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Morphological, proximate, and bioactive compound characteristics of three local avocado (*Persea americana*) varieties from Solok District, West Sumatra, Indonesia

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Abstract. *Novitasari R, Anggraini T, Hasbullah, Hervani D. 2025. Morphological, proximate, and bioactive compound characteristics of three local avocado (*Persea americana*) varieties from Solok District, West Sumatra, Indonesia. Biodiversitas 26: 5360-5370.* This study compares the morphological characteristics, proximate composition, and bioactive compound content of three local avocado (*Persea americana*) varieties from Solok District, West Sumatra: Mega Merapi, Mega Paninggahan, and Mega Gagauan. The methods used include exploratory research for morphological observations with 30 samples per variety. In addition, chemical analysis was conducted using the Completely Randomized Design (CRD) method with three replications. The variables observed were proximate, total sugar, tannin, and phenol. Data processing was carried out using Analysis of Variance (ANOVA) and continued with the Least Significant Difference (LSD) test. The results showed that Mega Gagauan had the most significant fruit weight (480.66 g) and fruit flesh (382.69%), as well as the highest water content (72.95%) and fat (4.79%) in the fruit seeds. The fruit flesh of this variety contains the highest carbohydrate (10.64%), fat (6.61%), and ash content (1.03%), with a low water content (81.02%). In comparison, Mega Paninggahan has a fruit height (12.44 cm) and seed weight (64.98 g) that are superior to the other two varieties, with carbohydrate content (27.84%), protein (1.91%) and ash content (1.28%) in the fruit seeds and protein (2.10%) in the fruit flesh that are higher than the other two varieties. Mega Merapi stands out with the highest water content (85.65%), polyphenol (102.64 mgGAE/g), and total sugar (20.60%) in the fruit flesh, while the fruit seeds contain tannin (0.61%) and polyphenol (943.45 mgGAE/g). Differences in peel color, texture, and flesh color were also found between varieties. These findings confirm significant variation in morphology, proximate composition, and bioactive compounds, which can inform the selection of superior varieties for consumption and inspire creative product development from avocado flesh and seeds.

Keywords: Avocado flesh, avocado seeds, bioactive compounds, local avocado, proximate

INTRODUCTION

Avocado (*Persea americana* Mill.) is a tropical fruit of high economic and nutritional value, rich in MUFA, fiber, vitamins (such as vitamins E, C, K, and B complex), minerals (potassium, magnesium), and phytochemicals such as polyphenols, carotenoids, and phytosterols (Dreher and Davenport 2013; Duarte et al. 2016; Bhuyan et al. 2019; Dreher et al. 2021), thus being recognized as a “superfood” with health benefits (Salazar-López et al. 2020; Nguyen et al. 2022; Lyu et al. 2023; Marra et al. 2024; Zapata-Luna et al. 2025), including lowering LDL, increasing HDL, and supporting cardiovascular health and circulation (Dreher and Davenport 2013; Duarte et al. 2016; Dreher et al. 2021). Avocados contain antioxidants, anti-inflammatory compounds, unsaturated fatty acids, fibre, and phytonutrients that prevent degenerative diseases, support skin health, and aid vitamin absorption (Tremocoldi et al. 2018; Bhuyan et al. 2019; Jimenez et al. 2020; Salazar-López et al. 2020; Cervantes-Paz and Yahia 2021; Ochoa-Zarzosa et al. 2021; Bangar et al. 2022; Agunloye et al. 2025; Zapata-Luna et al. 2025). Avocado oil also benefits skin health, aiding the absorption of fat-soluble vitamins and potentially preventing age-related eye diseases (Cervantes-Paz and Yahia 2021). With a complete nutritional profile, avocados are recommended as part of a healthy diet, such as a Mediterranean or low-saturated fat diet (Dreher and Davenport 2013; Duarte et al. 2016; Bhuyan et al. 2019; Dreher et al. 2021; Fleming et al. 2025), as their benefits arise both from their bioactive content and their interactions with other foods (Fulgoni et al. 2013; Dreher et al. 2021; Clarke et al. 2024; Sirirat et al. 2024; Fleming et al. 2025).

Avocados have high functional value; the flesh can be consumed directly or processed into healthy foods, bakery products, beverages, supplements (Jimenez et al. 2020; Salazar-López et al. 2020; Marra et al. 2024; Olas 2024), and oil for the food, pharmaceutical, and cosmetic industries thanks to its antioxidants, healthy fatty acids, and phytochemicals (Cervantes-Paz and Yahia 2021; Marra et al. 2024). Its extract is also used in skin care products due to its antioxidant properties and ability to improve hydration and elasticity (Marra et al. 2024; Yeoh et al. 2024). Meanwhile, avocado seeds have potential as a functional food ingredient (flour, powder, or additive), a natural preservative, an anti-inflammatory and anti-ageing cosmetic ingredient, and a source of starch for environmentally friendly bioplastics (Bangar et al. 2022; Siol and Sadowska 2023; Charles et al. 2022; Kupnik et al. 2023).

Solok Regency is a local avocado centre with high genetic diversity, divided into six accession groups (Yanto et al. 2024). Three of them have been designated as local superior varieties: Mega Paninggahan, Mega Gagauan, and Mega Merapi. These varieties have differences in fruit morphology that affect their nutritional content and bioactive compounds (Ge et al. 2017; Huaman-Alvino et al. 2021; Zapata-Luna et al. 2025).

Morphological diversity of naturally crossed avocados affects cultivation, harvest age, and nutrient content of each variety (Muralidhara et al. 2023; Martínez-Damián et al. 2025), including Mega Gagauan, Mega Merapi, and Mega Paninggahan (Ihsan et al. 2023). Genetic factors are a significant determinant of nutritional composition, such as proximate, mineral, and bioactive (Ge et al. 2017; Ford et al. 2023; Nasri et al. 2023; Yang et al. 2024; Martínez-Damián et al. 2025). However, fruit quality is also affected by the growing environment, harvest season, and agro-climatic conditions (Ge et al. 2017; Huaman-Alvino et al. 2021; Nguyen et al. 2022). which cause significant variations in the content of macronutrients, fatty acids, and mineral nutrients (Ge et al. 2017; Zanata et al. 2023; López-Hoyos et al. 2024; Tapia-Vargas et al. 2024).

Cultivation practices (planting density, fertilisation, irrigation, and sustainable agriculture), postharvest (drying or heating methods), and processing affect the quality and nutritional content of avocados (Viera et al. 2023: Ford et al. 2023). On the other hand, peels and seeds as waste have the potential to be utilised as a source of phenolic compounds and have high antioxidant activity, thus becoming a potential raw material for the food and health industry (Araújo et al. 2018; Salazar-López et al. 2020). Therefore, it is important to characterise the morphology, proximate composition, and bioactivity of local varieties to support the optimal utilisation of avocados in food and industry.

MATERIALS AND METHODS

Raw materials, reagents, and instruments

The main ingredients in this study were avocados from the Mega Gagauan variety (Parumahan Bawah Village, Paninggahan Village), Mega Paninggahan (Kampung Tangah Village, Paninggahan Village), and Mega Murapi (Muara Pingai Village), which were obtained from Lower Housing, Paninggahan Village in Muara Pingai Village, Junjung Sirih Sub-district, Solok District, West Sumatra, Indonesia. The materials used in the TBA chemical analysis include: NaCl, $Na_2S_2O_5$, CH_3COOH, H_3BO_3, NaOH, HCl, K_2SO_4, HgO, and H_2SO_4.

The tools used are analytical scales, analytical ovens, cups, desiccators, crucibles/Soxhlet extraction clamps, cool boxes (Marvel Coolers), rotary evaporators, Shimadzu 1800 UV VIS Spectrophotometers (Kyoto, Japan), and Colorflex EZ Colorimeters (Reston, Virginia, USA). 60 mesh sieves; porcelain mortars with a diameter of 16 cm; Kjedahl flasks, Erlenmeyer flasks, blenders, 1 L beakers, centrifuges, heaters, furnaces, and aluminum foil packaging or standing pouches measuring 10 × 17 cm. The chemicals and laboratory tools were obtained from the Agricultural Product Technology Laboratory of Universitas Andalas, which was procured in collaboration with PT. Smart Lab Indonesia is in South Tangerang City, Banten Province, Indonesia.

Sample preparation

Avocado fruit from three varieties, Mega Merapi, Mega Paninggahan, and Mega Gagauan, was selected by choosing healthy and uniform physiologically ripe fruit. Each fruit was cleaned of dirt, and then the total weight of the fruit was measured using a precision digital scale. Next, the fruit was carefully split to separate the flesh, seeds, and peel. Each part (flesh, seeds, peel) was weighed separately to obtain specific weight data for each component. Measurements of fruit height and diameter were carried out using a digital caliper, with the height measured from the base to the tip of the fruit, and the diameter was measured at the widest part of the fruit. The fruit, seeds, flesh, and peel volume can be measured using the water displacement method or calculated based on the ellipsoid volume formula with fruit length and diameter parameters. All morphological data were meticulously and systematically recorded for each variety, thus enabling comparative analysis of physical characteristics between varieties (International Plant Genetic Resources Institute 1995; OECD 2020). This procedure is important to ensure accurate morphological data and can be used to select superior varieties and develop avocado-based products.

Experimental design

This research is divided into exploratory research, measuring and observing the morphology of avocado fruit varieties, with 30 samples. Data are calculated as the average and±standard deviation. For proximate content (water, protein, fat, ash, and carbohydrate content), total sugar, tannin content, and phenol content were analyzed using a Completely Randomized Design (CRD) method with three replications. The variables observed were proximate content, total sugar, tannin, and phenol. Data processing was carried out using Analysis of Variance (ANOVA) and continued with the Least Significant Difference (LSD) test, with the following analysis method;

Water content analysis

An empty, cleanly washed cup is heated in an oven for 30 minutes at 105°C. Then, the cup is cooled in a desiccator for ±15 minutes. The cup is then weighed as W0. The cup is filled with 3-5 g of flesh or fruit seeds, then W_1 symbolizes the weight of the weighed flesh or fruit seeds. The cup containing flesh or fruit seeds is then oven-baked every 1 hour at a temperature of 105°C (± about 3 to 4 hours of oven-baking). Every 1 hour of oven-baking, the cup is removed from the oven, put in a desiccator for 30 minutes, and then weighed. This procedure is continued until a constant weight is obtained (after oven-baking, the weight obtained is ±0.2 g from the previous oven-baked weight). This constant weight is symbolized by W_2 (Alissa et al. 2020; Syukri 2021).

$$\text{Water content } \% = \frac{W1-(W2-W0)}{W1} x\ 100\% = \frac{W1-(W2-W0)}{W1} x\ 100\%$$

Protein content analysis

Flesh or fruit seeds' protein content analysis was performed using the Kjeldahl method. A total of 0.5 g of flesh or fruit seeds extract was placed in a Kjeldahl flask, added with 1 g of selenium mix and 15 mL of H_2SO_4, then digested until clear (±3 hours). After cooling, the solution was diluted in a 100 mL volumetric flask. A total of 10 mL was taken for distillation after adding 30 mL of 50% NaOH. The distillate was collected in 10 mL of 3% boric acid containing methylene red:blue (3:1) indicator, with the tip of the apparatus submerged. Distillation was carried out until the color changed to green (±15 minutes), then titrated with 0.02 N HCl until the color returned to purplish red (Rivera-González et al. 2019; Emelike et al. 2020; Syukri 2021).

$$\text{N } \% = \frac{(mL\ HCl\ test\ material - mL\ HCl\ blank)\ x\ N\ HCl\ x\ Fp\ x\ 14{,}007}{\text{weight of test material (mg)}} X100\%$$

% Protein = %N × protein conversion factor

Fat content analysis

A 10 g sample (W1) was weighed on filter paper and placed into a Soxhlet tube. The fat flask was dried at 105-110°C for 1 hour, cooled in a desiccator, then weighed (W2) and connected to the Soxhlet tube. Extraction was done using 250 mL of n-hexane and three boiling stones for 6 hours. Afterwards, the flask was oven-dried for 3 hours at 105°C, cooled, and weighed to a constant weight (W3). Fat content was calculated based on the weight difference (Ariani et al. 2024).

$$\text{Fat content } (\%) = \frac{W3-W2}{W1} X100$$

Ash content analysis

The ashing crucible was dried in a furnace for 15 minutes, cooled in a desiccator, and then weighed (W0). A 3-5 g sample of flesh or fruit seeds was weighed along with the crucible (W1), then burned until smoke-free. Ashing was carried out at 400°C and 550°C until the ash was grey or at a constant weight. After cooling in a desiccator, the crucible was weighed again (W2) (Yenrina 2015).

$$\text{Ash content calculation } (\%) = \frac{W2-W0}{W1-W0} \times 100$$

Carbohydrate analysis

Carbohydrate levels were analysed using the carbohydrate content by difference method using the formula (Yenrina 2015; Landhäusser et al. 2018):

Carbohydrate content (%) = 100 - (% water+% ash+% protein + % fat)

Total phenol analysis

A 0.5 mL flesh or fruit seeds extract was pipetted (V), then 4.5 mL of distilled water and 1 mL of Folin-Ciocalteu reagent were added, then shaken and left for 8 minutes. After that, the solution was added with 4 mL of 10% Na_2CO_3 solution and distilled water until the volume reached 10 mL, shaken again, and incubated for 2 hours at room temperature. Absorbance measurements were carried out at a wavelength of 766 nm using a UV-Vis spectrophotometer. The gallic acid standard curve equation calculated the total phenolic content using the absorbance value (Kurniawan and Rahmat 2023).

$$\text{Total phenolics} = \frac{(\text{Phenolic concentration x Extract volume (mL) x Dilution factor})}{\text{Sample weight}}$$

Total sugar analysis

Avocado seed or avocado flesh was analyzed using the anthrone-sulfuric acid method: 1 mL of sample extract was added to 5 mL of anthrone solution, homogenized, and then heated in a water bath at 100°C for 10 minutes. After cooling, the absorbance was measured at a wavelength of approximately 620 nm using a UV-Vis spectrophotometer, and the results were calculated based on a standard glucose calibration curve (Septiaji et al. 2017).

Tannin analysis

Tannin analysis in avocado seed or avocado flesh was carried out by extracting avocado seeds or avocado flesh using ethanol solvent, then tannin levels were measured quantitatively using the UV-Vis spectrophotometry method with tannic acid as a standard (Basri et al. 2023; Putri and Marybeth Tri 2024; Wardatun et al. 2025; Nugrahani et al. 2025). The extraction process used the maceration method with 96% ethanol for 72 hours, then the extract results were tested qualitatively using $FeCl_3$ reagent to ensure the presence of tannin, and quantitatively by measuring the absorbance at a wavelength of 770 nm.

RESULTS AND DISCUSSION

Fruit morphology

The results of measuring the size (weight, height, diameter) of avocado fruit, observations of avocado fruit morphology obtained data shown in Table 1. Based on the data obtained, there are variations in fruit size and weight, fruit height, diameter, and volume of avocado pulp in three avocado varieties: Mega Gagauan (480.66 g), Mega Paninggahan (406.81 g), and Mega Merapi (290.80 g). Mega Gagauan also has the highest volume (V = 489.14 mL), indicating a greater yield potential than the other two varieties. Mega Paninggahan also shows fruit size but with higher variation (significant standard deviation), indicating the presence of extensive genetic diversity in this variety (Sundharaiya et al. 2022; Sari et al. 2024; Yangaza et al. 2024). Mega Merapi has the smallest fruit size and weight, but its diameter is almost identical to Mega Paninggahan's. This variation aligns with findings in various avocado-producing countries, where genetic, environmental, and agronomic factors strongly influence morphometric differences in fruit (Sundharaiya et al. 2022; Abera et al. 2023; Luitel 2023; Yangaza et al. 2024).

The weight of the Mega Gagauan variety's fruit flesh is 382.69 g with a flesh thickness of 3.07 cm, also larger than the Mega Paninggahan variety, with a flesh weight of 318.66 g with a flesh thickness of 3.02 cm. Mega Merapi is the variety with the smallest flesh weight, 192.40 g, with a flesh thickness of 2.18 cm (Table 2).

Differences in avocado fruit size and morphology are primarily influenced by genetic diversity between varieties. Studies in India, Nepal, and Tanzania have shown that genotype significantly determines fruit weight, length, and diameter, with some varieties exhibiting superior flesh-to-seed ratios, which are important for selecting superior varieties (Sundharaiya et al. 2022; Luitel 2023; Yangaza et al. 2024; Sari et al. 2024). Measurements indicate that the seed weight and size of the three varieties are relatively similar. However, Mega Paninggahan has the highest seed weight (64.96 g), while Mega Gagauan has the lightest seed (54.09 g). This morphological variation aligns with previous research showing that fruit weight and size, seed size, and flesh proportion are key parameters in selecting and developing superior avocado varieties. This data can be used to determine the most promising varieties for development based on market needs and consumer preferences.

Morphological data have shown that the Mega Merapi, Mega Paninggahan, and Mega Gagauan avocado varieties have striking differences in shape, ripe fruit peel color, fruit flesh color, and fruit peel texture. Mega Paninggahan has an oval shape with a pointed base and a rounded tip, maroon skin color when ripe, buttery yellow flesh, and a smooth skin texture. Meanwhile, Mega Gagauan is round with a rounded base and tip, reddish skin color when ripe, yellow flesh, and a smooth peel. This variation reflects high genetic diversity in avocados, which is important for selecting superior varieties according to consumer preferences and market needs (Ishaq et al. 2023; Sari et al. 2024; Kouam et al. 2025). The research findings further illustrate that further genetic analysis identified markers and genes associated with fruit quality traits, such as size, color, and skin texture, which can be utilized in breeding programs (Shaw et al. 2020; Li et al. 2024).

From an agronomic perspective, cultivation practices such as seed selection, plant spacing, and pollination management also influence fruit size and yield. Cross-pollination has been shown to increase fruit size and weight compared to self-pollination, making cropping patterns and pollinator presence crucial for increasing fruit productivity and quality (Alcaraz and Hormaza 2021; Hapuarachchi et al. 2024; Trueman et al. 2024). Based on the above description, this study revealed that fruit size, shape, skin and flesh color, and skin texture are key characteristics that differentiate avocado varieties and contribute to the fruit's visual appeal and market value.

Table 1. The physical characteristics of avocado fruit from three local avocado varieties (Mega Merapi, Mega Paninggahan, and Mega Gagauan)

Size	Avocado fruit varieties (mean±SD)		
	Mega Merapi	**Mega Paninggahan**	**Mega Gagauan**
Weight (g)	290.80±39.60	406.81±95.97	480.66±116.11
Height (cm)	10.11±0.94	12.44±1.31	12.62±1.28
Diameter (cm)	8.31±1.24	8.20±0.82	8.84±0.85
Volume (mL)	306.86±49.64	460.57±158.43	489.14±146.93

Note: SD: Standard Deviation

Table 2. Physical characteristics of seeds, fruit flesh and skin, and avocado leaves from three local avocado varieties (Mega Merapi, Mega Paninggahan, and Mega Gagauan)

Size	Varieties (mean±SD)		
	Mega Merapi	**Mega Paninggahan**	**Mega Gagauan**
Seed			
Weight (g)	60.90±8.28	64.96±19.67	54.09±14.90
Height (cm)	5.33±0.48	5.91±0.64	6.03±0.95
Diameter (cm)	5.30±1.06	4.76±0.95	4.63±1.43
Fruit peel			
Weight (g)	37.50±5.93	31.92±6.85	35.71±10.77
Fruit flesh			
Weight (g)	192.40±34.40	318.66±90.12	382.69±103.34
Height (cm)	2.18±0.71	3.02±0.75	3.07±0.51
Volume (mL)	306.86±49.64	460.57±158.43	489. 14±146.93
Leaf shape	Oval and slightly wavy		
Fruit shape	Slightly round (the base of the fruit has a somewhat rounded tip)	The oval, the base of the fruit, is pointed with a rounded tip	Round (the base of the fruit has a rounded tip)
Color of ripe fruit for consumption	Dark green	Maroon	Redness
Fruit flesh color	Butter yellow	Butter yellow	Yellow
Texture of the fruit peel	A bit rough	Soft	Soft

Note: SD: Standard Deviation

Figure 1. Avocado fruit varieties from Solok District, West Sumatra, Indonesia. A. Mega Merapi, B. Mega Paninggahan, C. Mega Gagauan

Figure 2. Avocado seeds varieties from Solok District, West Sumatra, Indonesia. A. Mega Merapi, B. Mega Paninggahan, C. Mega Gagauan

Proximate composition

In Table 3 below, the data from chemical analysis consisting of proximate analysis of three local avocado varieties, namely Mega Merapi, Mega Paninggahan, and Mega Gagauan, will be displayed. Variations in proximate and bioactive compounds in avocado seeds and flesh have important implications for selecting superior varieties, developing functional food products, and utilizing agricultural waste. Varieties with high fat and polyphenol content in the flesh are preferred for fresh consumption and the nutraceutical industry, while seeds with high polyphenol and tannin content have the potential as a source of antioxidants for food, feed, or cosmetics (Rosero et al. 2019; Lyu et al. 2023). In addition, understanding this variation can be used to optimize cultivation and post-harvest techniques to increase the quality and economic value of the fruit (Abera et al. 2023; Vitrack-Tamam et al. 2025).

Water content

Figures 3 and 4 above show that in the seed section, Mega Merapi and Mega Gagauan have almost the same high-water content (around 72.83% and 72.95%). In comparison, Mega Paninggahan has a lower water content (64.25%). Meanwhile, in the fruit flesh, Mega Merapi has the highest water content (85.65 %), followed by Mega Paninggahan (84.74%), and Mega Gagauan has the lowest (81.20%). This difference in water content can affect the texture, taste, and shelf life of avocado fruit, where higher water content usually produces softer and juicier fruit flesh but more quickly deteriorates. Other studies have also shown that the water content in avocado fruit flesh varies considerably between varieties and is an important parameter in determining the quality and characteristics of the fruit (Ihsan et al. 2023; Nasri et al. 2023). Differences in water content between varieties can also be influenced by harvest age, growing environment, and cultivation techniques. This is illustrated by research in Ethiopia and Mexico, which suggests that growing environmental factors such as soil pH, altitude, and agro-ecology also play a significant role in addition to genetic factors. These studies confirmed that planting location influences the physical and chemical qualities of the fruit, including water content, pH, fat content, and consumer preferences (Reyes-Alemán et al. 2021; Abera et al. 2023). However, it is the variety of avocado that remains the primary determinant of water composition, a key point to remember from this research.

Protein content

The research results are shown in Figures 3 and 4. Specifically, the protein content of three avocado varieties, namely, Mega Merapi, Mega Paninggahan, and Mega Gagauan, shows variations in protein content in both seeds and fruit flesh. In seeds, Mega Paninggahan has the highest protein content (1.91%), followed by Mega Gagauan (1.21%) and Mega Merapi (0.87%). Meanwhile, in fruit flesh, Mega Paninggahan also stands out with the highest protein content (2.10%), followed by Mega Merapi (1.29%) and Mega Gagauan with the lowest (0.52%). The higher protein content in Mega Paninggahan makes this variety superior in terms of nutritional value, so it has better potential for consumption and the development of avocado-based processed products (Ihsan et al. 2023). The protein content in avocado fruit flesh varies between varieties and is important in determining the fruit's nutritional quality (Ihsan et al. 2023; Nasri et al. 2023). This finding is important when selecting avocado varieties to be cultivated or developed further, particularly if they are intended for food needs with optimal protein content.

Fat content

Research on the fat content of three avocado varieties, Mega Merapi, Mega Paninggahan, and Mega Gagauan, showed fat content variations in the seeds and the flesh. In the seeds, the fat content was relatively similar, namely Mega Gagauan (4.79%), Mega Merapi (4.73%), and Mega Paninggahan (4.08%). However, in the flesh, Mega Gagauan had the highest fat content (6.61%), followed by Mega Paninggahan (5.48%) and Mega Merapi (4.74%). The high fat content in avocado flesh is significant because fat is one of the main components determining the avocado fruit's nutritional value, taste, and texture. In their research, Ihsan et al. (2023) showed that the fat content in avocado flesh varies greatly between varieties, and varieties with higher fat content are generally preferred for fresh consumption and avocado oil processing. Furthermore, it was noted that Mega Paninggahan was considered the best variety overall, despite not having the highest fat content like Mega Gagauan. These findings are important for consideration when selecting avocado varieties to cultivate, particularly if they are intended for producing oil or processed products with high fat content.

Research shows that the fat content of avocados is strongly influenced by variety, with significant differences in both total fat content and fatty acid profile (Sánchez-Albarrán et al. 2019; Nasri et al. 2021, 2023; Fagundes et al. 2024). These differences also apply to fatty acid composition, with certain varieties being richer in oleic acid (a monounsaturated fat), which is good for health (Sánchez-Albarrán et al. 2019; Nasri et al. 2021, 2023). Environmental factors, harvest time, and growing location can also influence fat content, but variety remains the main factor differentiating fat content between avocados (Lu et al. 2009; Hernández et al. 2023).

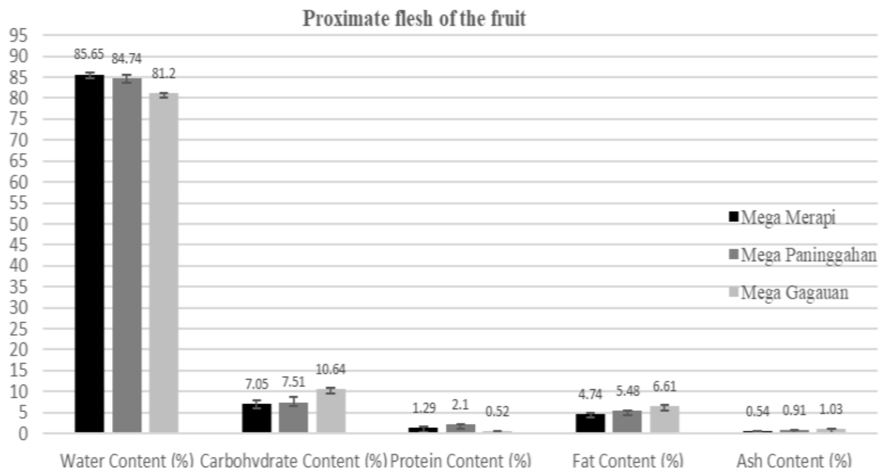

Figure 3. Proximate analysis of fruit flesh avocado varieties (Mega Merapi, Mega Paninggahan, and Mega Gagauan)

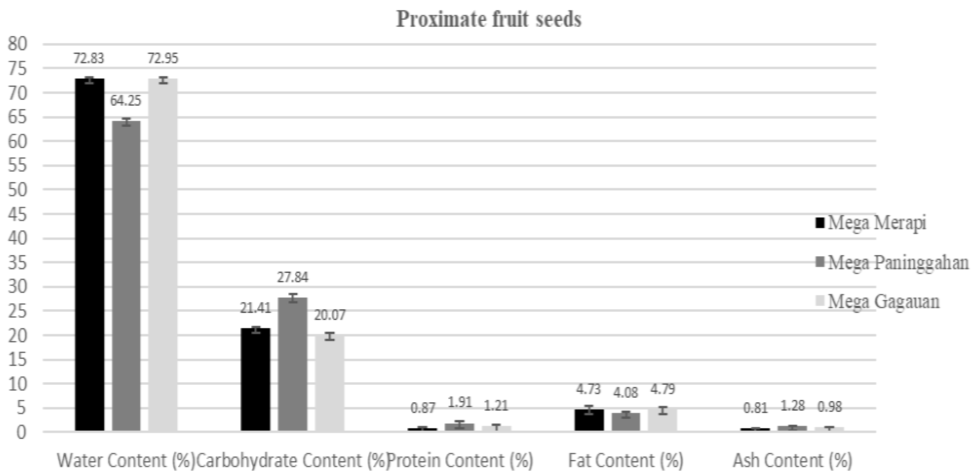

Figure 4. Proximate analysis of fruit seeds of avocado varieties (Mega Merapi, Mega Paninggahan, and Mega Gagauan)

Ash content

The results showed that the ash content, which reflects the total mineral content, in three avocado varieties: Mega Merapi, Mega, Paninggahan, and Mega Gagauan, varied in both the seeds and fruit flesh. In the seeds, Mega Paninggahan had the highest ash content (1.28%), followed by Mega Gagauan (0.98%) and Mega Merapi (0.81%). Meanwhile, in the fruit flesh, Mega Gagauan stood out with the highest ash content (1.03%), followed by Mega Paninggahan (0.91%) and Mega Merapi (0.54%). In addition, the content of macro minerals such as sodium, calcium, and magnesium also varied between varieties and fruit parts, where the seeds usually contain more minerals than the fruit flesh (Ge et al. 2017; Nasri et al. 2023). Higher ash indicates higher mineral content, which is important for the nutritional value of avocado fruit. Other studies also report that the ash content in avocados can vary between varieties, typically ranging from 0.57% to 1.37% in the fruit flesh, and these differences are influenced by genetic factors and the growing environment, including the soil in which the avocado tree grows. (Ge et al. 2017; Luitel 2022; Abera et al. 2023; Frances et al. 2023; Nasri et al. 2023). Mega Paninggahan and Mega Gagauan, with higher ash content, have the potential to provide better mineral intake than Mega Merapi. These findings are important for consideration when selecting avocado varieties for cultivation, especially when aiming for optimal mineral nutrition.

Carbohydrate content

The research results presented in Figures 3 and 4 above regarding the carbohydrate content of three avocado varieties, Mega Merapi, Mega Paninggahan, and Mega Gagauan, show quite clear variations in the seeds and flesh of the fruit. In the seeds, Mega Paninggahan has the highest carbohydrate content (27.84%), followed by Mega Merapi (21.41%) and Mega Gagauan (20.07%). Meanwhile, in the flesh, Mega Gagauan stands out with the highest carbohydrate content (10.64%), followed by Mega Paninggahan (7.51%) and Mega Merapi (7.05%). Although avocado flesh generally contains less carbohydrate than other fruits, it remains an important energy source and influences the fruit's texture and flavor (Nasri et al. 2023; Ihsan et al. 2023). Nasri et al. (2023) further explained that variations in carbohydrate content are influenced by genetic factors of the variety and also environmental conditions such as growing location, soil quality, and climate. Other studies also report that the carbohydrate content in avocado flesh can range from 5.6% to 14.6% depending on the variety. The genetic makeup of each variety influences the composition and distribution of sugars and starches in various parts of the fruit, so that certain varieties can have higher or lower carbohydrate content than others (Beiro-Valenzuela et al. 2023; Nasri et al. 2023). Mega Gagauan, with the highest carbohydrate content in the fruit flesh, has the potential to provide a sweeter taste and a different texture than other varieties. This finding is important when selecting avocado varieties for consumer or industrial processing needs.

Tannin content, phenol content, and total sugar content

The variety's genetics strongly influences differences in proximate, tannin, and polyphenol content. Genomic and metabolomic studies have shown that genotype determines metabolite profiles, including lipids, sugars, and bioactive compounds (Abera et al. 2023; Li et al. 2024; Miramontes-Corona et al. 2024). In Table 3 below, the following data will be displayed from chemical analysis, consisting of analysis of tannin content, phenol content, and total sugar content of three local avocado varieties, namely Mega Merapi, Mega Paninggahan, and Mega Gagauan.

Tannin content

The analysis results in Table 3 show that the tannin content in the seeds of three avocado varieties, Mega Merapi, Mega Paninggahan, and Mega Gagauan, differs significantly. Mega Merapi has the highest tannin content (0.61%), followed by Mega Gagauan (0.53%), while Mega Paninggahan has the lowest content (0.13%). Tannin is a polyphenol compound that acts as an antioxidant and can provide health benefits, but it can also affect the taste and bitterness of avocado seeds (Kurnia et al. 2024; Nugrahani et al. 2025). The higher tannin content in Mega Merapi and Mega Gagauan indicates greater antioxidant potential than Mega Paninggahan, suggesting that the seeds of these two varieties have better potential to be used as raw materials for health products or functional foods (Rosero et al. 2019; Kurnia et al. 2024; Nugrahani et al. 2025). Genetic factors such as variety and growing conditions influence this variation in tannin content. Furthermore, other studies have reported that avocado seeds generally contain high tannin levels, which can be extracted and utilized for various applications (Rosero et al. 2019; Basri et al. 2023; Nugrahani et al. 2025). Therefore, variety selection is crucial if avocado seeds are to be utilized as a natural source of tannin, with potential applications in health products and functional foods.

The high phenolic and tannin compounds in the flesh and seeds of the Mega Merapui avocado variety act as antioxidants, antimicrobials, and protect against oxidative stress/environmental stress, although genetic and environmental factors also influence specific responses (Bhuyan et al. 2019; Ortega-Arellano et al. 2019; Rojas-García et al. 2022; Marra et al. 2024). From the data in Table 3, it is known that the Mega Merapi variety is stronger than the other two varieties and plays an important role in plant defense mechanisms against environmental stress (biotic and abiotic stress), primarily through the antioxidant pathway and strengthening the cell defense system (Yu and Xiao 2021; Liu et al. 2022). However, environmental stress resistance in avocado varieties is also influenced by other genetic factors, physiological adaptation, and environmental interactions, not only bioactive content.

Table 3. Analysis of tannin content, phenol content, and total sugar content of avocado varieties: Mega Merapi, Mega Paninggahan, and Mega Gagauan

Size	Variety		
	Mega Merapi	**Mega Paninggahan**	**Mega Gagauan**
Tannin (%)			
Fruit seeds	0.61±0.007	0.13±0.014	0.53±0.35
Polyphenols (mgGAE/g)			
Fruit seeds	943.45±13.78	334.34±33.28	742.28±66.02
Fruit flesh	102.64±7.14	74.33±7.22	40.47±5.47
Total sugar (%)			
Fruit seeds	11.85±0.77	14.11±0.93	16.33±1.01
Fruit flesh	20.60±0.84	8.42±0.47	9.60±0.45

Note: SD: Standard Deviation

Phenol content

Research on the phenol content of three avocado varieties, Mega Merapi, Mega Paninggahan, and Mega Gagauan, showed striking differences in the seeds and the fruit flesh. In the seeds, Mega Merapi had the highest phenol content (943.45 mg), followed by Mega Gagauan (742.28 mg), and the lowest was found in Mega Paninggahan (334.34 mg). Meanwhile, in the fruit flesh, the highest phenol content was also found in Mega Merapi (102.64 mg), followed by Mega Paninggahan (74.33 mg), and the lowest in Mega Gagauan (40.47 mg). Phenolic compounds are natural antioxidants that prevent free radicals and provide health benefits, such as protection against degenerative diseases (Figueroa et al. 2018; Rosero et al. 2019). The high phenol content in the seeds and flesh of the Mega Merapi fruit shows greater antioxidant potential than the other two varieties, so this variety is superior for use as a raw material for functional or health food products (Figueroa et al. 2018; Huaman-Alvino et al. 2021). Moreover, it has been studied that the phenol content in the fruit seeds is higher than in the avocado flesh (Rosero et al. 2019; Lyu et al. 2023; Miramontes-Corona et al. 2024). The phenolic profile of the seeds is primarily composed of flavonoids (such as catechin and epicatechin), procyanidin, and phenolic acids, which contribute to high antioxidant activity (Rosero et al. 2019; Miramontes-Corona et al. 2024). Variations in phenol levels are influenced by genetic factors, growing conditions, and other environmental factors, and other studies confirm that avocado seeds are an emerging source of phenols for further extraction and utilization (Figueroa et al. 2018; Rosero et al. 2019).

Total sugar content

Research data on total sugar content in three avocado varieties, Mega Merapi, Mega Paninggahan, and Mega Gagauan, in Table 3, shows quite clear variations between the seeds and the fruit flesh. In the seeds, Mega Gagauan has the highest total sugar content (16.33%), followed by Mega Paninggahan (14.11%), and the lowest in Mega Merapi (11.85%). Conversely, in the fruit flesh, Mega Merapi has the highest total sugar content (20.60%), while Mega Gagauan (9.60%) and Mega Paninggahan (8.42%) have lower levels. The total sugar content in avocados, especially C7 sugars such as mannoheptulose and perseitol, plays an important role in the metabolic process and fruit ripening, as well as influencing the taste and nutritional value of avocados (Pedreschi et al. 2019).

Variations in total sugar content are influenced by genetic factors of the variety, stage of ripeness, and metabolic processes during fruit development (Pedreschi et al. 2019; Ihsan et al. 2023). Vitrack-Tamam et al. (2025) further explained that high photosynthetic activity can increase sugar accumulation in fruit. Variation in avocado fruit varieties significantly influences total sugar content, as each variety has a different genetic composition, thus affecting the type and amount of sugar stored in the flesh and seeds (Beiro-Valenzuela et al. 2023; Frances et al. 2023). The flesh of the Mega Merapi fruit, which has the highest total sugar content, has the potential to provide a sweeter taste and can be an option for consumers who want avocados with a sweeter taste. Meanwhile, the high sugar content in Mega Gagauan and Mega Paninggahan seeds presents an exciting opportunity for product development, inspiring new possibilities for avocado utilization. These findings emphasize the importance of selecting varieties according to needs for direct consumption and developing processed products.

In conclusion, this study confirms the morphological characteristics, proximate composition, and bioactive content (tannin and phenol), as well as the total sugar content of three local Solok avocado varieties (Mega Merapi, Mega Paninggahan, and Mega Gagauan), which reflect important genetic diversity for breeding superior varieties. Agronomically, the Mega Merapi variety with high bioactive content (tannin and phenol in both seeds and fruit flesh), shows the potential for better adaptation to environmental stress. At the same time, from a genetic perspective, this finding emphasizes the importance of preserving local germplasm. Furthermore, the flesh of the Mega Merapi variety is sweeter than the other two varieties because it contains a higher total sugar content (20.60%), making it more preferred by consumers for direct consumption. Meanwhile, selecting avocado flesh and seeds for processing into food and beverages typically depends on factors such as proximate content, bioactive compounds, and total sugar. The selection of varieties that are suitable for agroecological conditions also supports sustainable cultivation. Practically, these results create opportunities for developing functional foods based on local avocados, including fruit flesh and seeds, to increase economic value and regional food security.

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