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Chemical Composition of Garden Cress (*Lepidium sativum*) Seeds and Its Fractions and use of Bran as a Functional Ingredient

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Abstract. Garden cress (*Lepidium sativum*) belonging to the family Cruciferae grown in India, Europe and US is an underutilized crop. The edible whole seed is known to have health promoting properties. Hence, it was assumed that these seeds can be a functional food. A preliminary work on chemical composition of seeds was carried out and the possibility of using it as nutraceutical food ingredient in dietary fiber formulation was explored. Three fractions namely whole meal (WM), endosperm and bran were analyzed for chemical composition. The yield of the endosperm and the bran fraction were 72 and 28%, respectively. The WM, endosperm and bran had 22.5, 27.7 and 12.6% protein, 27.5, 33.1 and 6% fat, 30, 13.6 and 75% dietary fibre (DF), and 1193.00, 945.15 and 1934.57 mg% potassium respectively. The major protein on SDS-PAGE was of 29.5 kDa. The most abundant amino acid was glutamic acid (19.3%) and the essential amino acid, leucine was the highest (8.21 ± 0.01%) and methionine the lowest (0.97 ± 0.02%). The major fatty acid was linolenic acid (30.2%) and low amount of erucic acid (3.9%) was also present. Bran having high water holding capacity and high DF, its use as source of DF was explored. The product contained 12% protein, 4% fat and 74.3% DF and exhibited desirable functional properties such as dispersibility, gelling ability, stability, formed homogenous mild alkaline suspension and was comparable to proprietary DF.

Key words: Chemical composition, Dietary fibre, Electrophoresis, Fatty acid profile, Garden cress seeds, Milling fractions

Introduction

Lepidium sativum L commonly called garden cress belongs to the family Brassicaceae (Cruciferae) is cultivated in India [1], North America and parts of Europe [2]. While it is used in the form of vegetable in Europe and America, the seeds are harvested for food purpose in several parts of India. It is also known as common cress, land cress and Haliv in India. It figures prominently in Indian Materia Medica with Sanskrit name Chandrasura [1]. The seeds of *L. sativum* are claimed to possess varied medicinal properties like galactogogue, aperient, diuretic, alterative, tonic, demulcent, aphrodisiac, carminative and emmenagogue. Mucilage of the seeds allays the irritation of the mucous coat of intestines. Seeds are also useful in hiccup, dysentery, diarrhea and skin diseases caused by impurities and toxins in blood and chronic enlargements of spleen [1]. The seeds resemble some of the oil seeds morphologically with the dicotyledonous endosperm accounting to 80–85% of the seed matter, whereas the seed coat and the embryo account for 12–17% and 2–3% of the seeds, respectively. While the seed coat is of brick red to cream colored, the endosperm has yellow color. Despite its great medicinal value, *L. sativum* has not received the attention it deserves. So far there are very few reports about its chemical composition [3–5].

L. sativum seeds possessing number of pharmacological properties [6], can be a functional food ingredient about which there are no studies even though there are few studies on its phytochemistry [7, 8]. Also there are no studies on the composition of its different fractions—bran and endosperm, the study on which may help to identify the fraction for a particular use depending on its composition even though there are few studies on composition of the seed as a whole [3] and on *Lepidium campestre*, a member of the same family of *Lepidium sativum* [9]. So the present study was conducted to analyse the bran and endosperm fractions of garden cress seeds for their chemical composition, mineral contents, protein, amino acid and fatty acid profiles as a preliminary work to explore the possibility of using this as a functional ingredient in product formulations. In that direction, dietary fibre formulation was developed using bran fraction of garden cress seeds and its quality characteristics were studied.

Materials and Methods

Physical Properties of Garden Cress Seeds

Seeds of *L. sativum* were purchased from food market in India. Their colour, length, width and shape were examined. One thousand kernels were counted manually and weighed. The same was used to measure volume using measuring cylinder. Using the data of weight and volume density was calculated.

Preparation of Fractions

Seeds were ground to 60 mesh in a coffee grinder (Cuisinart™ DCG-20, New Jersey, US) as the whole meal fraction. Cleaned seeds were moistened with 10% water, tempered for 15 min, ground in coffee grinder and sieved in a 40 mesh sieve to separate bran and endosperm

including embryo. Grinding and sieving was repeated to get the maximum yield of bran and the endosperm. They were equilibrated and weighed.

Three fractions namely the whole meal, bran and endosperm were analysed for chemical composition using standard AOAC procedures [9]. Minerals were determined using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICPAES, Leeman Labs Plasma Spec Z.5, Lowel, MA) [10] in ash solution of the samples prepared as per AOAC procedure [9].

Electrophoresis

A known amount of the defatted sample was mixed with known amount of protein extraction reagent (4% sodium dodecyl sulphate {SDS}/2 M Urea/5% 2-Mercaptoethanol), vortexed and centrifuged for 10 min at 11,000 × *g*. The protein concentration of the extracts was measured using Sigma Diagnostics Protein Assay kit (Sigma Diagnostics, INC., St. Louis, USA). The extracts with known protein concentration were mixed with an equal volume of SDS-sample buffer and heated at 96 °C for 3 min in a water bath. The protein extract was subjected to fractionation by sodium dodecyl sulphate polyacryamide gel electrophoresis (SDS-PAGE) on a 15% SDS-PAGE gel [11] at a constant voltage of 200 V on a vertical electrophoresis system (Bio Rad Laboratories, Hercules, CA). The gel was then stained for protein assay with Coomassie brilliant blue R-250 (0.1%) in methanol–acetic acid–water (25:10:65) solvent system and destained in the above solution without the dye. The BenchMark™ Prestained Protein Ladder was used as standard to determine the molecular weight of the proteins of the sample using a software Kodak Digital Science 1D™ Image analysis (Eastman Kodak Co. New Haven, CT, USA) which determines molecular weight based on relative mobility of the sample protein with reference to the mobility of the standard protein. Percentage of each protein was calculated using software Image Quant® (Molecular Dynamics, Inc.).

Amino Acid Profile

Amino acid analysis was performed using a Hewlett Packard AminoQuant II system. The system consists of an HP 1090 Series II liquid chromatograph with a DR5 binary solvent delivering system, a variable volume injector, an autosampler and a temperature controlled compartment. The automatic operation of the system is under the control of an HP Chemstation that is equipped with software that controls the LC and collects, analyzes and reports the data.

The AminoQuant analyzes peptides and proteins by pre-column derivatization of hydrolyzed samples with *o*-phthalaldehyde (OPA) and 9-fluoromethyl-chloroformate (FMOC). The derivatized amino acids are separated by reverse phase HPLC and detected by UV absorbance with a diode array detector or by fluorescence using an in-line fluorescence detector [12].

A known amount of defatted sample of whole meal was mixed with internal standards (norvaline and sarcosine) dried in glass tubes in a vacuum concentrator and subjected to vapor phase hydrolysis by 6 *N* hydrochloric acid at 110 °C for 24 hours under argon atmosphere in the presence of phenol. The samples were subsequently reconstituted in borate buffer and transferred to the AminoQuant autosampler for automated derivatization and loading. Sixteen naturally occurring amino acids were analysed by this method. The derivatised amino acids were eluted from a narrow-bore (20 cm × 2.1 mm) reversed-phase column (Hewlett-Packard Amino Acid Analysis column, Catalogue No. 799-16AA-572) using a simple linear gradient. The analytical column is protected with a 2 cm × 2.1 mm guard column (Hewlett-Packard, Catalogue No. 79916KT-110). The mobile-phase compositions were as follows. For channel A, a 20 mM sodium acetate buffer was used containing 0.018% (v/v) triethylamine, adjusted to pH 7.2 with dilute acetic acid, and with 0.3% tetrahydrofuran added. For channel B, a 20% 100 mM sodium acetate buffer, adjusted to pH 7.2 with dilute acetic acid, 40% acetonitrile, and 40% methanol was used. A mobile phase gradient was used, starting with 100% A at 0 min increasing B from 0 to 60% over 17 min and to 100% by the 18th min, and then returning to 100% A by the 25th min. A UV-vis diode-array detector was used to detect the primary amino acids at a wavelength of 338 nm (reference at 390 nm) and the secondary amino acids at a wavelength of 262 nm (reference at 324 nm) [12].

Fatty Acid Profile

Fat from whole meal was extracted by acid hydrolysis followed by portioning into petroleum ether and ethyl ether. The extract is saponified with ethanolic potassium hydroxide and fatty acid methyl esters (FAMEs) were formed by reaction with boron trifluoride/methanol [9]. The FAMEs were quantitatively measured using the gas chromatograph (Hewlett Packard 6890 GC with FID detector) fitted with Supelco 2560 column (100 *M* × 0.25 mm id, 0.2 μm film thickness) operated in constant pressure mode at 75 PSI helium. Guard column was Supelco Non-polar fused silica (3 *M* × 0.53 mm id). Oven temperature was 140 °C initially for 5 min and then raised to 240 °C at 5 °C/min which was maintained for 15 min. The detector temperature was 260 °C. Helium gas was used as carrier. The percent of individual fatty acid methyl esters were calculated from a set of standards containing known concentrations of prepared methyl esters of selected fatty acids (Nu-Chek Prep, Elysian, MN, USA).

Preparation of Dietary Fibre Formulation

Cleaned garden cress seeds were moistened with 7% water, mixed well, tempered for 15 min for equilibration and milled in a horizontal plate mill (Milone, S.No. 95745, M/s Radhika Industries, Rajkot, India) set at 0.35 mm clearance between the plates. The meal was sieved through 500 micron openings sieve to separate the seed coat rich fraction from the endosperm admixed with embryo. The seed coat fraction was pulverized in a comminuting mill fitted with 0.5 mm opening screen and the particle size was −150 microns. The pulverized seed coat (5 kg) was blended with fresh carrot pulp (500 g), lime extract (100 g) and lecithin (Liquid, Lucas mayor gmbh, Germany) (100 g) and the blend was dispersed in potable water (100 l), heated to boiling, boiled for 5 min and homogenized in a colloidal mill. The slurry was spray dried in a pilot scale spray drier (Atomizer type, Bowen Engineering, INC, Somerville, New Jersey, USA, BE 1216) maintained at 150 °C inlet and 90 °C chamber temperature. The product was collected and stored in airtight containers for further analysis [14]. The Physical features such as hand feel, flow properties, colour, water holding capacity, gel stability, and the chemical composition were recorded.

Hand feel and the flow property were recorded by visual observation whereas the color was measured in a double beam UV visible spectrophotometer with integrating sphere model (UV 2100, 3100, Shimadzu, Japan). Water holding capacity was measured by modified method of McConnel et al. (1974) [15]. One gram of sample was mixed with 100 ml distilled water, stirred well and allowed to stand for 24 hours at room temperature and centrifuged at 12,000 rpm (Du Pont Sorvall RC-5B Refrigerated Superspeed Centrifuge with GSA rotor). The volume of supernatant was measured and subtracted from 100 ml. The difference was water holding capacity of the sample. Viscosity at 1, 2, 3, 4 and 5% slurry concentration was measured at ambient conditions in Brookefield Viscometer using appropriate spindles [16]. The pH of 5% (w/v) aqueous slurry was adjusted to 4–9 with 1 unit interval by addition of hydrochloric acid and sodium hydroxide solutions and the viscosity at different pH conditions was measured. A 5% (w/v) aqueous dispersion of the sample was allowed to stand for 96 hours at ambient conditions and observed for sedimentation. Chemical composition was analyzed using standard procedures [10]. The physicochemical characteristics of the formulation were compared with those of a popular proprietary dietary fiber formulation marketed.

Results and Discussion

The seeds were brownish red in colour and oval in shape. The seed length and width were 298 ± 3.2μm and 100 ± 1.9 μm respectively. One thousand kernel weight was 2.5 ± 0.13 g, volume 3.3 ± 0.15 ml and density 0.75 ± 0.016.

Table 1. Chemical composition (% dwb) of endosperm and bran fractions of garden cress seeds

Nutrients	Whole meal (Mean ± SD)	Endosperm (Mean ± SD)	Bran (Mean ± SD)
Moisture	4.14 ± 0.05	2.58 ± 0.01	4.27 ± 0.01
Protein	22.47 ± 0.78	27.74 ± 0.02	12.58 ± 0.21
Fat	27.48 ± 0.14	33.06 ± 0.16	6.34 ± 0.19
Carbohydrate*	34.24 ± 0.92	28.45 ± 0.21	50.31 ± 0.08
Crude fibre	7.01 ± 0.08	4.00 ± 0.13	14.29 ± 0.06
Ash	4.65 ± 0.09	4.06 ± 0.08	6.19 ± 0.01
Energy (Kcal)**	474 ± 1.06	523 ± 0.82	363 ± 0.87
Dietary fibre			
Insoluble	28.49 ± 0.38	13.10 ± 0.62	74.07 ± 1.48
Soluble	1.51 ± 0.09	0.50 ± 0.01	0.93 ± 0.01
Total	30.00 ± 0.47	13.6 ± 0.62	75.00 ± 1.49

*By difference.
**Calculated.

The yield of endosperm rich fraction was 72% and that of bran rich fraction was 28%. Incipient moist conditioning reduced the pulverisability of the seed coat followed by milling and sieving which enabled to separate largely the endosperm and the bran portions. Vose and Young [17] prepared low fibre malt flour from barley by incipient moist conditioning (5%) the malt followed by pulverizing and sieving. Further, Malleshi et al. [18] adapted the same principle to other malted cereals to prepare low fiber flours. However, there are no such studies on garden cress seeds. The same principle was used in the present study also to obtain relatively high yield of endosperm and bran fractions however, the purity was not hundred percent.

The chemical composition of the whole meal and the fractions is presented in Table 1. Protein and fat were concentrated in endosperm whereas dietary fibre, minerals and carbohydrate in the bran fraction. The high protein, fat, dietary fibre, calcium, phosphorous and iron contents in this seed bring out its high nutritive value which may be making it useful in post pregnancy diets in India [3]. In all the three fractions insoluble fibre was more than the soluble fibre. Particularly, in bran the insoluble fraction is 74.07 ± 1.48% and the soluble fibre is highly negligible compared to that. Mathews et al. [4] reported 24.3 ± 0.67% protein, 14.9 ± 0.79% fat, 55.4 ± 1.8% carbohydrate, 27.3 ± 0.43% acid detergent fibre and 35.7 ± 0.82% neutral detergent fibre in *L. sativum* seeds. Andersson et al. [18] reported 19% protein, 20% crude fat and 40% dietary fibre in *L. campestre*. Like in *L. sativum* in the present study, insoluble dietary fibre dominated in *L. campestre* and rapeseed and consisted mainly of Klason lignin, a phenolic constitutent mostly found in the husk of seeds [9, 19]. When seeds of *L. sativum* were soaked in water a large transparent gel was formed surrounding the whole seed. The gel could be a

polysaccharide gel containing soluble dietary fibres. Similar observation was made in *L. campestrae* [9] and linseed [20] also, which consists of uronic acids and arabinoxylan. The health benefits of dietary fibre are very well documented [21–24] and in that context *L. sativum*, particularly its bran can be used as source of dietary fibre like flax seed which is already made available over the counters in developed countries. The high fibre value of this seed can contribute to their use in treatment of constipation and diabetes. Patole et al. [25] reported that *L. sativum* seeds reduced the rate of starch hydrolysis in vitro and blood glucose in diabetic subjects. Insoluble fibre helps move food and digestive by-products through the large intestine (colon) and out of the body. The faster that food and by-products travel through the digestive tract, the less time there is for potential cancer-causing substances to work. Insoluble fibre acts as a laxative. Soluble fibre helps to reduce cholesterol thus reducing the incidence of cardiovascular diseases. Patel et al. [26] studied mucilage of *L. sativum* as emulgent and reported that it exhibited better emulsifying property than gum acacia.

Mineral compositions of the fractions of *L. sativum* are shown in Table 2. Potassium is highest in all the fractions followed by phosphorous, magnesium and calcium. Iron content is considerably high which in whole meal is 7.62 ± 0.04 mg/100 g, 8.31 ± 0.06 mg/100 g in endosperm and 6.61 ± 0.12 mg/100 g in husk fraction. Calcium, potassium and sodium are concentrated in bran whereas phosphorous, iron, zinc and magnesium are in endosperm. Gopalan et al. [5] reported 377 mg calcium, 723 mg phosphorous and 100 mg of iron in *L. sativum*. The difference between the reported values and the values obtained in the present study may be attributed to the varietal variations and also to the agronomical conditions. All the fractions have low sodium and high potassium content which makes it beneficial as an ingredient in health foods. High potassium diet is recommended for athletes who are involved in hard exercise and also for disorders related to high blood pressure [27].

Table 2. Mineral content (mg/100 g) of whole meal, endosperm and bran fractions of garden cress seeds

Minerals	Whole meal (Mean ± SD)	Endosperm (Mean ± SD)	Bran (Mean ± SD)
Potassium	1193.95 ± 10.51	945.15 ± 5.81	1934.57 ± 18.82
Phosphorous	514.59 ± 10.67	652.81 ± 14.59	209.92 ± 0.70
Magnessium	315.25 ± 3.63	334.95 ± 3.16	303.63 ± 1.37
Calcium	296.60 ± 1.04	210.51 ± 1.08	556.32 ± 3.03
Sulphur	293.02 ± 14.27	149.31 ± 3.48	239.48 ± 10.47
Sodium	24.64 ± 0.02	15.34 ± 1.04	57.06 ± 2.69
Iron	7.62 ± 0.04	8.31 ± 0.06	6.61 ± 0.12
Copper	5.53 ± 0.09	2.21 ± 0.03	1.63 ± 0.04
Zinc	5.05 ± 0.07	5.31 ± 0.02	2.98 ± 0.41
Aluminium	2.82 ± 0.13	2.55 ± 0.05	4.82 ± 0.05
Manganese	2.57 ± 0.04	3.03 ± 0.05	1.87 ± 0.03
Boron	1.41 ± 0.03	1.17 ± 0.03	1.98 ± 0.06
Molybdenum	0.43 ± 0.08	0.33 ± 0.16	0.58 ± 0.10

Table 3. SDS-PAGE of garden cress proteins

Whole meal		Endosperm		Bran	
Protein (kDa)	%	Protein (kDa)	%	Protein (kDa)	%
96.2	*	80.4	6.0	99.5	*
80.9	6.5	74.5	*	84.2	*
75.0	*	67.5	5.0	78.2	5.3
67.0	4.9	61.1	5.5	68.6	5.8
61.1	5.0	55.7	6.9	57.2	5.3
55.7	6.9	43.5	6.3	47.2	9.1
48.2	*	40.4	5.7	44.2	6.8
43.9	6.5	35.5	5.3	41.7	8.8
39.9	5.0	34.1	5.0	35.8	7.3
35.5	5.2	29.5	20.9	34.1	*
33.5	5.8	25.0	4.1	30.5	9.0
29.5	19.6	23.6	8.2	25.6	13.8
25.0	4.7	21.4	11.5	23.9	3.8
23.4	7.2	14.9	13.5	22.2	6.5
21.3	10.0	8.4	3.9	16.3	9.0
14.9	12.7	—	—	12.7	9.5

*Negligible

The electrophoretic patterns of the whole meal and the fractions are presented in Table 3. The samples had 16 different protein bands with molecular weights ranging from 14.9 to 96.2 kDa in whole meal, 8.4 to 80.4 kDa in endosperm and 12.7 to 99.5 kDa in bran. Among them, five were major bands with molecular weight 55.7 kDa (6.9%), 29.5 kDa (19.6%), 23.4 kDa (7.2%), 21.3 kDa (10%) and 14.9 kDa (12.7%) were in whole meal. The same proteins were 6.9%, 20.9%, 8.2%, 11.5% and 13.5% in endosperm, respectively. Bran fraction also had 5 major bands with molecular weight 57.2 kDa (5.8%), 47.2 kDa (9.1%), 30.5 kDa (9.0%), 25.6 kDa (13.8%) and 16.3 kDa (9.0%). The proportion of proteins of different molecular weights is less in bran as it contains less protein compared to endosperm and whole meal.

Table 4 shows the amino acid composition of garden cress seeds. The results indicated that aspartic (9.76 ± 0.03%) and glutamic acids (19.33 ± 0.19%) were the major abundant amino acids in this oilseed. This observation is in close agreement with Olaofe [28] for melon seed, pumpkin seed and gourd seed. Glutamic acid is an important excitatory neurotransmitter and also plays a vital role in metabolism of sugars and fats [29]. The total essential amino acid percentage is 47.08% which suggests that this seed will contribute significantly to the supply of essential amino acids in the diet. Garden cress seeds had 6.26 ± 0.39% lysine and 0.97 ± 0.02% methionine. Tryptophan and cysteine were not determined. Essential amino acid score was 28.53% with methionine as the most limiting amino acid. These play a very important role in human nutrition. Lysine helps to

Table 4. Amino acid profile of garden cress seeds

Non-essential amino acids	g/100g protein	Essential amino acids	g/100g protein
Aspartic acid	9.76 ± 0.03	Histidine	2.66 ± 0.09
Glutamic acid	19.33 ± 0.19	Threonine	4.51 ± 0.03
Serine	4.96 ± 0.09	Arginine	8.04 ± 0.03
Glycine	5.51 ± 0.07	Valine	5.67 ± 0.02
Alanine	4.83 ± 0.02	Methionine[a]	0.97 ± 0.02
Tyrosine	2.69 ± 0.09	Phenyl alanine	5.65 ± 0.03
Proline	5.84 ± 0.38	Isoleucine	5.11 ± 0.03
		Leucine	8.21 ± 0.01
		Lysine	6.26 ± 0.39
		Total (%)	47.08
		Essential amino acid score (%)[b]	28.53

Note. Tryptophan and cysteine not determined.
[a]limiting amino acid.
[b]Essential amino acid (EAA) content of egg protein was taken as reference to calculate EAA score [34].

maintain proper nitrogen balance. The body uses methionine to derive the brain food, choline. It also aids in digestion, as well as serving as a fat burner. It can interact with other substances to detoxify harmful agents, and is essential for the production of cysteine and taurine. L-Tryptophan acts as a sleep aid. It is also necessary for the production of niacin and is used by the body to make the neurotransmitter, serotonin [30].

Fatty acid profile showed that most of the saturated fatty acids were less than 0.1% except for myristic (1.9%), palmitic (8.7%), stearic acid (3.2%) and arachidic acid (3.2%). Among monounsaturated fatty acids, oleic acid was 19.9% followed by eicosenoic acid (10.3%). The essential fatty acids linoleic and linolenic acid comprised 12.1 and 30.2% of the total fat respectively. Bhakare et al. [4] reported 13.8, 86.7, 7.7 and 5.8 g total lipids, neutral lipids, glycolipids and phospholipids per 100 g seeds respectively and in total lipids (34.5%) and neutral lipids (33.8%) linolenic acid constituted major fatty acid. The presence of erucic acid was also noted which is 3.9%. Although there are no indications of erucic acid toxicity in man, it is known to cause cardiac liposis and necrosis in rats [31]. This may be the reason why *L. sativum* is given less importance. But if properly processed like how it is done in case of rapeseed (Canola oil) to reduce erucic acid content, *L. sativum* seeds can also be used as source of essential fatty acids which again proves that it can be used as functional ingredient in health food formulations.

Physical features and nutrient composition of the dietary fibre formulation are presented in Table 5. The formulation is a free flowing smooth powder with yellowness index of 37.2. Its water holding capacity and viscosity (5% slurry) were 23.6 ml/g and 5100 mPas whereas those of proprietary product were 17.1 ml/g and 4500 mPas respectively. The dietary fiber content of the formulation in the present study was 74.3% whereas that of proprietary product was 57.6%. A 5% (w/v) aqueous dispersion of the product retained its gel structure for at least 96 hours at ambient conditions without any sedimentation. One teaspoon (5 g) of the product provides about 3.7 g of dietary fiber and as it has high water holding capacity it increases the bulk in the stomach which increases post meal satiety and decreases subsequent hunger which in turn helps in weight regulation [32]. The product is of bland taste, easily dispersible in cold or warm water and forms homogeneous suspension that retains its consistency and texture for several hours at ambient conditions. It is not only rich source of dietary fiber but also a good source of calcium, protein, potassium and phytochemicals which are known to provide health benefits. The viscosity of the formulation in the present study is higher than that of the proprietary formulation at slurry concentration ranging from 1–5%. Its consistency is not affected by variations in acidity or alkalinity of the aqueous suspension exhibiting buffering action (Table 6), which indicated its beneficial effect in controlling acidity and similar complications of

Table 5. Physical features and nutrient composition of the spray dried fibre formulation

Physical features	Spray dried product	Proprietary product
Hand feel	Smooth powder	Crystalline powder
Flow property	Free flowing	Free flowing
Colour (Yellowness index)	37.2	47.0
Hydration power (ml/g)	23.6	17.1
Viscosity (5% slurry) (mPas)	5100	4500
Dispersibility	95	98
Protein (%)	10.5	8.6
Fat (%)	5.8	4.0
Dietary fibre (%)	74.3	57.6
Ash (%)	6.2	4.6

Table 6. Viscosity of dietary fiber formulation based on garden cress seeds (GCS) at different slurry concentrations and at pH conditions (5% slurry)

	Viscosity (mPas)			Viscosity (mPas)	
Slurry concentration (%)	GCS dietary fiber formulation	Proprietary dietary fiber formulation	pH	GCS dietary fiber formulation	Proprietary dietary fiber formulation
1	98	36	4.0	4900	4400
2	289	192	5.0	5050	5000
3	1238	960	6.0	5550	5700
4	4375	2200	7.0	5200	7300
5	6400	4500	8.0	4900	8300
			9.0	4850	8500

the digestive tract [33]. The formulation or the bran can be mixed with other traditional foods such as c*hapathi* or bread to enhance the dietary fibre content.

Traditionally, in India and many other countries, garden cress seeds are used for food and allied purposes and nothing about its adversities such as toxicity or other health hazardous or antinutritional aspects have been reported. The dietary fiber prepared with the seed coat fraction may provide health benefits acting as diuretic, hypoglycemic, anticarcinogenic and galactogogue. These need further studies.

Conclusions

The present study reveals that *L. sativum* seeds with high nutritional value can be exploited as a functional food ingredient. Among the fractions, bran isolated and processed could be used in developing a promising dietary fiber supplement. Endosperm can be used as source of protein rich in essential amino acids after extracting the fat. Oil extracted from the seeds can be a source of essential fatty acid linolenic acid even though it contains a small amount of erucic acid which can be removed using suitable processing methods. Future studies are required to study the bioavailability of minerals, protein quality and the possibility of using this non conventional under utilized grain as a functional food ingredient apart from using it as a source of dietary fiber.

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