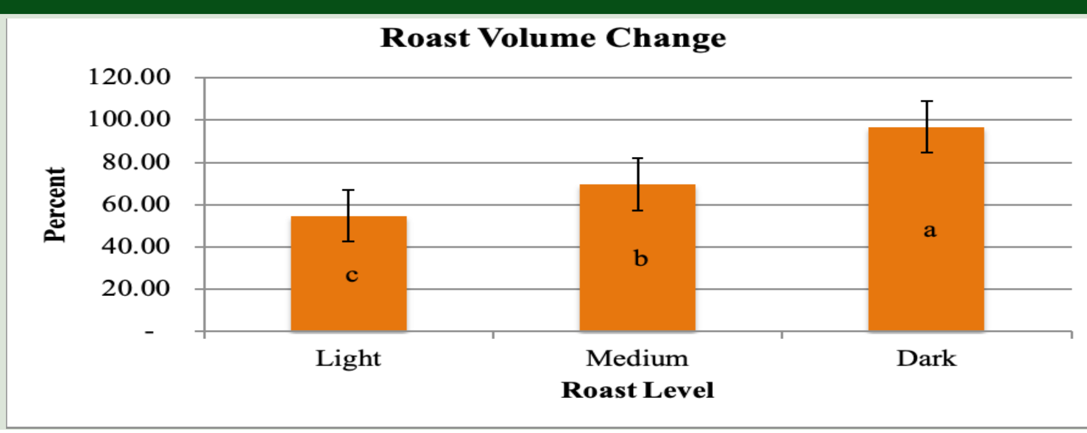
Effect of Roast Levels on Bean Dimensions and Volume Change of Roasted Coffee Beans

Roast levels	Dimensions			
	Length (mm)	Width (mm)	Thickness (mm)	Volume (mm³)
Green coffee bean	10.11	6.87	3.73	135.81
Light	10.67 [a]	7.56[a]	4.75[a]	201.8[a]
Medium	10.96[b]	7.94[b]	4.96[b]	227.3[b]
Dark	11.56[c]	8.23[c]	5.27[c]	263.6[c]
CV (%)	5.6	5.2	10.0	10.5

Mean values followed by the same letter in acolumn are significantly different at the P<0.05 level

Figure 3

Change in Roast Volume as Affected by Roast Levels



(2009) claimed that creaked coffee bean and volume increment are caused by moisture and dry matter loss during roasting. Sualeh et al. (2014) added that roast volume change may be due to chemical and physical changes in the coffee bean caused by heat energy.

Roast Weight Loss

The differences in weight loss due to roast levels were highly significant (P<0.001) as shown in Table 2. The dark roast recorded the maximum weight loss of 20.06% followed by the medium roast (16.21%) while the minimum from the light roast with 13.64%. The result implies that coffee bean loss mass during roasting and the degree of mass lost is positively related to the level of roast. Longer roasting duration as required by the dark roast resulted in greater mass loss. This result could be due to the reduction in moisture content and dry matter of the coffee beans. Various studies state that coffee beans lose mass during roasting due to loss in water and volatile materials (Franca et al., 2005). Further, Mwithiga and Jindal (2003), reported that reduction in mass is due to loss of moisture and decomposition of carbohydrates. Sualeh et al. (2014) also found that coffee roasted for eight (8) to 10 minutes showed respective weight loss of 13.41% and 19.06%, while Clifford (1985) reported a total roasting loss of 10% for dry matter and 25% for water.

Bulk Density

The effect of roast levels on RCB bulk density was highly significant (P<0.001) as revealed in Table 2. The highest mean value of bulk density (0.50g/ml) was recorded in the light roast coffee while the lowest was obtained from the dark roast with 0.33g/m. The result shows that bulk density is inversely related to the level of roast such that bulk density decreases as roasting duration increases. Frisullo et al., (2010) stated that during roasting, several physical changes like weight loss and volume increments take place in coffee beans resulting in the reduction of density. Mwithiga and Jindal (2003) attributed the lowering of density to puffing and an increase in brittleness. In addition, the density of coffee continued to decrease slowly and appeared to level off at the end of the roasting period (Illy & Viani, 1995).

Presence of Fungal Contaminants

The green coffee beans and roasted coffee beans were sampled for the isolation of microorganisms into culture media. The fungal species *Saccharomyces cerevisiae* and *Penicillium* spp. were isolated from the green coffee beans (Table 3). These species were also found in the wet processed Arabica coffee (Basalong et al., 2020) as they are commonly detected and known to facilitate the fermentation process of coffee (Silva et al., 2000; Masoud et al., 2004). No microbial contaminants, however, were found in the RCB. Results imply that roasting eliminated the fungal isolates present in the green coffee beans. In the study for mycoflora of coffee beans in the Philippines, Alvindia and Acda, (2010) reported that the roasting process at 218ºC for 30 minutes decreased the total fungal load in coffee beans by 93-97%. Thus, the result of this study implies that roasting may eliminate or reduce mycotoxin contaminants in coffee beans.

Table 2

Weight Loss and Bulk Density of Roasted Coffee Beans as Affected by the Different Roast Levels

Roast level	Roast Weight Loss (%)	Bulk Density (g/ml)
Light	13.64[c]	0.50[a]
Medium	16.21[b]	0.38[b]
Dark	20.06[a]	0.33[c]
CV (%)	4.1	1.6

Mean values followed by teh same letter in a column are not significantly different at the P<0.05 level

Table 3

Presence of Microbials on the Coffee Beans Subjected to Different Roast Levels

Coffee Beans	Microbial Contaminants
Green Coffee Beans	*Saccharomyces cerevisiae*
Roasted Beans	*Penicillium* sp.
Light	None
Medium	None
Dark	None

Cup Quality

The attributes evaluated in the cup quality, such as fragrance/aroma, flavor, residual flavor/ aftertaste, acidity, body, balance, preference, and sanitary quality of the bean, are important for the acceptance and definition of the bean quality (Feria-Morales, 2002). Under the SCA cupping standard, Arabica coffee with a total score of 80 to 100 is classified as a specialty while below 80 is referred to as below specialty quality or not specialty. Table 4 shows that the highest cupping score (83) was recorded from the medium roast coffee followed by dark roast with 81.75 and light roast with 81. The result indicates that the same coffee sample will vary in sensory characteristics when subjected to different roast levels because, during the roasting process, the coffee beans develop definite organoleptic properties like flavor and aroma that affect the quality of the coffee beverage. Among the roast levels, medium roast coffee scored high in terms of aroma and flavor. Medium roast coffee usually has a sweet balanced cup with good acidity and overall quality (Mwithiga & Jindal, 2007). Meanwhile, dark roast enhanced the body (mouth feel or linked with density and viscosity of the brew) while light roast emphasizes acidity. Acidity indicates the bitter or acidic balance and the presence of sweet caramelic after taste (ITC, 2002; Pertracco, 2000). To bring out these changes, an adequate roast degree is needed for coffee beans to be fragile and breakable, and as such proper grinding for making coffee beverages with pleasant sensory properties (Pittia et al., 2007). Abasanbi (2010), stated that organoleptic or sensory quality is affected by roasting i.e. according to the profile of temperature and length of roasting, the tastes and flavors perceived in the beverage will be different. When assessing cup quality, Prodolliet (2005) indicated that it is important to take into consideration that consumers have specific taste preferences according to their nationality, citing that Germans and Swedish prefer lighter coffee and are more acidic than Italians. Therefore, roasting is one of the very critical procedures in secondary postharvest processing as it could be done to suit one's preference for distinct aromas and flavors of a brew.

Table 4

Cup Quality of Arabica as Affected by Different Roasting Levels

Roast Level	Cupping Score	Notes
Light	81.00	Fruity, honey, soya, tea-like
Medium	83.00	Fruit, honey, muscovado, citrusy
Dark	81.75	Cacao, smoky

Conclusions

The results show that the physical properties of roasted coffee bean changes in terms of dimensions, bean volume, roast volume change, weight loss, and bulk density were affected by the levels of roast. As the level of roast leans towards dark roast, bean volume, roast volume, and weight loss increase. Conversely, lower bulk density ensues as the roast level increases.

Fungal species *Saccharomyces cerevisiae* and *Penicillium* sp. were detected in the green coffee beans, but none were isolated from the different roast levels which imply that roasting could eliminate fungal contaminants. On the other hand, coffee in the three roast levels offered varying sensorial qualities with the medium roast coffee having the highest cupping score than dark and light roasts but still falling under the specialty classification.

Recommendations

Results reveal that roast levels affect the physical properties of Arabica coffee beans; thus, this could be used as a guide for coffee processors in crafting appropriate roasted coffee product packaging designs. Lightly roasted coffee has a lower volume hence, occupies less space in contrast with medium and dark roasted coffee. Meanwhile, freshly roasted coffee is free from fungal contaminants; therefore, it is recommended that coffee be consumed immediately or stored using appropriate packaging materials to avoid contamination. Coffee roasted at different levels offers different sensorial qualities so the level of roast could be used as a guide for processors and consumers to develop the coffee flavor suited to their taste. Meanwhile, further studies on the occurrence of fungal contaminants during storage of roasted coffee beans and a survey of microbial contaminants on locally sold coffee are recommended.

Acknowledgment

The researchers are thankful to the BSU Administration for the funding, the Office of the Vice-President for Research and Extension, and the Office of the Research Services for the administrative support. Likewise, the researchers are very grateful to all the personnel of the Institute of Highland Farming Systems and Agroforestry who provided support during the implementation of the study.

References

Abasanbi, A. (2010). *Assessment of Coffee Quality and Its Related Problems in Jimma Zone of Oromia Regional State*. MSc thesis in Agriculture (Horticulture). 141p. Jimma (Ethiopia): Jimma University. https://cgspace.cgiar.org/handle/10568/2453

Alvindia, D.G., & Acda, M.A. (2010). Mycoflora of coffee beans in the Philippines. *Int. Soc. Southeast Asian Agric. Sci.,* 16: 116-125.

Ameyu, M.A. (2016). Physical Quality Analysis of Roasted Arabica Coffee Beans Subjected to Different Harvesting and Postharvest Processing Methods in Eastern Ethiopia. *Food Science and Quality Management,* 57: 1-9. https://core.ac.uk/download/pdf/234684472.pdf

Basalong, A., Amado, V., & Talbino, H. (2020). Impact of the different postharvest processing methods on the occurrence of Ochratoxin A and cupping quality of Arabica coffee. *Mountain Journal of Science and Interdisciplinary Research*, 80(1): 87-97.

Bustos-Vanegas, J. (2018). Developing predictive models for determining physical properties of coffee beans during roasting process. *Industrial Crops and Products*, 112: 839-845

Clarke, R. (1985). *Green coffee processing*. In: Clifford, M., and Wilson, K. *Coffee botany, biochemistry and production of beans and beverage.* Croom Helm, London. 149-196.

Clifford, M.N. (1985). *Chlorogenic Acids Chap. 5*. In R.J. Clarke & R. Macrae (Eds.), *Coffee volume 1: Chemistry* (pp. 153–202). Amsterdam: Elsevier Applied Science.

Coffee Review. (n.d.) Roast names. https://www.coffeereview.com/coffee-reference/coffee-basics/coffee-language/roast-names/

Culiao, A.L., & Barcelo, J.M. (2015). Fungal and mycotoxin contamination of coffee beans in Benguet Province, Philippines. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*, 32(2): 250-260. https://doi.org/10.1080/19440049.2014.1001796

Department of Agriculture-Cordillera Administrative Region. (2016). *Value chain analysis: Coffee. Department of Agriculture*. Philippine Rural Development Project. Regional Project Coordination Office-Cordillera Administrative Region. Pp. 4-36.

Dinçer, F., Gedik, S., & Guzel, S.O. (2016). New Approach In Gastronomy: Third Wave Coffee. *The Journal of International Social Research*, 9: 811-814.

Dutra, E.R., Oliveira, S., Franca, S., Ferraz, V., & Alfonso, R. (2001). A preliminary study on the feasibility of using the composition of coffee roasting exhaust gas for the determination of the degree of roast. *Journal of Food Engineering,* 47: 241-246.

Franca, A., Mendoca, C., & Oliveira, S. (2005). Composition of green and roasted coffees of different cup qualities. *Food Science and Technology*, 38: 709-715.

Frisullo, P., Delnobile, M., Barnaba, M., Navarini, L., & Suggiliverani, F. (2010). Coffee Arabica beans microstructural changes induced by roasting: An X-Ray Microtographic Investigation. *Proceedings of 23rd International Scientific Conference on Coffee Science (ASIC), Bali, Indonesia*. 553-558.

Frisvad, J., & Samson, R. (2004). Polyphasic taxonomy of *Penicillium subgenus* Penicillium. A guide to identification of food and air-borne terverticillate Penicillia and their mycotoxins. *Studies in Mycology*, 49: 1-174.

Feria-Morales, A.M. (2002). Examining the Case of Green Coffee to Illustrate the Limitations of Grading Systems/Expert Tasters in Sensory Evaluation for Quality Control. *Food Qual. Prefer.,* 13(6), 355–367. https://doi.org/10.1016/S0950-3293(02)00028-9

Illy, A., & Viani, R. (2005). *Espresso coffee: the science of Quality* (2nd Ed.). London: Elsevier Academic Press.

International Trade Center. (2002). *Coffee An exporter's guide*. International Trade Centre UNCTAD/WTO. Geneva. pp. 243-289

Kreger-van Rij, N.J.W. (1984). *The Yeasts: A Taxonomic Study*. Elsevier Biomedical Press, Amsterdam, Holland.

Kurtzman, C., Fell, J., Boekhout, T., & Robert, V. (2011). *Methods for Isolation, Phenotypic Characterization and Maintenance of Yeasts*. Yeasts 5th Edition. https://doi.org/10.1016/B978-0-444-52149-1.00007-0

Lokker, B. (2020). Coffee roasts from light to dark. *Coffee Crossroads*. https://www.coffeecrossroads.com/coffee-101/coffee-roasts-from-light-to-dark

Martini, A., & Martini, A. (1993). A Taxonomic Key for the Genus Saccharomyces. *Systematic and Applied Microbiology*, 16(1): 113-119. https://doi.org/10.1016/S0723-2020(11)80255-9

Masoud, W., Cesar, L.B., Jespersen, L., & Jakobsen, M. (2004). Yeast involved in fermentation of Coffea arabica in East Africa determined by genotyping and by direct denaturating gradient gel electrophoresis. *Yeast,* 21(7): 549-556.

Mekonen, H. (2009). *Influence of Genotype, Location and processing methods on the quality of coffee (Coffee arabica L.)*. An M.Sc. Dissertation, presented to the school of Graduate studies of Hawasa University, Hawasa, Ethiopia. Pp. 42-71

Mendes, C., De Menezes, C., Aparecida, M., & da Silva, A. (2001). Optimization of the roasting of robusta coffee (*C. canephora* conillon) using acceptability tests and RSM. Food Quality Preference, 12, 153-162.

Mwithiga, G., & Jindal, V. (2007). Changes in properties of coffee brew due to roasting. *World Applied Science Journal*, 2(5): 527-535.

Mwithiga, G., & Jindal, V. (2003). Physical changes during coffee roasting in rotary conduction-type heating units. *J. Food Process Engineer*, 26: 543-558.

Noor-Aliah, A., Fareez-Edzuan, A., & Noor-Diana, A. (2015). A review of quality coffee roasting degree evaluation. *Journal of Applied Science and Agriculture*, 10(7): 18-23.

Oksnevad, D. (2019). The differences between 1st, 2nd and 3rd wave coffee. https://www.drivencoffee.com/blog/coffee-waves-explained/

Petracco, M. (2000). *Organoleptic properties of Espresso coffee as influenced by coffee botanical varieties.* In: Sera, T.; Soccol, C.R., Pandey, A. and Roussos, S. (Eds.), *Coffee Biotechnology and Quality*. Kluwer academic Publishers, Dordrecht. pp. 347-355.

Philippine Coffee Board. (2017). *Philippine Coffee Board, Inc. Kape Pilipino – Green Coffee Quality Grading Competition Score Sheet*. http://philcoffeeboard.com/wp-content/uploads/2017/03/kp-results-v3.pdf

Philippine Coffee Quality Competition. (2018). TOP 12: Arabica Category. https://www.facebook.com/phcoffeeQC/

Philippine Information Agency-Cordillera Administrative Region. (2018). Benguet-grown Arabica coffee dominates 2018 Philippine Coffee Quality Competition. *Herald Express.* https://www.baguioheraldexpressonline.com/benguet-grown-arabica-coffee-dominates-2018-philippine-coffee-quality-competition/

Pitt, J.I. (2000). *A laboratory guide to common Penicillium species.* 3rd ed. CSIRO, 197 p.

Pittia, P., Nicoli, M., & Sacchetti, G. (2007). Effect of moisture and water activity on textural properties of raw and roasted coffee beans. *Journal of Texture Studies*, 38: 116-134.

Prodolliet, J. (2005). Coffee *Quality Assurance: Current Tools and Perspectives*. In: *20th International Scientific Colloquium on Coffee*. Bangalore. pp. 120-145

Raper, K.B., & Thom, C. (1949). *A Manual of the Penicillia*. The Williams & Wilkins Company, Baltimore.

Rodrigues, M., Borges, M., Franca, A., Oliveira, L., & Correa, P. (2002). Evaluation of physical properties of coffee during roasting. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Presented at the *ASAE Annual International Meeting/CIGR XVth World Congress*. Chicago, Il.

Silva, C., Schwan, R., Dias, E., & Wheals, A. (2000). Microbial diversity during maturation and natural processing of coffee cherries of Coffea Arabica in Brazil. *Int. J. Food. Microbiol.,* 60: 251–260.

Sualeh, A., Mohammed, A., & E. Solomon. (2014). Processing method, variety, and roasting duration effect on physical quality attributes of roasted Arabica coffee beans. *Sky Journal of Agricultural Research,* 3(5): 53-61.

Thom, C. (1930). *The Penicillia*. The Williams & Wilkins Company, Baltimore.