



A Study on Black Cumin (*Nigella sativa* L.) Fortified Processed Products: Formulation and Quality Evaluation

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ABSTRACT

Background: The aims of study to investigate physico-chemical properties do a proximate analysis of black cumin seeds (*Nigella sativa* L.) of AN-1 variety and development of value-added products by incorporating black cumin paste and powder in various proportions. **Methods:** The sensory evaluation of incorporating black cumin to have value-added products was performed using hedonic scale method. Physico-chemical properties of black cumin seeds were determined in the initial stage of study. Then, the proximate analysis was performed. In the second phase, Total Soluble Solids (TSS), pH, acidity, and antioxidant activity of the developed products were determined. The antioxidant activity of prepared products was determined by 2,2-diphenyl-1-picrylhydrazyl (DPPH) method. The antioxidant activity of coriander chutney was increased from 55.75 to 57.07 by increasing the fortification of black cumin paste, and in bottle gourd, Ready To Serve (RTS) was increased from 40.73 to 42.08 as by increasing the fortification of black cumin powder. **Results:** It was observed that level 1% incorporation of black cumin paste and RTS was found best by judges after sensory evaluation of chutney when compared to level 2 and 3% black cumin fortified paste. However, in biscuits, black cumin powder supplemented level up to 2% was found acceptable on the basis of spread factor and hardness as compared to 3 and 4% fortification powder. It was concluded that 1% black cumin paste supplemented in coriander chutney, 1% black cumin powder supplemented in bottle gourd RTS and 2% black cumin powder supplemented in biscuits, were the best selected value-added products. **Conclusion:** This study revealed that black cumin seeds are a potentially rich source of phytochemicals, and regular consumption of black cumin incorporated products with added value may reduce the risk of numerous diseases.

Introduction

Black cumin seed (*Nigella sativa* L.) belongs to the Ranunculaceae family, an annual flowering herb commonly known as black caraway, kalonji,

kalajeera or roman coriander in various parts of the world (Allah Ditta *et al.*, 2021). Black seed spice is native to Southern Europe, North Africa, and

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Southwest Asia (Lal *et al.*, 2020). It is further reported that black cumin is widely grown and consumed throughout India, particularly in Punjab, Bihar, Himachal Pradesh, Madhya Pradesh, Bengal, Assam, Rajasthan and Maharashtra. According to Hangargekar *et al.*, kalonji seeds have a spicy bitter taste, and aroma and black seeds are widely used as a spice in Indian and Middle Eastern cuisines (Hangargekar *et al.*, 2020). Wako stated that depending on the region, these seeds contain volatile oil (0.40-0.45%), non-volatile oil (32-40%), protein (16.00-20.85%), carbohydrates (31.0-33.9%), fiber (5.50-7.94%), alkaloids, tannins, saponins, minerals such as iron, calcium, potassium, magnesium, zinc, and copper (1.79-3.44%) along with the presence of vitamin A, ascorbic acid, thiamine, niacin, pyridoxine, and folate (Wako, 2020). Thymoquinone, dithymoquinone, thymohydroquinone, and thymol are major bioactive compounds present in kalonji seeds (Osman *et al.*, 2015, Shariq *et al.*, 2015, Shrivastava *et al.*, 2011, Yimer *et al.*, 2019).

Khan and Afzal reported on bioactive compounds of black seeds and acclaimed several medicinal properties such as antidiabetic, bronchodilatory, hypotensive, antiviral, antibacterial, antifungal, analgesic, anti-inflammatory, and immune-potentiating as black seeds play an important role as immune enhancer by enriching human immunity (Akram Khan and Afzal, 2016). Liu *et al.* studied the lipid profile of nigella seeds cultivated in Egypt and indicated that its oil contains a significant amount of sterols, linoleic, oleic, and palmitic as the main fatty acids (Liu *et al.*, 2013). Nigella seed also contains glucosides, melanthin, and melanthingenin as well as a crystalline active ingredient called nigellone, bitter compounds, fixed oil, resins, and tannins (Huchchannanavar *et al.*, 2019, Kinki, 2020, Sharma *et al.*, 2017, Thilakarathne and Navaratne, 2018). It was also documented that this seed spice is carrying antimicrobial, appetizing, digestive, aromatic, diuretic, antioxidant, and anti-inflammatory properties due to various nutraceutical compounds which actively contribute to nutritive and medicinal value with potential health benefits (Islam *et al.*, 2019, Javed *et al.*, 2012, Khazdair *et al.*, 2021).

According to Kiralan *et al.* due to phenolic components and tocopherols, black cumin oil has antioxidant effects while major bioactive compounds show important functions against microbes due to having antimicrobial properties (Kiralan *et al.*, 2014).

Black cumin seed powder not only imparts taste, flavour, aroma, and colour but also acts as a preservative by preventing the spoilage of various food products because it is considered a huge reservoir of essential oils and aromatic constituents. Apart from this, black cumin possesses nutritional, antioxidant, antimicrobial, and various health promoting properties. Efforts are therefore directed towards the development of value-added products by incorporating black cumin seed powder to ensure their long term preservation and optimum utilization for health benefits.

Materials and Methods

Procurement of raw material

Black cumin seeds (AN-1 variety) were procured from National Research Center on Seed Spices (NRCSS), Ajmer (Rajasthan), during the month of October 2021 at a properly matured (dark black color) stage. Fresh and fully matured black cumin (*Nigella sativa* L.) was free of dirt, decay, and insects and has a good commercial quality.

Preparation of black cumin seed powder

Black cumin seeds were visually sorted for uniform shape, size, characteristic colour, and any physical damage in order to obtain homogenous samples. After sorting, selected black cumin seeds were washed with water in order to remove dirt, dust, and other adhered undesirable particles from the surface of the seeds. Washed seeds were blotted on blotting paper and the shade dried at room temperature. Fine powder of dried seeds was acquired by electric grinder (Sujata Mixer) for 1 minute until fine powder was obtained (Khalid *et al.*, 2019).

Physico-chemical analysis of black cumin seeds

Physico-chemical analysis of Kalonji seeds was carried out during the initial stage of the study. In the second phase, pH, TSS, acidity, and

antioxidant activity of the desired products were determined.

Kernel weight

The kernel weight of the seeds was determined by taking the weight of 100 seeds in triplicates and multiplying them by the 10 factors (Singh *et al.*, 2015).

Bulk density

The volume contribution of interparticulate void volume is included in the bulk density of a powder, which is calculated as the mass of a powder sample divided by its volume. Thus, the bulk density is dependent on both the density of the powder particles, and specifically, the voids in their spatial arrangement in powder bed. The measurements were conducted using cylinders, which yield volume in ml, and bulk density is frequently stated in grams per millilitre ($1 \text{ g/ml} = 1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$) (Verma *et al.*, 2015).

Estimation of colour

The colour of raw materials was visually inspected while the colour of Kalonji powder, Chutney, and Ready to Serve (RTS) was measured using a Konica Minolta Chroma Meter CR-400 (Konica Minolta Sensing, Inc., Japan) with 8 mm aperture and D65 illuminant. The instrument was calibrated with a white standard plate. At room temperature, colour evaluation was conducted on the samples using the following colour scores which are expressed as: L*(lightness), a*(redness) and b*(yellowness). The three readings were noted for each sample, and results were expressed as mean and standard deviation.

Estimation of pH

The samples were crushed before the pH was estimated using a digital pH meter.

Estimation of total soluble solids (TSS)

Hand refractometers were used to estimate TSS at ambient temperature (0-32%) from fresh products.

Estimation of titratable acidity

Titratable acidity was determined using a method described by AOAC (1990). A sample of

5g was taken along with 50ml of boiling distilled water. After adding a few drops of 1% phenolphthalein indicator to 10 ml of this solution, titration with N/10 NaOH was performed. After a drop of NaOH was added, pink colour appeared.

Hydration capacity

Two g seeds were counted and transferred to a measuring cylinder before being mixed with water. The cylinder was wrapped in aluminium foil and kept at room temperature overnight. Next day, seeds were drained, superfluous water was removed with filter paper, and swollen seeds were reweighed. Hydration capacity per seed was determined as described by Williams (Williams *et al.*, 1983).

Proximate analysis of black cumin seeds

Proximal analysis for moisture, crude fat, protein, dietary fiber, and ash was performed according to respective methods of the official Methods of Analysis of the Association of Official Analytical Chemists (AOAC, 2005) followed by Khalid with slight modifications (Khalid *et al.*, 2019). The carbohydrate of *Nigella sativa* seeds was calculated by subtracting the total of protein, fat, moisture, fiber and ash from 100. All the analytical procedures were performed at least in triplicates in order to ensure the results. The values were expressed as mean \pm standard deviation.

Moisture content

The moisture content of the sample was ascertained by hot air oven method as described in AOAC (AOAC, 2005). Five g of sample was weighed in pre-weighed petri dish (without lid), and petri dish was heated in hot air oven for drying the seed powder at 70 °C for 6-7 hrs. After cooling in desiccator, weight of the petri dish was noted for calculating the percentage of dry matter from the sample.

Fat content

Fat content of the sample was determined using the standard procedure described in AOAC (AOAC, 2005). Five g of powdered sample was dried overnight in the oven at 45 °C temperature to remove the moisture, which was then transferred into pre-

weighed (dried) extraction thimble and extracted into Soxhlet extraction apparatus using petroleum ether as solvent for 5-6 h. After that, petroleum ether was removed by evaporation and the residue left was kept for drying at 100 °C in hot air oven for 10-15 min. After cooling in desiccator, weight was measured. The percentage of fat was calculated as a result of the weight loss of the thimble.

Protein content

Crude protein content in each sample was determined by Macro-kjeldahl method which is described in AOAC (AOAC, 2005).

Digestion: Some glass beads, a pinch of catalytic mixture, and 5 g of seed powder sample were put into digestion flask after proper weighing. Then, 20 ml of concentrated sulphuric acid was added, and digestion was continued for 3-4 h till the content of digestion flask attained transparent color. The content was then allowed to cool at room temperature. After filtration, the final volume was made up to 100 ml with distilled water.

Distillation: To a 150 ml conical flask, 10 ml boric acid and 2-3 drops of indicator were added and kept in contact with condenser. Next, to the distillation flask, 2 ml aliquot and 10 ml NaOH solution were transferred. Liberated ammonia was collected in conical flask, and distillation was carried out for at least 80 ml of the distillate. Then, the contents of flask were titrated against 0.01 N HCL solution. Reading of blank (same procedure except sample addition) was also obtained.

Ash content

Total ash content of the sample was calculated using the procedure described in AOAC (AOAC, 2005). In precisely weighed (dry) silica crucibles, a 2 g sample of seed powder was collected and placed on a hot plate for charring until smoke disappeared. After that, the charred samples were put into muffle furnace at 550 °C temperature for 5-6 h. Weight of the crucibles was noted after cooling in desiccator and percentage of ash was obtained.

Crude fiber

Crude fibre of the samples was calculated as per

standard AOAC method (AOAC, 2005). Residue of fat extract was used for determination of crude fibre. Briefly, 2 g fat free sample of seed powder and 200 ml of 0.128 M H₂SO₄ solution were added to a 1 litre tall beaker and were digested using crude fibre apparatus. After washing with distilled water and filtration using Buchner funnel, the samples were again digested with 200 ml of 0.313 M NaOH solution. Next, the samples were washed with distilled water and filtered again. Washing with alcohol (twice) and acetone (thrice times) was also carried out. The samples were dried at 100 °C till constant weight was achieved; after that, samples were placed in muffle furnace at 550 °C-650 °C for 3-4 h for obtaining grey ash.

Black cumin supplemented products

Black cumin seeds are consumed either raw or cooked and processed into value-added products viz. paste, powder fortified coriander chutney, RTS, juice, beverages, preservatives, additives, black cumin supplemented biscuits, and many more products. Black cumin has been already used for the preparation of soups, beverages, cookies, biscuits, and jams as blending agents as reported by (Datta *et al.*, 2012, Mamun and Absar, 2018).

Products fortified with black cumin

Black cumin can be strengthened to produce useful goods. Bread, biscuits, cookies, chutney, beverages, and other goods can be produced. Its addition boosts nutritional value and antioxidant activity of processed foods. According to Osman *et al.* flatbread can be fortified with black cumin. In the preparation of flatbread, to the defatted seed meal was added 5, 10, or 15% of whole wheat flour. It boosts wheat flour's nutritional and antioxidant value (Osman *et al.*, 2015). The utilization of black cumin seed fractions on cookie quality characteristics has been reported by Pawase and Pawase (Pawase and Veer, 2020). 2, 4, 6 and 8% of black cumin was added to cookies. The overall acceptability of black cumin (2%) added into cookies was higher than that of a control sample.

Black cumin fortified products

1. Preparation of black cumin paste: Black

cumin seeds were procured and placed on the sieve and were washed properly under the running tap water tap water. Seeds were soaked overnight. Then, water was removed and was grinded with the help of pestle and mortar. Finally, prepared paste was packed.

2. Preparation of coriander chutney fortified with black cumin paste: First of all, the peel of garlic and onion was removed by using the knives and was washed with water properly (Table 1). Garlic and onion were chopped finely, and detached coriander leaves were crushed. Then, crushed garlic, onion, chillies, salt and black cumin paste were added. It was stirred continuously while cooking on a slow fire until the mixture became tender. Sugar was added after that, and chutney was cooked again on slow fire until it thickened.

Table 1. Recipe for coriander chutney fortified with black cumin.

Ingredients	Quantity
Coriander leaf (g)	100
Black cumin seed paste (g)	1, 2, 3
Onion (g)	50
Tomato (g)	50
Garlic (g)	2
Sugar (g)	20
Red chillies (g)	1
Salt (g)	3

3. Preparation of bottle gourd RTS fortified with black cumin

For preparation of bottle gourd beverages, well-matured soft bottle gourd fruits, ripe lime, and fresh black cumin were selected (Table 2). Bottle gourd fruits were washed with the help of tap water. Then, the fruits were peeled via hand peeler and then chopped into small pieces by using knife. Blanching was done in boiling water at 75-80 °C for 2-3 minutes. After that, lime was cut into two halves by using knife, and juice was extracted by

squeezing. Bottle gourd pulp was prepared and mixed with water, sugar, and black cumin powder (1, 1.5 and 2%) and were boiled together for 10 minutes at 80 °C and were poured into sterilized juice bottles and left 2 to 2.5 cm headspace. Bottles were corked with sterilized crown corks using crown corking machine. The bottles filled with gourd RTS were pasteurized in boiling water at 80 °C for 15 minutes to attain required temperature.

Table 2. Recipe for bottle gourd RTS fortified with black cumin.

Ingredients	Quantity
Bottle gourd pulp (g)	50
Black cumin seed powder (g)	1, 1.5, 2
Sugar (g)	10
Lime (ml)	10
Water (ml)	30

4. Preparation of biscuits fortified with lack cumin powder:

Wheat flour was dried by mixing in dough mixer (Table 3, Figure 1). After mixing sugar and fat, a paste was prepared. The dried mix was mixed thoroughly with black cumin paste in various proportions. Then, dough was prepared in the dough mixer and rolled into proper shape and size. The rolls were cut with the help of cutter and baked at 230 °C for 15 minutes and then packed in polythene bags.

Table 3. Recipe for black cumin powder fortified biscuits.

Ingredients	Quantity
Wheat flour (g)	100
Fat (g)	30
Sugar (g)	35
Black cumin powder (g)	2, 3, 4
Baking powder (g)	2
Ammonium carbonate (g)	1
Milk (ml)	35

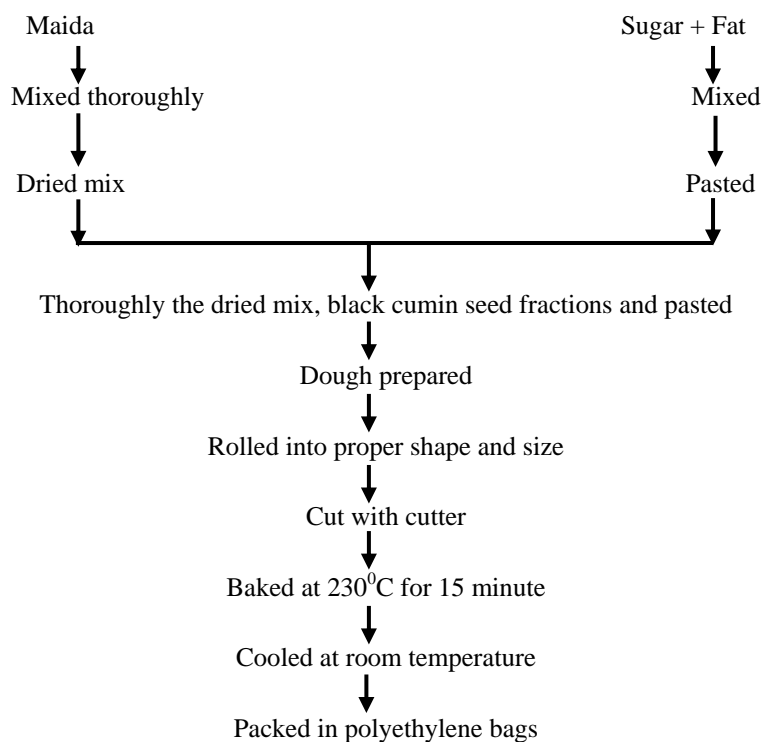


Figure 1: Flow sheet for preparation of biscuits fortified with black cumin powder

Determination of antioxidant activity using 1-diphenyl-2-picryl hydrazyl (DPPH)

An evaluation of antioxidant activity was carried out by using stable 1 and DPPH-free radical activity to evaluate the antioxidant activity of plant extracts and standards. To prepare diluted working solutions for test extracts, methanol was used as solvent. Ascorbic acid was used as the standard in a solution of 1-100 mg/ml. 0.002% of DPPH was added to diluted sample solutions, and 1 ml of the diluted solution was added separately to the diluted standard solution. The optical density of these mixtures at 517nm was measured using a UV-visible spectrophotometer, after being kept in the dark for 30 minutes. As a blank, 1 ml of methanol diluted with 0.02% DPPH solution was used. Based on optical density, inhibition was calculated as follows:

$$\text{Inhibition (\%)} \text{ of DPPH activity} = \frac{A-B}{A} \times 100$$

Sensory evaluation: It was performed using hedonic scale method. A panel of ten individuals was conducted for sensory evaluation. The prepared products were served on a white

disposable plastic tray. An average of ten evaluations was recorded. The good products were rated on a 9-point hedonic scale for colour, appearance, flavour, texture, taste, and overall acceptability.

Data analysis

The statistical analysis of the observed data was carried out using SPSS 16.0 software for ANOVA and all the observations were taken in triplicates. Standard deviation (SD) was used to perform all the possible pair comparisons between means of different values whether the samples were significantly different from each other or not.

Results

Physical parameters included kernel weight, bulk density, hydration index, and colour, which were measured as per the standard methods. Results of physical parameters are summarized in **Table 4**. The nutritional composition of black cumin seeds was observed as 8.20% moisture content, 25.33% protein content, 34.03% fat, 4.53% ash, 7.33% crude fibre and is 27.90% carbohydrate in **Table 5**. The different parameters

of prepared products were measured i.e. pH, TSS, acidity, and antioxidant activity.

Table 6 depicted the antioxidant activity of coriander chutney, which was observed as follow: control (55.35%), 1% supplement of black cumin (55.75%), 2% supplement amount (56.45%) and 3% supplemented amount (57.07%).

In **Table 7**, the following parameters were estimated, and the mean values of pH, TSS, acidity, and color value observed for the control was 4.45, 18.0, 0.45 and L (23.04), a (3.13), b (3.66). The mean values of pH, TSS, acidity, antioxidant activity and color value for 1% fortified black cumin paste were 4.46, 17.96, 0.44, 55.75 and L 26.92, a 1.90, b 6.96. The mean values of pH, TSS, acidity, antioxidant activity and color value for 2% fortified black cumin paste in coriander chutney were 4.50, 17.76, 0.45, 56.45, and L 25.71, a 2.13, b 7.75. The mean values of pH, TSS, acidity, antioxidant activity and color value for 3% fortified black cumin paste in coriander chutney were 4.50, 17.96, 0.45, 57.07, and L 22.35, 1.81, 7.60.

In case of bottle gourd RTS, the mean values of pH, TSS, acidity, and color value for control were 3.66, 7.46, 0.33, and L (37.51), a (0.18), b (3.39). The mean values of pH, TSS, acidity, antioxidant activity and color value for 1% fortified black cumin powder were 3.66, 7.46, 0.34, 40.73, and L (33.79), a (0.28), b (2.45). The mean value of pH, TSS, acidity, antioxidant activity, and color value for 1.5% fortified black cumin powder were 3.56, 7.43, 0.35, 41.05, and L 36.45, a 0.18, b 0.18. The mean values of pH, TSS, acidity, antioxidant activity, and color value for 2% fortified black cumin powder were 3.63, 7.36, 0.35, 42.08, and L (36.33), a (0.52), b (1.46). **Table 7** shows the control values for TSS, and acidity in bottle gourd RTS had significant numbers, while the concentration of black cumin fortification in coriander chutney was 1%, and in bottle gourd RTS with 1.5% , the values were the least significant.

Table 4. Physico-chemical properties of black cumin seeds.

Physico-chemical parameters	Composition
Kernel weight (g)	2.90±0.80
Seed coat content (g)	1.26±0.54
Bulk density (g/ml)	0.62±0.04
True density (g/ml)	0.46±0.20
Hydration index (g)	0.08±0.01
Seeds colour	
l*	21.23±0.70
a*	3.35±0.07
b*	3.99±2.46

Values represented as mean ± standard deviation and data performed in triplicate.

Table 5. Proximate analysis of black cumin seed powder.

Nutritional components	Composition (%)
Moisture	8.20±0.17
Crude protein	25.33±0.85
Crude fat	34.03±1.07
Crude fiber	7.33±1.04
Ash	4.53±0.30
NFE	4.53±0.30

Values represented as mean ± standard deviation and data performed in triplicate; NFE: Nitrogen free extract.

Table 6. Antioxidant activity of products fortified with black cumin.

Prepared products	Amount of fortification (%)	DPPH activity (%)
Coriander chutney	Control	55.35±14.34
	1	55.75±13.01
	2	56.45±11.68
	3	57.07±6.94
Bottle gourd RTS	Control	39.70±14.36
	1	40.73±13.12
	1.5	41.05±11.88
	2	42.08±6.96

Value represented in mean ± standard deviation and data performed in triplicate.

Table 7. pH, Color, TSS, and Acidity Value in Different Concentrations of Coriander Chutney and Bottle Gourd RTS fortified with Black Cumin.

Prepared products	Amount Fortified (%)	pH	TSS (°Brix)	Acidity (%)	Colour	Prepared products	Amount fortified
					L*	a*	B*
Bottle gourd RTS	Control	3.66±1.04	7.46±0.05	0.33±0.01	37.51±3.60	0.18±0.09	3.39±1.04
	1	3.66±0.05	7.46±0.05	0.34±0.02	33.79±0.32	0.28±0.18	2.45±0.26
	1.50	3.56±0.11	7.43±0.11	0.35±0.02	36.45±0.70	0.18±0.26	2.24±0.54
	2	3.63±0.05	7.36±0.11	0.35±0.05	36.33±0.64	0.52±0.15	1.46±0.10
Coriander chutney	Control	4.50±0.00	18.00±0.00	0.45±0.25	23.04±1.20	3.13±0.30	3.66±1.84
	1	4.46±0.11	17.96±0.05	0.44±0.02	26.92±0.27	1.90±0.08	6.96±0.32
	2	4.50±0.00	17.76±0.25	0.45±0.02	25.71±0.99	2.13±0.02	7.75±0.93
	3	4.50±0.00	17.96±0.05	0.45±0.05	22.35±2.77	1.81±0.21	7.60±1.18

Value represented in mean±standard deviation and data performed in triplicate; **RTS**: Ready To Serve; **TSS**: Total Soluble Solids.

Table 8 show demonstrates physical parameters such as diameter, thickness and spread regarding biscuits fortified with black cumin powder. Physical parameters for biscuits fortified with 2% black cumin powder was 5.8, 0.83 and 6.98, for biscuits 3% black cumin powder fortified biscuits (5.7, 0.85, 6.70) and for biscuits fortified with 4% black cumin powder was 5.8, 0.86, 6.74. It was evaluated that with an increased concentration of black cumin powder, the thickness of substituted biscuits expanded, while the width and spread ratio of biscuits decreased. Sensory analysis was done for the three products. The mean value of the acceptable coriander chutney fortified with 1% black cumin paste was 7.87. The mean value of acceptable bottle gourd RTS fortified with 1% black cumin powder was 7.27. The mean value of acceptable biscuits fortified with 2% black cumin powder was 8.01. Diameter of biscuits supplemented with black cumin powder was decreased from 6.0 control to 5.7 cm (3%) incorporation.

Sensory evaluation in **Table 9** shows that 1% incorporation of black cumin seed paste was the maximum limit beyond which the chutney decreased sensory acceptability, 1% incorporation of black cumin powder was also the maximum limit beyond which the bottle gourd RTS decreased sensory acceptability, and biscuits had a 2% maximum limit beyond which they lost sensory appeal.

Table 8. Physical characteristics of biscuits formulated with black cumin powder.

Sample	Diameter (cm)	Thickness (cm)	Spread ratio diameter/thickness
Control	6.0	0.85	7.05
2%	5.8	0.83	6.98
3%	5.7	0.85	6.70
4%	5.8	0.86	6.74

Sample s	Colour		
	L*	a*	b*
Control	67.53	8.41	20.24
2%	61.19	6.56	14.98
3%	55.10	7.59	16.47
4%	54.02	7.21	15.24

Each value is an average of a minimum of three determinations.

Discussion

Nigella sativa L. plant has been utilized in traditional medicine for many decades due to its efficiency in managing a variety of medical conditions; it is regarded a "wonder herb" (Kaushik and Barmanray, 2022). In product development, biscuits, RTS drink (beverage), and coriander chutney were fortified with black cumin. Black cumin seeds were used as herbal medicines commonly employed in eastern civilization. Results of Ramadan's study indicated that there is a difference between the four sesame nut samples in terms of protein, ash, crude fiber, carbohydrate, and moisture. Semsemia fortified with black cumin

and oat seeds have new characteristics. Addition of black cumin seeds to semsemia to make new formula (T2) increased protein compared to the control (semsemia). This improvement in protein content is the consequence of black cumin seeds, and the values observed are of the same order as those described by others (Ramadan and Mörsel, 2002, Takruri and Dameh, 1998, Tembhurne *et al.*, 2014). Ash content was high in all sweet nuts formulated with seeds which are related to the high mineral content of the seeds. In this study, black cumin seeds are high in fat content which would make the fortified products a better source of fat

compared with the others because high fat content in diets contribute significantly to energy requirement for humans and are good for flavour enhancing which causes a good feeling in the mouth. Therefore, black cumin can be fortified in products for flavour enhancing purpose. Apart from this, black cumin is also a good source of essential fatty acids (monounsaturated or polyunsaturated) as well as long chain omega-6 and omega-3 fatty acids which have favourable effects and positive health benefits compared with saturated fatty acids.

Table 9. Sensory evaluation of black cumin supplemented products.

Fortified products	Fortification amount	Colour	Flavour	Texture	Taste	Overall acceptability
Coriander chutney	Control	9.00	8.00	8.00	8.00	8.33
	1%	8.62	7.12	7.75	8.00	7.87
	2%	8.37	7.00	8.12	6.87	7.59
	3%	8.12	7.00	8.00	7.12	7.56
Bottle gourd RTS	Control	9.00	8.00	8.00	8.00	8.33
	1%	7.62	7.12	7.37	7.00	7.27
	1.50%	6.50	6.12	7.37	5.75	6.43
	2%	5.62	5.37	7.12	4.25	5.59
Supplemented biscuits	Control	8.10	8.48	8.28	8.34	8.30
	2%	7.25	8.40	8.2	8.20	8.01
	3%	6.10	8.20	8.1	8.10	7.62
	4%	4.30	6.40	7.20	6.20	6.02

It has been shown that antioxidant-rich diets can reduce oxidative damage to biomolecules such as carbohydrates, lipids, proteins, and nucleic acids, thus preventing a critical step at the onset of carcinogenesis Zhang *et al.*, Ahmad and Beg, and Hemalatha and Rao (Ahmad and Beg, 2013, Hemalatha and Rao, 2004, Zhang *et al.*, 2008). Many antioxidant activities are due to the presence of coumarin, lignans, flavonoids, flavones, anthocyanin, isocatechins, isoflavones, and catechins (Ahmad and Beg, 2013). In this study, it was found that increasing the amount of fortification increases the level of antioxidant potential in developed products which have constructive health effects and may be utilized as effective antioxidants in foodstuffs. Therefore, antioxidants also play an important role in contributing to stability and taste in processed food

products by preventing rancidity.

Based on sensory analysis, there was an increase in sensory score with the addition of oat seeds improved colour, taste, odour, texture, and acceptability of the final products. The acceptability of a product depends on taste, which has the highest impact in measuring the success of the product on the market. Moreover, an important factor for the initial acceptability of food products by consumers is the sweet colour (Chauhan *et al.*, 2016). The chemical characteristics of biscuits are attributed to the ingredients used in the recipe. In this regard, Bordes *et al.* reported the chemical composition of different cultivars of wheat (Bordes *et al.*, 2008). Therefore, the results were in accordance with the results of Sharif *et al.* and Pasha *et al.* (Pasha *et al.*, 2002, Sharif *et al.*, 2005). The biscuits were considered as an important

source of macronutrients and energy, especially for children and adolescents.

Hence, black cumin seed powder provided satisfactory results in chutney, RTS, and biscuits. It can be utilized in a variety of other products with similar advantages. As a result, additional research on black cumin seed powder is required to improve sensory and taste so that it can have better effects on food products, as demonstrated by this research.

Advantages and limitations of the study: Value addition is a procedure or series of processes where the raw material is exposed to another stage of manufacturing in order to gain higher market pricing. The benefits of adding value to spices include minimising post-harvest loss, improving employment possibilities, and fostering thriving export trade. The development of these products through incorporation is primarily focused on the assessment of food safety, quality, and preservation as well as offering the health advantages of spices. The value addition is still insufficient, nevertheless, as a result of underutilization of black cumin. Keeping all these in mind, it is essential to create such value-added products using black cumin and all other spices.

Conclusion

This study revealed that black cumin seeds are a potentially rich source of phytochemicals, and regular consumption of black cumin incorporated products with added value may reduce the risk of numerous diseases. The research study also concerned the antioxidant and immunity boosting properties of products incorporated with black cumin seeds and their utilization in the development of functional foods and nutraceuticals. This study revealed that products fortified with black cumin are a good source of protein, fiber, and fat as compared to unfortified ones. So, the use of black cumin in products preparation is recommended because of their quality, nutritional effectiveness and, antioxidant advantages.

Authors' contributions

Aradhita Barmanray was involved with conceptualization, review, supervision and approval, Nita Kaushik also conducted the

conceptualization, writing the original draft, reviewing and critical revision and Rajesh Kumardid the writing and editing . All the authors approved the final manuscript.

Conflicts of interests

The authors declared no conflict of interests.

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