The Effects of Processing and Varieties on Vitamins and Antioxidants of Sesame (*Sesamum indicum* L.)

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ARTICLE HISTORY
Received Date: 9th June, 2025
Accepted Date: 8th August, 2025

http: www.njphr.nspri.gov.ng
ISSN: 2630-7022

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CONFLICT OF INTEREST: None
ETHICAL APPROVAL: Not Applicable

This is a publication of the Nigerian Stored Products Research Institute (NSPRI)

OPEN ACCESS

Abstract

Sesame is rich in dietary nutrients; however, varietal selection and processing methods can alter its nutritional composition. Hence, in 2023, three sesame varieties (White Benue, Cameroon White, and E8) were cultivated for a duration of four months at Osun State University, using established agronomic practices. Following the harvest, standard analytical methods were employed to assess the variations in vitamin and antioxidant levels arising from processing. The Ferric Reducing Antioxidant Power (FRAP) was notably highest in the E8 variety, at a value of 17.80 mg/mL, and was lowest in Cameroon White, with a value of 17.30 mg/mL. The 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity (DPPH) was significantly highest in White Benue at 44.8%, while Cameroon White recorded the lowest at 41.0%. Vitamin C content was significantly greater in raw sesame flour (4.11 mg/100 g) compared to roasted sesame flour (1.37 mg/100 g). Vitamin A was also higher in raw sesame flour (0.13 mg/100 g) and significantly reduced in roasted sesame flour (0.08 mg/100 g). Similarly, Vitamin E levels were significantly higher in raw sesame flour (2.44 mg/100 g) and lower in roasted flour (2.08 mg/100 g). The antioxidant activity, measured via DPPH assays, indicated that the raw sesame flour had a significantly greater value (51.61%) than the roasted sesame flour (34.35%). Raw sesame flour possesses superior nutritional content; however, if heat treatment is necessary, it should be applied mildly to avoid damaging the beneficial compounds in the sesame flour.

Keywords:
Bioactive compounds, Dietary nutrients, Sesame flour, Value addition, Vitamins

Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest and most widely cultivated oilseeds globally. According to FAOSTAT data (FAOSTAT 2021), the annual yield of sesame rose in 2019, with Sudan, Myanmar, and India being the leading producers. The primary purpose of cultivating sesame is for oil production, which is utilised in various types of confectionery, cooking, tahini sauce, and as toppings for salads (Sarkis et al., 2015; Fasuan et al., 2018; Capellini et al., 2019; Ji et al., 2019), as well as in cosmetics and dietary supplements (Gharby et al., 2017). After oil extraction, the resulting sesame cake, which is a defatted by-product, is primarily used for animal feed or included in compost formulations. Nonetheless, this sesame cake can also be processed into flour, which has culinary applications and adds value to the food industry. It contains protein with both essential and non-essential amino acids, dietary fibre, and crucial bioactive compounds that have antioxidant properties and promote health, including lignans such as sedaminol triglucoside, sesamolinol diglucoside, and sesaminol diglucoside (Sarkis et al., 2014; Shu et al., 2019). This flour is rich in essential vitamins and antioxidants beneficial to human health, including vitamin E (tocopherol), B-complex vitamins, and phenolic compounds known for their antioxidant characteristics (Elleuch et al., 2007). The funda-

How to cite:
Oloyede, F. M., Taiwo, D. I., & Alade, T. I. (2025). The Effects of Processing and Varieties on Vitamins and Antioxidants of Sesame (*Sesamum indicum* L.). *Nigerian Journal of Post-Harvest Research*, 3(4), 32-38.

mental nutrients help to mitigate oxidative stress, enhance immune function, and elevate overall nutritional health (Namiki 2007).

However, the different types of sesame and the methods used in processing can influence the concentrations of vitamins and antioxidants in sesame flour. The nutrient profiles of various sesame strains differ from one another, with some exhibiting higher levels of vitamins and antioxidants due to their genetic heritage and environmental factors (Uzun et al., 2008). According to Kim et al. (2006), the vitamin E levels in various sesame types vary, which significantly affects their antioxidant potential and health benefits. Therefore, it is crucial to evaluate how different sesame varieties influence the nutritional quality of flour to identify and recommend the most beneficial types for healthy food production. The methods used in producing sesame flour also impact its vitamin and antioxidant content. Heat treatments can diminish heat-sensitive vitamins, such as vitamin E, while fermentation can enhance the bioavailability of certain antioxidants (Yoshida & Takagi, 1997). Therefore, it is essential to study and understand how different processing techniques affect the vitamins and antioxidants in sesame flour so that food manufacturers can create high-quality products. Recently, consumers have been seeking foods rich in nutrients and bioactive compounds that offer health benefits. They are inclined toward foods that provide improved nutritional value and contain natural ingredients. Consequently, consumers are encouraged to incorporate seeds into their diets due to their various nutritional advantages (Kopsahelis & Kachrimanidou, 2019; Melo et al., 2019). As the global population continues to rise rapidly, there is a pressing need for sustainably producing food to safeguard both food security and the environment (Nunes et al., 2018). This study aims to achieve two main objectives: to evaluate the effects of processing techniques on the vitamins and antioxidants in sesame seed oil and flour, and to compare the vitamin and antioxidant content among different sesame cultivars.

Materials and Methods

Field study

The experiment was conducted at Osun State University (UNIOSUN), Ejigbo Campus, Osun State. In August 2023, three sesame varieties (NCRIBEN (white Benue), NCRIBEN 2 (white Cameroon), and E8) were obtained from FUNAAB and grown for four months under standard agronomic practices for sesame. The harvested seeds were sorted, cleaned, and then processed into flour. For the flour preparation, two methods were employed: raw milling and roasting at 40 ^{o}C before milling (Makinde & Akinoso, 2014; Wei et al., 2022). Samples were analysed for specific vitamins (A, C, and E) and antioxidants.

Laboratory analysis

Determination of vitamin c (ascorbic acid)

A sample of 10 grams (10 g) was extracted using 50 mL of EDTA/TCA extracting solution for one hour, and then filtered through Whatman filter paper into a 50 mL volumetric flask, which was subsequently filled to the mark with the extracting solution. An aliquot of 20 mL from the extract was placed in a 250 mL conical flask, to which 10 mL of 10% KI and 50 mL of water were added. This mixture was titrated against a 0.01 N $CuSO_4$ solution until a dark endpoint was reached, and the amount of ascorbic acid was calculated as shown below:

Ascorbic acid (mg/100g) = 0.88 × Vf ×T

Where: Vf=Volume of extract, T=Titre (sample-blank)

Analysis of vitamin E (tocopherol)

This was determined by the Filter–Mayer method, with the association of vitamin chemists. 1 g of the sample was mixed with 10 mL of 10% ethanoic sulfuric acid and boiled gently under reflux for 30 minutes. It was transferred to a separating funnel and treated with three 30 mL portions of diethyl ether, recovering the ether layer each time. The ether extracted was transferred to a desiccator and dried at a low temperature (40 °C) for 30 minutes. It was then evaporated at room temperature (30 °C). The dried extract was dissolved in 10 mL of pure ethanol. One mL of the dried extract and equal volumes of standard vitamin E were transferred to separate tubes, after autoclaving at 120 °C for 30 minutes and then cooling. Absorbance was measured at 660 nm.

$$\text{Conc. of Vitamin E} = \frac{\text{Abs of Sample} \times \text{Conc. of Std}}{\text{Abs of Std}}$$

Vitamin A (retinol) assessment

Vitamin A was determined by the calorimetric method. 1g of the sample and standard was mixed with 3 mL of ethanol. A 50% KOH (Potassium Hydroxide) solution was added to it and boiled gently for 30 minutes under reflux. After boiling, the mixture was washed with distilled water, and vitamin A was extracted with three 50 ml portions of diethyl ether. The extract was evaporated to dryness at 40 °C and then dissolved in 10 mL of isopropyl alcohol. One mL of the standard vitamin A solution and the dissolved extract were transferred to separate cuvettes, and their respective absorbances were read in a spectrophotometer at 325 nm with the reagent blank set to zero.

$$\text{Conc. of Vitamin A} = \frac{\text{Abs of Sample} \times \text{Conc. of Std}}{\text{Abs of Std}}$$

Evaluation of 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity

The DPPH scavenging capability was assessed following the procedure outlined by Gyamfi et al. (2007). A 200 µL aliquot of each extract (at a concentration of 2 mg/mL) was added to 800 µL of 0.1 mM DPPH and allowed to react for 20 minutes at room temperature. The absorbance was measured at 517 nm using a VERSAmax microplate reader. The experiment was performed twice, and the average values were recorded. The radical scavenging activity was computed and expressed as a percentage of the control (the free radical solution minus the plant extract) using the following formula: A0 represented the absorbance of the blank (where the same volume of methanol was used instead of the sample), while A1 indicated the absorbance in the presence of the samples:

% Scavenging [DPPH] = $[(A_0 - A_1)/A_0] \times 100$.

Where*:* A_0 was the absorbance of the blank (in which the same volume of methanol was used in place of the sample), and A_1 was the absorbance in the presence of the samples.

Ferric reducing antioxidant power (FRAP)

The antioxidant activity assessment via the FRAP assay aligns with the method described by Vichitphan et al. (2007), which utilises FeSO4 · $7H_2O$ as the standard. The antioxidant capacity of the samples was evaluated based on their ability to reduce $Fe3^+$ ions to $Fe2^+$ (Halvorsen et al., 2002). The FRAP reagent was formulated by combining 0.1 M acetate buffer solution (pH 3.6), 2,4,6-tripyridyl-s-triazine (TPTZ) at 10 mM dissolved in 40 mM HCl (0.15 grams TPTZ in 50 mL of 40 mM HCl), and a solution of 20 mM $FeCl_3.6H_2O$ in a 10:1:1 volume ratio. A total of 50 mL and 150 mL of distilled water were added to a tube containing 1.5 mL of FRAP reagent. This solution was then incubated in a dark environment at room temperature for 8 minutes. The absorbance of the sample was recorded at a wavelength of 594 nm, and the results were calculated in terms of Fe2+ equivalents using a standard curve derived from FeSO4· 7H2O with concentrations ranging from 5 to 25 mg/mL.

Statistical analysis

The data collected were analysed using the analysis of variance with the general linear model of SAS, comparing treatment means with the least significant difference at a 5% probability level (SAS).

Results and Discussion

The vitamin and antioxidant profiles in three sesame cultivars (flour*)*

Figure 1 illustrates the vitamin C content across the three sesame cultivars. At a P level of 0.05, no significant difference was noted in Vitamin C, with values ranging from 2.50 mg/100 g to 3.00 mg/100 g. Figure 2 displays the Vitamin A content in the three sesame cultivars. The highest level of Vitamin A was significantly observed in White Benue (2.28 mg/100 g), while Cameroon White showed the lowest level (2.24 mg/100 g). Figure 3 presents the Vitamin E levels in the three sesame cultivars. White Benue exhibited the highest Vitamin E concentration at 2.28 mg/100 g, whereas the lowest value was again found in Cameroon White at 2.24 mg/100 g. A statistically significant difference was observed at a P-value of 0.05. The Vitamin and Antioxidant composition of the three sesame flour cultivars. Vitamin A is essential for maintaining healthy vision, supporting immune function, and promoting skin health. In sesame flour, Vitamin A exists primarily as beta-carotene. Nguyen et al. (2021) reported that White Benue and Cameroon White show elevated levels of Vitamin A compared to E8; this finding aligns closely with their research, since White Benue has the highest Vitamin A content, suggesting that incorporating flour from the E8 variety can enhance vision and skin health. Vitamin C plays a crucial role as an antioxidant, aiding in collagen synthesis and immune function.

Figure 4 illustrates the composition of 2,2-Diphenyl-1-picrylhydrazyl Radical Scavenging Activity in the three sesame cultivars. The highest DPPH radical scavenging activity (44.8%) was found in white Benue, while the lowest (41%) was recorded in Cameroon white. A significant difference was. A significant difference was noted at a P value of 0.05 among the parameters. Figure 5 depicts the Ferric Reducing Antioxidant Power (FRAP) in the three sesame cultivars. The Ferric Reducing Antioxidant Power showed a significant peak in E8 at 17.80 mg/mL, while Cameroon White exhibited the lowest value at 17.30 mg/mL. A significant difference was also observed at a P level of 0.05 among the parameters. White Benue generally displays slightly higher Vitamin C levels relative to E8 and Cameroon White (Smith et al., 2022). The differences were minor and typically influenced by post-harvest practices and storage conditions. This study similarly revealed no significant differences in Vitamin C levels among the cultivars, but indicated that Vitamin C was marginally higher in Cameroon White. Vitamin E functions as a powerful antioxidant that protects cells from oxidative stress and bolsters immune health. Sesame flour is recognised for its relatively high Vitamin E content, which may vary among cultivars due to oil content and genetic variations. E8 is associated with higher Vitamin E levels compared to White Benue and Cameroon White (Chen et al., 2019). The higher amounts in E8 are correlated with its greater oil content and tocopherol concentration; this study indicates that E8 has a medium value (2.26 mg/100 g), while White Benue presents the highest figure (2.28 mg/100 g) of Vitamin A content.

Antioxidants play a crucial role in protecting cells from oxidative stress due to their capacity to neutralise free radicals. Sesame seeds are well-known for their antioxidant properties, which contribute to their various health benefits. Two standard methods for assessing the antioxidant potential of sesame flour are the Ferric Reducing Antioxidant Power (FRAP) assay and the 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay, with results varying depending on the cultivar used (Prasad et al., 2018). Nnkongho et al. (2023) found that the E8 cultivar exhibits a relatively high FRAP value, indicating significant antioxidant activity.

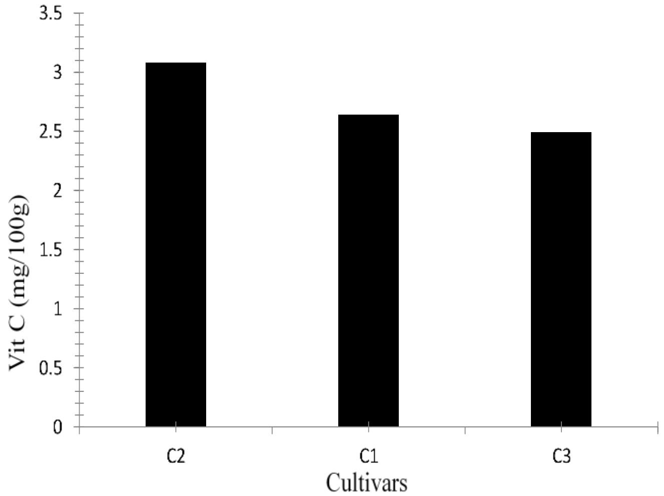

Figure 1: The Vitamin C (analysed in triplicate) in the three cultivars of sesame (Flour). *C1 represents White Benue, C2 represents Cameroon White, C3 represents E8 cultivar*.

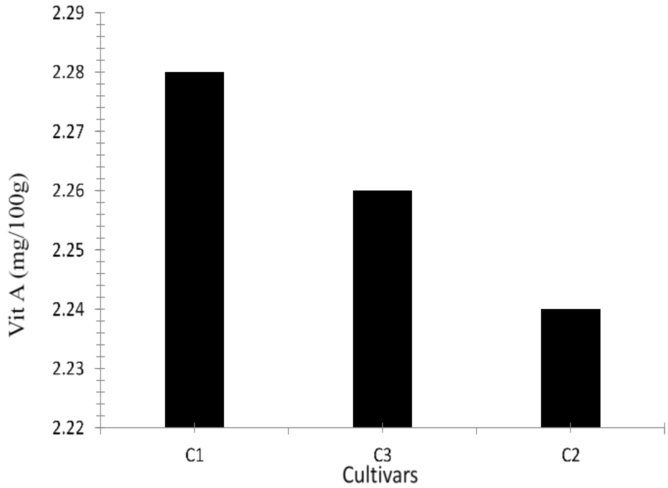

Figure 2: The Vitamin A (analysed in triplicate) composition in the three cultivars of sesame (Flour). *C1 represents White Benue, C2 represents Cameroon White, C3 represents E8 cultivar*

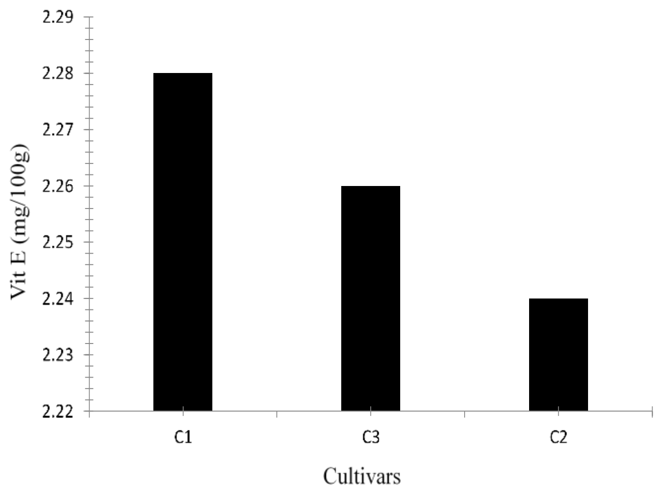

Figure 3: The Vitamin E (analysed in triplicate) composition in the three cultivars of sesame (Flour). *C1 represents White Benue, C2 represents Cameroon White, C3 represents E8 cultivar*

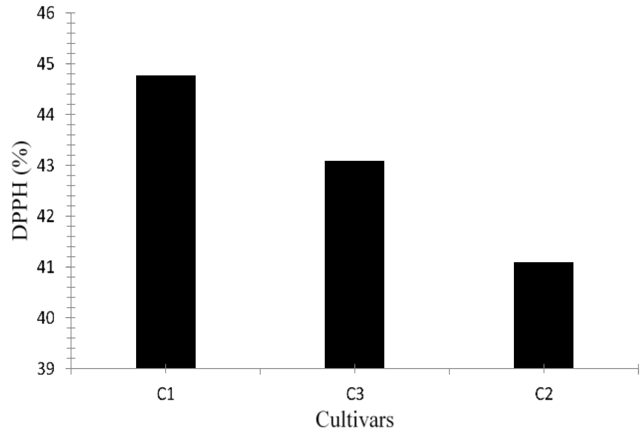

Figure 4: The 2,2- Diphenyl-1picrylhydrazyl (DPPH) Radical Scavenging Activity concentration (analysed in triplicate) in the three cultivars of sesame. *C1 represents White Benue, C2 represents Cameroon White, C3 represents E8 cultivar*

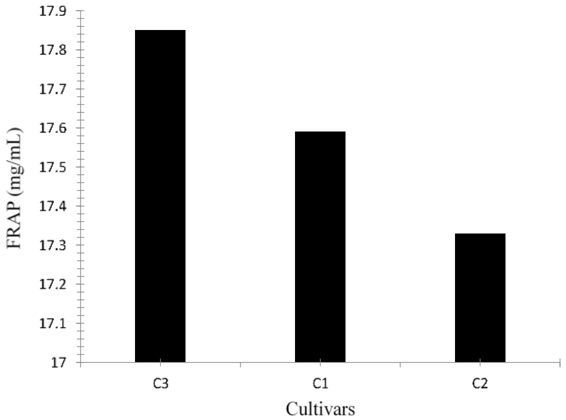

Figure 5: The Ferric Reducing Antioxidant Power (FRAP) (analysed in triplicates) composition in the three cultivars of sesame. *C1 represents White Benue, C2 represents Cameroon White, C3 represents E8 cultivar*

This enhanced activity is likely due to its increased levels of phenolic compounds and other antioxidant components. Akinmoladun et al. (2022) reported that White Benue has a moderate FRAP value in comparison to E8, while Adebisi et al. (2021) noted that Cameroon White has the lowest FRAP value among the three, suggesting a lower reducing power attributed to a reduced concentration of antioxidant compounds in this cultivar. As per the results, E8 consistently showed the highest values, followed by White Benue and Cameroon White.

The impact of processing methods on the vitamins and antioxidant levels in sesame flour.

Table 1 demonstrates the effect of processing methods on vitamin levels. Vitamin C was considerably higher in raw sesame flour (4.11 mg/100 g) and significantly lower in roasted sesame flour (1.37 mg/100 g). The highest significant levels of Vitamin A were found in raw sesame flour (0.13 mg/100 g), with the lowest in roasted sesame flour (0.08 mg/100 g). Vitamin E was also significantly higher in raw sesame flour (2.44 mg/100 g) compared to a lower significant value in roasted flour (2.08 mg/100 g). A significant difference was observed at a P level of 0.05 among the parameters. Table 2 presents the impact of processing methods on antioxidant content. The DPPH Radical Scavenging Activity had its most significant value in raw sesame flour (51.61%) and the least in roasted sesame flour (34.35%). In terms of Ferric Reducing Antioxidant Power (FRAP), the higher significant value was seen in raw sesame flour (17.86 mg/mL), while roasted sesame flour recorded a significantly lower value (17.32 mg/mL). Vitamin C is susceptible to heat, and as a result, roasting can significantly decrease its levels, as ascorbic acid degrades when exposed to high temperatures for extended periods (Reddy et al., 2020). This study also indicated a decrease in the vitamin C content of roasted sesame flour. Although vitamin A is more stable than vitamin C, roasting can still lead to substantial losses. The temperature and duration of the roasting process influence the extent of the reduction.

Table 1: The influence of processing methods on the vitamin composition of sesame flour.

Parameters (%)	Raw	Roasted	LSD
Vitamin C	4.11^a	1.37^b	0.646
Vitamin A	0.13^a	0.08^b	0.010
Vitamin E	2.44^a	2.08^b	0.012

^{abc} Means (of triplicate samples) on the same row with different superscripts are significantly different (P<0.05) according to Duncan's multiple range test. LSD means Least Significant Difference.

Table 2: The influence of processing methods on the antioxidant composition of sesame flour.

Parameters (%)	Raw	Roasted	LSD
DPPH (%)	51.61^a	34.35^b	0.040
FRAP (mg/100 g)	17.86^a	17.32^b	0.174

^{abc} Means (of triplicate samples) on the same row with different superscripts are significantly different (P<0.05) according to Duncan's multiple range test. LSD means Least Significant Difference.

The impact of roasting on fat-soluble vitamins, such as vitamin A, is generally less severe compared to water-soluble vitamins (Wang et al., 2017). Prolonged roasting, particularly at high temperatures, can lead to moderate losses of vitamin A, as noted by Osei et al. (2019), which suggests minimal reduction of vitamin A levels in roasted sesame flour. Despite being more stable than vitamin C, roasting can still affect vitamin E levels since tocopherols and tocotrienols can oxidise at elevated temperatures (Akinmoladun et al., 2020). This study also indicated a slight reduction in vitamin E content in roasted sesame flour. According to Zhang et al. (2018), toasting sesame seeds at 160 °C for 20 minutes resulted in a significant decrease in DPPH radical scavenging activity by approximately 35%. This decrease was attributed to the thermal degradation of antioxidants and phenolic compounds, indicating a reduction in DPPH content. Kim & Lee (2020) reported that toasting sesame seeds at 170 °C for 15 minutes resulted in a nearly 25% decline in FRAP values. The findings highlighted that the loss of crucial antioxidants in sesame seeds due to heat was responsible for the reduction in antioxidant capacity, as reflected in the recorded decrease in FRAP content.

Conclusion

This comprehensive study revealed that different processing techniques notably influence the nutritional profile of sesame flour. The findings indicated that flour made from raw seeds possesses a higher nutritional value; however, when heat treatment is necessary, it should be applied mildly to preserve the beneficial compounds found in sesame products. Each variety of sesame appears to have its distinct nutritional characteristics, allowing for selection based on specific requirements. To bolster the sesame industry, it is essential to introduce innovative products, such as snacks and spreads, and to inform consumers about the health benefits of sesame and the various processing techniques. Investigating the post-harvest handling of sesame is vital to minimise nutrient degradation and to uphold its quality, ensuring that the final sesame product maintains its standards. Collaboration among researchers, industry stakeholders, and government entities is needed to enhance processing methods, foster innovation, and guarantee consistent quality through standardisation. These initiatives will amplify the sesame sector's contribution to both nutrition and economic development at local and global levels.

Funding Statement

No funding was received for this project.

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