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Nutritional and antioxidant activities of newly released black cumin (*Nigella sativa*) seed varieties: suitability for food and industrial uses

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ABSTRACT

Black cumin (*Nigella sativa*) is an herbaceous spice that is grown worldwide, including in Ethiopia. To date, only small numbers of improved varieties of black cumin seeds have been produced by farmers in Ethiopia, and their composition has not been studied. Therefore, it is important to evaluate the composition of such improved varieties since black cumin seeds are often affected by geographical differences, climate, soil, harvesting and storage. This study investigated the nutritional and ant-nutritional composition of Improved Black Cumin (*Nigella sativa* L.) Seeds and the physicochemical properties and antioxidant profiles of the oil. All the analyses were conducted according to official standard procedures with grade chemicals and reagents. The results of the study showed that the proximate composition (mg/100g dwb) significantly ($P < 0.05$) varied and ranged from moisture (4.39–6.78), crude protein (18.22–23.05), crude fiber (5.11–8.60), crude fat (41.25–43.50), total ash (3.33–4.97), utilizable carbohydrates (15.42–31.70) and gross energy (476.23–548.81 kcal/100g). The mineral concentrations (mg/100g) of the black cumin seed varieties also significantly ($P < 0.05$) varied and ranged from 492.6–570 calcium, 659.15–826.065 potassium, 25.75–66.465 iron, 317–704 phosphorus, 5.395–7.365 zinc, and 71.585–98.215 sodium. The results of the ant nutritional (mg/100g, dwb) analyses were significantly different ($P < 0.05$) and ranged from 29.99–71.42 for phytate, 10.63–26.25 for tannin, and 1.35–1.56 for oxalate. The results of the study showed that black cumin seeds provide a significant amount of essential nutrients but are low in nutrient content. Specifically, the lagom variety contained significantly greater amounts of crude protein, crude fat, crude ash and iron. The total phenolic content of the black cumin seeds ranged from 98.84–194.30 mg GAE/g, and the total flavonoid content ranged from 15.10–48.01 mg CE/g. The current study revealed that the total phenolic and total flavonoid contents differed greatly among the different black cumin varieties, indicating that these compounds can be used as potential sources of antioxidants. The crude oil yield of the black cumin seeds varied significantly ($P < 0.05$) and ranged from 29.55–72.1%. The physicochemical properties of the black cumin seed oils varied significantly ($P < 0.05$), with acid values ranging from 0.064–0.085 mg KOH/g and peroxide values ranging from 0.609–1.143 mg equiv. O₂/kg, a saponification value of 141.253–215.05 mg KOH/g, which is suitable for food and industrial applications. The results of the current study also indicated that black cumin seed oils contained appreciable crude oil yield and excellent physicochemical properties, making them potential sources of edible oil and useful for industrial use. Hence, increasing the production of these nutrient-rich black cumin varieties will aid in new product development, food supplementation and fortification. Therefore, black cumin seed varieties could be used for fortification, formulation or supplementation of other food materials.

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Introduction

Black cumin seeds are high in essential fatty acids like tocopherols and sterols, as well as phenolic compounds, which function as antioxidants. Yellow oil also contains proteins, amino acids, reducing sugars, mucilage, alkaloids, organic acids, tannins, resins, toxic

glycosides, metarbine, bitter substances, saponin glycosides, crude fiber, minerals, and vitamins. Black cumin oil is especially high in phytochemicals and possesses antioxidant and health-promoting qualities among other oilseeds (Choudhury et al., 2023).

Anti-inflammatory, antibacterial, antioxidant, antimicrobial, and anticancer properties have been linked

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to the essential oils found in black cumin seeds (Singh et al., 2014). Eczema and asthma are two common conditions that are treated with black cumin seed oil (BCSO). The light amber color of BCSO is accompanied by a distinct herbal scent. Nowadays, BCSO is well-known for its nutritional qualities and finds wide use in the personal care and nutritional supplement sectors. Black cumin seed oil (BCS) contains high levels of essential fatty acids, tocopherols, and phenolic compounds and can significantly inhibit the formation of free radicals or lipid oxidation (Soleimanifar et al., 2019).

Apart from their nutritional value, black cumin seeds are utilized in food flavoring, nutraceuticals, and food preservation (Dessie et al., 2020). Black cumin seeds are a noteworthy source of protein (26.7%), fat (28.5%), and carbohydrates (40.0%) (Choudhury et al., 2023). Furthermore, substantial amounts of linoleic acid (C18:2, 57 point 49%), fat (39 point 37%), protein (21 point 65%), carbohydrates (32 point 58%), and ash (5 point 14%) are present in Turkish black cumin (Dessie et al., 2020). Black cumin seeds are also rich in Cu, Zn, Fe, Mn, phosphorus, Mg, Na, K, Ca, and Mg (Ramadan, 2007). Black cumin seed oil has a major impact on human health and nutrition. It is believed to be one of the edible oil sources from more recent times. As stated by Cheikh-Rouhou et al. (2007), the health benefits of black cumin can be attributed to its active ingredients, which are primarily concentrated in essential oils.

Black cumin seed oil contains a high percentage of unsaturated fatty acids, with polyunsaturated fatty acids being the most prominent at 48–70%. Monounsaturated and saturated fatty acids are present in smaller amounts (18–29% and 12–25%, respectively) (Dessie et al., 2020). The use of natural antioxidants for food preservation is becoming increasingly popular, with plant materials such as seeds, vegetables, fruits, and spices containing antioxidants as secondary metabolites. Black cumin seeds are known for their antioxidant properties, which can benefit human health by scavenging free radicals and chelating metals (Dessie et al., 2020). The composition of black cumin can vary based on factors like agro-ecological distribution and agronomic practices. While there have been several studies on the nutritional and antioxidant properties of black cumin from different regions around the world, there is a lack of research on varieties released by the Sinana Research Center in Ethiopia. Therefore, the objectives of this study is to provide information on the nutritional, antinutritional, and antioxidant properties of these specific black cumin seed varieties.

Materials and methods

Description of the sampling site

Varieties of black cumin were grown in the Sinana region of the eastern Bale zone in 2023. Situated in the Bale Administrative Zone of the Oromiya Regional State is the Sinana Agricultural Research Center (SARC). At an elevation of 2,400 meters above sea level, it is situated about 460 kilometers southeast of Addis Ababa. Its range of northern latitude is 07°06'12" to 07°07'29", and its range of eastern longitude is 40°12'40" to 40°13'52". According to Sinana Research Center, it is 276.55 acres in size.

Sample collection

The improved and released black cumin varieties were obtained from the Sinana Agriculture Research Center using sterile polyethylene plastic bags in order to perform the subsequent parameter analysis. The samples of black cumin seeds were cleaned and ground using an electric grinder (Zhejiang YiLi Tool Co., Model BLG401. Ltd., China), after which the samples of black cumin variety seed were cleaned and ground. The crushed samples were subjected to additional analysis.

Sample preparation

After being cleaned and ground with an electric grinder, the black cumin seeds were transferred for examination in an insulated receptacle or ice box. The samples of black cumin seeds were taken in an ice chest or insulating container for analysis after being cleaned and ground with an electric grinder.

Proximate analysis

The moisture content was determined on a wet weight basis using the AOAC (2000) 925.10 method and Cao et al. (2023) for determining moisture and dry matter of samples by oven drying (DHG-9055A) (Islam et al., 2019). The crude fat content of the samples was determined in a Soxhlet extractor using Ali et al. (2022) and Xu et al. (2021). Each sample's utilizable carbs were calculated using a different method (Soleimanifar et al., 2019; Islam et al., 2010). The gross energy value was calculated using Atwater conversion factors by multiplying the numbers for protein, carbohydrates, and fat by four and then by 9.00 kilocalories per 100g dry weight (Idris et al., 2011; Alam et al., 2022).

Sample preparation for mineral analysis

The organic matrix was destroyed using the AOAC (2000) ashing technique in a muffle furnace. Calcium (Ca), zinc (Zn), iron (Fe), magnesium (Mg), and nickel (Ni) levels in the solutions were determined using an atomic absorption spectrophotometer (Ildris et al., 2011). The levels of sodium and potassium were determined using a flame photometer in accordance with the procedures outlined in AOAC 2005, 966.16 and 965.30, respectively. A UV-visible spectrophotometer and the AOAC's 1998 Official Method 986.24 were used to determine phosphorus content.

Antinutritional analysis

The original method devised by Woldegiorgis et al. (2014) was used to assess oxalate. The phytate content was calculated using a technique developed by Latta and Eskin (1980) and refined by Vaintraub and Lapteva (1988). Woldegiorgis et al. (2014) calculated the tannin content, while Xu and Chang (2007) adjusted the condensed tannin content.

Antioxidant analysis

The colorimetric method described by Zhou et al. (2023), Xu and Chang (2007) and Woldegiorgis et al. (2014) was used to calculate total flavonoid content (TFC). The phenolic component contents in the extracts were determined using the methods outlined by Woldegiorgis et al. (2014). The DPPH* method was used to assess antioxidant scavenging activity by reducing a solution of DPPH* in methanol in the presence of an antioxidant to hydrogen via the production of the free radical form DPPH-H (Woldegiorgis et al., 2014; Rahman et al., 2024).

Black cumin extraction

The percentage oil yield was calculated using the Soxhlet extraction technique as outlined by AOAC (2000). Using 300 ml of n-hexane (40–60°C) in a Soxhlet extractor, about 50,000 g of black cumin seed powder was extracted in 4 hours. The solvent was then vacuum-distilled at 40°C in a Tokyo Rikakikal Co. Model N-1Eyela rotary evaporator. Inc. Japan. Weighing the extracted oil allowed us to ascertain its seed oil content. An airtight brown sterile glass bottle containing the extracted crude oil was kept in a refrigerator (4°C) (Ahmed et al., 2023; Woldegiorgis et al., 2014) for physicochemical analysis.

Physicochemical properties

Acid and peroxide values were determined according to the AOAC official method (2000) using subcomponent 965.33.

Statistical analysis

There were two replicates in a completely randomized design (CRD). SPSS version 22.0 for Windows was used to perform all statistical analyses on the obtained data. To assess the data, a one-way analysis of variance (ANOVA) was employed. The experiment means, denoted as mean $\pm$ standard error (SE), were separated using Duncan's multiple range tests. Statistical significance was defined as a *p* value of less than 0.05. The average of two replicate black cumin samples was used to calculate the antioxidant, total nutritional, and antinutritional levels.

Results and discussion

Proximate composition of black cumin seed varieties

Moisture content

Table 1 shows the moisture content (dwb) of six kinds of black cumin seeds. The moisture content of black cumin ranged from 4.39 g/100 g to 6.78 g/100 g in the Jarona and Darol types. The moisture content of the Darol variety was higher (6.78 g/100 g), but it did not differ significantly from that of the Macon variety (6.19 g/100 g). The moisture content of the Jarona variety was the lowest (4.39 g/100 g), but it did not differ significantly from that of the sadot (4.79 g/100 g) and legom (5.19 g/100 g). The mean moisture content (5.55 g/100 g) of the black cumin variety was nearly identical to the figure reported for black cumin seeds by Giri et al. (2018) (4.25%). According to Manzie et al. (2004), a moisture level of less than 10% suggests that a food product can be stored safely while maintaining acceptable quality. The seeds employed in this study also had low moisture content, which contributed to their good yield and stability (quality preservation).

Crude protein content

Proteins are principally responsible for tissue formation and replacement in the human body. Table 1 displays the crude protein content of the six black cumin seed types tested in this study. The crude protein content of black cumin seeds were between

Table 1. Proximate compositions (g/100g) of black cumin seed varieties (dry weight bases).

Name of varieties	Moisture content	Crude	Crude	Crude	Total	Utilizable	Gross
		Protein	Fiber	Fat	Ash	Carbohydrate	Energy
Darol	6.78 ± 0.02 ^a	21.73 ± 0.24 ^b	7.72 ± 0.26 ^c	41.25 ± 0.35 ^b	4.00 ± 0.00 ^{ab}	18.50 ± 0.84 ^c	532.21 ± 0.80 ^b
Sadot	4.79 ± 0.57 ^c	18.22 ± 0.24 ^d	6.80 ± 0.03 ^d	42.25 ± 0.35 ^{ab}	4.97 ± 0.46 ^a	22.97 ± 1.16 ^b	545.05 ± 0.47 ^{ab}
Nasibo	5.98 ± 0.54 ^{ab}	21.38 ± 0.24 ^b	5.11 ± 0.09 ^e	41.75 ± 0.35 ^b	4.64 ± 0.00 ^{ab}	20.12 ± 1.94 ^{bc}	541.65 ± 0.11 ^{ab}
Legom	5.19 ± 0.01 ^{bc}	23.05 ± 0.36 ^a	8.19 ± 0.08 ^b	43.50 ± 0.00 ^a	4.65 ± 0.96 ^{ab}	15.42 ± 1.23 ^d	545.38 ± 0.34 ^{ab}
Macon	6.19 ± 0.29 ^a	20.42 ± 0.36 ^c	8.60 ± 0.17 ^a	29.75 ± 1.06 ^c	3.33 ± 0.94 ^b	31.70 ± 0.60 ^a	476.23 ± 0.58 ^c
Jarona	4.39 ± 0.01 ^c	21.29 ± 0.37 ^b	6.90 ± 0.16 ^d	41.75 ± 0.35 ^b	3.65 ± 0.48 ^{ab}	21.97 ± 0.38 ^b	548.81 ± 0.21 ^a
Mean	5.55	21.01	7.22	40.04	4.20	21.78	531.55

Means within the same column with different superscripts are significantly different ($P < 0.05$). The values are presented as the means ± SEs, $n = 2$.

18.22g/100g and 23.05g/100g for the sadot and legom types, respectively. The legom variety had the highest crude protein content (23.05g/100g), followed by the darol (21.73g/100g), nasibo (21.38g/100g), and jarona (21.29g/100g). The sadot variety had the lowest crude protein content (18.22g/100g) on a dry weight basis.

The mean crude protein content of black cumin seeds (21.01g/100g) was higher than that reported by Giri et al. (2018) (16.52g/100g). *Nigella sativa* seeds contain 20.85–31.2% protein, similar to the mean crude protein content reported by Şanlıer (2009) and Amin and Hosseinzadeh (2016). This study found that black cumin seeds are a good source of protein for human nutrition. Plant foods that provide roughly 12% protein are considered good protein sources, according to Effiong et al. (2009). Plant foods that provide roughly 12% protein are considered good protein sources, according to Effiong et al. (2009). The seeds of these types of black cumin meet these requirements, implying that black cumin can be a rich source of protein. Thus, seed-eating should be encouraged in order to reduce protein deficiency in the country.

Crude fiber content

The crude fiber contents of the examined cultivars are shown in Table 1. The crude fiber content of the cultivars ranged from 5.11g/100g to 8.60g/100g for the nasibo and macon types. The Macon variety has a much higher crude fiber content (8.60g/100g) compared to the other kinds. However, the nasibo type exhibited significantly ($P < 0.05$) lower (5.11g/100g) crude fiber content on a dry weight basis. The varieties' mean fiber content was 7.22%, which was comparable to the crude fiber content of black cumin seeds reported by Omotoso (2006) (7g/100g) and Giri et al. (2018) (7.11g/100g). Kabir et al. (2019) showed a slightly greater crude fiber content (8.2g/100g), implying that the black cumin seeds in the current study can be used as a source

of dietary fiber, which may aid in the prevention of gastrointestinal diseases. A high-fiber diet may also help to avoid the onset of several chronic noncommunicable diseases, including coronary heart disease, diabetes, colon cancer, obesity, high blood pressure, and a variety of gastrointestinal disorders (Rasane et al., 2015).

Crude fat content

The crude fat content of each variety is shown in Table 1. The crude fat content of the black cumin type was between 29.75g/100g of macon and 43.50g/100g of legom. The legom variety had the highest crude fat content (43.50g/100g), substantially higher ($P < 0.05$) than the crude fat content of other types on a dry weight basis. On a dry weight basis, the macon variety exhibited a much reduced ($P < 0.05$) crude fat content (29.75g/100g). The average crude fat level for each cultivar was 40.04%. Şanlıer (2009) found a comparable figure for black cumin seeds (22–40.35g/100g). The high crude fat levels suggest that black cumin seed varieties can be used to improve the flavor of recipes including them. These seed types are prospective oil sources due to their high crude fat content. Black cumin flour has an oily and compacted appearance due to the high-fat content of the seeds, unlike fine powdery flours (Şanlıer, 2009).

Crude ash content

The food samples' ash concentration was shown to be positively associated with their mineral content. Table 1 shows the crude ash content of six kinds of black cumin seeds. The ash concentration in this study ranged from 3.33g/100g to 4.97g/100g for the macon and sadot types, respectively. The sadot variety had the highest crude ash content (4.97g/100g), but did not differ significantly from the other varieties. The macon variety had the lowest crude ash content (3.33mg/100g), but did not differ

significantly ($P < 0.05$) from the other four varieties on a dry weight basis. The mean crude ash content of black cumin types was 4.2 g/100 g, which was consistent with the values reported for black cumin seeds by Giri et al. (2018) (4.15 g/100 g) and Omotoso (2006). Ash content is a measure/reflection of the nutritionally significant mineral content in food. The results showed that the sample had a high ash level, indicating that black cumin seeds are rich in valuable minerals for body growth.

Utilizable carbohydrates

Carbohydrates are the primary source of energy in the human body. The difference determined how the carbohydrate content was utilized. Table 1 shows the utilizable carbohydrate content of the examined cultivars. The utilizable carbohydrate content of the legume and macon types ranged from 15.42 to 31.70 g/100 g, respectively. The macon variety had the highest utilizable carbohydrate content (31.70 g/100 g), followed by sadot (22.97 g/100 g), jarona (21.97 g/100 g), and nasibo (20.12 g/100 g). The legom variety had the lowest utilizable carbohydrate content (15.42 g/100 g) on a dry weight basis. The mean utilizable carbohydrate (21.78 g/100 g) content of black cumin varieties in the present study was lower than that reported for black cumin seeds by Omotoso (2006) (31.97 g/100 g).

Gross energy value

The mean gross energy in the current study (531.55 kcal/100 g) was consistent with that reported by Giri et al. (2018) (530.53 kcal). Tura et al. (2023) found that black cumin seeds had a high gross energy content (406–521 kcal/100 g). The high gross energy values found in the current study suggested that black cumin seeds could be a significant source of energy. The mean gross energy in the current study (531.55 kcal/100 g) was consistent with that reported by Giri et al. (2018) (530.53 kcal). The mean

gross energy in the current study (531.55 kcal/100 g) was consistent with that reported by Giri et al. (2018) (530.53 kcal). Tura et al. (2023) found that black cumin seeds had a high gross energy content (406–521 kcal/100 g). The high gross energy values found in the current study suggested that black cumin seeds could be a significant source of energy.

Mineral composition of black cumin seed varieties

Table 2 shows the calcium content of the different types. Calcium concentrations in the sample ranged from 492.6 mg/100 g to 570 mg/100 g for the Macon and Darol types. The Darol variety had the highest calcium level (570 mg/100 g), significantly higher than all other kinds ($P < 0.05$), whereas the Macon variety had a significantly lower calcium content (492.6 mg/100 g). Dry weight basis. The mean calcium content (530.07 mg/100 g) in the current study was comparable to that of black cumin seeds (570 mg/100 g), as reported by Sultan et al. (2009). Calcium is a major component of bone and assists tooth development. Calcium concentrations are also necessary for blood coagulation and the integrity of intracellular cement substances (Sultan et al., 2009).

Table 2 lists the potassium contents of the different black cumin varieties. Potassium levels varied from 659.15 mg/100 g in Darolto to 826.065 mg/100 g in Nasibo varieties. On a dry weight basis, no significant difference ($P < 0.05$) was observed among all samples. The average potassium level was 645.36 mg/100 g, and potassium was the most abundant element in black cumin seeds. The high K values found in the current study suggest that black cumin seeds may be an excellent source of K. A high amount of potassium in the body has been reported to increase iron utilization (Elinge et al., 2012) and is beneficial for people taking diuretics to control hypertension and suffering from excessive excretion of potassium through body fluids (Ugwu & Oranye, 2006).

Table 2 lists the iron contents of the different types. The iron level of the varieties ranged between

Table 2. Mineral concentrations (mg/100 g, dwb) of black cumin seed varieties (dry weight basis).

Varieties	Calcium	Potassium	Iron	Phosphorous	Zinc	Sodium
Darol	570±.08 ^a	659.15±.08 ^a	25.75±.05 ^b	317±.26 ^b	7.215 ± 0.98 ^a	19.8±.91 ^a
Sadot	525.78±.01 ^{abc}	787.69±.04 ^a	66.465±.01 ^a	704.78±.9 ^a	5.395 ± 0.005 ^b	73.93±.0.6 ^a
Nasibo	566.4±.01 ^{ab}	826.065±.01 ^a	42.105 ± 0.52 ^b	567.855±.5 ^{ab}	6.555 ± 0.025 ^{ab}	92.75 ± 0.05 ^a
Legom	497.04 ± 1.02 ^{bc}	751.845±.03 ^a	55.305 ± 0.94 ^a	619.12±.77 ^{ab}	6.11 ± 0.43 ^{ab}	106.22 ± 0.09 ^a
Macon	492.6±.01 ^c	784.96±.09 ^a	62.785 ± 0.06 ^a	547.11 ± 0.53 ^{ab}	7.365 ± 0.21 ^a	71.585 ± 0.09 ^a
Jarona	528.6±.04 ^{abc}	814.3±.05 ^a	45.23 ± 0.08 ^b	592.56±.5 ^{ab}	5.94 ± 0.27 ^{ab}	98.215 ± 0.05 ^a
Mean	530.07	645.36	49.106	558.07	6.42	77.08

The same columns with different superscripts are significantly different ($P < 0.05$). The values are presented as the means ± SEs, $n = 2$.

25.75 mg/100 g in Darol to 66.465 mg/100 g in Sadot. The Sadot variety had the highest iron content (66.465 mg/100 g), which was considerably higher ($P < 0.05$), while the Darol variety had a lower iron content (25.75 mg/100 g) on a dry-weight basis. The mean iron content was 49.106 mg/100 g, which was comparable to Sultan et al.'s (2009) findings on black cumin seeds (76.48 mg/100 g). Iron is an essential trace element for the production of hemoglobin, the efficient functioning of the central nervous system, and the oxidation of carbohydrates, proteins, and lipids.

Table 2 shows the phosphorus concentration of the seeds from six different black cumin cultivars. The phosphorus concentration in the sample ranged from 317 mg/100 g to 704.78 mg/100 g for the Darol and Sadot types. The Sadot variety exhibited a much higher phosphorus content (704.78 mg/100 g) compared to the Darol variety (317 mg/100 g) on a dry weight basis. The present study's mean phosphorus level (558.07 mg/100 g) was similar to the phosphorus content (543 mg/100 g) of black cumin seeds reported by Sultan et al. (2009).

Table 2 shows the zinc contents of the different types. The Zn concentration in the samples ranged from 5.395 mg/100 g to 7.365 mg/100 g for Sadot and Macon types. The Macon variety had the highest zinc concentration (7.365 mg/100 g), substantially higher ($P < 0.05$) than the other kinds. The Sadot variety showed significantly ($P < 0.05$) reduced zinc concentration (317 mg/100 g) on a dry weight basis. The mean zinc concentration was 6.42 mg/100 g, which was comparable to Sultan et al. (2009)'s research on black cumin seeds (6.23 mg/100 g).

Table 2 shows the salt content of black cumin across all kinds. The salt concentration in the sample was between 19.8 mg/100 g and 106.22 mg/100 g for the Darol and Legom types, respectively. The legume variety had the highest sodium level (106.22 mg/100 g), substantially higher than the other types ($P < 0.05$). On a dry weight basis, the Darol variety contained considerably less sodium (19.8 mg/100 g) than the other types ($P < 0.05$). The mean sodium content was 77.08 mg/100 g, which was lower than the value published by Sultan et al. (2009) for black cumin seeds (110.5 mg/100 g).

Antinutritional composition of black cumin seed varieties

Antinutritional factors are substances contained in food that interfere with metabolic functions such as nutrient growth and bioavailability following

consumption (Agbaire, 2012). Antinutritional components found in food systems include phytic acid, oxalic acid, and nitrates. The bioavailability of phytic acid and oxalic acid is reduced due to their ability to form chelates with divalent and trivalent metallic ions such as Cd, Mg, Zn, and Fe. These chelates produce poorly soluble compounds that the gastrointestinal system cannot easily absorb (Nangula et al., 2010). According to Ladeji et al. (2004), oxalic acid produces swelling and irritation in the tongue and throat. They discovered that phytic acid inhibits the activity of various digestive enzymes.

Table 3 shows the phytate contents of the several black cumin cultivars. The phytate level in the current study ranged from 29.99 mg/100 g for Jarona to 71.42 mg/100 g for Darol. Darol showed a substantially higher phytate concentration (71.42 mg/100 g) compared to Jarona (29.99 mg/100 g) on a dry weight basis. The difficulty with phytate in diet is that it can bind some vital mineral nutrients in the digestive tract, causing mineral shortages (Phillippy et al., 2004). When phytate is present in the diet at a concentration of 10–60 mg/100 g, it may not be hazardous to health; nevertheless, if consumed over time, it has been proven to diminish mineral bioavailability. On the other hand, current research suggests that dietary phytate may be beneficial as an antioxidant and carcinogen, as well as play an important role in regulating hypercholesterolemia and atherosclerosis at low levels (Adeparusi, 2001).

Table 3 shows the tannin concentrations of the several black cumin cultivars. The tannin concentration in this study ranged between 10.53 in the Legom variety and 26.25 in the Macon variety. The Macon variety exhibited a substantially higher tannin content (26.25 mg/100 g) compared to the Legom variety (10.53 mg/100 g) on a dry weight basis. Tannins have been shown to affect protein digestibility, reducing nonheme iron bioavailability and resulting in poor iron and calcium absorption. Carbohydrates are similarly affected, resulting in a lower energy

Table 3. Ant-nutritional content (mg/100 g, dwb) of black cumin seed varieties.

Sample	Phytate	Tannin	Oxalate
Darol	71.42±.04 ^a	10.63±.07 ^a	1.35±.04 ^c
Sadot	62.54±.01 ^a	10.84±.07 ^a	1.42±.04 ^{bc}
Nasibo	68.75±.09 ^a	11.54±.09 ^a	1.46±.02 ^b
Legom	36.25±.02 ^{bc}	10.53±.08 ^a	1.49±.02 ^b
Macon	43.07±.01 ^b	26.25±.22.04 ^a	1.56±.02 ^a
Jarona	29.99±.7.07 ^c	11.61±.04 ^a	1.45±.01 ^b
Mean	52.003	13.56	1.455

The same superscript letters in the same column indicate significant ($P < 0.05$) differences. The data are expressed as the means ± standard errors of replicate determinations ($n = 2$).

value in a tannin-containing diet; however, their antinutritional/toxic effects vary depending on their chemical structure and dosage (Bhandari & Kawabata, 2004). Therefore, the toxic effects of tannins may not be significant because the total acceptable daily intake of tannic acid for humans is 560 mg/100 g (Omotoso, 2006). Because the tannin content of black cumin varieties is relatively low in comparison to their critical toxicity effect, and it is further reduced during processing, its nutritional value may be negligible in both raw and processed black cumin varieties.

Table 3 displays the oxalate content of the seeds from the six black cumin cultivars. The oxalate concentration in the current study varied from 1.35 mg/100 g to 1.56 mg/100 g in the Darol and Macon types, respectively. The Macon type had a much greater (1.56 mg/100 g) oxalate content, whereas the Darol variety had a lower (1.35 mg/100 g) dry weight basis. In this investigation, the mean value for each variety was 1.455 mg/100 g. Oxalates can be hazardous to human nutrition and health, particularly by lowering calcium absorption and promoting the production of kidney stones (Omotoso, 2006). High-oxalate diets can raise the risk of renal calcium oxalate formation in certain individuals (Habtamu & Negussie, 2014). Because calcium oxalate stones account for the bulk of urinary stones in humans, patients are now advised to reduce their oxalate consumption to no more than 50–60 mg per day (Bhandari & Kawabata, 2004). The black cumin seed variety studied in this study had lower oxalate levels than individuals with CaOx kidney stones. According to these recommendations, eating the seeds of the studied black cumin variety may be beneficial not only to generally healthy people, but also to patients who have a history of calcium oxalate kidney stones.

Antioxidant properties of black cumin seed varieties

Rapeseed oil combined with *N. sativa* essential oil was tested on a regular basis to determine its antioxidant potential. *Nigella sativa* essential oil has a significantly higher antioxidant activity than butylated hydroxytoluene (BHT). Monitoring the rise in peroxide concentrations enabled researchers to understand more about their inhibitory influence on the linoleic acid pathway. The radical scavenging activity of the DPPH radical outperformed that of synthetic antioxidants. The antioxidant activities of *Nigella sativa* essential oil were also investigated by

measuring its reducing power (Hassanien et al., 2015). The antioxidant activities of *Nigella sativa* essential oil were also investigated by measuring its reducing power (Hassanien et al., 2015). The high concentration of phenolic chemicals contained in *N. sativa* L. seeds defines a raw material's medicinal and functional potential.

The high phenolic content of the three varieties of bitter cumin can be linked to its excellent antioxidant properties. As a result, bitter cumin, which has a high phenolic content and strong antioxidant activity, can be used in recipes to improve both food preservation and nutrition. The stable free radical diphenyl-1-picrylhydrazyl (DPPH) can convert an electron or a hydrogen ion into a stable molecule. DPPH radical scavenging is a common approach for determining the antioxidant activity of phenolic compounds. A decrease in DPPH radical concentration indicates antioxidant activity.

Table 4 shows the total phenolic content of the several black cumin seed cultivars. The total phenolic content of the black cumin types ranged between 98.84 mg/g GAE and 194.30 mg/g GAE in the sadot and Jarona treatments, respectively. The Jarona variety had a higher total phenolic content (194.30 mg GAE/g) than the Legom variety (193.71 mg GAE/g), while the sadot variety had the lowest phenolic content (98.84 mg GAE/g) but was not significantly different ($P < 0.05$) from the Nasibo variety (100.05 mg GAE/g) on a dry weight basis. The values obtained in this study were higher than the values reported by Thippeswamy and Naidu (2005), which varied from 58.56 to 95.7 mg GAE/g. This indicated that black cumin seeds are a rich source of phenolic compounds.

Table 4 displays the total flavonoid content of the six black cumin seed cultivars tested in this study. On a dry weight basis, the total flavonoid concentration of black cumin seed varieties varied significantly ($P < 0.05$), from 15.10 mg QE/g in Nasibo to 48.01 mg QE/g in Jarona, which might be attributed to genetic variables. The Jarona variety had the highest total flavonoid content (48.01 mg QE/g), which was

Table 4. Total phenolic and flavonoid analysis of black cumin seeds.

Sample	Total phenols (mg GAE/g)	Total flavonoids (mg QE/g)
Darol	114.66±.19 ^b	18.31±.21 ^d
Sadot	98.84±.51 ^d	44.02±.91 ^b
Nasibo	100.05±.97 ^{cd}	15.10±.48 ^d
Legom	193.71±.02 ^a	35.83±.15 ^c
Macon	104.31±.29 ^c	40.35±.27 ^b
Jarona	194.30±.61 ^a	48.01±.76 ^a

The same superscript letters in the same column indicate significant ($P < 0.05$) differences.

significantly ($P < 0.05$) greater than the total flavonoid content of all the varieties, whereas the total flavonoid content of the nasibo variety was significantly ($P < 0.05$) lower than the total flavonoid content (15.10 mg QE/g) of all the varieties except the Darol variety (18.31 mg QE/g). flavonoid content, which is 58.56 among cumin varieties (Aumeeruddy et al., 2019), which is higher than the present finding.

Antioxidant activities

The findings from the concentration–response curves comparing the DPPH scavenging activity of the seeds from the six black cumin extracts with the positive controls are displayed in Figure 1. The positive control, which was utilized at the same concentration, was the artificial antioxidant butylated hydroxytoluene (BHT). The six black cumin kinds' seeds were tested at concentrations ranging from 1 to 6 mg/ml to determine the percentage inhibition of their ability to scavenge DPPH. A rise in the quantities of black cumin seed extract was seen in the DPPH radical scavenging activity. This finding was consistent with the research of Fidan et al. (2019), which demonstrated that when sample and standard concentrations rise, so do the scavenging effects on the DPPH radical. The legom and jarona cultivars exhibited higher % inhibition at every concentration compared to the other varieties. More than all the black cumin seeds combined, the synthetic antioxidant BHT had a stronger scavenging impact. For DPPH scavenging, the black cumin seeds' effective concentrations (EC₅₀) varied from 1.10 to 3.45 mg/ml. According to the study's findings, the Macon variety showed poor antioxidant qualities and high EC₅₀ values for DPPH scavenging, whereas the Jarona variety exhibited superior antioxidant qualities.

Oil yield and physicochemical properties

Table 5 shows the crude oil yields for the six varieties of black cumin seeds. Notably, the yield of black cumin seed oil varied between 29.55% and 72.1%. The Sadot variety had a significantly higher crude oil content (72.1%) than the Darol variety (69.10%). However, the Macon variety produced a low oil yield of 29.55%. The average oil yield (46.33%) of black cumin seeds obtained in this study was comparable to the value reported by Demirci et al. (2019) (30–45%).

Table 5 shows the acid values (mg KOH/g) of black cumin oil seeds. The acid content ranged from 0.064 mg KOH/g Sadot to 0.085 mg KOH/g Darol. The acid contents of Darol (0.085 mg KOH/g) and Jarona (0.077 mg KOH/g) were not significantly higher ($P < 0.05$), followed by Legom (0.075 mg KOH/g) and Macon (3.425 mg KOH/g). Sadot had a low acid value of 0.064 mg KOH/g, which was not significantly different ($P < 0.05$) from Nasibo's (0.065 mg KOH/g). The current study's mean acid value (0.0725 mg KOH/g) was similar to that reported for black cumin seed oil (0.396 mg KOH/g) (Abdelhadi et al., 2017), but lower than that previously reported. The lower the acid value, the more acceptable it is for human consumption (Sani et al., 2014). Cooking oil should have an acid concentration of 0.00 to 3.00 mg KOH/g, according to Barkatullah et al. (2012). Thus, all seed oils are suitable for cooking.

Table 5 shows the peroxide values (mgEquiv O₂/kg) of black cumin seed oils. Sadot, Nasibo, Legom, Macon, and Jarona seed oils had peroxide values ranging from 0.609 mg equiv. O₂/kg to 1.143 mg equiv. O₂/kg. The darol peroxide value of black cumin oil-seeds. The Darol concentration (1.143 mg equiv. O₂/kg) was high, but the other parameters were comparable. The average peroxide value (0.698 mgEquiv. O₂/

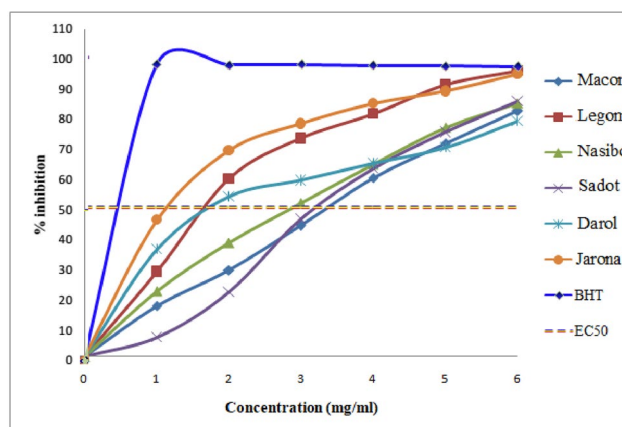


Figure 1. DPPH scavenging activity of black cumin seed and control.

Table 5. Oil yield and physicochemical properties of black cumin seed oil.

Varieties	Oil yield (%)	Acid value (mgKOH/g)	Peroxide value (mgEquiv. O2/kg)	Saponification value (mgKOH/g)
Darol	69.10±.22	0.085±.004 ^a	1.143±.07 ^a	215.05±4.4 ^a
Sadot	72.10±.22	0.064±.001 ^d	0.609±.01 ^c	166.061±2.9 ^c
Nasibo	35.0±.5	0.065±.001 ^d	0.609±.009 ^c	141.253±5.7 ^d
Legom	35.75±.15	0.075±.0007 ^b	0.609±.006 ^b	191.045±15.8 ^b
Macon	29.55±.13	0.069±.0007 ^c	0.609±.01 ^b	150.782±3.3 ^{cd}
Jarona	36.5±.65	0.077±.001 ^b	0.609±.009 ^b	163.065±1.4 ^c

The same superscript letters in the same column indicate significant ($P<0.05$) differences. The data are expressed as the means±standard errors of replicate determinations ($n=2$).

kg) of black cumin seed oils. The highest peroxide value in this study, 1.143, is comparable to the 1.7033 reported by Abdelhadi et al. (2017).

The peroxide value is a measure of oxidative rancidity and deterioration of the oil level and can be used to determine the quality and stability of fats and oils; thus, a high peroxide value of oil indicates poor resistance to peroxidation while in storage. The peroxide values of black cumin seed oils from all varieties were less than the maximum acceptable value (10mg equiv. O2/kg) established by the Codex Alimentarius Commission for oils (Abayeh et al., 1998; Codex Alimentarius Commission, 1993).

Table 5 shows the saponification values (mg KOH/g) of black cumin oilseeds. The saponification values ranged from 141.253mg KOH/g for "Nasiboto" to 215.05mg KOH/g for "Darol". Saponification values for Darol (215.05mg KOH/g) and Legom (191.045mg KOH/g) were not significantly high ($P<0.05$), while Sadot (166.061mg KOH/g) and Jarona (163.065mg KOH/g) had higher levels. Nasibowas had a low saponification value of 141.253mg KOH/g, which was not significantly different ($P<0.05$) from Macon's (150.782mg KOH/g). The mean acid value (171.209mg KOH/g) in the current study was comparable to the values reported for black cumin seed oil (172.56 and 190mg KOH/g) by Şanlier (2009) and Abdulhadi et al. (2017), respectively. Oils with high saponification values are preferred in the soapmaking industry (Akanni et al., 2005). This suggests that black cumin seed oil is suitable for industrial soap-making because its saponification value is within the range of oils that are currently used for the purpose. Ogungbenle and Omosola (2015) also reported that dry black cumin seed oils have the potential to be used in the industrial production of soap and cosmetics.

Conclusion

The proximate, mineral, nutritional, and antioxidant compositions of the seeds of six improved black

cumin varieties were investigated. The physicochemical properties of black cumin seeds were further studied. This study found a significant difference ($P<0.05$) in proximate and mineral compositions between black cumin seed varieties. The most remarkable finding of the current study is that the seeds of black cumin varieties are high in essential nutrients such as crude protein, crude fiber, crude ash, calcium, and iron. Specifically, the lagom variety had significantly higher levels of crude protein, fat, ash, and iron. The nutritional value of the black cumin variety was low. The current study also found that total phenolic and total flavonoid levels vary greatly among black cumin seeds, which are considered a source of natural antioxidants that could be used as functional food ingredients. The current study also found that black cumin seed oils have an appreciable crude oil yield and high physicochemical quality, making them potential sources of edible oil for industrial applications. Thus, increasing production of these nutrient-rich black cumin varieties will help with new product development, food supplementation, and fortification. Therefore, black cumin seed varieties can be used for the fortification, formulation, and supplementation of other food materials.

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Authors contributions

All authors have made substantial contributions to the following: LA, the conception and design of the study; acquisition of data; analysis and interpretation of data; HFG, drafting the article or revising it critically for important intellectual content; and final approval of the version to be submitted.

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Data availability statement

The data supporting the findings of this study are included within the article.

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