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Evaluation of Nutritional and Antioxidant Potential of Clove Basil and Sweet Basil Seeds for Utilisation as Functional Ingredients

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ABSTRACT

The present era witnessed altered food habits and lifestyle which led to consumption of unhealthy diets concomitant with augmented prevalence of life style diseases worldwide. Consequently, the health consciousness among food consumers was spurred and demand for functional foods was drastically improved amidst COVID 19 pandemic. The underutilised clove basil (*Ocimum gratissimum*) and sweet basil (*Ocimum basilicum*) seeds were found to be good source of protein (9.16, 8.55 g/100 g), dietary fibre (56.45, 48.46 g/100 g), calcium (603.60, 568.40 mg/100g), magnesium (270.72, 261.36 mg/100g), potassium (384.61, 594.41 mg/100g), zinc (4.17, 6.95 mg/100g), polyphenols (17.28, 17.71 mg GAE/g ethanol extract) and flavonoids (10.63, 12.15 mg QE/g ethanol extract). Further, the clove basil and sweet basil seeds exhibited ferric reducing antioxidant power of 127.46 and 235.73 TE/g ethanol extract respectively and total antioxidant capacity of 232.76, 120.57, 531.98 mg TE/g ethanol extract and 301.41, 309.28, 609.83 TE/g ethanol extract for scavenging DPPH, $ABTS^+$, O^2 radicals respectively with a potential to reduce the risk of diseases induced by oxidative stress. Henceforth, both the seeds of clove basil and sweet basil with superior nutritional profile and antioxidant potential can be efficiently utilized as functional ingredients for the formulation of designer foods.

Keywords : Basil seeds, Dietary fibre, Antioxidants, Functional ingredients

FUNCTIONAL foods are foods which exhibited positive impact on human health apart from meeting basic nutritional requirements (Fathima *et al.,* 2021). There was around per cent annual increase in global demand for plant based functional foods in particular for medicinal seeds with nutraceutical properties and enormous health benefits (Khursheed *et al.,* 2023). This has largely been attributed to the increased prevalence of lifestyle diseases such as diabetes, obesity, cardiovascular problems and cancers worldwide which amplified the consumer awareness (Deshpande *et al.,* 2019).

The clove basil (*Ocimum gratissimum*) and sweet basil (*Ocimum basilicum*) are culinary herbs, widely grown in warm and tropical areas of Southern Asia (India, Pakistan) and Africa for utilisation in traditional medicines due to their antioxidant, antimicrobial, antidiabetic, anti-inflammatory, antiviral, analgesic, antistress and antipyretic properties (Nadeem *et al.,* 2020). Basil is widely grown throughout India especially among states such as Karnataka, Andhra Pradesh, Telangana, Madhya Pradesh, Maharashtra, Jammu, Assam, West Bengal, Bihar and Uttar Pradesh. The annual production of basil in India has accounted for 250-300 tons against global production of 500 tons (Nazir and Wani, 2021).

The ripe, fully mature seeds of basil are generally dark brown or black in colour, small in size, ellipsoid in shape with dimensions ranged between 2.31 - 3.11 mm length, 1.3 - 1.82 mm width, 0.99 - 1.34 mm thickness and porous surface (Uematsu *et al.,* 2020 and Bravo *et al.,* 2021). Basil seeds are edible

Clove basil plant Clove basil seeds Sweet basil plant Sweet basil seeds

Plate 1 : Basil plants and seeds

and produce considerable amount of mucilage in aqueous solutions which remain tightly bound to seed core (Choi *et al.,* 2020). Being rich source of dietary fibre, protein, polyphenols, flavonoids and other antioxidants, basil seeds are considered as super seeds of 21st century (Khursheed *et al.,* 2023). In general, they were added as whole to beverages (Sharbat, fruit-based drinks), ice creams, frozen desserts (falooda) or in milled form to bakery products for aesthetic, functional and nutritional purposes (Bravo *et al.,* 2021).

However, they varied in the composition of nutrients and bioactive constituents in accordance to agronomic management practices, soil properties, geographical location, altitude, environmental conditions, origin of seeds, genetic factors and extent of absorption of water (Ndulaka, 2016). Thus, the present study was carried out to determine the nutritional composition and antioxidant potential of locally available clove basil and sweet basil seeds for utilisation as functional ingredients in the formulation of designer foods.

Material and Methods

Procurement of Basil Seeds

The clove basil (*Ocimum gratissimum*) and sweet basil (*Ocimum basilicum*) seeds were procured from local markets of Kadapa district, Andhra Pradesh, India. The seeds were cleaned manually, freed from broken seeds, other variety seeds and inert matter. The obtained pure seeds were pooled and utilised for further investigation.

Nutritional Parameters of Basil Seeds

The proximate composition (moisture, ash, protein, fat, crude fiber, carbohydrate, energy), insoluble, soluble and total dietary fibre contents, mineral composition (calcium, magnesium, phosphorous, sulphur, sodium, potassium, iron, zinc, copper, manganese) of clove basil and sweet basil seeds was determined following standard AOAC (2019) methods.

Extraction of Bioactive Constituents of Basil Seeds

A known quantity of finely ground basil seeds sample was extracted in 20-times volume of solvent *viz.,* 80.0 per cent ethanol or distilled water by continuous shaking at 600 rpm at 25ºC for 3 hours. The homogenate obtained was centrifuged at 3500 rpm at 20ºC for 15 min and the supernatant was filtered through Whatman no.1 filter paper and collected. The residue was reextracted with 10-times volume of same solvent. The obtained supernatants were pooled and concentrated to dryness in a rotatory vacuum evaporator at 40ºC and stored at 4ºC in microcentrifuge tubes until further use. The yield of basil seeds extracts was calculated as follows:

$$\text{Extraction yield (\%)} = \frac{\text{Weight of dried extract (g)}}{\text{Dry weight of sample (g)}} \times 100$$

Antioxidant Potential of Basil Seeds

The ethanol and aqueous extracts of basil seeds were assessed for total phenols and flavonoids contents following standard protocols given by Amri and Hossain (2018). Further, the ferric reducing power and total antioxidant capacity to scavenge free radicals (DPPH, $ABTS^+$, O^{2-}) were assessed following standard protocols given by Xiao *et al.* (2020).

Statistical Analysis

All experiments were conducted in replicates and the results obtained were presented as mean ± standard deviation (SD). The treatment means were compared for significant difference by independent sample t-test and two-way ANOVA (Analysis of Variance) at 1.0 per cent level using SPSS 20.0 (Statistical Package for the Social Sciences) (IBM, NY, USA). The Pearson correlation calculation was done using Microsoft Excel 2021.

Results and Discussion

Nutritional Parameters of Basil Seeds

Proximate Composition of Basil Seeds : The proximate composition of clove basil seeds and sweet basil seeds is as presented in Table 1. The moisture content of clove basil seeds and sweet basil seeds per 100 g was 9.07 g and 8.20 g, respectively with a significant difference between them at $p \le 0.01$. Bradford *et al.* (2020) reported that the moisture content of seeds should be below 12.0 per cent for better storage (over 1 year) without microbial spoilage and growth of insect pests. Thus, both the clove basil and sweet basil seeds can be stored for longer duration in air tight containers placed in a cool and dry place. The ash (total minerals) content of clove basil seeds and sweet basil seeds per 100g was 4.04g and 5.36g respectively with a significant difference between them at $p \le 0.01$. The sweet basil seeds exhibited better ash content than the chia seeds (4.3g/100g) (Khursheed *et al.,* 2023).

The protein content of clove basil seeds and sweet basil seeds per 100g was 9.16g and 8.55g, respectively with a significant difference between them at $p \le 0.01$. Plant based foods which provided more than 12 per cent of their calorific value from protein were considered as remarkable suppliers of protein and were receiving attention in present days due to augmented demand for vegetarian and vegan diets (Bravo *et al.,* 2021). The clove basil and sweet basil seeds provided 13.3 and 10.4 per cent of their total calories from protein respectively. Thus, clove basil seeds can be considered as a remarkable source of protein.

The fat, fiber, carbohydrate and energy contents of clove basil seeds per 100g were 14.27g, 36.23g, 27.24g, 274 Kcal, respectively while of sweet basil seeds per 100g were 19.61g, 28.85g, 29.43g, 328 Kcal respectively with a statistically significant difference between them at $p \le 0.01$. Both the clove

TABLE 1

Proximate composition of clove basil seeds and sweet basil seeds

Nutrient (per 100 g)	Clove basil seeds	Sweet basil seeds	Mean	SE_m	t value
Moisture (g)	9.07 ± 0.01	8.20 ± 0.01	8.63	0.00	131.00 *
Ash (g)	4.04 ± 0.01	5.36 ± 0.01	4.70	0.00	140.01 *
Protein (g)	9.16 ± 0.01	8.55 ± 0.01	8.85	0.00	64.70 *
Fat (g)	14.27 ± 0.01	19.61 ± 0.01	16.94	0.01	506.91 *
Crude fibre (g)	36.23 ± 0.01	28.85 ± 0.01	32.54	0.01	699.81 *
Carbohydrate# (g)	27.24 ± 0.03	29.43 ± 0.03	28.33	0.01	88.73 *
Energy## (Kcal)	274 ± 0.05	328 ± 0.03	301	0.02	1702.63 *

Note : Values expressed as mean ± standard deviation of three determinations. #Calculated by difference method. ##Determined by computation. * Significant difference between two independent samples at $p \le 0.01$, NS: Non-significant difference, SE_m: Standard error of mean. t table value (0.01) = 9.93.

basil seeds and sweet basil seeds exhibited lower fat and carbohydrate contents than the chia seeds (20.09 g/100 g and 47.74 g/100 g, respectively) (Khursheed *et al.,* 2023). The findings of present study were on par with the results reported by Ndulaka *et al.* (2016), Bravo *et al.* (2021), Nazir and Wani (2021) where the moisture, ash, protein, fat and fiber contents of Indian basil seeds ranged between 8.9-9.6 g/100 g, 5.0-7.7 g/100 g, 9.4-14.8 g/100 g, 13.8-33.0 g/100 g and 22.6-41.6 g/100 g respectively.

Dietary Fiber content of Basil Seeds : Both the clove basil seeds and sweet basil seeds can be considered as unconventional sources of dietary fiber as depicted in Table 2. The insoluble, soluble and total dietary fiber contents of clove basil seeds and sweet basil seeds per 100 g were 38.26 g, 18.19 g, 56.45 g and 31.26 g, 17.20 g, 48.46 g, respectively. Statistically significant difference was observed between the clove basil and sweet seeds for insoluble, soluble and total dietary fiber contents at $p \leq 0.01$. The findings were on par with the results reported by Khursheed *et al.* (2023), where the insoluble, soluble and total dietary fiber contents of Himalayan basil (*Ocimum basilicum* var. *thyrsiflora*) seeds per 100g was 31.68g, 19.17g and 50.85g, respectively. Further, the Himalayan basil seeds possessed significantly higher ($p \leq 0.05$) soluble and total dietary fiber contents than chia seeds (3.74 g/100g, 37.74g/100g) and lower insoluble dietary fibre content than chia seeds (33.72g/100 g), which was non-significant at 5.0 per cent level.

The high dietary fiber content of clove basil and sweet basil seeds was desirable as the consumption of dietary fiber was associated with reduced risk of obesity, cardiovascular diseases, diabetes, gastrointestinal disorders and cancers. The soluble dietary fiber (SDF) consumption significantly lowered the blood cholesterol levels and helped to stabilise the blood glucose levels while the insoluble dietary fiber (IDF) consumption protected against colon cancer and other inflammatory bowel disorders (Hung *et al.,* 2012). However, the insoluble to soluble dietary fiber ratio should be in the range of 1.0 to 2.3 in order to obtain the physiological benefits of both soluble and insoluble fractions and promote good health (Hajmohammadi *et al.,* 2016). The IDF/SDF ratio of clove basil and sweet basil seeds was 2.1 and 1.8 respectively. As the ratio of both the seeds was in ideal range, they can be considered as well-balanced dietary fiber sources.

Mineral Composition of Basil Seeds : Although minerals comprised only 4-6 per cent of human body, their incorporation in diet significantly helped in management of numerous diseases and promoted wellbeing (Nayak *et al.,* 2020). The principal minerals or macrominerals required in higher amounts from diet (>100 mg/day) included calcium, phosphorus, magnesium, sulphur, sodium, potassium, chloride which are the structural components of tissues, essential for cellular and basal metabolisms, regulating water and acid-base balances in body. Trace minerals or microminerals required in lesser amounts from diet (<100 mg/day) included iron, zinc, copper, manganese, chromium, fluoride, iodine, selenium which are crucial for hormones, vitamins and enzymes activities (Godswill *et al.,* 2020).

The calcium, magnesium, phosphorus and sulphur contents of clove basil seeds were 603.60, 270.72, 69.25, 59.96 mg/100 g, respectively while that of

TABLE 2

Dietary fibre content of clove basil seeds and sweet basil seeds

Nutrient (per 100 g)	Clove basil seeds	Sweet basil seeds	Mean	SE_m	t value
Insoluble dietary fibre (g)	38.26 ± 0.01	31.26 ± 0.01	34.76	0.00	1399.00 *
Soluble dietary fibre (g)	18.19 ± 0.01	17.20 ± 0.01	17.70	0.01	70.00 *
Total dietary fibre (g)	56.45 ± 0.01	48.46 ± 0.01	52.46	0.01	505.33 *

Note: Values expressed as mean ± standard deviation of two determinations. * Significant difference between two independent samples at $p \leq 0.01$, NS: Non-significant difference, SE_m: Standard error of mean. t table value (0.01) = 9.93

sweet basil seeds were 568.40, 261.36, 106.68, 71.51 mg/100 g, respectively. Both the seeds were found to be rich source of calcium compared to chia seeds (463 mg/100 g), ragi (364 mg/100 g), almonds (228 mg/100 g) and milk (121 mg/100 g). Moreover, they were good source of magnesium like amaranth seeds (270 mg/100 g), soybean (259 mg/100 g) and cowpeas (213 mg/100 g) (Longvah *et al.*, 2017 and Cormick & Belizan, 2019).

The sodium and potassium contents of clove basil seeds were 2.93 and 384.61 mg/100 g, respectively while of sweet basil seeds were 2.85 and 594.41 mg/100 g, respectively. Both the seeds were found to be good source of potassium like chia seeds (407 mg/100 g) and banana (358 mg/100g) (Ranjha *et al.,* 2022 and Khursheed *et al.,* 2023). Consumption of foods rich in calcium, magnesium and potassium was beneficial in combating stroke, hypertension, osteoporosis, cardiovascular diseases, muscular diseases and type 2 diabetes (Cormick & Belizan, 2019; Sussman *et al.,* 2020 & Barbagallo *et al.,* 2021).

The iron, zinc, copper and manganese contents of clove basil seeds were 0.89, 4.17, 2.13, 4.34 mg/100 g, respectively while that of sweet basil seeds were 3.28, 6.95, 1.87, 1.88 mg/100 g, respectively. These microminerals were found to be crucial for the proper functioning of immune system (Chowdhury and Barooah, 2020). Basil seeds were good source of zinc and comparable to pumpkin seeds (6.60 mg/100 g), cashew (5.34 mg/100 g) and flax seeds (4.86 mg/100g) (Longvah *et al.*, 2017). Further, they possessed higher amounts of copper and manganese than the chia seeds (0.9 mg/100 g, 2.7 mg/100 g) (Khursheed *et al.,* 2023). The zinc, copper and manganese are the cofactors of superoxide dismutase, an antioxidant enzyme which scavenged free radicals and reduced disease risk (Godswill *et al.,* 2020).

The findings were on par with the results reported by Ziemichod *et al.* (2019) and Khursheed *et al.* (2023) where the magnesium, zinc, copper, manganese contents of holy basil (*Ocimum tenuiflorum*) seeds were 293.0, 5.52, 1.94, 1.95 mg/100 g, respectively and the sodium, potassium, calcium, iron, copper, manganese contents of Himalayan basil (*Ocimum basilicum* var. *thyrsiflora*) seeds were 2.01, 481, 636, 2.27, 1.21, 1.01 mg/100 g, respectively. Statistically significant difference ($p \leq 0.01$) was observed between the clove basil and sweet basil seeds for all the minerals assessed except for sodium content.

Antioxidant Potential of Basil Seeds

Extraction of Bioactive Constituents from Basil Seeds : The extraction of bioactive compounds from

TABLE 3

Mineral composition of clove basil seeds and sweet basil seeds

Nutrient (per 100 g)	Clove basil seeds	Sweet basil seeds	Mean	SE_m	t value
Calcium (mg)	603.60 ± 0.575	568.40 ± 0.57	586.00	0.28	62.23 *
Magnesium (mg)	270.72 ± 0.682	261.36 ± 0.34	266.04	0.27	17.44 *
Phosphorus (mg)	69.25 ± 0.38	106.68 ± 0.38	87.97	0.19	98.95 *
Sulphur (mg)	59.96 ± 0.28	71.51 ± 0.28	65.74	0.14	40.84 *
Sodium (mg)	2.93 ± 0.01	2.85 ± 0.01	2.89	0.01	5.66 NS
Potassium (mg)	384.61 ± 0.01	594.41 ± 0.01	405.39	0.01	10578.32 *
Iron (mg)	0.89 ± 0.01	3.28 ± 0.01	2.09	0.00	336.58 *
Zinc (mg)	4.17 ± 0.04	6.95 ± 0.04	5.56	0.02	65.53 *
Copper (mg)	2.13 ± 0.01	1.87 ± 0.01	2.00	0.00	36.49 *
Manganese (mg)	4.34 ± 0.01	1.88 ± 0.01	3.11	0.00	348.75 *

Note : Values expressed as mean ± standard deviation of two determinations. * Significant difference between two independent samples at $p \leq 0.01$, NS: Non-significant difference, SE_m: Standard error of mean. t table value (0.01) = 9.93.

TABLE 4

Total phenols and flavonoids contents of basil seeds extracts

Seeds	Extract	Yield (%)		Total phenols content (mg GAE/g)		Total flavonoids content (mg QE/g)	
Clove basil	Ethanol	11.25 ± 0.08		17.28 ± 0.01		10.63 ± 0.01	
	Aqueous	4.42 ± 0.08		3.92 ± 0.01		3.40 ± 0.01	
Sweet basil	Ethanol	11.86 ± 0.08		17.71 ± 0.01		12.15 ± 0.01	
	Aqueous	4.76 ± 0.08		4.38 ± 0.01		4.51 ± 0.01	
	Mean	8.08		10.82		7.67	
	SE_m	0.03		0.00		0.00	
		F value	CD at 1.0%	F value	CD at 1.0%	F value	CD at 1.0%
Seeds		*	0.00	*	0.02	*	0.02
Extract		*	0.00	*	0.02	*	0.02
Seeds × Extract		NS	-	NS	-	*	0.03

Note : Values expressed as mean ± standard deviation of two determinations. GAE: Gallic acid equivalent, QE: Quercetin equivalent, SE_m: Standard error of mean, CD: Critical difference. * Significant difference at $p \leq 0.01$, NS: Non-significant difference

plant materials was influenced by various factors such as nature of phytochemicals, sample composition, particle size, sample to solvent ratio, extraction method employed, chemical nature and polarity of solvents used for extraction (Garcia *et al.,* 2022). The bioactive constituents of clove basil and sweet basil seeds were extracted using 80 per cent ethanol and distilled water as solvents. Among different polar organic solvents, ethanol was preferred for the extraction as it is relatively safe for human consumption (Pasrija and Anandharamakrishnan, 2015).

Further, 80 per cent ethanol was preferred as the mixture of ethanol and water was more polar than the absolute ethanol which had positive influence on the yield of extracted phytochemicals (Perumal *et al.,* 2021). The yield of ethanol and aqueous extracts of clove basil and sweet basil seeds is as given in Table 4. The ethanol extracts of both clove basil and sweet basil seeds exhibited significantly ($p \leq 0.01$) high yield (11.25 and 11.86 per cent) than the aqueous extracts (4.42 and 4.76 per cent). Statistically significant difference was also observed between the yield of clove basil and sweet basil seeds at 1.0 per cent level.

Total Phenols Content of Basil Seeds : A daily intake of phenols of approximately 200/ mg/day reduced the disease risk and enhanced human health. Phenolic compounds were readily absorbed through intestinal tract walls and served as antioxidants to avert the cell damage from free radicals. They promoted anti-inflammation capacity of humans and reduced the risk of oxidative stress related diseases (cardiovascular, diabetes and cancers). Their potential therapeutic applications had drawn the attention of scientific community for extraction of phenols from natural sources (Kumar and Goel, 2019).

The total phenols content of ethanol and aqueous extracts of clove basil seeds and sweet basil seeds was determined in terms of gallic acid equivalent and is as depicted in Table 4. The ethanol extracts of clove basil and sweet basil seeds exhibited significantly ($p \leq 0.01$) higher phenols content (17.28 and 17.71 mg GAE/g) than the aqueous extracts (3.92 and 4.38 mg GAE/g). Statistically significant difference was also observed between the total phenols content of clove basil and sweet basil seeds at 1.0 per cent level. Likewise, Khursheed *et al.* (2023) reported that the total phenols content of Himalayan basil seeds was 17.66 mg GAE/g of ethanol extract.

Now a days, naturally occurring phenols are commercially available in the form of dietary supplements such as grape seed extract, green tea extract etc. However, regular consumption of foods rich in phenols is always recommended over the dietary supplements (Musa *et al.,* 2012). Further, basil seeds exhibited better phenols content than the chia seeds (1.65 mg GAE/g) (Khursheed *et al.,* 2023). Thus, the clove basil and sweet basil seeds can be utilised for the development of functional foods with better phenols content and other nutrients. Munir *et al.* (2017) showed that drink with 0.3 per cent basil seeds exhibited improved fiber, protein, minerals and phenols contents along with desirable sensory properties. Rezapour *et al.* (2016) utilised basil seeds as a source of dietary fiber and other components to improve the nutritional profile and dough properties for preparation of enriched baguette bread.

Total Flavonoids Content of Basil Seeds : Flavonoids are the most substantial group of phenolic compounds which played vital role in preventing or curing human diseases due to their significant antioxidant, antidiabetic, anticancer, anti-inflammatory, cardioprotective and antiobesity potential (Ballard and Junior, 2019). The total flavonoids content of ethanol and aqueous extracts of clove basil and sweet basil seeds was determined as quercetin equivalent and depicted in Table 4.

The ethanol extracts of both clove basil seeds and sweet basil seeds exhibited significantly ($p \leq 0.01$) high flavonoids content (10.63 and 12.15 mg QE/g) than the aqueous extracts (3.40 and 4.51 mg QE/g). Statistically significant difference was observed between the total flavonoids content of clove basil seeds and sweet basil seeds at 1.0 per cent level. Basil seeds exhibited better flavonoids content than the chia seeds (0.12 mg QE/g ethanol extract) (Scapin *et al.,* 2016). The interaction between basil seeds variety and solvent used for extraction of bioactive constituents had non-significantly influenced the extract yield, total phenols content while significantly influenced the total flavonoids content of basil seeds extracts at 1.0 per cent level.

Total Antioxidant Capacity of Basil Seeds : Antioxidants were known to reduce the risk of / diseases associated with oxidative stress (cancers, cardiovascular diseases, neurodegenerative diseases etc.) by virtue of their radical scavenging ability, metal ion chelating capacity and reduction potential. Several techniques have been developed to determine the antioxidant potential of dietary components (Kumar *et al.,* 2018). Due to the complexity of oxidation-antioxidation processes, no single method was capable of providing a comprehensive picture of antioxidant capacity of foods and hence multimethod approach was recommended (Pal *et al.,* 2018).

The total antioxidant capacity of ethanol and aqueous extracts of clove basil and sweet basil seeds was determined in terms of reducing ferric ions, scavenging free radicals (DPPH, $ABTS^{\bullet+}$, O^{2-}) and presented in Table 5. The ethanol extracts of both clove basil and sweet basil seeds exhibited significantly ($p \leq 0.01$) high ferric reducing antioxidant power than the aqueous extracts. The ferric reducing antioxidant power of clove basil and sweet basil seeds was 127.46, 235.73 mg TE/g, respectively for ethanol extracts and 31.00, 53.64 mg TE/g respectively for aqueous extracts. Significant difference was noticed between the clove basil and sweet basil seeds for ferric reducing antioxidant power at 1.0 per cent level. The interaction between basil seeds variety and solvent used for extraction of bioactive constituents had significantly influenced the ferric reducing antioxidant power of basil seeds extracts at 1.0 per cent level.

Free radicals were produced naturally in body to perform essential physiological functions. However, their excess production was associated with numerous health disorders due to triggered inflam matory cascade. The excess free radicals can be scavenged by consumption of foods rich in antioxidants (Lalhminghlui and Jagetia, 2018). Basil seeds were found to be better source of antioxidants compared to sesame, garden cress and ajwan seeds and consumption of basil seeds was associated with several health benefits. Further, basil seeds extracts can be efficiently utilised as natural antioxidants to

TABLE 5

Total antioxidant capacity of basil seeds extracts

Seeds	Extract	FRAP (mg TE / g)	Free radical scavenging activity (mg TE / g)		
			DPPH	$ABTS^{\bullet +}$	Superoxide anion (O^{2-})
Clove basil	Ethanol	127.46 ± 0.70	232.76 ± 0.23	120.57 ± 0.14	531.98 ± 0.71
	Aqueous	31.00 ± 0.70	131.76 ± 0.23	73.04 ± 0.08	298.43 ± 0.40
Sweet basil	Ethanol	235.73 ± 0.70	301.41 ± 0.24	309.28 ± 0.35	609.83 ± 0.82
	Aqueous	53.64 ± 0.70	167.94 ± 0.24	83.47 ± 0.09	289.78 ± 0.39
Mean		111.96	208.47	146.59	432.50
SE_m		0.25	0.08	0.07	0.22

	F value	CD at 1.0%	F value	CD at 1.0%	F value	CD at 1.0%	F value	CD at 1.0%
Seeds	*	2.88	*	0.01	*	0.51	*	0.90
Extract	*	2.88	*	0.01	*	0.51	*	0.90
Seeds × Extract	*	4.07	*	0.01	*	0.72	*	1.28

Note : Values expressed as mean ± standard deviation of two determinations. FRAP: Ferric reducing antioxidant power, TE: Trolox equivalent, SE_m: Standard error of mean, CD: Critical difference. * Significant difference at $p \leq 0.01$, NS: Non-significant difference

prevent oxidative deterioration of foods (Bravo *et al.,* 2021).

The ethanol extracts of clove basil seeds and sweet basil seeds exhibited significantly ($p \leq 0.01$) high total antioxidant capacity than the aqueous extracts for scavenging free radicals. The total antioxidant capacity of ethanol extracts of clove basil seeds and sweet basil seeds for scavenging DPPH radicals was 232.76, 301.41 mg TE/g respectively, scavenging $ABTS^{\bullet +}$ was 120.57, 309.28 mg TE/g, respectively and scavenging O^{2-} was 531.98, 609.83 mg TE/g, respectively. While the total antioxidant capacity of aqueous extracts of clove basil and sweet basil seeds for scavenging DPPH radicals was 131.76, 167.94 mg TE/g, respectively scavenging $ABTS^{\bullet +}$ was 73.04, 83.47 mg TE/g, respectively and scavenging O^{2-} was 298.43, 289.78 mg TE/g, respectively.

Significant difference ($p \leq 0.01$) was noticed between the total antioxidant capacity of clove basil and sweet basil seeds for scavenging free radicals (DPPH, $ABTS^{\bullet +}$, O^{2-}). The interaction between basil seeds variety and solvent used for extraction of bioactive constituents had significantly influenced the total antioxidant capacity of basil seeds extracts to scavenge free radicals at 1.0 per cent level. Afifah and Gan (2015) identified the peptides with antioxidative property in basil seeds that were able to donate electrons to quench free radicals and terminate the radical chain reactions.

Pearson Correlation Between Phenols, Flavonoids and Antioxidant Potential of Basil Seeds Extracts : The relationship between total phenols content, total flavonoids content and total antioxidant capacity of basil seeds extracts was determined using the Pearson's correlation coefficient (r) (Table 6). Significant correlation ($r = 0.9896$) was noticed between the total phenols and total flavonoids content of basil seeds extracts at $p \leq 0.05$ as flavonoids represented the largest group of naturally occurring phenolic compounds (Tian *et al.,* 2022).

The total phenols content of basil seeds extracts was significantly correlated with the superoxide anion scavenging capacity ($r = 0.9839$) at $p \leq 0.05$. Likewise,

TABLE 6

Pearson correlation between antioxidant compounds and antioxidant capacity of basil seeds extracts

	TPC	TFC	FRAP	DPPH	ABTS	SOSA
TPC	1.0000					
TFC	0.9896 *	1.0000				
FRAP	0.8848	0.9369	1.0000			
DPPH	0.9186	0.9654 *	0.9892 *	1.0000		
ABTS	0.7314	0.8071	0.9619 *	0.9170	1.0000	
SOSA	0.9839 *	0.9907 **	0.9463	0.9569 *	0.8364	1.0000

Note : * Significant at $p \leq 0.05$, ** Significant at $p \leq 0.01$. TPC: Total phenols content, TFC: Total flavonoids content, FRAP: Ferric reducing antioxidant power, DPPH: DPPH radical scavenging activity, ABTS: $ABTS^{\bullet+}$ scavenging activity, SOSA: Superoxide anion scavenging activity.

Dong *et al.* (2013) reported a positive correlation between phenols content and superoxide anion scavenging capacity of unifloral honeys. The total flavonoids content of basil seeds extracts was significantly correlated with the DPPH radical scavenging capacity (r = 0.9896) at $p \leq 0.05$ and superoxide anion scavenging capacity (r = 0.9907) at $p \leq 0.01$. Likewise, Kavitha *et al.* (2015) reported that the flavonoids content of irradiated ber fruits was significantly correlated with the DPPH radical and superoxide anion scavenging activities at $p \leq 0.05$.

Significant correlation was also observed between the different assays employed to determine the total antioxidant capacity of basil seeds extracts. The ferric reducing power of basil seeds extracts was significantly correlated with their DPPH radical (r = 0.9892) and $ABTS^{\bullet+}$ (r = 0.9619) scavenging capacities at $p \leq 0.05$. Further, the DPPH radical scavenging activity of basil seeds extracts was significantly correlated with their superoxide anion scavenging activity (r = 0.9569) at $p \leq 0.05$. Likewise, Rumpf *et al.* (2023) reported that the ferric reducing antioxidant power of lignin was positively correlated with its DPPH and ABTS radical scavenging activities. Kavitha *et al.* (2015) reported significant correlation between DPPH radical scavenging activity and superoxide anion scavenging activity of irradiated ber fruits at $p \leq 0.01$.

Now-a-days an immense interest has shifted towards consumption of medicinal seeds due to their nutraceutical properties associated with the presence of health-promoting bioactive constituents. Basil seeds were found to be potential source of protein, dietary fibre, minerals (calcium, magnesium, potassium, zinc), phenols and flavonoids. Further, they exhibited significant antioxidant potential to reduce ferric ions and scavenge free radicals (DPPH, $ABTS^{+}$, O^{2-}). Thus, they can be efficiently utilised as functional ingredients for enrichment of regularly consumed foods with additional nutrients and bioactive constituents for potential health benefits.

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