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Abstract

Sesame (*Sesamum indicum* L.) is an oilseed crop rich in nutrients. Several varieties of Burkina Faso are cultivated, but their nutritional composition remains poorly studied. This study aims to evaluate the physicochemical and nutritional properties of four sesame varieties (*A Kilom*, *Wollega*, *Pakre-saaya*, *Bo nognora*) available in Burkina Faso, whole and after hulling, produced in Burkina Faso. Color parameters were evaluated according to the CIE Lab* system, and physicochemical and nutritional parameters according to standard methods. The results revealed that hulling significantly influences seed color, with an increase in lightness values (L*) and a reduction in chromatic components (a*, b*). The A Kilom variety that was black in color, the other varieties were white. The results showed that whole seeds have significantly higher mineral contents. On the other hand, hulled seeds revealed a higher lipid and energy content. Significant variations were also observed between the different varieties, highlighting the influence of genotype on nutritional composition. The weight of 1000 grains varied from 1.29 g to 1.32 g. The percentage of moisture and ash ranged from 2.30±0.09 to 3.95±0.01% and 2.33±0.02 to 6.90±0.02%, respectively, and that of fat 41.80±7.07 to 63.86 ± 1.41%, while the protein content ranged from 9.35±7.78 to 20.15 ± 1.41%. Carbohydrate content ranged from 3.78±7.92 to 10.61±1.63%, energy value 2145.69±16.07 to 3657.05±7.07 Kj/100g. The contents of calcium, potassium, magnesium, zinc and iron ranged from 92.66±7.07 to 594.81±7.07 mg/100g, 203.57±7.07 to 467.55±7.07 mg/100g, 163.54±7.07 mg/100g to 265.38±7.07 mg/100g, 3.71±7.07 to 4.84±7.07 mg/100g and 3.25±0.00 to 10.38±7.07mg/100g, respectively. This study helps to better guide the choice of varieties according to food or industrial uses, and highlights the interest of sesame as a source of essential nutrients in diets.

Keywords: Sesame varieties, Color parameters, Proximate composition, Mineral composition, Burkina Faso

1. Introduction

Sesame (*Sesamum indicum* L.) is an oilseed crop of major economic and nutritional importance in many tropical regions, particularly in West Africa [1]. In Burkina Faso, sesame cultivation has grown considerably over the last decade and occupies an increasingly important place in agricultural systems, due to its good adaptation to local climatic conditions, low cultivation requirements, and high commercial value on national and international markets [2,3]. Beyond its agronomic interest, sesame is an excellent source of nutrients for human consumption, particularly due to its high content of unsaturated lipids (45 to 55%), high-quality proteins (19 to 25%), dietary fiber, minerals (calcium, iron, zinc, magnesium, potassium), vitamins (B, E), and antioxidant compounds such as lignans [4–9] .These characteristics make it a strategic food for nutritional security, particularly in areas of high food vulnerability. Sesame is a very important source of protection against oxidative stress owing to its composition of phenolic compounds and lignans [10–14]. It has activity owing to its sesamine composition [15–18] .

In terms of sesame use and processing, around 70% of the sesame seeds produced worldwide are used to produce oil and derived foods. Tanzania is the largest consumer of sesame seeds in the world (21%), followed by China (19%), Sudan (9%), and Myanmar, India, Ethiopia, and Nigeria (6% each)[19]. White sesame seeds are usually roasted and used as topping material in baked goods, snacks, and salads. Black sesame is a high-value ingredient exported to Japan and other countries, and mixed seeds (red, brown, yellow) are used for oil extraction and medicinal purposes[19]. In Burkina Faso, sesame seeds are not sufficiently consumed, and local processing remains low compared to the volume exported in raw form. Although limited, sesame processing is semi-artisanal. However, efforts are underway to industrialize the sector to add value.

Despite the diversity of varieties grown in Burkina Faso, including local and introduced varieties, few studies have been conducted to evaluate their physical, chemical, and nutritional characteristics. Previous research on sesame has focused primarily on agromorphological and pedoclimatic conditions and varietal improvement. This study, conducted by the Institute of Environment and Agricultural Research (INERA), has focused more on increasing production yields than on studying the biochemical composition of sesame seeds [20]. Studies conducted on nutritional characterization were performed on the S42 and Humera Real varieties by Oboulbiga et al[21].

The present study, therefore, aims to characterize the main sesame varieties grown in Burkina Faso in terms of nutrition, highlighting their physical characteristics (weight of 1,000 grains, color), macronutrient content, and mineral content. Such an analysis will contribute to a better utilization of local sesame, both for domestic consumption and for the agri-food and export sectors.

2. Materials and methods

2.1. Plant material and sample pretreatment

The plant material consisted of seeds of four sesame varieties obtained from the INERA Kamboinsin Research Station (Ouagadougou). These are the *Wollega*, *Bonogora, Pakre-saaya, A Kilom*. The experiment was conducted using a divided plot design in a randomized complete block design with two replications. Three samples were collected from each sesame variety for the analysis. Whole sesame seeds from these varieties were manually cleaned to remove any damaged seeds. Then, the cleaned seeds were sorted and ground using a stainless-steel electric grinder SEAAN type and stored in the freezer Boreal at -20°C for analysis. The seeds were ground to enable better nutritional analysis. Hulled sesame seeds were obtained from each sesame variety. These were obtained by hulling using a wooden mortar. The physicochemical analyses were carried out in triplicate.

2.2. Determination of physicochemical parameters

The thousand Kernel Weigh (TKW) was determined using the method described in the standard[22]. This method involves weighing a sample and then separating the whole grains from the impurities and broken grains. Whole grains were then counted, and their total mass was divided by their number to obtain the average mass of a grain. The results were then reported for thousand grains. For the samples analyzed, the TKW grains were determined from a 30 g test sample after the removal of impurities and broken grains. It is expressed in grams and corresponds to an average mass of a thousand whole grains.

The acidity of a fatty substance refers to the percentage of fatty acids contained in that substance. Depending on the nature of the fatty substance, the acidity can be expressed as oleic acid, palmitic acid, or lauric acid. However, the acidity of most vegetable oils is expressed in terms of oleic acid. Acidity and acid number were determined using this method [23]. This method consisted of weighing five (5) g of each sample in an Erlenmeyer flask. After weighing, the samples were suspended in 30 ml of alcohol-water and then placed on a hot plate at 150° Celsius until a homogeneous mixture was obtained. After cooling the sample-alcohol mixture, the solution was supplemented with a few drops of phenolphthalein (color indicator) and titrated with 0.1N sodium hydroxide until a pink color was obtained, indicating the end of the titration. Total acidity was expressed as a percentage of citric acid using the following equation:

$$\text{Acidity (\%)} = (7{,}35\text{x } (V1 - V0)\text{x } C\,)/Pe \quad \text{(in g of H2SO4 per 100g of product)}$$

V1 = Volume of NaOH required to titrate the sample, V0 = Buret drop for the sample, Pe = Test portion, C = Concentration in moles of NaOH

Determination of color parameters (Lab): The color of the different sesame samples was measured using a colorimeter (PCE-CSM 1, PCE instruments, Im Langel 4, D-59872 Meschede, Germany) based on the color system of the International Commission on Illumination (CIE): L*, a*, b* and *, C*, h°, a*/b*. Measurements of the parameters L*, a*, and b* were performed three times for each sample by placing the objective of the colorimeter on a homogeneous surface of the sesame seeds. The parameter L* approximately measures brightness or luminance and is expressed on a scale between black and white (0=black, 100=white). This was measured at an angular angle. Parameter a* takes positive values for reddish colors and negative values for greenish colors, whereas b* takes positive values for yellowish colors and negative values for bluish colors[24].

The values of the parameters C* are calculated as follows:

$C* = \sqrt{(\text{ a *2+b*2})}$

The C* index represents the saturation of the color.

2.3. Determination of the proximate composition of sesame grains

The water content of the sesame samples was determined by differential weighing before and after oven drying at 105 ± 2 °c for 24 h of a 5 g sample according to the international standard[25] .

The ash levels were determined according to international standards [26]. Five (5) g of the ground sample were weighed in an empty weight crucible and then placed in a furnace at 550°C for 12 h. The calcined samples were removed from the furnace, placed in a desiccator for cooling, and weighed.

The fat content of the samples was determined by Soxhlet extraction using hexane [27]. Fat content was determined by weighing after evaporation of the hexane by distillation. 5 g of each ground sample (Pe) were placed in a cartridge, then placed in the hexane Soxhlet extractor and placed in a beaker (Pv) of known weight, all adapted to the Soxhlet. Extraction was carried out by reflux for 4 hours. The solvent was then evaporated by distillation using a rotary evaporator. The distillate was then dried in an oven for 1 hour. The beaker containing the fat was cooled in a desiccator and then reweighed, and the final weight (Pf% Lipids = (Pf-Pv)×100/Pe) was determined.

Pe: test sample.

Pv: weight of the beaker.

Pf: weight of the flask + fat.

Total sugars were determined by the orcinol method described by [28] . 0.2 g of each sample was placed in a centrifuge tube. 5 ml of distilled water was added, and the mixture was stirred magnetically for 10 minutes. It was then transferred to a 100 ml volumetric flask, the volume was made up with distilled water, and then homogenized. 1 ml of homogenate was taken into a test tube, to which 2 ml of orcinol reagent and 7 ml of 60% H_2SO_4 were added. The mixture was stirred and then heated in a boiling water bath for 20 minutes. The mixture was then placed in the dark for 45 minutes, then at room temperature for 10 minutes. Absorbance was measured at 510 nm using a spectrophotometer after homogenization. The total sugar content was calculated using a calibration curve with d-glucose as the reference sugar. Total sugar levels are expressed in g/100 g dry matter according to the formula:

$$\%ST = \frac{\mathrm{Fd} \times \mathrm{d} \times \mathrm{V} \times 100}{\mathrm{Pe}}$$

With: % ST: Total sugar content; V: Volume; c: concentration on curve; Fd: dilution factor.

The protein content of the samples was determined using the Kjeldahl method as described in ISO Standard [29]. In a Kjeldahl flask were introduced 1 mg of the sample, a Kjeltabs catalyst pellet and 10 ml of concentrated sulfuric acid. The mixture was subjected to mineralization for

4 hours at 400 ° C until a completely discolored solution was obtained. After cooling, 50 ml of distilled water was added to the mineralized product, which was then neutralized with a 40% sodium hydroxide solution. The neutralized solution was distilled and the ammonia solution collected in an Erlenmeyer flask. The distillation was stopped when the final volume in the Erlenmeyer flask reached 150 ml. The distillate was then titrated with a 0.1 N sulfuric acid solution until the indicator color changed from green to pink. The volume of sulfuric acid was then recorded.

A blank was prepared using the same procedure, replacing the sample with distilled water. The total nitrogen content was calculated using the following formula:

$$\%P = (N \times 14 \times (Ve - Vb) \times 6{,}25)/Pe \times 100$$

%P: Total protein content

With Vb: Volume of acid required to neutralize the blank (in ml), Ve: Volume of acid required to neutralize the sample (in ml), Pe: Test portion, N (0.1) = Normality of the sulfuric acid solution

The theoretical energy value was calculated using Atwater coefficients [30].

Energy value (kcal/100 g) = (g protein) ×4 + (g carbohydrate) ×4 + (g fat) ×9.

2.4. Determination of minerals

The determination of minerals (calcium, magnesium, potassium, iron, and zinc) in the sesame samples was carried out according to the flame atomic absorption spectrometry method after mineralizing the sample according to the method described by the AOAC International[31]. For mineralization and acid digestion of the mineralized material, a test portion of 2 g of the sample was placed in crucibles for mineralization by a dry process in a muffle furnace. After cooling, 10% nitric acid was added to the crucibles, and the resulting mixture was filtered using filter paper and transferred to 50 ml flask tubes until filling. The resulting solution was stored at room temperature until the injection. The concentrations of the standard ranges (ppm) were defined. The standard solutions were prepared by diluting the commercial solution in 10% nitric acid (20 ml of HNO3 (76%) in a 1000 ml volumetric flask and topping up with ultrapure water to the mark.

2.5. Statistical analysis of data

Data were entered into Excel 2019 software. Analyses of variance (ANOVA) were performed using XLSTAT version 2016. The means of the different values were compared using analysis of variance (ANOVA) with the Tukey test at a 5% level of significance. The results are expressed as mean values ± standard deviation and presented in tables.

3. **Results and discussion**

3.1. Physicochemical parameter

Table 1 presents the thousand Kernel Weigh (TKW) of whole sesame grain samples and the basic seeds of the four sesame varieties. The TKW is widely used in the field of grain technology and agronomy. It is one of the components of agronomic yield. It is an essential physical parameter that provides information on quality, density, and technological performance.

The TKW varied between 1.29 g for the *Bo nogora* whole variety and *Wollega* whole and base at 1.32 g for the *Pakre-saaya* variety. Statistical analyses showed no significant difference between varieties or between whole grains and basic seeds of the same variety ($p<0.05$). The weight of 1000 grains are lower than those found by [32–36] with respective values of 2.79-3.64g; 3.29; 3.1-3.9g; 3.26-4.18g and 2,74-3,16g. This difference could be explained by the growing conditions[33]. This difference may be due to the agronomic and environmental conditions that influence the weight of sesame grains. This could be explained by a genetic origin that gives the plant the ability to synthesize more organic and mineral matter during seed production.

Table 1: Weight per thousand grains of the four sesame varieties

Varieties	Shape	Thousand Kernel Weigh (TKW) (g)
Pakre saaya	Whole	1.32 ± 0.25^{a}
	Base	1.32 ± 0.95^{a}
Bo nogora	Whole	1.29 ± 0.14^{abc}
	Base	1.31 ± 0.14^{ab}
At Kilom	Whole	1.30 ± 0.12^{abcd}
	Base	-
Wollega	Whole	1.29 ± 0.50^{abc}
	Base	1.29 ± 0.85^{abc}
	P-value	0.000

In the same column, values assigned the same alphabetical letter are not significantly different according to the test at the 5% threshold

The acidity index of cultivated sesame varieties is shown in Table 2. The acidity and acidity index of whole sesame seeds and base seeds of the varieties ranged from 2.23 ± 0.32 to 5.83 ± 0.25 (% oleic acid) and from 1.12 ± 0.54 to 2.91 ± 0.36 mg KOH, respectively. The lowest values of acidity and acidity index were for hulled A *Kilom* and the highest value was for base *Pakre-saaya*. The results of the statistical analysis showed a significant difference between the whole and hulled sesame varieties. These results are similar to those of [37]Saudi Arabia, which found acidity ranging from 0.19 to 2.00% oleic acid in several sesame varieties. The low acidity index in some sesame samples indicates that sesame has not undergone any spoilage reactions, such as oxidation reactions. The high acidity index in sesame samples may be an indication of rancidity, oxidation, a high degree of biological activity, and deterioration of non-fatty substances such as carbohydrates and proteins[37]. This difference can be explained by the fact that the seed, in addition to fat, contains other substances that can affect the acidity index. The acidity content may depend on the shelf life of sesame seeds.

Table 2: Acidity index of cultivated sesame varieties

Varieties	Shapes	Acidity (% oleic acid)	Acidity index (mg KOH)
	Whole	5.43 ±0.67^{ab}	2.72 ±0.23^{ab}
Pakre-saaya	Base	5.83±0.25^{a}	2.91±0.36^{a}
	Hulled	4.35 ±0.15^{abcd}	2.17±0.19^{abcd}
	Whole	-	-
Bo nogora	Base	4.91± 0.24^{abc}	2.45± 0.24^{abc}
	Hulled	4.25 ±0.18^{abcd}	2.13±0.15^{abcd}
	Whole	4.48± 0.27^{abc}	2.24 ±0.14^{abc}
At Kilom	Base	3.35 ±0.14^{abcd}	1.67± 0.32^{abcd}
	Hulled	2.23 ±0.32^{cd}	1.12± 0.54^{cd}
	Whole	3.03±0.19^{bcd}	1.52± 0.84^{bcd}
Wollega	Base	-	-
	Hulled	-	-
	P-value	0.000	0.000

In the same column, values assigned the same alphabetical letter are not significantly different according to Turkey's test at the 5% threshold

The color parameters (L*, a*, b*, and c*) of the four sesame varieties are listed in Table 3. Photographs are shown in Figure 1. The luminance (L*) was between 28.87 (*A Kilom* Base) and 56.69 (*Bo nogora* base). The color parameter a* ranged between 2.06 (*A Kilom* whole) and 9.69 (*Wollega* base). The color parameter b* oscillated between 11.75 (*Pakre-saaya* base) and 25.41 (*Bonogora* base). The color parameter, C* was between 10.67 (*Pakre-saaya* base) and

27.18 (*Wollega base*). Analysis of variance revealed statistically significant ($P<0,005$) differences between sesame variety grains for color parameters.

Sesame color is related to biochemical properties, antioxidant content, and disease resistance of sesame crops[38]**.** The color of the seed coat is related to the oil, protein, and lignan content of sesame seeds[39]**.** The color of grains is related to the metabolism of sesame proteins and oil[40]**.** The L* luminance of the *Wollega*, *Pakre-saaya*, and *Bo nogora* varieties was high. This indicates that these varieties tend toward white. The Bo nogora variety is whiter than the *Pakre-saaya* and *Wollega* varieties, because its L* luminance value is higher. The A *Kilom* variety is black because its luminance is very low, tending toward 0. Figure 1, which presents their photographs, shows the same results. The L* values are similar to those obtained by, [40]with values ranging from 10.53 to 63.40. The sesame seeds of the varieties tend to have toward reddish color rather than a greenish color because the a* value obtained is positive. According to(Granato & Masson, 2010), the a* parameter has positive values for reddish colors and negative values for greenish colors. The b* parameter has positive values for yellowish colors and negative values for bluish colors[41]. The b* values obtained for these sesame varieties were positive, indicating that they tended toward yellow. *A Kilom* is less red and yellow than the other varieties because it has lower a* and b* values. The C* index indicates the brightness and dullness. The C* values obtained for the varieties were high, which indicates that their colors are vivid (bright).

Table 3: Color parameters of sesame seeds

Samples/ Color parameters		L*	a *	b *	C *
Pakresaaya	Whole	50.60^{a}	8.01^{a}	24.11^{a}	25.42^{a}
	Base	29,5737^{b}	7.77^{a}	11.75^{b}	10.67^{c}
Bonogora	Whole	55,185^{a}	6.89^{ab}	21.77^{a}	22.83^{ab}
	Base	56.69^{a}	6.91^{ab}	25.41^{a}	26.35^{a}
Wollega	Whole	40.04^{ab}	6.40^{ab}	19.04^{ab}	20.12^{abc}
	Base	50.54^{a}	9.69^{a}	25.37^{a}	27.18^{a}
A Kilom	Whole	28.87^{b}	2.06^{b}	14.94^{c}	15.14^{bc}
	Base	-	-	-	-
	P-Value	<0.0001	0.000	<0.0001	<0.0001
	Significant	Yes	Yes	Yes	Yes

In the same column, values assigned the same alphabetical letter are not significantly different according to Turkey's test at the 5% threshold

Figure 1: Photos of sesame seed colors

3.2. Proximate composition of sesame varieties

Table 4 presents the proximate composition of the four sesame varieties. The moisture contents of whole sesame samples ranged from 3.30±0.03 for whole *Pakre-saaya variety to 3.95±0.01% for whole Wollega* variety; those of hulled grains ranged from 2.30±0.09 for *A Kilom* variety to 3.31±0.03% for *Wollega* variety. Concerning the ash contents, they ranged from 2.91±0.02 (*Bo nogora* base) to 6.90±0.02% (whole *Pakre-saaya*) for whole sesame grain samples, from

2.33±0.03 (*A Kilom*) to 3.84±0.06 (*Pakre-saaya*) for hulled grains. As for the fat contents, they varied from 41.80±7.07 (*A Kilom* base) to 63.86±1.41% (*Pakre-saaya* whole) for whole sesame seeds and between 50.97±3.54 (*Pakre-saaya*) to 85.70±7.07% (*A Kilom)* for hulled ones. The protein contents varied from 14.77±7.07 (*Pakre-saaya*) to 19.26±0.00% (*Bo nogora* base) for whole and base sesame seeds and from 9.35±7.78 (*Wollega*) to 20.15±1.41% (*A Kilom)* for hulled ones. The minimum and maximum values of carbohydrate content ranged from 6.09±9.12 (*A Kilom* whole) and 10.61±1.63 (*Bo nogora*) for whole and base sesame grains. For hulled grains, they ranged from 3.78±7.92 (*Wollega*) to 5.78±4.74% (*A Kilom*). The energy values ranged from 2145.689±16.07 (*Pakre-saaya* base) to 2847.812±7.07 kJ /100gMS (*Pakre-saaya* whole) for whole and base sesame grains and from 2166.72±7.07 (*Wollega* f) to 3657.05±7.07 (*A Kilom)* kJ /100g MS for hulled grains.

Statistical analysis revealed significant differences between the nutritional parameters studied at the 5% threshold, including water content, ash, lipids, proteins, and carbohydrates present in the seeds of the whole, base, and hulled sesame varieties studied.

The water contents obtained in this study were lower than the values obtained for [42] whole and hulled white and black sesame, with values ranging from 4.18 to 5.58% and 5,47 to 5,69%. The water content obtained is also lower than the values obtained by [8] on local and introduced varieties, with values ranging from 5,47 to 5,69%.

These values were similar to those obtained for (Zebib, Bultosa and Abera, 2015) [34] the Ethiopian sesame varieties, with values from 3.17 to 3.40%. The ash contents obtained were similar to those obtained for [42,43] the whole and hulled sesame varieties. The protein contents obtained were lower than those (21.94 to 26.79% and 22,34 to 23,05%) obtained [8,42] respectively in whole and hulled sesame seeds. The fat content of some forms of the seeds of the varieties obtained were higher than those of [8,9,42]. The carbohydrate content obtained was lower than those of Makinde & Akinoso[42] with the two varieties of whole and hulled sesame and [8] on local and introduced varieties.

The variation in water, ash, protein, carbohydrate, and fat contents between the varieties in this study and those of other authors could be explained by environmental and genetic conditions. Sesame seed hulling resulted in decreased ash, protein, and carbohydrate contents. (Makinde and Akinoso, 2013; Yewande Bamigboye, Chinyeaka Okafor and Thomas Adepoju, 2010) [42,44]also found a decrease in ash and protein content after hulling the grains. treatment of sesame fats by hulling leads to a decrease in ash content and, consequently, a decrease in minerals**.** This shows that the ash was mainly concentrated in the germ of the [42] seed. Processing sesame seeds by hulling resulted in a decrease in protein content**.**

The sesame seeds studied are rich in fat, protein, carbohydrates and minerals,

Owing to its interesting nutritional value, sesame can be used as a food supplement to improve the nutrient content of other foods low in protein and minerals. It can also be used as a food supplement or an additive in the formulation of complementary diets for infants.

Table 4: Nutritional composition and energy value of sesame seeds dry matter

Variety	Shapes	Moisture (%)	Ash (%)	Protein (%)	Fats (%)	Carbohydrates (%)	Energy value (kJ)/100g
Pakre saaya	Whole	3.30±0.03^{bcde}	6.90 ± 0.02^{b}	17.69 ± 7.07^{h}	63.86 ± 1.4^{1}	8.91 ± 0.00^{abc}	2847.81± 7.07^{c}
	Base	3.75±0.01^{abcd}	4.70 ± 0.05^{d}	14.77± 7.07^{p}	47.69 ± 7.07^{n}	6.28± 3.71^{abc}	2145.69± 16.07^{o}
	Average	**3.50 ±0.28**	**5.80 ±1.56**	**16.23 ±2.06**	**55.77 ±2.02**	**7.59 ±11.43**	**2496.75 ±7.07^{b}**
	Hulled	3.00±0.06^{bcde}	3.84 ± 0.06^{d}	14.93± 7.07^{o}	50.97± 3.54^{l}	5.61± 1.58^{abc}	2237.49± 7.07^{k}
Bo nogora	Whole	3.80 ±0.08^{abc}	4.42±0.3^{i}	17.81± 6.36^{g}	50.26± 7.07^{m}	7.17 ± 0.00^{abc}	2308.83 ± 9.10^{d}
	Base	3.50 ±0.06^{bcd}	2.91±0.02^{f}	19.26 ± 0.0^{b}	58.22 ± 7.07^{e}	10.61± 1.63^{a}	2690.16 ± 7.07^{e}
	Average	**3.65 ±0.21**	**3.66 ±1.07**	**18.54 ±1.03**	**54.24 ±2.52**	**8.89 ±5.63**	**2499.49 ±7.07^{b}**
	Hulled	2.80 ±0.04^{cde}	2.91±0.6^{n}	16.38± 1.41^{d}	52.28± 0.00^{i}	4.00± 10^{c}	2306.28± 7.07^{d}
At Kilom	Whole	3.31±0.07^{bcde}	3.50 ±0.06^{k}	19.06± 7.07c	52.14± 7.07^{d}	6.09± 9.12^{abc}	2382.87± 10.07^{h}
	Base	3.70 ±0.05^{abcd}	3.40 ±0.23^{l}	19.04± 7.07^{d}	41.801± 7.07^{s}	6.70 ± 4.74^{abc}	2003.20 ± 2.41^{q}
	Average	**2.30 ±0.09^{e}**	**2.33 ±0.03^{r}**	**20.15± 1.41^{a}**	**52.21± 7.07^{a}**	**5.78 ± 4.74^{abc}**	**3657.05± 7.07^{a}**
	Hulled	3.50 ±0.28	3.45 ±0.85	19.05 ±0.77	46.97	6.39 ±23.73	2193.03 ±7.08
Wollega	Whole	3.95 ±0.01^{ab}	4.50±0.1^{g}	15.77± 1.41^{k}	46,533± 3.5^{q}	9.92 ± 3.95 ^{ab}	2180.25± 1.41^{m}
	Base	-	-	-	-	-	-
	Average	**3.90 ±0.01**	**4.50±0.1**	**15.77± 1.41**	**46.53± 3.5**	**9.92± 3.95**	**2180.25± 1.41**
	Hulled	3.31±0.03^{bcde}	2.91±0.36^{o}	9.35± 7.78^{s}	51.17± 7.78^{k}	3.78± 7.92^{c}	2166.72± 7.07^{n}
	P-value	<0.0001	<0.0001	<0.0001	<0.0001	0.005	<0.0001

In the same column, values assigned the same alphabetical letter are not significantly different according to Tukey's test at the 5% threshold.

3.3. Mineral content

The mineral compositions of whole sesame grains and hulled basic seed seeds are presented in Table 5.

The calcium content was between 367.33±7.07 (*Pakresaaya* Base) and 594.81±7.07 mg/100 g (Whole *Wollega). As for the hulled sesame, it was between 92.66±7.07 (Bonogora) and 367.15±7.07 (A Kilo*). As for potassium, the contents were between 203.57± 7.07 mg/100 g (*A*

Kilom base) and 467.55± 7.07 (Whole *Pakre-saaya*). The potassium content of hulled sesame was between 277.29±7.07 (*Bonogora*) and 407.78±7.07 mg/100 g (*Wollega*). As for magnesium, the content was between 163.54± 7.07 (*A Kilom* Base) and 215.292± 6.36 mg/100 g (whole *Pakre saaya*). As for hulled sesame grains, the magnesium content was between 179.74± 7.07 (*Wollega*) and 265.38± 7.07 mg/100 g *(Bonogora*). The zinc content was between 3.71±7.07 mg/100 g *(A Kilom* Base) and 4.28 ±7.07 (*Pakre saaya* base). As for hulled sesame seeds, the zinc content was between 3.81 ± 7.07 (Bonogora) and 4.84 ± 7.07 mg/100 g (*A Kilom*). The iron content was between 3.61 ± 7.07 (whole *Pakre saaya*) And 10.38 ± 7.07 mg/100 g (*A Kilom* base). As for hulled sesame grains, iron was between 3.25± 0.00 (*Wollega*) and 4.35 ± 7.07 mg/100 g (*Bonogora*).

Statistical analyses of macro-mineral and trace element compositions showed that their contents were significantly different ($P < 0.0001$) between varieties and whole and hulled samples. For all varieties, calcium content was higher in whole sesame seeds than in hulled sesame seeds. These results are similar to those of, [42] who also found that the calcium content decreased after seed hulling. This could be explained by the fact that sesame germ contains a significant portion of the minerals. For potassium, magnesium, zinc, and iron, hulling increased or decreased the mineral element content, depending on the variety. [44] showed that hulling sesame increased the potassium content and decreased the calcium, zinc, and iron levels.

Calcium was the most abundant mineral element, followed by potassium and magnesium. The same order in sesame seeds has already been noted by authors such as[4,9,45]. The contents of calcium, magnesium, potassium, and iron were similar to those of [42] and lower than those obtained [9] in several varieties of sesame in Senegal. The calcium, potassium, magnesium, zinc, and iron contents were lower than those obtained [43] in sesame seeds from Belgium. The potassium, magnesium, and iron contents were lower than those [46] with respective values of 468.324 and 14.6 mg/100 g.

This variability in macroelement and trace element contents could be due to environmental and genetic factors, as well as to the methods used for analysis[9]. The studied sesame varieties contained high amounts of calcium, potassium, magnesium, iron, and zinc. They are a good source of these elements and can contribute to the fight against malnutrition through their consumption. Minerals play an important structural and regulatory role in the body. These materials partly comprise bones and teeth. As regulators, they are responsible for the proper functioning of the nerves and muscles. Minerals also play a role in the water balance, blood cell formation, and growth. Intake must be ensured through diet. Incorporating sesame into a balanced and varied diet provides the body with a sufficient quantity of its minerals.

Table 5: Mineral content of sesame seeds

Localities	Varieties	Ca (mg/100g	K (mg/100g)	Mg (mg/100g)	Zn (mg/100g)	Fe (mg/100)
Pakre saaya	Whole	547.58 ± 7.07^{f}	467.55± 7.07^{a}	215,292± 6.36^{d}	3.72± 7.07^{d}	10.38 ± 7.07^{a}
	Base	367.33± 7.07^{m}	280.62± 7.07^{f}	204.73 ± 7.07^{f}	4.28 ± 7.07^{f}	4.19 ± 7.07^{d}
	Average	**457.46**	**374.09**	**210.01**	**4.00**	**7.29**
	Hulled	113.22± 7.07^{o}	300.29 ± 7.07^{e}	214.41± 6.36^{e}	4.34± 7.07^{e}	4.35 ± 7.07^{i}
Bo nogora	Whole	507.24± 7.07^{i}	222.52± 7.07^{m}	191.71± 7.07^{i}	3.72 ± 7.07^{d}	5.09± 0.00^{g}
	Base	516.22± 7.07^{h}	236.45 ± 7.07^{l}	163.62 ± 7.07^{n}	3.51± 7.07^{k}	3.65± 0.00^{m}
	Average	**511.73**	**229.49**	**177.67**	**3.61**	**4.37**
	Hulled	92.66± 7.07^{r}	407.78 ± 7.07^{b}	265.38± 7.07^{a}	3.81 ± 7.07^{i}	4.34± 0.00^{i}
At Kilom	Whole	498.05± 7.07^{d}	212.66± 7.07^{n}	172.38± 7.07^{m}	3.95 ± 7.07^{g}	3.69± 7.07^{kl}
	Base	487.83± 7.07^{k}	203.57± 7.07^{o}	163.54± 7.07^{o}	3.71± 7.07^{d}	3.61 ± 7.07^{n}
	Average	**492.94**	**208.12**	**167.96**	**3.83**	**3.65**
	Hulled	367.15± 7.07^{n}	280.48± 7.07^{g}	204.64± 7.07^{g}	4.84 ± 7.07^{a}	3.72 ± 7.07^{k}
Wollega	Whole	594.81± 7.07^{d}	279.32± 7.07^{h}	198.22± 7.07^{h}	3.88± 7.07^{h}	9.67 ± 0.00^{b}
	Base	-	-	-	-	-
	Average	**594.81**	**279.32**	**198.22**	**3.88**	**9.67**
	Hulled	103.39± 7.07^{p}	277.29± 7.07^{i}	179.74± 7.07^{l}	4.43± 7.07^{c}	3.25± 0.00^{p}
	P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

In the same column, values assigned the same alphabetic letter as a superscript are not significantly different according to Turkey's test at the 5% threshold.

3.4. Principal component analyses, hierarchical ascending classification and class profile of physicochemical and nutritional composition

Principal component analysis was used to establish relationships between proximate and mineral levels in whole and hulled sesame seed samples (Figure 2). The results showed that the first two axes explained 62.35% of the observed variation, with 39.07% of the variation associated with axis 1, and 23.28% of the variation associated with axis 2. Variables such as acidity, acidity index, water content, ash, protein, fat, carbohydrate, calcium, and iron were positively correlated with axis F1, whereas fat, energy value, potassium, magnesium, and zinc were negatively correlated with axis F1. In contrast, variables such as acidity, acidity index, potassium, and magnesium were positively correlated with the F2 axis, while water content, ash, protein, fat, carbohydrates, energy value, calcium, zinc, and iron were negatively correlated with the F2 axis.

The class profile and hierarchical ascending classification (HAC) of the analyzed parameters allowed the classification of the samples into five groups (Figure 3 and 4). Group 1 was the whole *Pakre-saaya variety* characterized by high acidity, acid index, iron, water content, and carbohydrates; group 2 consisted of the whole *Bo nogora variety* , whole *A Kilom* , and whole *Wollega* characterized by high contents of protein, ash, calcium, carbohydrates, and water content; group 3 consisted of the hulled *Pakre-saaya variety* and hulled *Wollega* characterized by low nutrient contents; group 4 consisted of the hulled *Bo nogora variety* characterized by high contents of magnesium and potassium. Group 5 consisted of the hulled *A Kilom variety* is characterized by high protein, fat, zinc, and energy content. The variance decomposition showed an intra-group variability of 8.72% and an inter-group variability of 91.28%.

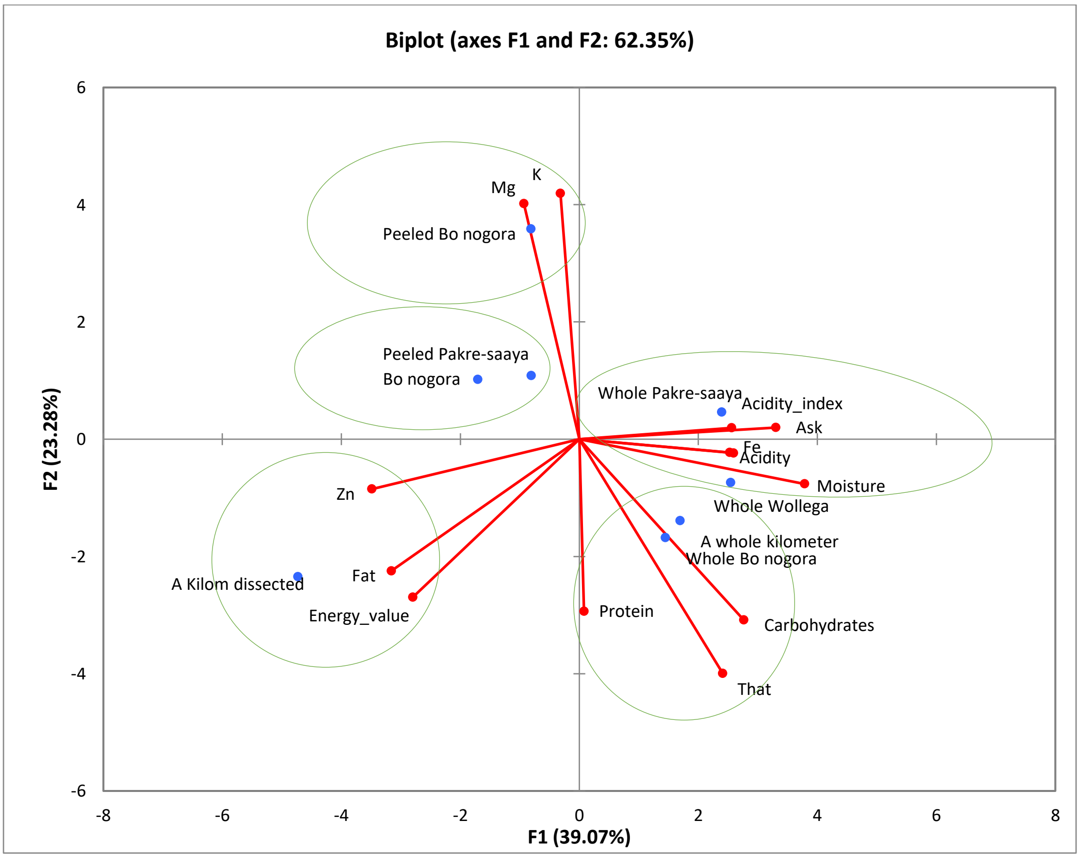

Figure 2. Principal component analyses of physicochemical and nutritional composition

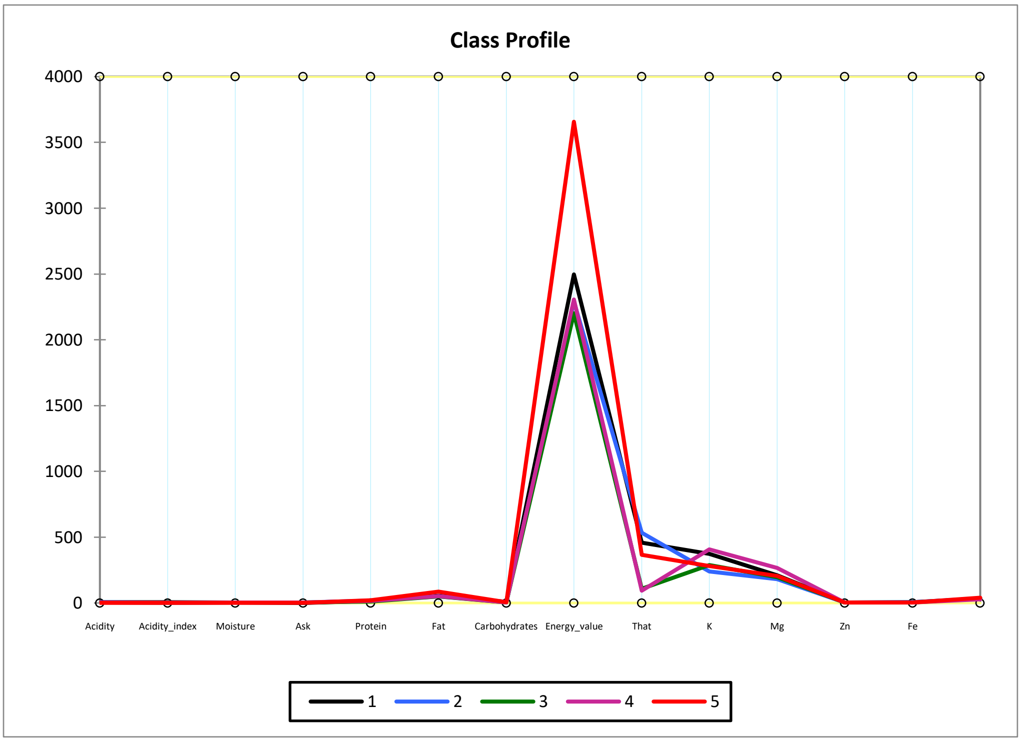

Figure 3. Profile of physicochemical and nutritional composition classes

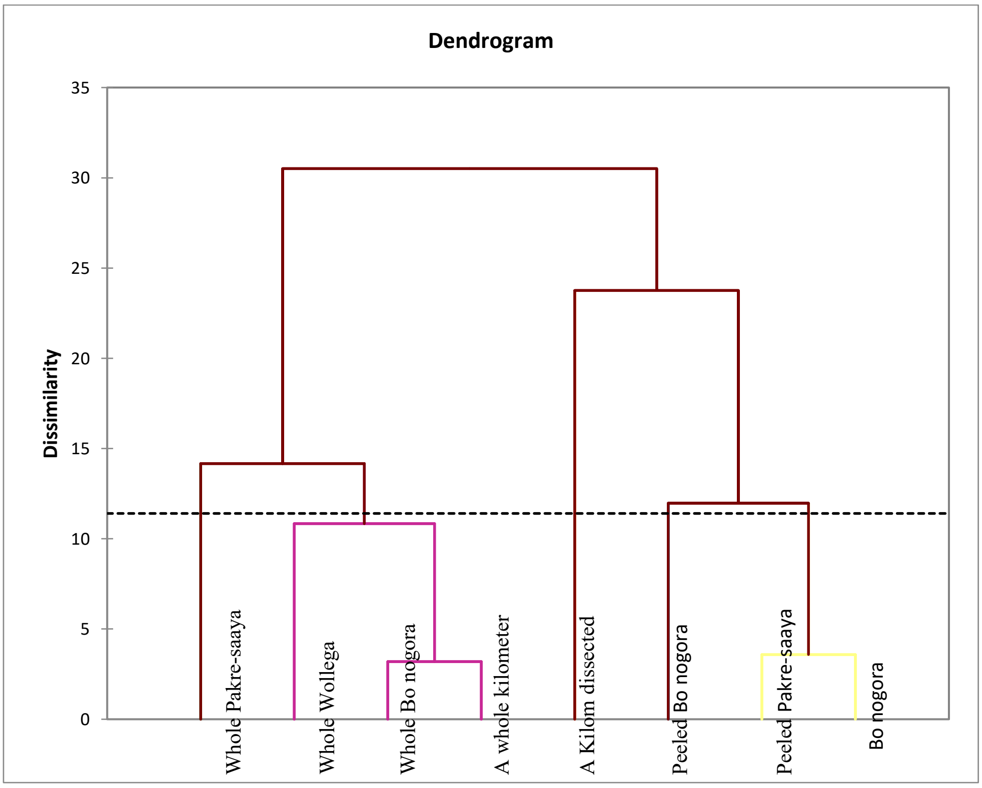

Figure 4: Dendrogram of the hierarchical ascending classification (HAC)

3.5. Scope of the study in terms of human health and nutrition

The four varieties of sesame studied contain high levels of fat, protein, and minerals. Sesame fat contains unsaturated fatty acids such as omega-6 and omega-9, which can help reduce bad LDL cholesterol, maintain heart health, and improve blood sugar levels and insulin sensitivity[7,47]. Its high magnesium, calcium, zinc, and phosphorus content helps strengthen bones, especially in older people. Sesame has antioxidant and anti-inflammatory effects due to its lignase (sesamine, sesamoline) and vitamin E content [16,17]. These antioxidant compounds combat oxidative stress, which is involved in cellular aging and chronic diseases (cancer, hypertension)[7,48]. Sesame can help combat micronutrient deficiencies due to its high mineral content. Because of its high fat and calorie content, it can help combat acute malnutrition in children aged 0 to 5 years.

Conclusion

The study on the physicochemical and nutritional characteristics of four varieties of sesame from Burkina Faso, both whole and hulled, revealed significant differences related to variety and processing (hulling). In general, whole seeds have a higher protein and mineral content, while hulled seeds are characterized by a lighter color and higher fat content.

The results also show that hulling affects certain technological quality parameters, such as moisture content and acid value, which can affect seed storage and stability. In terms of nutritional composition, certain varieties stand out for their high nutrient content, reinforcing their value in high value-added food formulations. The whole *Pakre-saaya* variety is a good source of iron, water, and carbohydrates; the whole *Bo nogora*, whole *A Kilom*, and whole *Wollega* varieties are rich in protein, ash, calcium, and carbohydrates; the hulled Pakre-saaya and Wollega varieties are low in nutrients; and the hulled *Bo nogora* variety is characterized by high magnesium and potassium content. The hulled *A Kilom* variety is rich in protein, lipids, zinc, and energy. All varieties were rich in minerals. However, calcium remained the most important element in all the varieties studied, followed by potassium, magnesium, iron, and zinc.

In conclusion, this study highlights the importance of choosing the variety and type of processing (whole or hulled) according to the intended use: direct human nutrition, oil extraction, or food processing. These four varieties can be used as protein and mineral additives for dietary supplements. The *Bo nogora, Kilom, and Wolleya* varieties can be used for oil extraction. These results open up interesting prospects for the promotion of local sesame varieties, taking into account both their nutritional qualities and their suitability for industrial processing.

Data availability statement

Study data are available from the corresponding author for researchers upon request.

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E.B.O. and D.C-S.: Conceptualization, investigation, project administration, methodology, writing-original draft, writing-review and editing. R.D. and S.Y.: Formal analysis, writing-original draft and writing-review and editing. A.S.D., G.Z., and F.N.: Methodology and formal analysis. Z.S.: Writing-review and editing. C.I.D., F.H-B., M.H.D. and D.K.: Supervision and writing-review and editing.

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Competing interests

The authors declare no competing interests.

Informed consent

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Ethics approval and consent to participate

Not applicable