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COMPARISON OF THE NUTRITIONAL PROPERTIES OF ROASTED NIXTAMALIZED AND NON-NIXTAMALIZED IPB VAR 6 CORN AS COFFEE SUBSTITUTE

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ABSTRACT
Coffee is a widely consumed beverage known for its stimulating and cognitive effects. However, the undesirable effects attributed to its consumption have led to an increased interest in coffee substitutes. Coffee substitutes made from roasted plant materials are gaining popularity due to their distinct flavor profiles and potential health benefits. This study compared the nutritional properties of roasted nixtamalized and non-nixtamalized IPB var 6 corn, a corn variety known for its higher protein quality, tryptophan, and lysine content, as a coffee substitute. Twelve treatments were analyzed to evaluate the effects of nixtamalization on the proximate and mineral content of corn. Based on the results obtained from this study, significantly higher moisture, ash and iron content was obtained from nixtamalized treatments. Although significantly higher crude fiber, crude fat, zinc, and potassium content were observed from non-nixtamalized treatments. The differences in the roasting time and temperature in terms of the nutritional properties of the roasted IPB var 6 corn treatments were also determined. At increased roasting temperature and time, the ash, and mineral content were observed to be higher. While varying effects of different roasting time and temperature to the moisture, crude fat, crude protein, and crude fiber were also observed. The non-nixtamalized roasted at 240°C for 45 min obtained the highest crude fiber, zinc, and potassium content. While Treatment 12 (nixtamalized; 240°C for 45 min) obtained the highest ash, moisture, nitrogen free extract, and iron content.

1.Introduction

Caffeine is a stimulant that provides physical capacity, and cognitive function (Ruxton, 2008). It is one of the most widely consumed compounds in the world and is usually found in common food and beverages like cacao, chocolates, sodas, and tea, as well as coffee (Rodak et al., 2021; Mahoney et al., 2019). Although excessive consumption of caffeine can cause dehydration, headache, anxiety, and sleep disturbances (Ruxton, 2008). Coffee, the most common source of caffeine, is a dark-colored sweet-bitter aromatic beverage brewed from roasted coffee beans (Reyes and Cornelis, 2018; Samoggia and Riedal, 2018). It is considered as a household staple in the Philippines, especially to lower socioeconomic classes. This beverage, due to its caffeine content, provides a stimulating effect to humans and enhances consumers' alertness, vigilance, and cognitive abilities. Previous studies also proved that coffee consumption lowers the risk of having high blood pressure and adult-onset diabetes when consumed moderately (Cornelis, 2019; Anese, 2016). But, since it contains caffeine, side effects such as insomnia, nervousness, nausea, diuresis, and palpitations may be experienced (Cornelis, 2019; Barahona, 2002; Waizenegger et al., 2011). The Food and Drug Administration (FDA) recommends a maximum of 400 milligrams a day of caffeine for healthy adults which is equivalent to 4-5 cups of coffee. Excessive coffee intake can lead to gastroesophageal reflux, palpitations, and hypertension, as well as anxiety and sleep disturbances. Some studies also suggest that frequent coffee consumption can hinder the growth and development of young individuals which may also contribute to long term consequences like kidney-related diseases and anxiety disorders (Torres-Ugalde et al., 2020).

Due to the potential risk of caffeine from drinking coffee, several non-coffee products called coffee substitutes became available which are usually made from ingredients like barley, rice, soybean, and chicory root (Anese, 2016). Coffee substitutes are non-coffee products which mimic the taste of coffee (Mostafa et al., 2021). These substitutes are processed and prepared the same way as coffee, whereas raw materials are roasted, grounded, and brewed (Anese, 2016). Although limited information is available regarding these products, studies should be conducted to evaluate their potential benefits in terms of nutrition, food safety, consumer acceptability and marketability of these beverages.

Corn, as the second most important crop in the Philippines, is used to produce valuable products like starches, syrups, oil, and snacks according to the Philippine Department of Agriculture Regional Field Office 3 (DA-RFO3) utilizing this crop, specifically its kernels in introducing and developing another high value product can be considered since it is easily propagated in the country. IPB var 6 corn, a white flint-type corn variety developed by the Institute of Plant Breeding in the University of the Philippines Los Baños (IPB-UPLB), was used in the recent product developments such as corn flour and rice-corn blends. It is known to have higher protein quality, tryptophan, and lysine content compared with other corn variants (Sunico et al., 2020; Salazar et al., 2016). It is also known for its resistance to lodging and promising ear-fill characteristics. With the mentioned properties of IPB var 6 corn, using it as a raw material to produce a coffee substitute might be considered. Moreover, recent studies also proved that a pre-treatment process called nixtamalization, done by steeping a raw material in an alkaline solution, can increase the quality of the corn. This process also changes the starch properties, improves the protein quality, and increases the bioavailability of calcium, niacin, and iron (Arendt and Zannini, 2013; Suri and Tanumihardjo, 2016). It can also reduce phytic acid levels and aflatoxins present in corn (Guzmán-de-Peña, 2010). With the benefits provided by nixtamalization, it can be reasonable to be used in the production of a corn coffee substitute.

This study focuses and limited on the comparison between roasted nixtamalized and non-nixtamalized IPB var 6 corn in terms of proximate (moisture, crude fat, ash, crude protein, crude fiber, and nitrogen-free extract), and mineral (zinc, potassium, iron, calcium, and magnesium) content. It also focuses and limited on determining the differences of the roasting temperatures (200^{o}C, 220^{o}C, and 240^{o}C) and time (30 and 45 minutes) in each of the mentioned parameters, as well as in determining the treatment that will achieve the highest nutritional properties.

2. Materials and methods

2.1. Raw Materials

Dried IPB var 6 corn kernels was obtained from the Institute of Plant Breeding, University of the Philippines Los Baños (IPB-UPLB). The corn samples were stored in a freezer prior to use in nixtamalization, roasting, and further analyses. The chemical reagents needed for the analyses were analytical grade reagents, while distilled water was used in all experiments unless otherwise specified.

2.2. Place and Time of Study

The nixtamalization and production of roasted nixtamalized and non-nixtamalized IPB var 6 corn was conducted in a kitchen setup in Olongapo City, Philippines. The proximate (moisture, ash, and crude fat) were analyzed in the Institute of Food Science and Technology, University of the Philippines Los Baños (IFST-UPLB). While the total nitrogen, crude fiber, and mineral content analyses were conducted in Department of Agriculture Regional Field Office 3 (DA-RFO3) Regional Feed Chemical Analysis Laboratory (RFCAL) and Regional Soils Laboratory (RSL). All laboratory analyses were done in the year 2022.

Table 1. Roasted nixtamalized and non-nixtamalized IPB var 6 corn treatments

Treatments	Nixtamalization	Time (min)	Temperature (ºC)
Treatment 1	Non-nixtamalized	30	200
Treatment 2			220
Treatment 3			240
Treatment 4		45	200
Treatment 5			220
Treatment 6			240
Treatment 7	Nixtamalized	30	200
Treatment 8			220
Treatment 9			240
Treatment 10		45	200
Treatment 11			220
Treatment 12			240

2.3. Nixtamalization of IPB var 6 corn

The IPB var 6 corn was nixtamalized using an ecological method used by Sunico her colleagues with some modifications. One kilogram of dried IPB var 6 corn was cooked at 95°C for 30 minutes with two liters of distilled water having 1% (w/w) calcium carbonate (Sunico et al., 2020). The cooked grains were steeped in the same solution for 16 hours at room temperature before decanting the liquid. After that, the nixtamalized kernels were dried in an oven- drier at 50-55°C for 12 hours minimum and were packed in sealed polyethylene bags before roasting (Sunico et al., 2020; Rodriguez-Mendez et al., 2013; Das et al., 2016).

2.4. Production of Roasted IPB var 6 Corn Treatments

Different treatments of roasted nixtamalized and non-nixtamalized IPB var 6 corn as shown in Table 1. were produced using a coffee roaster. Then, the roasted kernels were ground using a multi-functional high-speed disintegrator and were packed in a laminated aluminum-polyethylene container per treatment. Each container was stored in a freezer prior to use in the analyses.

2.5. Proximate Analyses

The methods used in obtaining the moisture content, crude protein, crude fat, crude fiber, and nitrogen-free extract content of the roasted IPB var 6 corn treatments were analyzed based on the standard conventional methods in AOAC (2005).

The moisture content was determined using the oven-drying method, whereas approximately 1g of sample was weighed in tared crucibles and placed in an oven at 100 ± 5 °C for at least 5 hrs. Afterward, the crucibles were placed into the desiccator and cooled to room temperature before weighing. The procedure was repeated until the weights of the two previous readings are constant. The percent moisture content (%MC) of the sample was calculated using the percent of the weight loss. For the ash content, the crucibles with the dried samples from the moisture content analysis were placed in a muffle furnace and ignited at 550oC for 5 hrs. Then, the muffle furnace was turned off and cooled overnight. The crucibles were then placed in an oven at 100 ± 5 °C for at least 2 hrs. After that the crucibles were transferred to a desiccator to cool before weighing. The drying procedure was repeated until the weights of the two previous readings are constant. The percent ash content (%Ash) of the sample was calculated using the percent of the weight remaining. The crude fat content was obtained by placing one gram of the sample inside a pre-weighed folded filter paper and dried in an oven at 105 °C for 2 hours and then transferred to a desiccator to cool for 30 mins before weighing. The samples were placed in the extraction chamber of a Soxhlet set-up using petroleum ether as the extracting solvent. The fat in the samples were extracted for 16 hours, after that, the samples were removed from the extraction chamber, air-dried under the fume hood for about 15 minutes, and then transferred inside the oven (100 ± 5 °C) for at least 30 mins. The samples were cooled in a desiccator for 30 mins before weighing. The percent crude fat content (%Crude fat) was calculated using loss in weight. The crude fiber analyses were obtained using the method for crude fiber by ANKOM Technology using filter bags. The samples were weighed and inserted in the filter bags, sealed, and labeled. Before conducting the analysis, the filter bags containing the samples were soaked in petroleum ether for 10 minutes to remove fat. Then the filter bags were air-dried. The air-dried filter bags were inserted in the vessel of the ANKOM crude fiber analyzer, and the extraction of non-fiber components were done automatically. After extraction, the bags were soaked in acetone for 3 to 5 minutes and allowed to be air dried. The air-dried bags were also dried using an oven at 102oC for 2 to 4 hours and cooled for weighing. Percent crude fiber (%Crude Fiber) is calculated using the loss in the weight of the organic matter. The Kjeldahl method was used to obtain the total nitrogen, whereas the crude protein content of the samples was obtained by multiplying a protein factor to the total nitrogen. The sample was weighed and transferred into the Kjeldahl digestion flask. Then a catalyst and concentrated H2SO4 were added. The mixture was digested in the digestion set-up which was heated until it became colorless. The Kjeldahl digestion flask with the digested sample was cooled and transferred into distillation setup. The Kjeldahl flasks were washed with distilled water and the combined washings were transferred to a distillation flask. A receiver flask containing 4% boric acid solution and mixed indicator was placed at the end of the condenser, while 40% NaOH solution was added to the sample in the distillation flask through a valve. The setup was distilled, and the distillate was titrated with 0.1 N standard HCl solution up to the first appearance of faint orange color. A blank titration was done to correct any nitrogen that may be present on the reagents. The total nitrogen of the samples was calculated, as well as the percent crude protein (%Crude Protein) using the protein factor 6.25. Lastly, the percent nitrogen-free extract (%NFE) content of the roasted IPB var 6 corn treatments were calculated by subtracting the %MC, %Ash, %Crude Fat, %Crude Protein, and %Crude Fiber to 100%.

2.5. Mineral Content

The magnesium, iron, calcium, and zinc content analyses of the roasted IPB var 6 corn treatments were obtained using acid digestion and Flame Atomic Absorption Spectroscopy (FAAS) method. While the potassium content of the treatments was obtained using acid digestion and Flame Atomic Emission Spectroscopy

(FAES). The different corn coffee treatments were ashed and dissolved in an acid and were diluted to 50 mL using deionized water. The solutions were measured using Flame Atomic Absorption Spectroscopy (FAAS) at 285 nm, 510 nm, 422 nm, and 213nm for magnesium, iron, calcium, and zinc, respectively. While the potassium content of the IPB var 6 corn coffee treatments were obtained using the same method but using Flame Atomic Emission Spectroscopy at 766 nm.

2.6. Statistical Analyses

The data obtained from the proximate and mineral analyses were statistically treated to determine the differences and significance of the results. The Student's T-test was used to determine significant differences between nixtamalized and non-nixtamalized treatments. Analysis of Variance (ANOVA) and Tukey's Honest Significant Difference (HSD) were used to determine significant differences between the temperature (200°C, 220°C and 240°C), while Student's or Welch's T-test was used to compare the roasting time (30 and 45 minutes).

3.Results and discussions

3.1. Proximate Analyses

Proximate analysis is an analytical system which determines the moisture, ash, crude fat, crude protein, and crude fiber as well as nitrogen-free extract (NFE). It is important because it gives an estimate on the composition of a food product and serves as a basis for nutritional data and government regulation compliance. Table 2. shows the results of the proximate analyses (moisture, ash, crude fat, fiber, total nitrogen, protein, and nitrogen free extract) on the roasted IPB var 6 corn treatments. Generally, significantly higher moisture and ash content were recorded for nixtamalized (Treatments 7 to 12) as compared with the non-nixtamalized (Treatments 1-6) treatments. While most of the non-nixtamalized treatments were found to be significantly higher in terms of crude fiber, and crude fat. Moreover, varying significant differences were observed on the crude protein.

Moisture Content. Moisture content is the measure of the water content in food, unlike water activity, moisture content is the measure of the totality of the water in the product, not just the free or unbound water. Determining the moisture content of a product is important because it can affect the appearance, texture, sensory qualities, consumer acceptability, and shelf-life stability during processing and storage (Saloko et al., 2019). It was observed that the moisture content of the roasted IPB var 6 corn treatments is within the range of 0.167% to 1.650%. It was also observed that most nixtamalized treatments have significantly higher moisture content ($P \leq 0.05$) compared with non-nixtamalized treatments. Moreover, the results show that roasting temperatures 200°C, 220°C, and 240°C are significantly different from each other ($P \leq 0.05$) in terms of moisture content as shown in Figure 1. While, in terms of roasting time, it was observed that nixtamalized treatments roasted at 200°C and non-nixtamalized treatments roasted at 220°C when roasted for 30 minutes have significantly higher moisture content ($P \leq 0.05$) compared when roasted for 45 minutes.

Crude Fat. Crude fat estimates the fat content of a food sample which is done by separation of fat in the food matrix using a non-polar solvent and estimating the fat content using the weight loss. It is an accurate indicator of coffee quality because it contributes to the aroma and flavor of the coffee product (Koshima et al., 2020). Measuring crude fat is important to include in the nutrition label of the product to inform consumers the estimated amount of energy they can acquire from the fat content of the product as well as to comply with the regulations.

Table 2. Proximate composition* of roasted nixtamalized and non-nixtamalized IPB var 6 corn treatments[1].

Proximate composition	Roasting Time (min)[2]	Temperature (ºC)					
		200		220		240	
		Non-nixtamalized	Nixtamalized	Non-nixtamalized	Nixtamalized	Non-nixtamalized	Nixtamalized
Moisture, %	30	1.144 ± 0.193^{b}	1.650 ± 0.127^{aA}	0.622 ± 0.022^{bA}	0.705 ± 0.017^{a}	0.167 ± 0.032^{bB}	0.420 ± 0.094^{aB}
Ash, %		1.461 ± 0.088^{b}	1.491 ± 0.060^{a}	1.433 ± 0.087^{b}	1.535 ± 0.061^{a}	1.434 ± 0.014^{b}	1.544 ± 0.051^{a}
Crude Fat, %		6.986 ± 0.115^{aA}	5.973 ± 0.143^{bA}	6.383 ± 0.103^{a}	5.714 ± 0.129^{bA}	6.298 ± 0.095^{aA}	5.536 ± 0.105^{bA}
Crude Protein, %		9.13 ± 0.13^{b}	9.63 ± 0.19^{a}	9.00 ± 0.06^{aB}	9.00 ± 0.06^{a}	9.50 ± 0.19^{aA}	8.88 ± 0.13^{b}
Crude Fiber, %		3.7 ± 0.2^{a}	3.2 ± 0.3^{b}	3.6 ± 0.4^{aB}	4.0 ± 0.3^{a}	4.9 ± 0.3^{aB}	4.4 ± 0.2^{b}
NFE, %		77.6	78.1	79.0	79.0	77.7	79.2
Moisture, %	45	1.153 ± 0.087^{b}	1.451 ± 0.054^{aB}	0.176 ± 0.019^{bB}	0.634 ± 0.077^{a}	0.496 ± 0.027^{bA}	1.292 ± 0.177^{aA}
Ash, %		1.441 ± 0.017^{b}	1.513 ± 0.099^{a}	1.438 ± 0.031^{b}	1.551 ± 0.042^{a}	1.448 ± 0.017^{b}	1.592 ± 0.047^{a}
Crude Fat, %		6.217 ± 0.116^{aB}	3.984 ± 0.195^{bB}	6.166 ± 0.171^{a}	3.827 ± 0.112^{bB}	5.569 ± 0.197^{aB}	3.317 ± 0.124^{bB}
Crude Protein, %		8.94 ± 0.13^{b}	9.56 ± 0.19^{a}	9.50 ± 0.19^{aA}	8.88 ± 0.13^{b}	9.13 ± 0.13^{aB}	8.75 ± 0.13^{b}
Crude Fiber, %		4.2 ± 0.4^{a}	3.5 ± 0.2^{b}	4.3 ± 0.4^{aA}	3.8 ± 0.3^{a}	6.1 ± 0.3^{aA}	4.7 ± 0.3^{b}
NFE, %		78.0	80.0	78.4	81.3	77.3	80.3

** In each row, results are mean ± SD of triplicate analysis except for NFE.*

[1] Mean ± SD followed by different small letters within rows represent significant differences between nixtamalized and non-nixtamalized treatments (P ≤0.05) compared using Student's T-test.

[2] Mean ± SD followed by different capital letters within columns represent significant differences between 30 and 45 minutes of roasting time (P ≤0.05) compared using Welch's or Student's T-test. NFE- nitrogen free extract.

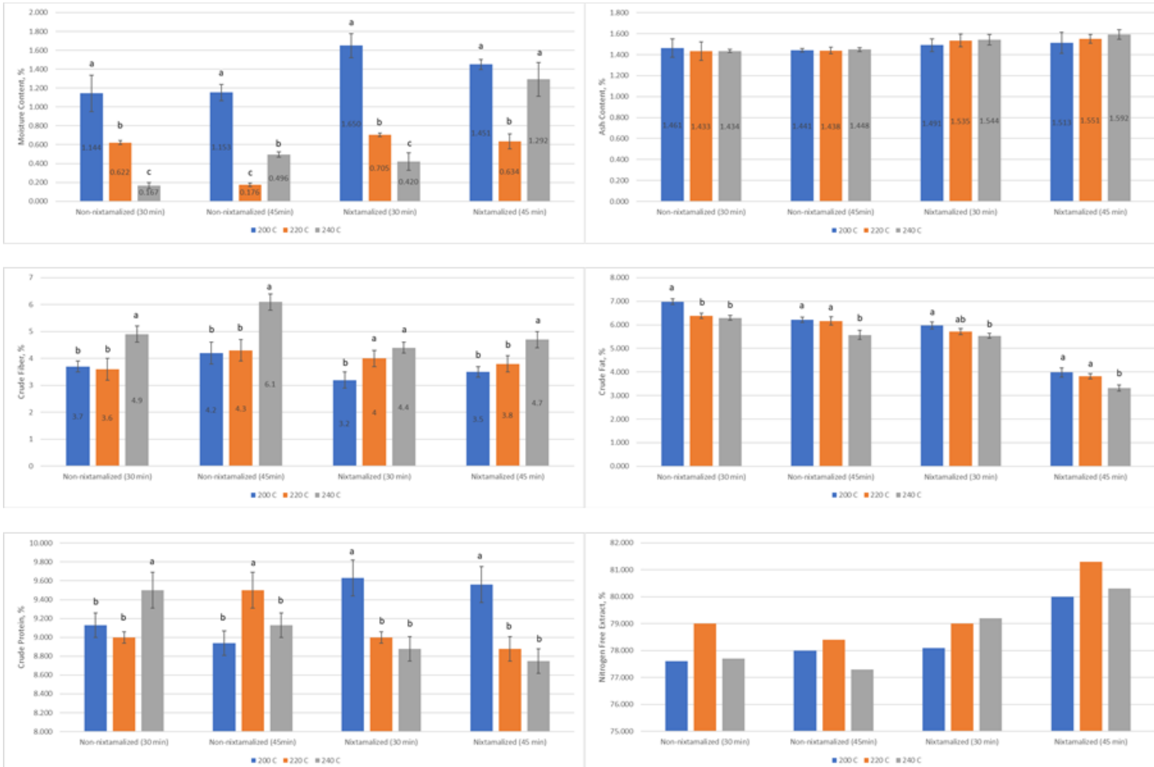

Figure 1. Proximate composition of roasted nixtamalized and non-nixtamalized IPB var 6 corn treatments. Different small letters represent significant differences between roasting temperatures 200°C, 220°C and 240°C (P ≤0.05) compared using ANOVA and Tukey's HSD.

The crude fat content of the roasted IPB var 6 corn treatments ranges from 3.317 to 6.986 % as shown in Table 2. It was observed that non-nixtamalized treatments have significantly higher (P≤0.05) crude fat content compared with the nixtamalized treatments. The data also shows that roasting temperatures 200°C, 220°C, and 240°C have varying significant differences from each other (P≤0.05) in terms of crude fat as shown in Figure 1, whereas higher crude fat was observed on treatments roasted at 200°C. In terms of roasting time, results show that most of the treatments roasted for 30 minutes have significantly higher crude fat (P≤0.05) than the treatments roasted for 45 minutes.

Ash Content. The ash content is the estimate of the mineral content and other inorganic materials in a food. The ash content of food sample is done by igniting it in a muffle furnace to vaporize water and volatile substances and convert organic matter into carbon dioxide and water, whereas the remaining substance is referred as the ash which is composed of mineral oxides, sulfates, phosphates, chlorides, and silicates (Ismail, 2017). The ash content of the roasted IPB var 6 corn treatments ranges from 1.433% to 1.592%, as is shown in Table 2. All the nixtamalized treatments have significantly higher ash content (P≤0.05) compared with the non-nixtamalized treatments. While no significant differences were observed between the roasting time (P>0.05) and temperatures (P>0.05) in terms of ash content as shown in Figure 1.

Crude Protein. Crude protein analysis is used to estimate the protein composition of a food product, known methods used are Kjeldahl and Dumas that measures the total nitrogen of a product and a protein conversion factor is used to obtain the crude protein value (Chang and Zhang, 2017). Similar to crude fat, measuring crude protein is important to include in the nutrition label of the product to inform consumers the estimated amount of energy they can acquire from the protein content of the product as well as to comply with the regulations. Using the conversion factor of 6.25, the crude protein was found to be at a range of 8.88 to 9.63%, whereas varying significant differences (P≤0.05) were found between nixtamalized, and non-nixtamalized roasted corn treatments as shown in Table 2. The crude protein of nixtamalized treatments at 200°C was significantly higher (P≤0.05) than non-nixtamalized treatments. While at 220°C and 240°C, it was observed that most of the non-nixtamalized treatments have significantly higher crude protein (P≤0.05). In terms of the roasting temperatures, 200°C, 220°C, and 240°C have varying significant differences from each other (P≤0.05) as shown in Figure 1. The results also show that non-nixtamalized treatments roasted at 240°C have significantly higher crude protein (P≤0.05) when roasted for 30 minutes compared with 45 minutes. While non-nixtamalized treatments roasted at 220°C have significantly higher crude protein (P≤0.05) when roasted for 45 minutes.

Crude Fiber. The crude fiber content estimates the indigestible carbohydrates in food. It involves continuous extraction of food samples using hot sulfuric acid and hot sodium hydroxide solutions leaving some residues that are the crude fiber content of the food sample. Crude fiber is also important to include in the nutrition label of the product to inform consumers the estimated amount of fiber they can acquire from the product as well as to comply with the regulations. It is referred to as the type of dietary fiber that remains as a residue after acid and alkali treatment. It is also known to help in digestion and serve as a prebiotic material for bacterial growth in the gut. The crude fiber content of the roasted IPB var 6 corn treatments ranges from 3.2% to 6.1% as shown in Table 2. Most of the non-nixtamalized treatments have significantly higher crude fiber (P≤0.05) compared with nixtamalized treatments. The results also show that roasting temperatures 200°C, 220°C, and 240°C have varying significant differences from each other (P≤0.05) in terms of crude fiber as shown in Figure 1, whereas higher crude fiber was observed on treatments roasted at 240°C. In terms of roasting time, results show that non-nixtamalized treatments roasted at 220oC and 240°C have significantly higher crude fiber (P≤0.05) when roasted for 45 minutes compared with 30 minutes.

Nitrogen Free Extract. Nitrogen free extract (NFE) is a rough estimate of the carbohydrate content of a product which was obtained by subtracting the sum of the percentages of moisture, crude protein, crude fat, crude fiber, and ash from 100. It refers to the non-fibrous carbohydrates in a food material which is composed mostly of simple sugars and starches. Nitrogen free extract results of roasted IPB var 6 corn treatments are shown in Table 2. which ranges from 77.3 to 81.3%.

3.2. Mineral Content

The determination of mineral content is important in determining the nutritional value of a food product, as well as to determine if the food product has mineral components that comply with regulations (Ward and Legako, 2017). Table 3. shows the potassium, zinc, iron, calcium, and magnesium content of the roasted IPB var 6 corn treatments. A general observation is that significant differences between nixtamalized and non-nixtamalized treatments are found in terms of potassium, zinc, and iron content. While there were no significant differences in terms of magnesium and calcium content.

Zinc. Zinc, even though the human body needs only small amounts, has a huge role especially in enzymatic and other biochemical reactions in the human body. It also has an important role in DNA and cell functions, protein building, tissue regeneration, and the immune system. It was observed that the zinc content of the roasted IPB var 6 corn treatments ranges from 29.31 to 44.72 ppm, where the non-nixtamalized treatment roasted at 240°C for 45 minutes obtained the highest value. It was also observed that non-nixtamalized treatments have significantly higher zinc ($P \leq 0.05$) compared with nixtamalized treatments as shown in Table 3. Moreover, in terms of roasting time, it was observed that treatments roasted for 45 minutes obtained significantly higher zinc ($P \leq 0.05$) than the treatments roasted for 30 minutes. In terms of roasting temperature, no significant differences ($P > 0.05$) between 200°C, 220°C, and 240°C were observed on non-nixtamalized treatments roasted for 30 minutes. Although, in other treatments higher zinc content was obtained from treatments roasted at 240°C as shown in Figure 2.

Potassium. Potassium is an important essential mineral needed by the body to function; one of its roles is maintaining the fluid balance inside our cells. It was observed that the potassium content of roasted IPB var 6 corn treatments ranges from 0.22 to 0.38 %. It was also observed that significantly higher potassium content ($P \leq 0.05$) was obtained from non-nixtamalized treatments compared with nixtamalized treatments as shown in Table 3. In terms of roasting temperatures, no significant differences ($P > 0.05$) between 200°C, 220°C, and 240°C were observed on nixtamalized treatments. Although higher potassium content was observed from non-nixtamalized treatments roasted at 240°C as shown in Figure 2.

Iron. Iron is known to be an important component of hemoglobin in blood that carries oxygen around the body. It was observed that the iron content of roasted IPB var 6 corn treatments ranges from 26.06 to 36.11 ppm, and the majority of the nixtamalized treatments have significantly higher ($P \leq 0.05$) iron compared with the non-nixtamalized treatments as shown in Table 3. It was also observed that treatments roasted for 45 minutes obtained significantly higher iron ($P \leq 0.05$) than the treatments roasted for 30 minutes. The data also shows that roasting temperatures 200°C, 220°C, and 240°C are significantly different from each other ($P \leq 0.05$) in terms of iron as shown in Figure 2, whereas higher iron was observed on treatments roasted at 240°C.

B var 6 corn treatments ranges from 0.04 to 0.05 %, although no significant differences were observed in the calcium contents of roasted nixtamalized and non-nixtamalized treatments as shown in Table 3. Moreover, no significant differences were observed from the roasting time ($P > 0.05$) and temperatures ($P > 0.05$) as shown in Figure 2.

Magnesium. Magnesium plays an important role in several enzymatic reactions in the body, as well as other processes such as protein building, maintenance of the bones, regulation of blood sugar and pressure, and muscle and nerve functions. It was observed that the magnesium content of roasted IPB var 6 corn treatments ranges from 0.04 to 0.06 %, and that there are no significant differences ($P > 0.05$) between the roasted nixtamalized and non-nixtamalized IPB var 6 corn treatments in terms of magnesium content as shown in Table 3. It was also observed that treatments roasted for 45 minutes obtained significantly higher magnesium ($P \leq 0.05$) than the treatments roasted for 30 minutes, while no significant differences were observed from the roasting temperatures ($P > 0.05$) as shown in Figure 2.

3.3. Effects of Ecological Nixtamalization on the Roasted IPB var 6 Corn Treatments

Nixtamalization is a well-known pre-treatment for milled corn products. This process involves cooking and steeping corn in an alkaline solution, softening its pericarp, and altering the grain structure releasing the bound nutrients (Sunico et al., 2020, Wacher, 2003). Studies show that nixtamalization enhances the nutritional value of corn not only the protein quality, but also increases the amounts of calcium and niacin bioavailability, reduction of phytic acid levels, and increases iron digestibility and bioavailability (Suri and Tanumihardjo, 2016). This process is also known to eliminate 97% to 100 % of aflatoxins from grains contaminated with mycotoxin (Guzmán De Peña, 2010).

Table 3. Mineral composition* of roasted nixtamalized and non-nixtamalized IPB var 6 corn treatments[1].

Mineral	Roasting Time (min)[2]	Temperature (°C)					
		200		220		240	
		Non-nixtamalized	Nixtamalized	Non-nixtamalized	Nixtamalized	Non-nixtamalized	Nixtamalized
Zinc, ppm	30	30.93 ± 0.05[aB]	29.31 ± 0.04[bB]	31.08 ± 0.48[aB]	30.97 ± 0.30[aB]	31.13 ± 0.59[aB]	31.08 ± 0.03[aB]
Potassium, %		0.30 ± 0.02[a]	0.24 ± 0.02[b]	0.35 ± 0.01[a]	0.24 ± 0.01[b]	0.36 ± 0.01[aB]	0.25 ± 0.01[b]
Iron, ppm		26.06 ± 0.02[bB]	26.40 ± 0.01[aB]	26.95 ± 0.43[aB]	27.02 ± 0.07[aB]	27.49 ± 0.01[bB]	29.45 ± 0.02[aB]
Calcium, %		0.04 ± 0.01[a]	0.05 ± 0.01[a]	0.04 ± 0.01[a]	0.05 ± 0.01[a]	0.04 ± 0.01[a]	0.05 ± 0.01[a]
Magnesium, %		0.04 ± 0.01[a]	0.05 ± 0.02[a]	0.04 ± 0.01[aB]	0.05 ± 0.02[a]	0.05 ± 0.02[a]	0.06 ± 0.01[a]
Zinc, ppm	45	31.58 ± 0.28[aA]	31.20 ± 0.05[bA]	39.29 ± 0.12[aA]	35.11 ± 0.08[bA]	44.72 ± 0.14[aA]	42.53 ± 0.03[bA]
Potassium, %		0.33 ± 0.02[a]	0.22 ± 0.01[b]	0.34 ± 0.01[a]	0.23 ± 0.01[b]	0.38 ± 0.01[aA]	0.23 ± 0.02[b]
Iron, ppm		30.60 ± 0.02[bA]	30.97 ± 0.03[aA]	31.53 ± 0.05[bA]	34.04 ± 0.01[aA]	35.12 ± 0.02[bA]	36.11 ± 0.01[aA]
Calcium, %		0.04 ± 0.01[a]	0.05 ± 0.02[a]	0.04 ± 0.01[a]	0.05 ± 0.01[a]	0.04 ± 0.01[a]	0.05 ± 0.02[a]
Magnesium, %		0.05 ± 0.01[a]	0.06 ± 0.01[a]	0.06 ± 0.01[aA]	0.06 ± 0.01[a]	0.06 ± 0.02[a]	0.06 ± 0.01[a]

** In each row, results are mean ± SD of triplicate analysis.*

[1] Mean ± SD followed by different small letters within rows represent significant differences between nixtamalized and non-nixtamalized treatments (P ≤0.05) compared using Student's T-test.

[2] Mean ± SD followed by different capital letters within columns represent significant differences between 30 and 45 minutes of roasting time (P ≤0.05) compared using Welch's or Student's T-test.

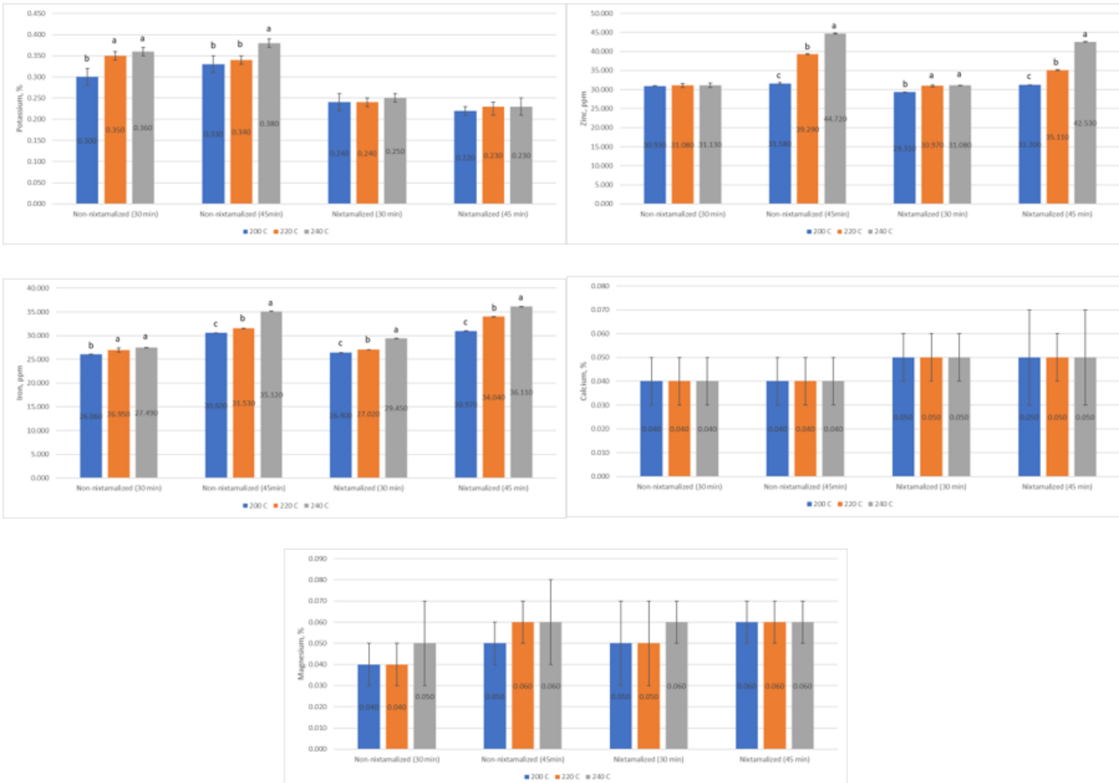

Figure 2. Mineral composition of roasted nixtamalized and non-nixtamalized IPB var 6 corn treatments. Different small letters represent significant differences between roasting temperatures 200°C, 220°C and 240°C (P ≤0.05) compared using ANOVA and Tukey's HSD.

Other than traditional and classical method, one way of nixtamalizing a product is by ecological nixtamalization, which makes use of calcium salts like food grade calcium carbonate, in this type of nixtamalization changes in the nutritional and functionality of corn is more observed. The effects of ecological nixtamalization on the nutrient content, mineral content, antioxidant, and phytochemical properties of nixtamalized and non-nixtamalized roasted IPB var 6 corn treatments were determined as shown in Table 2 and Table 3.

Generally, various advantages and disadvantages of nixtamalization were observed on the treatments. Considering the process of nixtamalization, whereas the dried IPB var 6 corn kernels were introduced to an aqueous solution containing calcium carbonate, and having it cooked and steeped, there is a partial gelatinization that occurred and have altered the intrinsic properties of the kernels including its water retention capacity.

This explains why the results show that most of the nixtamalized treatments obtained significantly higher moisture content (P≤0.05) than non-nixtamalized treatments. While the incorporation of calcium carbonate during nixtamalization may have contributed to the higher ash content of the roasted nixtamalized IPB var 6 corn treatments. For crude fat content, the results show that non-nixtamalized treatments have significantly higher (P≤0.05) crude fat content compared with nixtamalized treatments, which agrees with the study of Maureen et al. (2020). It is possible that during the steeping process some organic compounds including crude fat from the kernels have seeped out to the aqueous solution which was discarded after the nixtamalization process. On the other hand, the nixtamalization process also has a decreasing effect on the crude fiber content of the roasted IPB var 6 corn kernels, which can be explained by the partial degradation of the seed coat of the kernels, leaving a higher percentage for the other components. The varying significant differences between the crude protein of nixtamalized and non-nixtamalized treatments has been observed to be different with each roasting parameter. Hence, nixtamalization may not be the only step in the whole process that influences the crude protein content.

In terms of mineral content, the results suggest that nixtamalization has a lowering effect on the potassium and zinc content of the roasted IPB var 6 corn kernels. According to some studies, the steeping step during nixtamalization contributes to the significant losses in the zinc and potassium content of the corn during processing which can explain the results (Sunico et al., 2020; Bressani et al., 2002; Morales and Zepeda, 2017). Unlike what was observed on the potassium and zinc content, the iron content of the nixtamalized roasted IPB var 6 corn kernels are higher than the non-nixtamalized treatments. Based on Similarly, Sunico and her colleagues (2020), observed nixtamalization had influenced the increase in the iron concentration, whereas they explained that it is due to the removal of the pericarp on the corn kernels leaving the endosperm and the germ, which are the parts of a kernel with high iron concentration. Contrary to earlier studies about nixtamalized products, no significant differences were observed in the calcium contents of roasted nixtamalized and non-nixtamalized treatments. One possible reason for this is that the limitation of the equipment used in the analysis, whereas limited significant figures were obtained which is not enough to have a significant difference between nixtamalized and non-nixtamalized treatments even though the numerical values are higher on the nixtamalized treatments. Another reason is possible losses of calcium carbonate during the steps in production such as decantation, drying, roasting, and grinding. The same possible reasons were also sought to explain the results for the magnesium content, which results show that nixtamalized and non-nixtamalized treatments are not significantly different from each other.

3.4. Differences of Roasting Time and Temperature in terms of the Nutritional of the Roasted IPB var 6 Corn Treatments

During roasting, different chemical reactions like Maillard reaction, caramelization, and pyrolysis are favored giving distinctions in chemical, physical, and sensory properties of coffee and coffee substitutes (Anese, 2016). The differences of roasting time and temperature in terms of the nutritional parameters of the Roasted IPB var 6 Corn Treatments were shown in Figure 1. and Figure 2. In the present study, it was observed that the moisture content of the treatments has a decreasing trend at increasing roasting temperature and time. Although all treatments roasted at 240^{o}C, a higher temperature, were observed to have a significantly higher moisture content when roasted for 45 minutes compared with treatments roasted at lower roasting time and temperature. Theoretically, it is expected that the moisture content of the treatments roasted at higher temperature and longer time are lower, which was observed on most of the results except for some treatments mentioned. A possible reason for the observed phenomenon is the changes in the intrinsic properties of the corn kernels, specifically hygroscopicity when roasted at very high temperatures (Nakilcioğlu-Taş and Ötleş, 2019). While the roasting time and temperatures were not observed to have an influence on the ash content of treatments, which disagrees with the previous studies. According to Saloko and his colleagues (2019), the ash content increases during roasting because the non-mineral components such as moisture, fat, protein, fiber, and carbohydrates decrease during processing. The observed increase in the ash content from the previous studies might not be observed in the present study due to the limited range of the roasting time and temperatures used. In terms of crude fat, crude protein, and crude fiber the results shows that roasting temperatures 200ºC, 220ºC, and 240ºC have varying significant differences from each other (P≤0.05), hence the effect of roasting temperature on crude fat and crude protein cannot be established. For the roasting time, results show that most of the treatments roasted for 30 minutes have significantly higher crude fat (P≤0.05) than the treatments roasted for 45 minutes. In the study conducted by Oboh and his colleagues (2010), roasting have led to an increase of the crude fat in corn kernels, which they have discussed to be caused by the break down the bonds between the fat and matrix, releasing the oil reserve more efficiently. Unlike the present study, the corn kernels in the study of Oboh and his colleagues (2010) were roasted at a lower temperature (120ºC to 130ºC). It is possible that crude fat content in the present study might have volatized during the roasting, which may be the reason why crude fat was observed to decrease at increasing roasting time and temperature. From the same study, they also have observed that roasting can cause a significant decrease in the crude protein and crude fiber content of corn (Oboh et al., 2010). Although, the effect of roasting time for crude protein and crude fiber in the present study cannot be also established due to varying significant differences observed.

In terms of mineral content, the results show that roasting for a longer time led to a higher zinc, potassium, magnesium, and iron content of the treatments. Based on the study of Oboh and his colleagues (2010), significant increase in the mineral content like calcium, sodium, magnesium, and zinc were observed after roasting the corn. Although it was observed from the present study that roasting temperature has no effect on the zinc, potassium, and magnesium content. Moreover, unlike what was observed by Oboh and his colleagues (2010), it was observed from the present study that there is an increasing amount of iron content when the roasting temperature is increased as observed. In terms of calcium there was no significant differences were observed from the roasting time (P>0.05) and temperatures (P>0.05), which does not agree with the previous studies (Oboh et al., 2010).

3.3. Ideal Roasting Time and Temperature of Roasted IPB var 6 Corn Treatments each Parameter

The nutritional properties of roasted nixtamalized and non-nixtamalized IPB var 6 corn treatments varies on each parameter. In terms of proximate analyses, highest ash (1.592%), moisture (1.292%), and nitrogen free extract (80.3%) was obtained from Treatment 12 (nixtamalized; 240ºC for 45 min), although this treatment also obtained the lowest crude fat and crude protein. While Treatment 1 (non-nixtamalized; 200ºC for 30 min) and Treatment 5 (non-nixtamalized; 240ºC for 45 min) obtained the highest crude fat (6.986%) and crude fiber (6.1%), respectively. Treatment 7 (nixtamalized; 200ºC for 30 min), on the other hand obtained the highest crude protein (9.63%). For mineral content, Treatment 5 stood out in terms of zinc (44.72 ppm) and potassium (0.38%), while Treatment 12 obtained the highest iron (36.11 ppm). Nixtamalized treatments (Treatment 7 to 12) obtained the highest calcium content (0.05%). Moreover, the highest magnesium content was also obtained from nixtamalized treatments which ranges from 0.05% to 0.06%. In terms of antioxidant and phytochemical properties of roasted nixtamalized and non-nixtamalized IPB var 6 corn treatments.

4. Conclusions

Coffee is one of the most popular and widely consumed beverages globally due to its stimulating and cognitive effects. However, undesirable effects attributed to its consumption, such as palpitations and sleep disturbances, have led to increased interest in coffee substitutes. Coffee substitutes made from roasted plant materials are gaining popularity due to their distinct flavor profiles and potential health benefits, including cereal-based coffee substitutes. The effects of ecological nixtamalization on the nutrient content, mineral content, antioxidant, and phytochemical properties of roasted IPB var 6 corn treatments were determined. Based on the results obtained from this study, in terms of nutrient content, significantly higher moisture, ash and iron content was obtained from nixtamalized treatments. Although significantly higher crude fiber, crude fat, zinc, and potassium content were observed from non-nixtamalized treatments. The differences in the roasting time and temperature in terms of the nutritional properties of the roasted IPB var 6 corn treatments were also determined. At increased roasting temperature and time, the ash, and mineral content were observed to be higher. While varying effects of different roasting time and temperature to the moisture, crude fat, crude protein, and crude fiber were also observed. The non-nixtamalized roasted at 240°C for 45 min (Treatment 5) obtained the highest crude fiber (6.1%), zinc (44.72 ppm), and potassium (0.38%) content. While Treatment 12 (nixtamalized; 240°C for 45 min) obtained the highest ash (1.592%), moisture (1.292%), nitrogen free extract (80.3%), and iron (36.11 ppm). For crude fat and crude protein, the highest results were obtained from Treatment 1 (non-nixtamalized; 200°C for 30 min) (6.986%) and Treatment 7 (nixtamalized; 200°C for 30 min) (9.63%), respectively. Moreover, nixtamalized treatments (Treatment 7 to 12) obtained the highest calcium content (0.05%). Moreover, the highest magnesium content was also obtained from nixtamalized treatments which ranges from (0.05% to 0.06%).

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