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Impact of roasting temperature on the chemical composition and quality of avocado seed flour [*Persea americana* Mill.]

Pengaruh suhu pemanggangan terhadap komposisi kimia dan kualitas tepung biji alpukat [*Persea americana* Mill.]

Rifni Novitasari*, Tuty Anggraini, Hasbullah, Dini Hervani

Graduate School of Agricultural Sciences, Postgraduate Studies, Universitas Andalas, Padang 25163, Indonesia

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*Corresponding author
E-mail: rifniliya@gmail.com

ABSTRACT

Avocado seeds (*Persea americana* Mill.) are an underutilized agricultural byproduct with significant starch content, making them a potential raw material for flour production. Roasting is a key processing method that enhances drying efficiency and improves sensory attributes. This study investigates the impact of roasting temperature (120°C, 130°C, 140°C, and 150°C) on the chemical composition and quality of avocado seed flour (ASF). The experiment was conducted using a completely randomized design (CRD) with three replications. Proximate analysis and tannin content were determined through standard laboratory methods. Data were analyzed using analysis of variance (ANOVA) followed by the least significant difference (LSD) test. The results indicate that the optimal roasting temperature for ASF is 150°C, yielding the following composition: moisture content (5.47±0.76%), tannin content (0.0723±0.0004%), protein content (1.66±0.033%), carbohydrate content (86.45±0.91%), fat content (2.08±0.23%), and ash content (4.34±0.03%). Higher roasting temperatures resulted in lower moisture and tannin levels, which are beneficial for improving ASF quality. This study provides valuable insights into optimizing roasting conditions for ASF production, enhancing its potential application in food processing.

ABSTRAK

Biji alpukat (*Persea americana* Mill.) merupakan limbah pertanian yang kurang dimanfaatkan, tetapi memiliki kandungan pati yang signifikan sehingga berpotensi digunakan sebagai bahan baku tepung. Pemanggangan atau *roasting* merupakan metode pengolahan utama yang dapat meningkatkan efisiensi pengeringan serta memperbaiki sifat sensoris tepung. Penelitian ini bertujuan untuk mengevaluasi pengaruh suhu *roasting* (120°C, 130°C, 140°C, dan 150°C) terhadap komposisi kimia dan kualitas tepung biji alpukat (TBA). Percobaan dilakukan dengan rancangan acak lengkap (RAL) dengan tiga kali ulangan. Analisis proksimat dan kadar tanin dilakukan menggunakan metode laboratorium standar. Data dianalisis menggunakan analisis sidik ragam (ANOVA) dan uji beda nyata terkecil (BNT). Hasil penelitian menunjukkan bahwa suhu roasting optimal untuk TBA adalah 150°C dengan komposisi sebagai berikut: kadar air (5.47±0.76%), kadar tanin (0.0723±0.0004%), kadar protein (1.66±0.033%), kadar karbohidrat (86.45±0.91%), kadar lemak (2.08±0.23%), dan kadar abu (4.34±0.03%). Semakin tinggi suhu roasting, semakin rendah kadar air dan tanin, yang berkontribusi pada peningkatan kualitas TBA. Penelitian ini memberikan wawasan penting dalam mengoptimalkan kondisi roasting untuk produksi TBA serta memperluas potensinya dalam industri pengolahan pangan.

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INTRODUCTION

Indonesia ranks as the fourth-largest producer of avocados (*Persea americana* Mill.) globally, following Mexico, Colombia, and Peru. According to the Central Bureau of Statistics (Badan Pusat Statistik [BPS], 2024), Indonesia produced approximately 874,046 tons of avocados in 2023. However, despite increasing avocado production, appropriate processing technologies for avocado waste, particularly seeds, remain underdeveloped. Avocados are commonly consumed in Indonesia as beverages, such as avocado juice, or as toppings for salads, bread, or fruit-based pizzas. The waste generated from avocado processing, particularly seeds and peels, presents an opportunity for valorization into new products with competitive economic value.

Avocado seeds can be processed into oil, herbal teas, composite flour, and avocado seed flour (ASF). Composite flour incorporating ASF has been explored as an alternative ingredient in various flour-based food products, such as butter cakes (Yusuf & Paramita, 2019; Violita, 2021), donuts (Sari, 2019), brownies (Adisty et al., 2020), bread (Aldila & Hariyani, 2023; Oktaviani & Ulilalbab, 2020), noodles (Azalia, 2021; Ganefati et al., 2022), and biscuits (Prambandita et al., 2022). Additionally, ASF has been used in the formulation of herbal beverages resembling coffee, combining ASF with coffee, palm sugar, or coconut water (Novitasari, 2020). Such products can be consumed as either hot or cold beverages.

Traditional drying methods of ASF, such as sun drying and low-temperature oven drying, is often limited by the presence of anti-nutritional factors, browning reactions, and bitterness. Avocado seeds contain various anti-nutritional compounds, including phytates, oxalates, glycosides, tannins, phytic acid, and alkaloids, which can negatively affect the nutritional quality and sensory properties of ASF (Bahru et al., 2019). Several processing techniques, such as soaking, peeling, cooking, fermentation, germination, and steaming, have been explored to reduce these undesirable components (El-Suhaibani et al., 2020). These methods aim to enhance the nutritional profile and acceptability of ASF by mitigating the impact of anti-nutritional factors.

Tannins, which are abundant in avocado seeds, contribute significantly to bitterness and browning reactions, ultimately reducing the acceptability of ASF-based products. During processing, tannins undergo both enzymatic oxidation and non-enzymatic reactions, such as Maillard reactions and caramelization, which alter ASF's color and flavor (Novitasari, 2020). Malangngi et al. (2012) reported that avocado seeds contain tannin concentrations as high as 117 mg/kg, which can lead to excessive bitterness and dark coloration in derived food products, thereby limiting their application in bakery and flour-based formulations. Prambandita et al. (2022) further highlighted the need for processing techniques that effectively control tannin levels to enhance the sensory quality of ASF.

Drying is a crucial step in ASF processing, with roasting being one of the most effective methods. Roasting has long been utilized for coffee processing, with optimal roasting temperatures ranging from 200°C (Pamungkas et al., 2021) to 220°C (Heriana et al., 2023). Higher roasting temperatures generally result in darker coloration and a more pronounced aroma due to the formation of volatile compounds. This process involves the degradation of phenolic compounds, sugars, trigonelline, free amino acids, and non-enzymatic browning reactions (Bahru et al., 2019). However, natural sun drying, which is traditionally used for ASF, is highly dependent on weather conditions, leading to inconsistencies in final product quality. Controlled roasting is advantageous as it improves sensory attributes while also reducing microbial contamination and toxin levels (Sruthi et al., 2021).

Lidi et al. (2021) developed ASF by slicing avocado seeds, drying them at 60°C for six hours, and grinding them into fine powder. Recent studies have explored roasting as an alternative drying method for ASF, particularly in the production of avocado seed-based beverages resembling coffee. Roasting at 160°C has been reported to produce dark brown ASF with a strong roasted aroma (Pușcaș et al., 2022). The optimal roasting temperature for ASF as a beverage ingredient ranges between 180°C for 25–30 min and 200°C for five min, yielding dark brown flour with a distinctive roasted flavor. However, excessively dark coloration and an overly strong roasted aroma may not be suitable for ASF intended for use in bakery products, noodles, or composite flour formulations.

While previous studies have examined high-temperature roasting conditions for ASF as a coffee substitute, limited research has been conducted on moderate roasting temperatures (120–150°C) aimed at producing ASF suitable for bakery and food applications. No studies have specifically focused on optimizing roasting conditions to minimize tannin content while preserving ASF's functional properties for composite flour production. This study aims to determine the optimal roasting temperature (120–150°C) for ASF by evaluating its effects on moisture content, tannin levels, proximate composition, and overall quality. The findings will contribute to refining ASF processing techniques, making it more suitable for bakery applications and flour-based formulations. This study provides a novel approach to optimizing moderate roasting temperatures for ASF production, ensuring improved functional properties suitable for bakery and flour-based applications.

MATERIALS & METHODS

Materials and equipment

Fresh avocado seeds (*Persea americana* Mill.) were collected from juice outlets in Padang, Indonesia. Sodium chloride and sodium metabisulfite were used as treatment agents (purity $\geq$ 99.9%). Chemical reagents used for compositional analysis were of analytical grade and obtained from PT. Smart Lab Indonesia. Drying was conducted using a Gene Café roaster (Model CBR 101A), and proximate analysis was performed using standard Association of Official Analytical Chemists (AOAC) methods. A UV-Vis spectrophotometer (Shimadzu UV-1800, Japan) was used for tannin analysis, while fat content was determined using a Soxhlet extraction apparatus (VELP Scientifica, Italy).

Sample preparation and pre-treatment

The avocado seeds were cleaned and boiled for 30 min before being thinly sliced and soaked in boilded water again. The soaking process lasted for three days to allow spontaneous fermentation, aimed at reducing bitterness caused by tannins while also mitigating acidity and enzymatic browning, which could impact the quality of the resulting ASF. Following the initial soaking, the samples underwent additional pre-treatment by kneading with fine salt and further soaking. Based on preliminary research findings, a 10% sodium chloride solution was used for 30 min to enhance the reduction of bitterness and browning reactions. To further prevent browning, the avocado seed slices were immersed in a 3,000 ppm sodium metabisulfite solution for 45 min. This step was intended to inhibit enzymatic browning reactions and preserve the flour's sensory properties.

Experimental design

This study employed a completely randomized design (CRD) with four levels of roasting temperature treatments: 120°C (T1), 130°C (T2), 140°C (T3), and 150°C (T4). After roasting, the sliced avocado seeds were reduced in size using a grinder and sieved through a 60-mesh sieve. Each treatment was conducted in triplicate, resulting in a total of 12 experimental units. The effects of roasting temperature on ASF were evaluated based on moisture content, tannin content, protein content, carbohydrate content, fat content, and ash content. The data were analyzed using Analysis of Variance (ANOVA), and significant differences between treatments were determined using the least significant difference (LSD) test at significance levels of $p<0.05$ and $p<0.01$.

Moisture content analysis

The moisture content of ASF was determined using the oven-drying method (AOAC 925.09) (AOAC, 2019). An empty crucible was cleaned, dried in a hot air oven at 105°C for 30 min, and then cooled in a desiccator for 15 min before weighing (W_0). A sample of 3–5 g of ASF was placed in the crucible and weighed (W_1). The sample was oven-dried at 105°C, with intermittent weighing every hour until a constant weight was obtained (W_2), which was defined as a weight change of ≤0.2 g between measurements. The moisture content was calculated using the following formula (Yenrina, 2015; Syukri, 2021):

$$\text{Moisture content (\%)} = \frac{W_1-(W_2-W_0)}{W_1} \times 100 \quad (1)$$

Tannin content analysis

Tannin content was quantified using UV-Visible spectrophotometry at 278 nm (Fajrina et al., 2016; Ryanata et al., 2015). A 1,000 ppm standard tannin solution was prepared by dissolving 50 mg of dry extract in 70% ethanol. A 10 ppm test solution was obtained through serial dilution, and absorbance was measured at 278 nm using a spectrophotometer.

Protein content analysis

The protein content was determined using the Kjeldahl method (AOAC 960.52) (AOAC, 2019), and the percentage of nitrogen was calculated using the following formula:

$$\text{Nitrogen (\%)} = \frac{(V_{\text{HCl sample}} - V_{\text{HCl blank}}) \times N_{\text{HCl}} \times 14{,}007}{\text{Sample weight (mg)}} \times 100\% \quad (2)$$

where V is the volume of HCl used in titration, N is the normality of HCl, and 14.007 is the molecular weight of nitrogen. If the sample was diluted before titration, a dilution factor (*Fp*) was applied accordingly. The protein content was then determined by multiplying the nitrogen content by the protein conversion factor.

Fat content analysis

Fat content was determined using Soxhlet extraction (AOAC 963.15) (Ariani et al., 2024). A 10 g sample (W_1) was placed in a pre-dried and weighed Soxhlet extraction flask (W_2). The sample was extracted with 250 mL n-hexane for 6 h. The solvent was then evaporated, and the remaining fat was dried at 105°C for 3 h before weighing (W_3). The fat content was calculated using the following equation:

$$\text{Fat content (\%)} = \frac{W_3-W_2}{W_1} \times 100 \quad (3)$$

Ash content analysis

Total ash content was determined following AOAC 923.03 (Yenrina, 2015). A cleaned and pre-dried crucible was weighed (W_0). 3–5 g of ASF was placed in the crucible and weighed (W_1), then incinerated in a muffle furnace at 550°C until a constant weight was obtained. The final weight (W_2) was recorded, and the ash content was calculated using:

$$\text{Ash content (\%)} = \frac{W_2-W_0}{W_1-W_0} \times 100 \quad (4)$$

Carbohydrate content analysis

The carbohydrate content was calculated using the by-difference method (AOAC, 2019) (Yenrina, 2015; Syukri, 2021), as follows:

$$\text{Carbohydrate (\%)} = 100 - (\text{\%Moisture} + \text{\%Ash} + \text{\%Protein} + \text{\%Fat}) \quad (5)$$

RESULTS & DISCUSSIONS

Moisture content

Moisture content is a crucial factor influencing the shelf life and stability of food products. A higher moisture content generally corresponds to a shorter shelf life due to increased susceptibility to microbial growth and spoilage. Conversely, lower moisture content enhances the longevity of food products, making proper processing and storage essential (Prasetyo et al., 2019). As discussed in the introduction, ASF-based composite flour is intended to be used as an alternative ingredient for flour-based food products, particularly wheat flour, which is commonly used in food processing. Therefore, the proximate composition of ASF, including its moisture content, was compared to the standard for wheat flour as specified in SNI No. 3751 (Badan Standardisasi Nasional [BSN], 2009) regarding wheat flour for food applications.

Table 1. Moisture, tannin, and protein content of ASF at different roasting temperatures

Treatment	Moisture content (%)	Tannin content (%)	Protein content (%)
T150	5.47±0.76 ^{A}	0.0723±0.0004 ^{A}	1.66±0.33 ^{a}
T140	9.93±0.42 ^{B}	0.0747±0.0008 ^{B}	2.32±0.34 ^{b}
T130	10.21±0.60 ^{BC}	0.0760±0.0006 ^{BC}	2.32±0.33 ^{b}
T120	11.83±0.60 ^{C}	0.0767±0.0007 ^{C}	2.65±0.01 ^{b}

Note. Numbers followed by the same superscript letters indicate no significant difference at the 5% level or no highly significant difference at the 1% level.

Roasting is a known processing method that effectively reduces the moisture content of food materials (Mazaheri et al., 2019). As shown in Table 1, an inverse relationship was observed between roasting temperature and moisture content. At the highest roasting temperature of 150°C, the moisture content of ASF decreased to 5.47±0.76%, indicating that higher roasting temperatures accelerate water evaporation. This finding aligns with the results of Corrêa et al. (2016), who reported that increasing roasting temperature leads to greater moisture loss due to the evaporation of water. Additionally, a higher temperature gradient between the heating medium and the food material enhances heat transfer, thereby expediting moisture removal through evaporation.

These findings are further supported by Tenyang et al. (2021), who studied the roasting process in sunflower seeds (*Helianthus annuus* L.) and concluded that moisture reduction during roasting is primarily attributed to dehydration caused by increased temperature under dry roasting conditions. Similar results have been reported in studies on different seeds, including watermelon seeds (*Citrullus lanatus*) (Gholami & Ansari, 2021), sesame seeds (*Sesamum indicum* L.) (Ahmed et al., 2021), and dates (*Phoenix dactylifera* L.) (Fikry et al., 2019), all of which demonstrated significant moisture reduction following roasting.

The moisture content of ASF at 150°C (5.47±0.76%) was notably lower than the moisture limit established for wheat flour under SNI No. 3751 (BSN, 2009), which is 14.5%. This lower moisture content enhances the quality and stability of ASF, as reduced water activity inhibits microbial growth, prevents undesirable odors, and maintains the functional properties of the flour. Consequently, the lower moisture content of ASF produced at higher roasting temperatures may contribute to its suitability as a functional ingredient in food formulations.

Tannin content

Tannin content significantly influences the taste, color, and overall quality of food products. By determining tannin levels, it is possible to regulate and ensure that ASF meets the desired quality standards. As shown in Table 1, the highest tannin content was observed at a roasting temperature of 120°C (0.0767±0.0007%), and it progressively decreased as the roasting temperature increased. The lowest tannin content was recorded at 150°C (0.0723±0.0004%), indicating that higher roasting temperatures contribute to tannin degradation. The optimal ASF obtained at 150°C exhibited the lowest tannin concentration, making it more suitable for flour-based applications. A high tannin content in flour can result in brown to dark brown coloration (Prambandita et al., 2022) and contribute to a bitter taste (Malangngi et al., 2012).

Thus, tannin content was inversely correlated with increasing roasting temperature. According to Hagerman (2011), tannins belong to the polyphenol group and function as natural antioxidants. However, exposure to high temperatures, such as during drying or roasting, can lead to decomposition and reduction of tannins. This observation is further supported by Sekarini (2011), who reported that tannins contain epigallocatechin gallate, a flavonoid compound recognized as one of the strongest antioxidants alongside quercetin in the flavanol group. These tannin components undergo significant chemical changes when subjected to high temperatures. Moreover, Ezegbe et al. (2023) emphasized that roasting is more effective in reducing anti-nutritional factors, particularly tannins, compared to prolonged cooking methods.

Protein content

Measuring the protein content of ASF is essential for ensuring the quality and nutritional value of the final product. It also helps optimize composite flour formulations for specific flour-based processed products based on their protein percentage. Protein content plays a crucial role in determining the texture, taste, and functional properties of flour. As presented in Table 1, protein content decreased as the roasting temperature increased. Roasting at 140°C, 130°C, and 120°C resulted in statistically non-significant differences in protein content, with values of 2.32±0.34%, 2.32±0.33%, and 2.65±0.01%, respectively. When compared to the minimum protein requirement for wheat flour (7%) as per SNI No. 3751 (BSN, 2009), the protein content in ASF was significantly lower. The optimal roasting temperature for maximizing protein content was 120°C.

In general, roasting temperature influences the protein composition and structure of ASF by inducing chemical reactions that modify its components, including proteins. When avocado seeds are heated, protein undergoes structural changes due to thermal processing. However, the impact of roasting on protein content depends on multiple factors, such as roasting temperature, duration, application, and the specific avocado seed variety used. Higher roasting temperatures tend to denature proteins, altering their structural integrity and potentially affecting their biological activity (Dularia et al., 2024; Wijaya & Yuwono, 2015). Protein denaturation disrupts its three-dimensional structure, influencing its functionality and properties. However, it does not necessarily reduce the total protein content in the material. Some analytical methods may inaccurately measure protein in its denatured state, leading to underestimated values in certain cases.

Alibas et al. (2021) reported similar findings, highlighting that high temperatures negatively impact nutritional composition, resulting in lower protein and nutrient content in dried materials compared to fresh ones. Furthermore, Ezegbe et al. (2023) demonstrated that roasting, despite its shorter processing time, reduces protein content more effectively than prolonged cooking methods. Their study on velvet bean (*Mucuna pruriens*) indicated that higher roasting temperatures and extended roasting durations significantly decreased protein content. This finding is particularly relevant in optimizing roasting conditions for ASF to prevent excessive browning caused by the formation of Amadori compounds (1-amino-1-deoxy-2-ketose) in the early stages of the Maillard reaction (Corzo-Martínez et al., 2014; Gupta et al., 2022). Conversely, lower roasting temperatures or more conservative processing methods can preserve a significant portion of the protein content, although some degree of protein denaturation remains inevitable.

Fat content

Fat analysis in ASF is not only essential for determining its nutritional value but also for maintaining its quality and ensuring food safety. Fat content is closely related to the thiobarbituric acid (TBA) value, where a lower TBA value indicates minimal lipid oxidation, preventing undesirable effects on flavor, aroma, and food safety. Fat plays a significant role in determining texture, taste, and softness in food products. Therefore, analyzing the fat content of ASF is crucial in ensuring that it meets the desired functional properties for specific food applications.

As shown in Table 2, increasing the roasting temperature had no significant effect on fat content in ASF. The fat content remained relatively stable across the different roasting treatments, with only slight variations between 1.89% (at 120°C) and 2.08% (at 150°C). According to Matin et al. (2017), the apparent increase in fat content during roasting may be attributed to the reduction in moisture content, which results in a higher fat concentration on a dry-weight basis. Furthermore, the roasting process causes a minor loss of volatile lipid compounds, which contribute to aroma formation (Pamungkas et al., 2021). Wahyuni et al. (2020) also noted that roasting can enhance the perceived fat content due to the concurrent decrease in moisture levels.

Table 2. Average carbohydrate, fat, and ash content of ASF at different roasting temperatures

Treatment	Fat content (%)	Ash content (%)	Carbohydrate content (%)
T120	1.89±0.05	3.76±0.31 ^{A}	79.90±0.27 ^{A}
T130	1.90±0.06	4.26±0.02 ^{B}	81.33±0.22 ^{AB}
T140	1.91±0.03	4.32±0.03 ^{B}	81.52±0.80 ^{BC}
T150	2.08±0.23	4.34±0.03 ^{B}	86.45±0.91 ^{D}

Note. Numbers followed by the same superscript letters indicate no highly significant difference at the 1% level.

The lowest fat content was recorded at 120°C (1.89±0.05%), while the highest fat content was found at 150°C (2.08±0.23%). According to Melis and Delcour (2020), the typical fat content of wheat flour ranges from 2.0% to 3.0%. The ASF fat content observed in this study (1.89–2.08%) closely aligns with the fat content of wheat flour, indicating its potential suitability as a wheat flour alternative. Flours with high fat content (>3%) may be more prone to lipid oxidation, leading to off-flavors and rancidity. Conversely, flours with very low fat content (<0.5%) may result in products with suboptimal texture and mouthfeel. The fat content of ASF across different roasting temperatures remained within an acceptable range, maintaining its functional and sensory qualities for food applications.

Ash content

Ash content represents the residual mineral components left after the combustion of organic matter. The total ash content of a material depends on its intrinsic mineral composition. As presented in Table 2, the highest ash content was recorded at 150°C (4.34%), whereas the lowest was observed at 120°C (3.76%). Statistical analysis using the Least Significant Difference (LSD) test indicated that roasting at 130°C, 140°C, and 150°C did not result in statistically significant differences in ash content. However, the ash content at 120°C was significantly lower than that at 130°C, 140°C, and 150°C. This trend suggests that roasting generally increases ash content, which is likely associated with the reduction in moisture content and subsequent concentration of minerals in ASF.

The increase in ash content is strongly correlated with the mineral content in avocado seeds. This observation is supported by Riansyah et al. (2013), who reported that higher drying temperatures and longer drying durations tend to increase ash content. Similarly, Tenyang et al. (2021) demonstrated an inverse relationship between moisture content and ash content during the roasting of sunflower seeds (*Helianthus annuus* L.). Their study found that ash content increased progressively at roasting temperatures of 60°C, 80°C, 100°C, and 120°C for 30 min, with the highest ash content recorded at 120°C. A comparable trend was also observed in the study by Harivaindaran et al. (2023) on roasting cumin seeds, confirming that mineral concentration increases as moisture content decreases. The high ash content in ASF further indicates the presence of essential minerals, reinforcing its potential as a nutrient-dense flour alternative.

Carbohydrate content

Carbohydrates, particularly starch, serve as a primary energy source and play a crucial role in determining the texture and structure of food products. Starch contributes to gel formation, thickening, and binding of ingredients, making it essential in bread, cakes, and other processed flour-based foods. Carbohydrates are also key participants in caramelization and the Maillard reaction, two chemical processes that occur when food is heated, significantly influencing color, aroma, and flavor. During the drying process of pretreated, sliced avocado seeds, moisture loss has notable effects on the proximate composition of ASF. In general, the reduction in water content increases the relative concentration of carbohydrates, fats, and ash in the resulting flour. As shown in Table 2, the highest carbohydrate content was recorded at 150°C (86.45±0.91%), while the lowest was observed at 120°C (79.90±0.27%). The increase in roasting temperature corresponded to a higher carbohydrate concentration, which was also visually indicated by a progressive color change from light brown to darker brown as roasting intensity increased.

Lower roasting temperatures and shorter roasting durations do not fully promote caramelization (Heriana et al., 2023). In contrast, roasting at 150°C leads to sucrose dehydration and its subsequent conversion into caramel compounds, which are responsible for caramel formation. Gupta et al. (2022) found similar results, describing the caramelization process as the thermal degradation of carbohydrate-containing substances, particularly sugars. Their study indicated that when sugars are exposed to dry heat, they begin to melt at around 160°C and undergo structural transformation. The melted sugars gradually develop a brown coloration and form caramelized sugar, with heat extracting water from the sugar molecules, leading to the formation of furfural derivatives and the onset of browning and flavor development.

Roasting temperature plays a critical role not only in caramelization but also in the Maillard reaction, which involves the interaction between carbohydrates, particularly reducing sugars, and amino acids. This reaction is responsible for the formation of brown pigments and the characteristic aroma of various roasted and baked products, including ASF (Wronkowska et al., 2016; Taş & Gökmen, 2017; Lin et al., 2016; Berk et al., 2019; Bhinder et al., 2019). Roasting for 30 min has been reported to achieve an optimal balance between the Maillard reaction, antioxidant activity, and nutritional quality (Wronkowska et al., 2016). Furthermore, Taş & Gökmen (2017) highlighted that roasting at 150°C for a shorter duration provides the best balance between Maillard reaction intensity, caramelization, and nutritional retention in the final product.

As shown in Table 2, the highest carbohydrate content (86.45±0.91%) was obtained at a roasting temperature of 150°C. Avocado seed flour falls into the category of non-available carbohydrates, meaning it contains a high amount of dietary fiber, particularly indigestible fiber that resists enzymatic digestion in the human gastrointestinal tract. Flour with high non-available carbohydrate content typically exhibits a low glycemic index, making it a potentially healthier alternative to conventional flour. Non-available carbohydrates include resistant starch and dietary fiber, which are not digested or absorbed in the small intestine for immediate energy supply (Afandi et al., 2019).

CONCLUSIONS

This study demonstrated that roasting temperature significantly influences the physicochemical properties of ASF, particularly its moisture, tannin, protein, fat, ash, and carbohydrate content. Higher roasting temperatures resulted in a lower moisture and tannin content, contributing to improved stability and sensory attributes of ASF. However, an increase in roasting temperature also led to protein denaturation, which may impact its functional properties. Fat content remained relatively stable across different roasting temperatures, while ash content increased due to mineral concentration following moisture reduction. The highest carbohydrate content (86.45 ± 0.91%) was observed at 150°C, correlating with caramelization and the Maillard reaction, which influenced color, flavor, and overall acceptability. From a nutritional and functional perspective, the optimal roasting temperature for ASF depends on its intended application. A roasting temperature of 150°C yielded the best balance between moisture reduction, tannin degradation, and carbohydrate enhancement, making ASF a potential alternative to wheat flour. Additionally, the presence of non-available carbohydrates (dietary fiber and resistant starch) suggests that ASF may be a healthier, low-glycemic index ingredient suitable for food formulations. Future studies should explore the functional applications of ASF in various food systems, particularly in baking and gluten-free formulations. Further investigation into the sensory characteristics, storage stability, and bioavailability of its nutrients will enhance its potential as a sustainable and value-added ingredient in the food industry.

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