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RESEARCH ARTICLE

Fatty Acid Composition and Seed Meal Characteristics of *Brassica* and Allied Genera

Binay Kumar Singh · Manju Bala · Pramod Kumar Rai

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Abstract Nineteen different species of *Brassica* and allied genera were evaluated for their seed oil and meal properties. Besides, iodine value (IV) and cetane number (CN) of fatty acid methyl esters of oils were empirically determined. The content of saturated fatty acids in oils of majority of the species was recorded less than 7.0 %, the maximum threshold recommended for edible oils. The content of total monounsaturated fatty acids ranged from 38.41 % in *Capsella bursa-pastoris* to 79.89 % in *Crambe abyssinica*. The highest content of oleic acid (C18:1) was obtained in *Lepidium sativum* (27.57 %). Erucic acid (C22:1) content ranged between 4.65 and 57.51 % with the maximum in *C. abyssinica*. Amongst the polyunsaturated fatty acids, linoleic acid (C18:2) was found to be maximum in *Arabidopsis thaliana* (25.44 %) while linolenic acid (C18:3) was highest in *Camelina sativa* (32.57 %). Based on IV and CN, fatty acid methyl esters of the oils of *Brassica juncea*, *B. carinata*, *B. fruticulosa*, *B. spinescens*, *B. tournefortii*, *C. abyssinica*, *Eruca sativa*, *Erucastrum canarience* and *Sinapis alba* showed good prospects for use as feedstock for biodiesel production. Glucosinolates content in the seed meal were found to be higher than the desired level of <30 μ moles/g defatted seed meal in all the species. Crude fibre content ranged from 4.54 % in *Diplotaxis siettiana* to 14.62 % in *Brassica tournefortii.* Maximum phenol content was observed in *S. alba* (72.56 mg/g GAE) while the minimum (16.14 mg/g GAE) was detected in *B. tournefortii.* Lectin activity from 4 to 8 HU/ml was detected in saline extracts of *B. fruticulosa*, all the species of *Diplotaxis* except *D. tenuisiliqua*, and *L. sativum.* Briefly, present study reports significant diversity in the seed oil and meal properties in different species of *Brassica* and allied genera which could find utility for specific applications as edible as well as renewable industrial or fuel oils.

Keywords Biodiesel · *Brassica* · Cetane number · Fatty acid methyl ester · Iodine value · Oil content · Seed meal composition

B. K. Singh (✉) · M. Bala · P. K. Rai
Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur 321303, Rajasthan, India
e-mail: binaybio@gmail.com

Introduction

Mustard family (*Brassicaceae*) includes 338 genera and 3,709 species comprising of several species of crops, weeds and ornamental plants [1]. Amongst crops, *Brassica* is the most important genus which includes a total of 41 species. *Brassica napus*, *B. rapa* and *B. juncea*, with average seed oil content between 40 and 45 %, are economically very important species and constitutes the world's third important source of edible oils [2]. Some of the other economically important genera of the family *Brassicaceae* are *Eruca*, *Sinapis*, *Lepidium*, *Crambe* and *Camelina.* These are cultivated as minor oilseed and fodder crops, particularly on marginal agricultural locations with poor soils or suboptimal climatic conditions [3]. Moreover, the family *Brassicaceae* also comprises above 100 wild and weedy species and genera which are gaining renewed attention nowadays as alternative oilseed crops and potential sources of genes of economic importance [4].

Seed oils are a high-value agricultural commodity for use in refined edible oil products and as renewable industrial or fuel oils [5]. The suitability of seed oils for human consumption as well as for fuel purposes is determined largely by its fatty acid composition. Seed oils having

higher proportion of 16 and 18 carbons unsaturated fatty acids, particularly monounsaturated fatty acids (MUFAs) are considered suitable for use both as edible oil and feedstock for biodiesel production [6, 7]. Therefore, one of the important objectives in *Brassica* improvement programmes involve reduction in erucic (C22:1) and linolenic (C18:3) acids and increase in oleic (C18:1) and linoleic (C18:2) acids. Simultaneously, it is also imperative to identify alternative production sources of seed oils to overcome the prevailing competing situation between their use for energy and industrial application. In this sense, sources that produce non-edible oils and therefore don't compete with edible oil supply or that can be cultivated on marginal lands are highly valuable.

The meal remaining as a by-product after extraction of oil is another valuable commodity obtained from the oilseeds. The *Brassica* seed meal posses about 40.0 % protein (dry weight after oil extraction) with a favourable composition of amino acids, including comparatively high contents of the essential amino acids, methionine and cysteine [8]. In addition, it is also rich in minerals (particularly Ca, Mg and P) and contains vitamin B_4 and E. Presently, *Brassica* seed meal is largely used as animal feed but can also be utilized for production of value-added products [9]. However, in comparison to other popular sources such as soybean, *Brassica* seed meal contains high amounts of antinutritive fibre compounds, sinapine and related phenolic acids, phytate and glucosinolates, which lessen its feed value [10, 11]. The amelioration of nutritional qualities of seed meal of oil seed Brassicas, therefore, can be of high economic value. Keeping these in mind, the present investigation was designed to characterize some of the cultivated and wild species of *Brassica* and allied genera for seed oil content and composition, and antinutritional components of the seed meal to review their potential for exploitation directly or in qualitative improvement of other species from nutritional perspective. In addition, seed oils of these species were also evaluated for their potential use as feedstocks in industrial and or biodiesel production.

Materials and Methods

Plant Materials

Nineteen species from eleven different genera of the family *Brassicaceae* were analyzed in this study. The seed samples of these species i.e. *A. thaliana*, *B. juncea*, *B. carinata*, *B. fruticulosa*, *B. spinescens*, *B. tournefortii*, *Crambe abyssinica*, *Capsella bursa-pastoris*, *Camelina sativa*, *Diplotaxis assurgens*, *D. gomez-campoi*, *D. muralis*, *D. siettiana*, *D. tenuisiliqua*, *Eruca sativa*, *Erucastrum canariense*, *Enarthrocarpus lyratus*, *Lepidium sativum* and *Sinapis alba* were obtained from National Research Centre on Plant Biotechnology (NRCPB), New Delhi, India.

Determination of Oil Content and Seed Meal Preparation

The seeds were thoroughly ground in a pestle and mortar and 10.0 g triplicates of ground seeds were extracted with hexane for 24 h in a Soxhlet apparatus [12]. Subsequently, hexane was removed from the oil by rotary evaporator under reduced pressure and the weights of the residual oils were calculated. The seed meal remaining after the extraction of total oil was preserved for estimation of various antinutritional components.

Fatty Acid Analysis by Gas Liquid Chromatograph (GLC)

Methyl esters of oil samples were prepared by transesterification according to the method described by [13] with slight modifications. 1.0 µl of the methyl ester sample was injected into SP 2300 + 2310 SS column. A Nucon model 5765 gas chromatograph equipped with flame ionization detector (FID) was used. The oven, injector and detector temperature were 240, 230 and 250 °C, respectively. The carrier gas was nitrogen, at flow rate of 40-50 ml/min^{-1}. Peaks of fatty acid methyl esters were identified by comparing their retention time with that of the known standards run under similar separation conditions. Individual fatty acids were expressed as % of the total fatty acids.

Saponification Number (SN), Iodine Value (IV) and Cetane Number (CN)

Saponification number (SN) and iodine value (IV) were calculated from fatty acid methyl esters (FAMEs) compositions of oil with the following equations [14]:

$$\mathrm{SN} = \sum [(560 \times \mathrm{Ai})/\ \mathrm{MWi}]$$

$$\mathrm{IV} = \sum [(254 \times \mathrm{D} \times \mathrm{Ai})/\ \mathrm{MWi}]$$

where *Ai* is the percentage, D is the number of double bonds and MWi is the molecular mass of each component.

Cetane number (CN) of FAMEs was calculated from the following equation [15]:

$$\mathrm{CN} = 46.3 + 5458/\mathrm{SN} - 0.225 \times \mathrm{IV}$$

Stability Index

Stability index of oils were calculated empirically by the ratio of oleic to linoleic acid.

Chemical Analysis of Seed Meal

Total glucosinolates content in the seed meal was estimated by complex formation between glucosinolates and sodium tetrachloropalladate solution. The intensity of the colour produced was measured using microplate reader at 405 nm [16]. Crude fibre content in seed meal was estimated using modified AOAC method [17]. Total phenol content in seed meal was measured according to the method described by [18]. Phytic acid content in the seed meal was determined by a spectrophotometric procedure described by [19].

Extraction of Lectins and Determination of Haemagglutination Activity

The lectins were extracted from the seeds using normal saline (0.9 % NaCl solution). The crude extract obtained was used for determination of haemagglutination activity. The haemagglutination activity of lectin extract was assayed using serial dilution technique described by [20].

Results and Discussion

Oil Content

High oil content in the seeds is the most remarkable characteristics of oilseed Brassicas. However, the recent increase in biodiesel production from *Brassica* oils has created a competing situation between its food and non-food uses. Therefore, search for alternative sources with optimum oil content is pertinent to meet the non-food requirements of the oil. In the present study, 19 species of *Brassica* and allied genera, mostly of wild and non-food nature were analyzed. The seed oil content of these species ranged between 25.4 and 51.0 % (Table 1). The maximum oil content (51.0 %) was observed in *C. abyssinica*, while in the wild species it ranged from 25.4 % in *B. tournefortii* to 39.0 % in *C. bursa-pastoris.* In general, amongst the wilds, *Diplotaxis* species showed considerably high oil content, with the maximum of 37.5 % in the seeds of *D. siettiana*. These results are in close agreement to the previous studies [21–23].

Fatty Acid Profile

The fatty acid composition of seed oils is indicated in Table 1. The contents of total saturated fatty acids (SFAs) ranged between 2.88 and 12.34 %. In the present study, total SFA comprised of the sum total of the contents of palmitic (C16:0) and stearic (C18:0) acids, the major SFAs found in *Brassica* oils. In *Brassica* species, *C. abyssinica*, *E. canariense*, *E. lyratus* and *S. alba*, the contents of SFAs was found to be less than 7.0 %, the maximum threshold acceptable for human consumption [24]. It is particularly important from the perspective of human health as higher proportion of SFAs in oil causes hypercholesterolemia. However, species with high SFAs content are also important and they may find utility in soap and oleo-chemical industries.

The total MUFAs, represented by the sum total of the contents of oleic (C18:1), eicosenoic (C20:1) and erucic (C22:1) acids in the seed oils, ranged from 38.41 % in *C. bursa pastoris* to 79.89 % in *C. abyssinica*. The highest content of oleic acid was obtained in *L. sativum* (27.57 %) while that of eicosenoic and erucic acids was observed in *A. thaliana* (21.27 %) and *C. abyssinica* (57.51 %), respectively. The minimum percentage of erucic acid was found in the seed oil of *L. sativum* (4.65 %). Seed oils with a high content of oleic acid are of interest for nutritional and industrial purposes [25]. High oleic acid content in the seed oil increases its thermo stability, making it more suitable as cooking oil [26]. Further, oils with high oleic acid are considered to be good for human consumption owing to the property of oleic acid to increase the level of high-density lipoproteins (HDLs) and reduce the level of low-density lipoproteins (LDLs) in blood [27]. On the other hand, oils containing high erucic acid content are not desired for human consumption and they are reported to impair myocardial conductance and increase blood cholesterol. Nevertheless, erucic acid derivatives can be used as chemical additives in plastic, tannery and cosmetic industries [28].

The contents of linoleic (C18:2) and linolenic (C18:3) acids, the major polyunsaturated fatty acids (PUFAs) found in seed oils, ranged between 9.22 and 25.44 % and 6.93–32.57 %, respectively. The highest content of linoleic acid was found in the seed oil of *A. thaliana* (25.44 %) while minimum was observed in *L. sativum* (9.22 %). The maximum content of linolenic acid was recorded in the seed oil of *C. sativa* (32.57 %) followed by *C. bursa-pastoris* (30.59 %) and minimum in *C. abyssinica* (6.93 %). A rich content of linoleic and linolenic acids in the seed oils of *C. sativa* and its superiority over other vegetable oils in terms of proportions of PUFAs has already been reported [29]. Linoleic and α-linolenic acids are essential fatty acids and are the precursors of bioactive long-chain (>20-carbon) fatty acids which are reported to have health beneficial effects and involved in many important metabolic functions of human body like synthesis of prostaglandins. Moreover, oils containing about 50.0 % PUFA, as recorded in *C. bursa-pastoris* (49.40 %), *C. sativa* (50.69 %) and *D. gomez-campoi* (48.63 %) may find several industrial applications, especially in the manufacture of oil based paints.

The ratio of oleic to linoleic fatty acids (stability index) in the seed oils ranged from 0.45 in *D. gomez-campoi* to

Table 1 Variability for oil content, fatty acid composition and biodiesel traits in 19 different species of *Brassica* and allied genera

Species	Seed oil content (%)	SFA (%)			MUFA (%)				PUFA (%)			Oleic/ linoleic ratio	ω-6/ ω-3 ratio	SN	IV	CN
		C16:0	C18:0	Total	C18:1	C20:1	C22:1	Total	C18:2	C18:3	Total					
Arabidopsis thaliana	34.6	7.98	3.52	11.50	16.29	21.27	6.87	44.43	25.44	18.62	44.06	0.64	1.37	194.62	134.26	44.13
Brassica juncea	40.3	3.16	0.66	3.82	13.80	4.80	47.96	66.56	16.38	13.21	29.59	0.84	1.24	182.81	118.15	49.58
Brassica carinata	40.7	3.79	0.78	4.57	14.83	10.67	36.99	62.49	17.69	14.96	32.65	0.84	1.18	185.05	122.8	48.16
Brassica fruticulosa	27.0	3.98	1.60	5.58	15.18	11.00	37.32	63.50	18.46	12.43	30.89	0.82	1.49	185.34	118.1	49.18
Brassica spinescens	28.0	4.15	0.89	5.04	14.25	9.52	44.0	67.77	15.67	11.47	27.14	0.91	1.37	183.35	113.37	50.56
Brassica tournefortii	25.4	2.63	1.21	3.84	8.35	10.58	47.23	66.16	14.16	15.74	29.90	0.59	0.90	181.79	120.31	49.25
Crambe abyssinica	51.0	1.91	0.97	2.88	16.52	5.86	57.51	79.89	10.12	6.93	17.05	1.63	1.46	178.65	100.08	54.33
Capsella bursa pastoris	39.0	8.16	3.94	12.10	16.08	15.0	7.33	38.41	18.81	30.59	49.40	0.85	0.61	195.71	150.03	40.43
Camelina sativa	31.0	6.43	2.60	9.03	14.81	16.97	8.43	40.21	18.12	32.57	50.69	0.82	0.56	194.76	155.49	39.33
Diplotaxis assurgens	34.0	8.43	2.73	11.16	10.69	7.60	28.57	46.86	17.38	24.57	41.95	0.62	0.71	190.05	135.99	44.42
Diplotaxis gomez-campoi	32.0	7.76	1.23	8.99	11.05	9.00	22.32	42.37	24.35	24.28	48.63	0.45	1.00	191.85	144.6	42.21
Diplotaxis muralis	32.0	6.50	2.50	9.00	14.16	8.23	23.20	45.59	23.21	22.18	45.39	0.61	1.05	191.35	139.6	43.41
Diplotaxis siettiana	37.5	7.96	1.57	9.53	11.14	9.37	25.50	43.01	22.92	21.52	44.44	0.49	1.07	190.68	137.22	44.05
Diplotaxis tenuisiliqua	27.0	6.42	1.20	7.62	10.63	9.60	31.01	51.24	17.61	23.50	41.11	0.60	0.75	188.48	136.88	44.46
Eruca sativa	33.8	4.58	1.47	6.05	24.16	11.74	32.72	68.62	13.75	11.51	25.26	1.76	1.19	186.66	112.26	50.28
Erucastrum canariense	–	3.50	1.10	4.60	11.00	7.93	47.35	66.28	15.86	13.19	29.05	0.69	1.20	182.43	116.72	49.96
Enarthrocarpus lyratus	28.0	5.83	0.97	6.80	16.55	11.68	29.61	57.84	17.28	18.01	35.29	0.96	0.96	188.25	127.22	46.68
Lepidium sativum	24.0	9.71	2.63	12.34	27.57	16.54	4.65	48.73	9.22	29.38	38.60	0.99	0.31	196.07	138.93	42.88
Sinapis alba	31.6	3.36	1.12	4.48	22.12	11.91	38.16	72.19	10.78	12.52	23.30	2.05	0.86	184.68	112.05	50.64

2.05 in *S. alba*, while for the linoleic (ω-6) and linolenic (ω-3) acids it varied from 0.31 in *L. sativum* to 1.49 in *B. fruticulosa* (Table 1). These ratios are critical and important for human diet [30]. In general, it is recommended that, we should strive for a diet in which oleic/linoleic and ω-6/ω-3 approaches 2:1 and 4:1, respectively [31]. In the present study seed oil of *S. alba* was found to meet the recommended specification with regards to oleic/linoleic. The remainder of the species exhibited ω-6/ω-3 and oleic/linoleic ratio less than the recommended value. Since majority of the vegetable seed oils presently in use, fall short of these recommendations, they are marketed in blended forms.

Biodiesel Potential

Biodiesel is a non-petroleum-based fuel consisting of monoalkyl esters of long-chain fatty acids prepared from plant oils, animal fats or other lipids [32]. It can either be used alone, or blended with petroleum diesel in conventional diesel-engine vehicles. In general, any vegetable oil can be utilized as feedstocks for the production of biodiesel. However, the biodiesel prepared from them must be compliant with fuel standards such as ASTM D6751 [33] or the Committee for Standardization (CEN) standard EN 14214 [34]. These institutions consider fuel properties such as cold flow, kinematic viscosity, oxidative stability, and

most importantly, IV and CN as standard parameters for the commercial use of biodiesel as a blend component in petro-diesel. By and large, these fuel properties are determined by the fatty acid composition of biodiesel. Therefore, fatty acid profile has been suggested as a tool for screening feedstocks for biodiesel production [35] and the following selection criteria are recommended: SFAs < 15 %; MUFAs > 62 %; TFAs < 7 % and VLCFAs < 1 % where, TFAs and VLCFAs stand for trienoic fatty acids and very long-chained fatty acids, respectively. In the present investigation, seed oils of 19 species of *Brassica* and allied genera were evaluated for their efficacy as feedstocks for biodiesel production. In this sense, FAMEs of seed oils were prepared and based on them IV and CN were calculated, empirically.

Based on the recommended concentrations of SFAs, MFAs and linolenic acids in the FAMEs, *B. fruticulosa* (5.58, 63.50, 12.43), *B. spinescens* (5.04, 67.77, 11.47), *C. abyssinica* (2.88, 79.89, 6.93), *E. sativa* (6.05, 68.62, 11.51), *E. canariense* (4.60, 66.28, 13.19) and *S. alba* (4.48, 72.19, 12.52) were found to be suitable for use as raw materials for biodiesel production. The remainder of the species had either lower or higher concentration of MFAs and linolenic acids, respectively, than the recommended value.

CN, one of the primary indicators of diesel fuel quality, is a dimensionless measure of the ignition performance. It is obtained by comparison to reference fuels in a standardized engine test. Hexadecane, a high-quality reference standard, has been arbitrarily assigned a CN value of 100. On the other hand, 2,2,4,4,6,8,8-heptamethyl-nonane, a low quality reference standard, has been arbitrarily assigned a CN of 15. The Biodiesel Standards of USA (ASTM D6751) and The Committee for Standardization (CEN) standard EN 14214 have restricted the CN value to a minimum of 47 and 51, respectively [33, 34]. CN values of seed oils of the taxa included in this study ranged from 39.33 to 54.33. *B. juncea* (49.58), *B. carinata* (48.16), *B. fruticulosa* (49.18), *B. spinescens* (50.56), *B. tournefortii* (49.25), *E. sativa* (50.28), *E. canariense* (49.96), *E. lyratus* (46.68) and *S. alba* (50.64) exhibited CN values between 46.68 and 50.64 and thus fulfill the criteria for consideration of a feedstock suitable for biodiesel production.

IV is a structural index and quantifies the total content of double bonds in lipids. It is a measure of the average amount of unsaturation and is expressed as grams of I_2 adsorbed per 100 g of lipid. Consequently, IV increases with increasing unsaturation and it enhances the potential of oil to polymerize. The feedstocks with higher IV exhibit oxidative stability below the minimum specifications contained in ASTM D6751 and or EN 14214 [36, 37] and are not considered suitable for biodiesel production. The European biodiesel standard, EN 14214, has restricted IV to a maximum value of 120 g I_2 100 g^{-1} [35]. In the present study IV ranged from 100.08 to 155.49 (Table 1). *C. abyssinica* showed minimum IV of 100.08. The IV value of FAMEs obtained from the seed oils of *B. juncea* (118.15), *B. fruticulosa* (118.1), *B. spinescens* (113.37), *E. sativa* (112.26), *E. canariense* (116.72), *S. alba* (112.05), were found to be less than 120. The IV of *B. carinata* (122.8) and *B. tournefortii* (120.31) were also found close to the specified value.

In summary, based on CN and IV of FAMEs, seed oils of *B. juncea*, *B. carinata*, *B. fruticulosa*, *B. spinescens*, *B. tournefortii*, *C. abyssinica*, *E. sativa*, *E. canariense* and *S. alba* meet the specifications of ASTM D6751 and/or EN 14214. Previous reports suggest that seed oils obtained from mustard (*B. juncea*, *B. carinata* and *S. alba*) have the potential to be a cheaper feedstock than canola and soybeans, the two most common oilseeds used for biodiesel. It is also reported that mustard biodiesel performs well in cold weather [38] and therefore, suitable for use in temperate regions and on high altitudes. Mustard oil contains more long-chain fatty acids than canola oil. Therefore, sometimes mustard biodiesel turns out to be slightly more viscous and may have a higher distillation temperature than the ASTM D6751 specification allows. In this case, mustard biodiesel can be blended with other fuels in order to meet the specifications [39]. Biodiesel obtained from *E. sativa* seed oil is also reported to show good fuel properties when tested against ASTM D6571 standard [40]. *C. abyssinica*, however, is an almost unknown crop with a promissory future to produce biodiesel [41]. In the present investigation methyl esters obtained from *C. abyssinica* seed oil showed IV, CN and linolenic acid content close to the specified range and therefore, can be a potential candidate for use as a blend component in biodiesel production. *B. tournefortii* is yet another species which has not gained its due importance as biodiesel crop despite of having substantial oil content with suitable fatty acid profile. FAMEs obtained from the seed oil of *B. tournefortii* exhibited IV and CN values well within the specified range. The content of linolenic acid was however found to be on the higher side.

The FAMEs properties of *B. fruticulosa*, *B. spinescens* and *E. canarience* also revealed its competence as feedstocks for biodiesel production. These species largely grow as weeds on degraded and marginal lands and yield very poorly. However, these species may be utilized as gene sources for the improvement of other species from biodiesel perspective.

Seed Meal Composition

Seed meal obtained after the extraction of oil from the seeds of nineteen different species of *Brassica* and allied

Table 2 Seed meal composition of *Brassica* and allied genera

Species	Glucosinolates (μmoles/g seed meal)	Crude fiber (%)	Total phenol (mg/g GAE)	Phytate (%)	Lectin (HU/ml)
A. thaliana	56.89	8.21	41.51	1.03	–
B. juncea		9.26	21.02	1.03	–
B. carinata	69.87	6.5	23.5	0.23	
B. fruticulosa	77.43	10.86	29.98	1.15	4.0
B. spinescens	88.83	9.26	21.02	1.19	–
B. tournefortii	52.55	14.62	16.14	0.84	–
C. abyssinica	86.86	7.40	18.36	0.96	–
C. bursa pastoris	64.29	12.4	28.38	1.03	–
C. sativa	44.68	11.29	31.93	1.03	–
D. assurgens	91.84	5.12	34.68	0.62	8.0
D. gomez-campoi	91.61	4.57	27.23	0.65	4.0
D. muralis	81.42	5.16	30.42	1.09	4.0
D. siettiana	60.25	4.54	29.36	1.34	8.0
D. tenuisiliqua	97.16	4.79	22.44	0.76	–
E. sativa	115.50	7.8	27.54	0.89	–
E. canarience	60.61	5.43	24.46	0.65	–
E. lyratus	50.81	4.69	25.37	0.61	–
L. sativum	38.37	8.64	40.54	1.00	4.0
S. alba	79.22	13.94	72.56	0.92	–

genera were evaluated for their nutritive and/or industrial prospects. In this sense, glucosinolates, crude fiber, total phenol, phytic acid and lectin content of seed meal were analyzed (Table 2). Glucosinolates, a large group of sulfur-containing glucosides, are secondary plant metabolites derived from different amino acids such as methionine, phenylalanine and tryptophan. Intact compounds are non-toxic while their hydrolysis products are considered detrimental to health of non ruminants such as poultry and pigs. They interfere with the functioning of the thyroid gland and also cause liver damage [42]. In the present investigation, glucosinolates content in the seed meals ranged from 38.37 to 97.16 μ mol/g defatted seed meal which is considerably higher than the desired level of <30 μ moles/g defatted seed meal. The contents of crude fiber, represented as the sum total of cellulose, hemicelluloses, lignin and similar substances was found to be minimum in *D. siettiana* (4.54 %) while maximum value (14.62 %) was observed in *B. tournefortii*. High fiber content in seed meal reflects lower value of metabolizable energy. Since, crude fiber is present in larger amounts in the hulls of oilseeds, dehulling of the seeds could reduce fiber content in the seed meal and consequently improve its digestibility. Reduction from 10 to 3 % in the crude fiber content of *B. juncea* seed meal is already reported. The total phenol content in the seed meals ranged from 16.14 mg/g GAE to 72.56 mg/g GAE. Maximum phenol content was observed in *S. alba* (72.56 mg/g GAE) followed by *A. thaliana* (41.51 mg/g GAE) while minimum value (16.14 mg/g GAE) was observed in *B. tournefortii*. In the present study, the total phenol content of defatted *S. alba* was found to be considerably higher than the earlier report (37–46 mg/g GAE) [43]. The total phenol content ranging between 7.8 and 23.9 mg/g in rapeseed-mustard has been previously reported [44]. High phenol content in seed meal imparts bitter taste and hence diminishes the value of animal feed particularly for poultry. Nevertheless, phenolic compounds nowadays are gaining much importance as antioxidants. Therefore, substantially high phenol content, as obtained in *S. alba*, renders it economically important source of antioxidants and could find use as nutraceuticals. Phytic acid (1, 2, 3, 4, 5, 6-hexakis dihydrogen phosphate myoinositol) content in the seed meals ranged from 0.23 % in *B. carinata* to 1.34 % in *D. siettiana*. It is a major storage form of phosphorus in most seeds and its concentration ranging from 2 to 5.6 % in rapeseed-mustard seed meals is already reported [45]. In general, Phytic acid is considered to be an antinutritional factor due to strong chelating activity. However, the chelating activity of phytates is nowadays being exploited in a number of medical applications [46]. Analysis of lectin activity conducted by hemagglutination assay of seed meals indicated that *B. fruticulosa*, *L. sativum*, and all the species of genus *Diplotaxis*, except *D. tenuisiliqua* exhibit activity from 4 to 8 HU/ml. Their availability in seed meals in such small quantity bears no significance from the health point of view. However, the

toxicity of plant lectins towards insects, especially sap-feeding hemipterans, is particularly important as potential control agents.

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