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Physico-Chemical Properties of Sesame (*Sesamum indicum* L.) Varieties Grown in Northern Area, Ethiopia

Haftom Zebib[1], Geremew Bultosa[2], Solomon Abera[3]

[1]Abergelle Agricultural Research Center, Tigray Agricultural Research Institute, Abi-Adi, Ethiopia
[2]Department of Food Science and Technology, Botswana College of Agriculture, Gaborone, Botswana
[3]Department of Food Technology and Process Engineering, Haramaya University, Dire Dawa, Ethiopia
Email: hzhzebib6@gmail.com, gbultosa@bca.bw, solomon_abera2001@yahoo.com

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Abstract

This study was conducted to evaluate the physico-chemical properties of three sesame varieties: *Adi*, *Bawnji and T*-85. Sesame varieties showed significant ($p \leq 0.05$) differences on some physical properties, proximate, mineral, anti-nutritional (phytic acid) and antioxidant compositions. The average values of 1000 seed weight were ranged from (2.74 - 3.16 g) and true density from (1190.66 to 1215.58 kg m^{-3}). The moisture (wb), crude protein, ash, fat, fiber, total carbohydrate, Ca, Zn and Fe (db) were ranged: 3.17% - 3.96%, 22.58% - 24.27%, 4.46% - 6.19%, 50.88% - 52.67%, 5.60% - 6.26%, 8.3% - 11.69%, 1172.08 - 1225.71 mg/100g, 4.23 - 4.45 mg/100g and 10.2 - 10.75 mg/100g, respectively. Phytic acid contents were ranged from 307.61 to 324.91 mg/100g, total phenolics from (23.16 - 25.69 mg GAE/g) and ferric ion reducing power value from (32.33 - 34.53 μmol/g) (db). The results were compared with some other sesame varieties grown worldwide. Results showed that Ethiopian sesame varieties were good source in nutrients and were functional foods for human nutrition and utilization.

Keywords

Anti-Nutritional, Antioxidant, Mineral, Physical Properties, Proximate Composition, Sesame Varieties

1. Introduction

Sesame (*Sesamum indicum* L.) is herbaceous annual plant belonging to the *Pedaliaceae* family [1]. Sesame seed

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is also known as benniseed (Africa), benne (Southern United States), gingelly (India), gengelin (Brazil), sim-sim, semsem (Hebrew) and tila (Sanskrit) [2]. It is one of the world's important and oldest oilseed crops [3] [4] and has been used extensively for thousands of years as a seed of worldwide significance for edible oil, paste, cake, confectionary purposes and flour due to its highly stable oil contents, nutritious protein (rich in methionine, tryptophan and valine) and savory nutty roasted flavor [4] [5].

Oilseeds cover a total of 7.63% (about 855,000 hectares) of the grain crop area and 3.83% (6.6 million quintals) of yield production to the national grain production. For instance, Neoug (Niger seed), sesame and linseed covered 2.8%, 2.48% and 1.61% of grain crop area, respectively; and about 1.11%, 1.27% and 0.91% of the grain production, respectively [6]. Study reports indicate that Ethiopia is among the six producers of sesame seed, linseed and niger seed in the world [7]. The major sesame seed producing regions are situated in the North West and South West Ethiopian in Humera, North Gondar and Wollega [8]-[10].

Most of the sesame traded in the world is light seeded, but seed coats of local varieties can vary from white to buff, tan, gold, brown, reddish, gray and black [11]. Some of the variations in the seed are hundred seed weight that can range 0.11 - 0.46 g [12], protein 19% - 30% [13] [14], oil 34.4% - 59.8% [13], carbohydrates 6.4% - 21.0% [15]. In Ethiopia, improved sesame seed varieties were developed through researches that have good disease resistance, improved yields, different oil composition, size and color [16]-[18].

Sesame contains important minerals and vitamins such as Ca, P, and Fe, niacin and thiamin [15] [19] [20]. It has also some potential of nutraceutical compounds such as phenolic and tocopherols with antioxidant activity that have significant effect on reducing the blood pressure, lipid profile and degeneration of vessels and an impact in reducing chronic diseases [21]-[23]. On the other hand, other chemical components such as anti-nutritional factors such as phytate, trypsin, α-amylase inhibitors, lectin, and tannins are in existence in sesame seeds and can limit their utilization in the food system [24]-[27].

As sesame seed is nutritionally important in some parts of the world, few reports were documented about color, size and oil content of Ethiopian sesame seeds in the literature [17]-[19] and oil characteristics [28]. So, limited scientific research has been done on the physico-chemical composition of sesame varieties. The scientific information generated from this research could serve as an important input for production, marketing, food industry, human nutrition and maximum utilization, particularly for the benefits of sesame growing areas. The objective of this study was to investigate some physical properties, proximate, mineral, phytic acid, total phenolics and antioxidant power compositions.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted at Haramaya University from October 2011 to June 2012 in Food Science and Postharvest Technology laboratory for proximate, mineral, anti-nutritional and antioxidant compositions.

2.2. Experimental Materials and Preparation

The samples for the investigation were sesame (*Sesamum indicum*) varieties: adi, bawnji and T-85 were collected from Humera Agricultural Research Center (HuARC) in November 2011. Sesame seeds were cleaned manually to remove foreign matters, immature and damaged seeds. Then cleaned seeds were sorted out and crushed into smaller particles in a glass mortar and were stored in plastic bags at 4˚C till used for the experiment.

2.3. Physical Properties of Sesame Seed Varieties

2.3.1. Thousand Seed Weight

Thousand seed weight was determined by using electronic grain counter (Numigral, CHOPIN). The mass of 1000 seeds counted were measured on electronic balance [29].

2.3.2. True Density

A group of 100 seeds with a known average weight was counted using electronic grain counter (Numigral, CHOPIN). Then true density was determined after measuring the volume occupied by 100 seeds [30].

Color—the color of sesame varieties were evaluated visually.

2.4. Chemical Analysis

Moisture content (%) was carried out by drying in oven (Model: 101-1A, Tianjin Taisite Instrument Co. Ltd.). Sample (about 3.0g) was dried at 100˚C for 6 h [31].

Crude protein (%)-sample (about 0.3 g) was analyzed by *micro-Kjeldahl* method (digester: F30100184, SN: 111051, VELP Scientifica; distiller: F30100191, SN: 111526, Europe) [31] using urea as control. protein (%) = N (%) × 6.25.

Crude fat (%) was determined by Soxhlet extraction (Model: EV 16, SN: 4002824, Germany) of sample (about 2.0 g) using petroleum ether as a solvent [31].

Crude fiber (%) was determined by taking about 3.0 g sample as portion of carbohydrate that resisted sulfuric acid (1.25%) and NaOH (1.25%) digestion followed by sieving (75 µm), washing, drying and ignition to subtract ash from fiber [31].

Total ash (%) was determined by ashing about 3.0 g sample in a muffle furnace (Model: MF120, SN: 04-1524, Ankara Turkey) at 550˚C until ashing complete (over 12 hrs) [31].

Total carbohydrates (%) was determined by difference: 100 − (% Moisture content + % Crude protein +% Crude fat + % Crude fiber +%Total ash).

Iron (mg/100g) was determined after digestion of sample (about 2.0 g) by measuring absorbance of Fe^{2+} -1, 10-phenanthroline red complex color at 510 nm using UV-VIS spectrophotometer [32]. The iron level was estimated from standard calibration curve (0.0 - 10.0 µg Fe/ml) prepared from analytical grade iron wire.

Calcium (mg/100g) was determined after digestion of sample (about 2.0 g) by Atomic Absorption spectrophotometer (AAS) at 422.7 nm by adding enough La stock solutions. Calcium level was then estimated from standard calibration curve (5.0 - 25.0 µg Ca/ml) prepared from analytical grade calcium carbonate ($CaCO_3$) [32].

Zinc (mg/100g) was determined after digestion of sample (about 2.0 g) by Atomic Absorption Spectrophotometer (AAS) at 213.8 nm using air-acetylene as a source of flame for atomization [32]. Zinc level was then estimated from standard calibration curve (0.5 - 3.0 µg Zn/ml) prepared from ZnO.

Phytic acid was determined through phytate phosphorus (Ph-P) analysis [33]. Sample (about 0.25 g) was extracted with 12.5 ml of 3% trichlorol lacetic acid (TCA) for 45 min in a water bath (GLS 400 water bath, England) with vortex mixing (REAX top, Germany) at ambient temperature (23˚C) and centrifuged (4000 rpm10 min) (Centrurion Scientific Model 1020 DE, United Kingdom). About 4 ml of $FeCl_3 \cdot 6H_2O$ was mixed to 10 ml of the sample solution and the precipitate ferric phytate formed was analyzed for phytate phosphoru analyzed by measuring the absorbance at 822 nm using UV-Vis spectrophotometer (Model 6505, Genway LTD, U.K) [34]. The absorbance for sample was subtracted from the blank and phosphorus level was estimated from the calibration curve (0.0 - 1.2 mg/ml) prepared from KH_2PO_4. Then the phytic acid content was estimated by multiplying the amount of phytate-phosphorus by the factor 3.55 based on the empirical formula $C_6P_6O_{24}H_{18}$ (660 g) and phytic phosphorus (P_6) molecular mass (186 g) (*i.e.*, phytate = P × 3.55) and results were expressed as phytic acids in mg per 100 g (db).

Total phenolics content (TFC) was determined colorimetrically using Folin-Ciocalteau reagent, as described by [35]. Sample (about 0.4 g) was extracted with 20 ml of acidified methanol (1% HCl in methanol) for 1 hour at 25˚C, with vortex mixing at 5-minute intervals. Samples were centrifuged (Model 1020 D.E, UK) for 10 minutes at 1200 × g. Three replicate sample extract supernatants (0.5 ml) was mixed with 2.5 ml of Folin-Cicalteau reagent and allowed to stand at 25˚C for 8 min. Then 7.5 ml of 20% sodium bicarbonate solution was added to the mixture. After 2 h at 25˚C, absorbance was measured at 760 nm using a UV-visible spectrophotometer. A standard curve was prepared using various concentration of gallic acid and the results were reported as mg gallic acid equivalents/g of sample (db).

Antioxidant property analysis was measured by ferric ion reducing antioxidant power method as described by [36]. Sample (about 0.5 g) was extracted with 80% methanol (1 ml) on wrist action shaker for 2 h. Sample extracted supernatants was mixed with 2.5 ml of phosphate buffer (0.2 M, pH 6.6) and 2.5 ml potassium ferricyanide (1%) was mixed followed by incubation at 50˚C for 20 min. After then 2.5 ml of trichloroacetic acid solution (10%) was added to mixture and was then centrifuged (Model 1020 D.E, U.K.) at 3000 g for 10 min. The upper layer solution (2.5 ml) was mixed with 2.5 ml distilled water and 0.5 ml ferric chloride (0.1%). The absorbance of the mixture was measured at 700 nm immediately. Increased in the absorbance of the mixture is an indicator of increased reducing power. A standard curve was prepared using various concentration of ascorbic acid and the results were reported as µmol ascorbic acid equivalents/g of sample (db).

2.5. Statistical Analysis

Triplicate data were subjected to ANOVA [37] using Statistical Analysis System (SAS Institute and Cary NC) Version 9.0. Significant differences between means were determined with Duncan's multiple range tests at $p \leq 0.05$.

3. Results and Discussion

3.1. Some Physical Properties of Sesame Seed Varieties

Table 1 shows color, thousands seeds weight and bulk density of the sesame seed varieties. Results showed significant ($p \leq 0.05$) differences in thousands seed weight between varieties. However, adi and T-85 varieties were not significantly different ($p \geq 0.05$) in their thousands seed weight from each other. The highest (3.16 g/1000seeds) thousands seed weight was recorded for adi variety and lowest (2.74 g/1000seeds) was for bawnji variety. These findings are similar with range reported (2.0 to 3.5 g/1000seeds) by [38] and (2.76 - 3.96 g/1000seeds) by [39] for 12 sesame genotypes cultivated in Turkey. [38] reported that the results may vary depending on variety and cultural conditions. There were significant ($p \leq 0.05$) differences in true density values of sesame seed varieties. True density of the sesame seed varieties had ranged from 1190.66 to 1215.62 $kg \cdot m^{-3}$. The result of current study is lower than 1224 $kg \cdot m^{-3}$ for Nigerian sesame seed reported by [40]. Information on the true sesame density is used to design sesame seed separation or cleaning processes. Slight color variability between sesame varieties was found. The sesame color of this study is with the class of reported by [41]. Seed color varied from white, yellow, reddish, brown or black [41]. [42] reported that genotypic effects may be responsible for the variation in seed characteristics.

3.2. Proximate Composition of Sesame Seed Varieties

Table 2 shows results of proximate composition of sesame varieties. Moisture content of the sesame varieties are significantly ($p \leq 0.05$) different and ranged (3.17% - 3.96%). The results obtained are in the range (2.7% - 4.7%) reported by [42] for some varieties of Sudan and USA sesame genotypes but significantly lower than the range (5.12% - 7.8%) for 13 sesame accessions of south eastern Nigeria [43]. Crude fiber content was observed to be significantly ($p \leq 0.05$) higher in the adi and T-85 varieties 6.26 and 6.09% respectively than bawnji variety (5.6%). These values are in the range 3.2% - 10.0% reported by [44] but are higher than the range 3.3% - 4.66% reported by [42] for Sudan varieties and USA genotypes. Fiber in the diet is important as it helps to maintain human health by reducing blood cholesterol and glucose level in the body [45].

Ash content was observed significantly ($p \leq 0.05$) different between sesame varieties. T-85 had the highest (6.19 g/100g) ash content and least was for bawnji (4.46 g/100g). [46] reported ash values to be between 1.4 and 6.6 g/100g for Saudi Arabia and foreign varieties (Lebanese, Indian and World collection), which is similar with the results of this study. Chemical composition of seeds can be affected not only by the genotype but also by agro-climatic conditions [47] [48]. High level of ash makes the oilseed a good source of mineral nutrition to the consumer [49].

Fat content had varied significantly ($p \leq 0.05$) between varieties in **Table 3**. The highest fat (52.67%) was obtained in bawnji followed by T-85 (51.18%) and adi (50.88%). [51] reported the oil content can range from 43.4% to 58.8% for 42 strains of sesame with the highest oil content found in white-seeded strain. [52] reported oil content in Saudi and Indian sesame seeds ranging from 43.2% to 54.0%. Both the above results are consistent with the result of current study. [53] and [54] reported a significantly higher oil content (54.26% - 63.25%) in the Turkish sesame seeds of the TSP 933749 line selected from the TSP 9337 population, as compared to that of

Table 1. Some physical properties of sesame seed varieties.

Parameters	Varieties		
	Adi	Bawnji	T-85
Color	White	White	Dull white
1000 seeds weight (g)	3.16 ± 0.09^a	2.74 ± 0.12^b	2.98 ± 0.09^c
True density ($kg \cdot m^{-3}$)	1190.66 ± 0.37^a	1215.58 ± 0.53^b	1213.62 ± 0.38^c

Table 2. Proximate composition of three sesame varieties compared with other world sesame varieties.

Composition (%)	Adi	Bawnji	T-85	Sudanese[42] genotype	USA[42] genotype	Egyptian[2] varieties	Nigrian[50] sesame
Moisture	3.17 ± 0.05[a]	3.40 ± 0.04[b]	3.96 ± 0.15[c]	3.75	3.71	2.96	1.91
Crude fiber	6.26 ± 0.10[a]	5.60 ± 0.08[b]	6.09 ± 0.08[c]	3.76	4.03	7.03	3.56
Total ash	5.42 ± 0.01[a]	4.46 ± 0.09[b]	6.19 ± 0.07[c]	9.00	8.82	3.25	5.83
Crude fat	50.88 ± 0.24[a]	52.67 ± 0.47[b]	51.18 ± 0.22[b]	47.37	47.18	58.52	52.7
Crude protein	22.58 ± 0.18[a]	22.49 ± 0.21[a]	24.27 ± 0.38[b]	34.41	37.24	22.30	26.23
Carbohydrate	11.69 ± 0.31[a]	11.39 ± 0.66[a]	8.31 ± 0.25[b]	1.80	1.60	5.64	9.77

Table 3. Mineral composition of three sesame varieties compared with other world sesame varieties.

Minerals (mg/100g)	Adi	Bawnji	T-85	Sudanese[42] genotypes	USA[42] genotypes	White[46] Saudi varieties	World[69] collection	Indian[64] varieties	Lebanese[62] varieties	Japanese[68] brown
Ca	1182.79 ± 0.21[a]	1172.08 ± 0.35[b]	1225.71 ± 0.76[c]	1030	650	1228	1160	1450	1200	1200
Zn	4.37 ± 0.01[a]	4.23 ± 0.05[b]	4.45 ± 0.01[c]	-	-	3.6	-	-	-	-
Fe	10.51 ± 0.0[a]	10.24 ± 0.04[b]	10.75 ± 0.06[c]	3.09	2.88	10.4	10.50	10.5	10.4	9.6

the current study result. The differences might be attributed to the different regions of seeds production [48]. Variation in the oil yield of sesame may be due to variation in variety, soil type, climatic, maturity of plant, the harvesting time of the seeds and the extraction method used [55] [56].

There is a significant ($p \leq 0.05$) difference in the protein content between varieties. Adi and bawnji varieties had no significant ($p \geq 0.05$) differences in their protein content. The highest protein content (24.27%) was recorded in T-85 while the lowest (22.49%) was for bawnji. This results is consistent with range (18% - 25%) reported by [15] but are lower than those reported by [42] for Sudan varieties and USA genotypes (32.5% - 40.0%) and by [43] for 13 sesame accessions of Nigeria (27.50% - 45.68%). [39] found protein content (19.81% to 24.45%) in Turkey's sesame genotype. Varietal differences in protein content may have been attributed to soil, climate, strain and fertilizer treatment [48] [52] [57]. Carbohydrate contents of adi and bawnji varieties were 11.69% and 11.39% respectively and significantly higher than that of T-85 (8.31%). Carbohydrate content had ranged (8.31% - 11.69%) between varieties studied which is in agreement with range (6.4% - 21.0%) reported by [16] but are higher than the range 1.05% - 2.88% reported by [42] for Sudan varieties and USA genotypes. The highest carbohydrate values (27.90% - 45.15%) were reported in 13 sesame accession of Nigeria by [43]. Compositional differences can exist among the different varieties of sesame seeds, and among the sesame variety grown in different countries [58]. Further studies by [59] on some legume crops reported that there might be differences between varieties of the same species.

3.3. Mineral Composition of Sesame Seed Varieties

Calcium, zinc and iron contents had varied significantly ($p \leq 0.05$) between varieties in **Table 3**. T-85 variety had the highest Ca (1225.71 mg/100g) and the lowest was for bawnji (1172.08 mg/100g). The calcium content of this study is lower than 1450 mg/100g reported by [60] and [61] in some Indian sesame varieties. However, some Lebanese sesame varieties exhibited the lowest (228.3 mg/100 g) calcium content [62]. The current study results are in the range 600 - 2000 mg/100g for two Egyptian sesame seed varieties reported by [63]. The highest zinc content (4.45 mg/100g) was recorded in T-85 variety while the lowest content (4.23 mg/100g) was found in bawnji. This zinc content found is higher than the range (0 - 3.8 mg/100g) reported by [46] for Saudi Arabia and varieties (Lebanese, Indian, Nigerian and World collection). The highest iron content was found for T-85 variety and the lowest content was for bawnji variety. The results obtained in this work are in the range (9.6 - 11.7 mg/100g) previously reported by [60] [62] [64]. [65] reported that a wide variation in ash content of sesame varieties exists which is an index of total mineral matter present in the seeds.

Table 4. Anti-nutritional and antioxidants of sesame varieties compared with other world sesame.

Components	Adi	Bawnji	T-85	Iranian[23] sesame varieties	Indian[70] sesame cake extracts	USA[67] black sesame	USA[67] soybean	Nigerian[50] sesame
Phytic acid (mg/100g)	324.61 ± 1.73[a]	307.61 ± 1.73[b]	324.91 ± 1.73[a]	-	-	379 - 494	380 - 415	315.90
TPC (mg GAE/g)	23. 16 ± 0.65[a]	24. 84 ± 0.42[b]	25.69 ± 0.85[c]	20.1 - 70.97	26.20	-	-	-
FRAP (μ·mol/g)	32.33 ± 0.56[a]	33.31 ± 0.37[b]	34.53 ± 0.32[c]	30.00 - 97.00	161.04	-	-	-

3.4. Anti-Nutritional and Antioxidant Contents of Sesame Seed Varieties

Table 4 shows anti-nutritional and antioxidant contents of raw sesame varieties. Results showed significant ($p \leq 0.05$) differences in phytic acid contents between varieties. T-85 (324.91 mg/100g) and adi (324.61 mg/100g) had significantly higher than bawnji (307.61 mg/100g). The results obtained are lower than reported by [66] for black sesame seeds (379 - 494 mg/100g). Similar phytic acid value (315.9 mg/100g) was obtained in sesame seed by [50]. [67] found higher amount of phytic acid in bigger size whole white sesame (62.67 mg/100 g) than in small size whole black sesame (52.60 mg/100g) which are lowest values when compared with the current study results, who reported that the amount of the phytic acid depends on the size of seed. Also, [46] had reported that the phytic acid contents of the sesame varieties were affected by genotypes. The total phenolic content and antioxidant power value had varied significantly ($p \leq 0.05$) between the varieties. The highest TPC (25.69 mg GAE/g) was in T-85 variety and the lowest (23.16 mg GAE/g) was for adi variety. The result found in this work are in the range of (20.1 - 70.95 mg GAE/g) reported by [23] for eight Iranian sesame varieties and (73.74 to 128.80 mg tannic acid/100g) for raw, roasted, soaked roasted, micro waved roasted and defatted meal of sesame varieties by [63]. The highest reducing power value (34.53 μmol /g) was recorded in T-85 variety and the lowest was recorded in adi (33.31 μmol/g). The results obtained are in the range of (30.00 - 97.00 μmol/g) reported by [23] for eight Iranian sesame varieties but higher than the range value 25.31 - 27.21 μmol/g for two Egyptian raw sesame varieties by [63].

4. Conclusion

The local Ethiopian sesame varieties are a good source rich in protein, crude fiber, minerals, crude fat, phenols and reducing power values when compared with other world grown sesame varieties. T-85 variety shows quite good protein, mineral and anti-oxidant compositions when compared to each other. But more research is required in processing to reduce phytic acid content of the seed to utilize nutrients efficiently. And sesame seeds should be processed in different product and blended with concentrated fruits to utilize as functional food for human nutrition. It is concluded that a better understanding of the physico-chemical nature of sesame seed varieties is important for production, nutrition, marketing, food application and maximum utilization.

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