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Composition of underexploited Indian pulses. Comparison with common legumes

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Abstract

There is increasing interest in finding new food sources to alleviate malnutrition in developing countries. Moth beans and horse gram are two underexploited Indian legumes growing in adverse conditions but their composition is little-known. Total and resistant starch (RS), dietary fibre (DF) and soluble sugars including oligosaccharides were determined, along with protein, fat, ash and polyphenols. They were compared with other legumes common in Asian and Western countries: black gram, green gram, haricot beans and chickpeas. No apparent differences among the proximate compositions were observed. All samples were rich in DF (18–31% d.m.), made mainly of insoluble DF, whilst RS varied between 3.4 and 8.3%. Oligosaccharides were the main soluble sugars in all legumes; haricot beans and chickpeas were rich in sucrose. All legumes had a high content of non-digestible carbohydrates (37–48% of carbohydrates). In summary, from the composition study, moth beans and horse gram are of a good nutritional quality, making them suitable for more extensive uses.

Keywords: Legumes; Proximate composition; Resistant starch; Dietary fibre; Oligosaccharides

1. Introduction

The nutritional value of legumes as sources of protein and carbohydrates in the diet is undeniable, not only for vegetarians but more especially in developing countries where large segments of the population suffer from protein malnutrition and where legumes are of utmost importance.

As a consequence of this, there is an increasing need to identify and evaluate new potential food sources. Research efforts are being directed towards the study of underexploited legumes that are well adapted to adverse environmental conditions and highly resistant to disease and pests. Among these little-used legumes, a wide variety of tribal pulses consumed in different regions of Asia and Africa has been studied (Siddhuraju, Vijayakumari, & Janardhanan, 1992, 1995, 1996; Marconi, Ruggeri, & Carnovale, 1997). Most literature studies of little-known food legumes are focused on their protein fractions and, in some cases, on the presence of antinutritional factors such as enzyme inhibitors, phytic acid, oligosaccharides, hemagglutinins and phenols as well as on the effect of processing on protein digestibility and antinutrients (Boharde, Kadam, & Salunkhe, 1984; Carnovale, Lugaro, & Marconi, 1991; Sudha, Begum, Shambulingappa, & Babu, 1995; Vijayakumari, Siddhuraju, & Janardhanan, 1995, 1996). In general, these legumes proved to be a good source of protein (15–30% dry matter), matching the FAO/WHO reference patterns (FAO, 1990), except for sulphoamino acids as limiting ones.

Although carbohydrates are the major component of legumes, constituting from 50–70% of the dry matter, little work has been carried out on this fraction. Most reports on the carbohydrate content of underexploited legumes refer to the nitrogen-free extract, with no specific information on the different digestible and non-digestible carbohydrates. Distinction among these two fractions is important, however, when attempting to alleviate the nutritional problems of developing countries, since the nutritional value of carbohydrates is related to their digestibility in the human small intestine. Starch, which has until recently been considered as a totally available carbohydrate, is now known to be only partly digestible. A starch fraction, called resistant starch (RS), is not digested or absorbed in the small intestine (Asp, Van Amelsvoort, & Hautvast, 1996).

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This fact has a double implication relating to a reduction of the actual energy intake on the one hand and the physiological effects associated with the colonic fermentation of RS on the other. These effects of RS are similar to those of the soluble fraction of dietary fibre (DF), the other unavailable carbohydrate fraction of legumes, along with certain oligosaccharides (raffinose, verbascose and stachyose).

Although the reduction of the energy value of legumes due to the presence of RS, DF and oligosaccharides can be considered as a negative effect of these non-digestible carbohydrates, they also confer a number of positive health effects such as a decrease of the risk of intestinal diseases (gallstones, diverticulosis, constipation and colon cancer) and coronary heart disease, the prevention of dental caries or positive implications for the treatment of diabetes (Kritchevsky & Bonfield, 1995; Asp et al., 1996; Oku, 1996).

The aim of the present work was to characterise the proximate composition and carbohydrate fraction of two underexploited legumes grown in southern regions of India. Moth bean (*Vigna aconitifolia* Jacq. (Marechal)) and horse gram (*Macrotyloma uniflorum*, Lam. (Verdc.) previously *Dolichos biflorus*) are consumed by rural communities and the urban poor, as well as by the Malayali and Kurumba tribes in these regions. In 1979, the National Academy of Sciences, in its report on tropical legumes, identified these two little-known pulses as potential food resources (National Academy of Sciences, 1979). These pulses were compared with two legumes commonly consumed in Asian countries, black gram or urd bean (*Vigna mungo* L.) and green gram or mung mean (*Vigna radiata* L.), as well as with two others common in Western and Asian countries, haricot bean (*Phaseolus vulgaris* L.) and chickpea (*Cicer arietinum* L.).

2. Materials and methods

2.1. Samples

Legumes were purchased from local markets either in India or Spain according to their origin. Moth beans were kept at 45°C overnight to kill infesting pests. All samples were cleaned manually and milled to a particle size less than 1 mm in a Cyclone Sample Mill (Tecator, Höganäs, Sweden).

2.2. Methods

2.2.1. Starch analysis

Total starch content was determined after dispersion of the starch granules in 2 M KOH (100 mg sample, 6 ml KOH) at room temperature (30 min, constant shaking) and hydrolysis of the solubilized starch with 80 μl amyloglucosidase (EC 3.2.1.3; Cat. no. 102857, Boehringer-Mannheim, Germany) at 60°C during 45 min (Goñi, García-Alonso, & Saura-Calixto, 1997). Glucose was quantified using the Peridochrom Oxidase/Peroxidase (GOD-PAP) reagent (Cat. no. 676543, Boehringer-Mannheim). Total starch was calculated as glucose ×0.9, after correction of the free glucose content.

Free glucose. The glucose content of legumes, both free glucose and the glucose moiety of sucrose, was determined in order to correct the total starch values obtained before. Samples dispersed in 2M KOH were treated with invertase (E 3.2.1.26; Cat. no. 390203D, BDH, Madrid, Spain) during 30 min at 37°C. After centrifugation, a 1 ml aliquot was precipitated with 2 ml 96% ethanol, centrifuged again and glucose analysed in the supernatants using the Peridochrom Oxidase/Peroxidase (GOD-PAP) reagent.

Resistant starch (RS) was analysed in boiled samples. Whole grains were cooked in distilled water until edible. Cooking water was drained and the samples homogenised (Polytron® PCU, Kinematica, GmBH, Switzerland). Samples (100 mg) were treated with 20 mg pepsin (1 g pepsin/10 ml KCl-HCl buffer; Merck no. 7190, 2000 FIT-U g^{-1}) to remove protein and then incubated for 16 h at 37°C with 1 ml pancreatic α-amylase (solution containing 40 mg α-amylase/ml Tris Maleate buffer; EC 3.2.1.1, A-3176, Sigma Chemical Co., Madrid, Spain) to remove digestible starch. After centrifugation (15 min, 3000×***g***) and removal of supernatants, the pellets were dispersed with 2 M KOH, hydrolysed with amyloglucosidase and the liberated glucose quantified, all as described above for total starch. RS was calculated as glucose ×0.9 (Goñi, García-Diz, Mañas, & Saura-Calixto, 1996).

Digestible starch content was calculated as TS−RS. Additionally, a fraction of resistant starch associated with insoluble dietary fibre (IDF-RS) was quantified separately. IDF residues were isolated after sequential treatment with heat-stable α-amylase, protease and amyloglucosidase as described below. After centrifugation and washing, IDF residues were treated with 2M KOH to disperse RS that was then hydrolyzed with amyloglucosidase. IDF-RS was also calculated as glucose ×0.9 (Saura-Calixto, Goñi, Bravo, & Mañas, 1993).

2.2.2. Dietary fibre analysis

Dietary fibre (DF) in raw legumes was analysed by the enzymatic–gravimetric method of Prosky, Asp, Schweizer, de Vries, & Furda (1988) modified to prevent some errors associated with the ethanol precipitation step (Mañas, Bravo, & Saura-Calixto, 1994). Samples were treated with heat-stable α-amylase (EC 3.2.1.1; A-3306), protease (P-3910) and amyloglucosidase (EC 3.2.1.3; A-9913, all from Sigma Chemical Co., Madrid,

Spain) to remove digestible starch and protein. After centrifugation (15 min, 3000×*g*) and washing with distilled water, soluble dietary fibre (SDF) fractions were separated by aspiration and transferred into dialysis tubes (12 000–14 000 MWCO; Dialysis Tubing Visking, Medicell International Ltd., London, UK). These were kept in a 42 l methacrylate dialysis chamber at 25°C with a water flow of 7 l h^{-1}, where they were dialysed for 48 h. After dialysis, SDF were hydrolysed with 1M sulphuric acid during 90 min in a boiling water bath.

The residues from the enzymatic treatments were further washed twice with ethanol and acetone and centrifuged under the same conditions as before, constituting the insoluble dietary fibre (IDF) fractions. IDF residues were sequentially hydrolysed with 12 M (1 h, 30°C) and 1 M (1.5 h, 100°C) sulphuric acid. The residues of the acid hydrolysis were dried (105°C, constant weight) and quantified as Klason lignin (KL).

Uronic acids (UA) and neutral sugars (NS) were quantified in the hydrolysates, UA spectrophotometrically by the Scott (1979) method using galacturonic acid as standard, and NS by GLC as alditol acetates (Englyst & Cummings, 1988) using inositol as internal standard. A Shimadzu GC-14A (Shimadzu Co., Kyoto, Japan) chromatograph fitted with a flame ionisation detector and an AOC-14 autoinjector, and connected to a C-R4A Chromatopac computing system, was used. The column was a SP-2330 capillary column (30 m×0.32 i.d.; Cat. no. 2-4073, Supelco, Bellefonte, PA). The operating conditions were: column temperature 240°C (isothermal), injector temperature 270°C; detector temperature 270°C; carrier gas was nitrogen. IDF content was calculated as (NS + UA) + KL, and SDF as NS + UA.

2.2.3. Soluble sugars

Soluble sugars, including other oligosaccharides, were analysed by HPLC after extraction with water for instrumental analysis (Panreac Química S.A., Barcelona, Spain) for 1 h in a water-bath at 60°C with constant shaking. Soluble polysaccharides were precipitated in 85% ethanol (1 h, 4°C) (Daveby & Åman, 1993). After centrifugation (15 min, 3000×*g*) supernatants were evaporated to dryness in a rotary evaporator at 50°C, resuspended in water for instrumental analysis and filtered through 0.45 μm filters for aqueous solutions (Part No. SLHA025BS, Millipore S.A., Molsheim, France). Extracts (50 μl) were injected into a Bio-Rad Aminex HPX-87P column (300×7.8 mm) with two Bio-Rad microguard cartridges (30×4.6 mm; Cat. no. 125-0118, Bio-Rad, Hercules, CA, USA). The column was isocratically eluted with degasified water for instrumental analysis at 85°C at a flow rate of 0.6 ml min^{-1}. A Kontron HPLC consisting of a 360 autosampler, 325 pump system and a 450-MT2 data system was used (Kontron, Milan, Italy), fitted to a R-401 Waters differential refractometer (Waters, Millipore Co., Milford, MA) and a Jones Chromatography thermostatic oven. Sugars were identified and quantified by comparison with known standards.

2.2.4. Polyphenolic compounds

Both soluble polyphenols and condensed tannins were analysed in the raw legumes. Soluble polyphenols (SPP) were obtained after sequentially washing 1 g sample with 40 ml each of methanol/water (50:50, v/v; 1 h, room temperature, constant shaking) and acetone/water (70:30, v/v; 1 h, room temperature, constant shaking) in 50-ml centrifuge tubes. After centrifugation (15 min, 3000×*g*) supernatants were combined and made up to 100 ml. Total polyphenols were quantified as gallic acid equivalents using the Folin-Ciocalteau's reagent (Montreau, 1972). Condensed tannins (CT) were analysed in the residues obtained after SPP extraction by reading the absorbance at 553 nm of the anthocyanidin solutions obtained after treatment with 5% HCl-Butanol (3 h, 100°C) (Reed, McDowell, Van Soest, & Horvath, 1982). Carob pod (*Ceratonia siliqua*) condensed tannins from Nestlè (Vevey, Switzerland) were used as standard.

Total nitrogen was determined in samples by the Kjeldahl method. A 1030 Kjeltec Autoanalyzer (Tecator, Höganäs, Sweden) was used. Protein was calculated as N×6.25. *Ash* content was determined after calcination in a muffle furnace at 550°C for 16 h. *Fat* was quantified after extraction in a Soxtec equipment (Tecator, Höganäs, Sweden).

3. Results and discussion

3.1. Proximate composition

The proximate composition of all the studied legumes is shown in Table 1. The carbohydrate content, calculated as the sum of the non-starch polysaccharides constituents of the dietary fibre fraction plus total starch (TS) and soluble sugars, ranged from 59 to 67% of the dry matter. Black gram and chickpeas were the legumes with the highest carbohydrate content, whilst horse gram and haricot beans had the lowest values. Moth beans and green gram showed intermediate values. These carbohydrate contents agree with values reported earlier for these pulses (Boharde et al., 1984; Sudha et al., 1995).

Crude protein content was similar in all little-known and common legumes (20–25% dry matter, Table 1), the lowest value corresponding to chickpeas (20.7%). Although the similar protein content might suggest a comparable nutritional value of the underexploited legumes in terms of protein digestibility, in-depth studies of this should be carried out. It is known that

Table 1
Proximate composition of raw legumes (g/100 g dry matter)

	CHO[a]	Protein	Polyphenols[b]	KL[c]	Fat	Ash
Moth bean	61.8	25.3 ± 0.54	3.08 ± 0.07	4.57 ± 0.35	0.69 ± 0.05	3.51 ± 0.01
Horse gram	59.3	24.9 ± 1.01	3.49 ± 0.05	5.61 ± 0.39	0.58 ± 0.05	3.31 ± 0.03
Black gram	67.0	23.6 ± 0.26	3.98 ± 0.04	6.60 ± 0.46	0.45 ± 0.10	3.51 ± 0.00
Green gram	61.9	24.5 ± 0.17	2.25 ± 0.06	4.40 ± 0.35	0.71 ± 0.04	3.45 ± 0.03
Haricot bean	59.3	25.1 ± 0.24	0.49 ± 0.05	2.38 ± 0.28	0.90 ± 0.01	4.04 ± 0.02
Chickpea	63.4	20.7 ± 0.21	1.84 ± 0.11	2.49 ± 0.72	4.16 ± 0.08	3.03 ± 0.02

Mean values ± STD ($n = 6$).
[a] Carbohydrates (CHO): calculated as NSP + TS + SS (NSP: non-starch polysaccharides (Total dietary fibre—KL); TS: total starch; SS: soluble sugars).
[b] Polyphenols are the sum of soluble polyphenols and condensed tannins.
[c] KL: Klason lignin.

different antinutritional components may decrease protein digestibility, e.g. factors such as trypsin inhibitors, phytic acid or polyphenols (Marconi et al., 1997). To our knowledge, there is no work in the literature dealing with the study of protein digestibility of the underexploited legumes analysed in the present work.

As to the polyphenolic content of the studied legumes, haricot beans only had minor amounts of polyphenols (PP), which was in accordance with the white colour of its seed coat. Black gram, that was the legume with the darkest seed coat, also had the highest polyphenolic content (3.98% d.m.). PP are mainly located in the seed coat, which could explain the apparent relationship between seed colour and PP content. However, although moth beans and chickpeas showed a similar cuticle colour, the PP content was higher in moth beans due to the smaller size of this pulse as compared to chickpeas. A correlation between tannin content and seed weight in *Vigna* spp. with similar seed coat colours was reported by Carnovale et al. (1991). On the other hand, dehulling of horse gram seeds caused a reduction in the tannin content of about 65% (Sudha et al., 1995). These authors proposed dehulling as a potential means to remove certain antinutrients. PP have traditionally been considered as antinutrients due to their capacity to decrease protein digestibility either by inhibiting digestive enzymes or by forming complexes with dietary protein, rendering it indigestible (Butler, 1989). However, recent work has provided evidence about the role of polyphenolic compounds as antioxidants, antimutagens, antimicrobials or anti-inflammatory agents (Shahidi & Wanasundara, 1992; Okuda, 1993). Therefore, the antinutritional status of legume polyphenols should be reconsidered.

Ash content of the studied little-known pulses agree with previous data (Boharde et al., 1984; Sudha et al., 1995) and is similar to the other more commonly consumed legumes (Table 1). Also, fat content was similar in all samples ($< 1\%$ d.m.) except for chickpea, that was comparatively rich in fat (4.16% d.m.).

In the case of black gram, the sum of all the analysed constituents added up to 105%. In previous works we reported the presence of other substances such as tannins and protein along with lignin in the gravimetric residue quantified as Klason lignin (Saura-Calixto, Goñi, Mañas, & Abia, 1991; Bravo & Saura-Calixto, 1988) which could explain the results obtained here. This phenomenon is more notorious in black gram, but it cannot be ruled out in the other samples.

3.2. Starch content

Table 2 shows the total, digestible and resistant starch content of the six legumes. Total starch (TS) ranged between 31.8 and 39.9% in chickpeas and green gram, respectively. The lowest TS contents corresponded to chickpeas and haricot beans, two of the most widely consumed legumes world-wide. Green gram and moth beans showed the highest TS values, close to 40% of the dry matter.

However, only between 76 and 90% of this TS was digestible due to the presence of resistant starch (Table 2). The resistant starch (RS) content of boiled legumes varied between 3.4% in black gram to up to 8.3% in haricot beans. Of the two little-known legumes, moth beans showed a low RS value (3.9% dry matter), lower than that of green gram and chickpeas. On the other hand, although the RS content of horse gram was rather high (5.2% d.m.), it was not as high as that of a commonly-consumed pulses such as haricot beans.

RS, which is defined as the starch and the products of starch degradation not absorbed in the small intestine of healthy individuals (Asp et al., 1996), reaches the large intestine where it is fermented by the colonic microflora. Along with gas, the main end-products of carbohydrate fermentation in the colon are short chain fatty acids (SCFA; acetic, propionic and butyric acids). Fermentation of RS is characterised by a high production of butyrate (Phillips, Muir, Birkett, Lu, Jones, O'Dea, &

Table 2
Composition of the starch fractions of raw legumes (g/100 g dry matter)

	Total starch	Digestible starch[a] (% of TS)	Resistant starch	IDF-RS[b]
Moth bean	39.5 ± 1.74	35.6 (90)	3.90 ± 0.06	1.08 ± 0.14
Horse gram	36.0 ± 1.17	30.8 (85)	5.21 ± 0.64	1.22 ± 0.03
Black gram	37.9 ± 1.05	34.5 (91)	3.40 ± 0.06	1.89 ± 0.11
Green gram	39.9 ± 0.70	35.7 (90)	4.18 ± 0.11	1.60 ± 0.06
Haricot bean	34.9 ± 0.42	26.6 (76)	8.31 ± 0.34	0.82 ± 0.04
Chickpea	31.8 ± 0.08	27.7 (87)	4.17 ± 0.10	0.63 ± 0.06

Mean values ± STD ($n = 3$).
[a] Calculated by difference as TS−RS (Total starch−Resistant starch).
[b] IDF-RS: Resistant starch associated to insoluble dietary fibre.

Young, 1995) which is believed to exert a protective effect against colorectal cancer (Scheppach, Bartram, & Richter, 1995). On the other hand, a reduced starch digestibility in legumes is related to a lower glucose release into the blood stream. This would result in reduced postprandial glycaemic and insulinaemic responses, with potential beneficial effects in the dietary management of diabetes (Jenkins et al., 1988). Therefore, the presence of a starch fraction resisting digestion and absorption in the small intestine could have beneficial health effects.

Several factors may result in the presence of RS in foods. When foods are heated in excess water, starch granules swell and loose their crystallinity. Amylose is solubilised and a starch gel is formed. Upon cooling, amylose reorganises into a crystalline structure formed by amylose chains linked by hydrogen bonds in a process known as retrogradation (Colonna, Leloup, & Buleon, 1992). Retrograded starch is indigestible and constitutes the main RS fraction in processed foods. However, boiled legumes in our experiment were analysed immediately after cooking to avoid starch retrogradation. Therefore, the RS content of the boiled legumes should consist of other starch fractions, different from retrograded starch.

Legumes are known to contain α-amylase inhibitors, which may decrease in vitro starch digestibility resulting in high RS values. However, this factor can also be ruled out. Prior to the starch hydrolysis step a pepsin treatment at pH 1.5 was carried out, which should be expected to neutralise the activity of the α-amylase inhibitors. Besides, cooking also markedly reduces the effects of heat-labile antinutrients such as α-amylase inhibitors (Mulimani, Rudrappa, & Supriya, 1994). Another possible explanation for the different starch digestibility found in the studied seed legumes could be a decreased accessibility of the hydrolytic enzymes to their substrate. Since all the boiled samples were homogenised in identical conditions prior to analysis, the influence of particle size can also be discarded. All legumes have a similar crystalline form according to their diffractometric spectra (C-form) (Colonna et al., 1992), although their starch granules might have different amylose/amylopectin contents, which could account for their different susceptibility to α-amylase. On the other hand, the entrapment of the starch material within cell wall components could also hinder enzyme accessibility and result in different starch digestibilities. Actually, there is a RS fraction associated with the insoluble residue of dietary fibre (IDF-RS, Table 2) that can be quantified as dietary fibre by most analytical procedures.

3.3. Dietary fibre

The dietary fibre (DF) content of the studied legumes is shown in Table 3. Black gram and chickpeas were the samples with the highest total dietary fibre (TDF) content (30.9 and 26.0%, respectively), whilst moth bean showed the lowest value (18.5% d.m.). TDF was composed mainly of insoluble fibre with soluble dietary fibre (SDF) accounting for only between 0.96% d.m. in horse gram and 4.69% in black gram.

Only black gram and haricot beans showed significant amounts of neutral sugars (NS) in the SDF fraction, the other legumes having only minor amounts. Pectic substances, both neutral (arabinogalactans) and acidic (galacturonates), were the main soluble non-starch polysaccharides (NSP) in the former. Pectins were also present in minor amounts in the other pulses.

The major NS in the IDF residues was glucose. As seen before, a fraction of this glucose may come from the RS associated with IDF residues. The rest corresponds to cellulose, the main NSP of the insoluble fraction of DF. Significant amounts of hemicelluloses (arabinoxylans) were present in the IDF as well. Also, the uronic acid content of IDF, which was higher than in SDF, suggests the presence of pectic substances linked to other cell wall polysaccharides. Trace amounts of rhamnose were detected in some samples, and minor quantities of fucose were also present in black gram, haricot beans and chickpeas.

As to the Klason lignin (KL) content, the highest value corresponded to black gram (Table 3). Actually, the KL content of IDF residues correlated with the polyphenolic content of the studied samples: the higher the PP content, the higher the KL (Table 1). Some polyphenols may be retained along with resistant protein and lignin in the residue quantified as KL (Saura-Calixto et al., 1991; Bravo & Saura-Calixto, 1998).

3.4. Soluble sugars

Table 4 shows the content of soluble sugars analysed in the extracts obtained from raw legumes.

Moth beans and chickpeas were the pulses with the highest amounts of soluble sugars, up to 8.3% of the dry matter. Horse gram and haricot beans showed similar soluble sugar contents, about 6.4%, whilst the

Table 3
Composition of the dietary fibre fractions of raw legumes (g/100 g dry matter)

	Moth bean			Horse gram			Black gram		
	IDF	SDF	TDF	IDF	SDF	TDF	IDF	SDF	TDF
Fucose	nd	nd	nd	nd	nd	nd	0.11 ± 0.01	0.07 ± 0.03	0.17 ± 0.02
Arabinose	2.14 ± 0.08	0.18 ± 0.02	3.00 ± 0.07	4.14 ± 0.08	0.17 ± 0.03	4.30 ± 0.05	4.02 ± 0.27	2.20 ± 0.20	6.22 ± 0.08
Xylose	2.16 ± 0.03	0.03 ± 0.01	2.19 ± 0.02	1.93 ± 0.10	nd	1.93 ± 0.10	2.18 ± 0.10	0.04 ± 0.01	2.21 ± 0.10
Mannose	0.08 ± 0.01	0.22 ± 0.04	0.30 ± 0.03	0.11 ± 0.01	0.22 ± 0.05	0.33 ± 0.04	0.12 ± 0.01	0.19 ± 0.04	0.31 ± 0.05
Galactose	0.32 ± 0.01	0.13 ± 0.01	0.44 ± 0.02	0.41 ± 0.02	0.11 ± 0.03	0.52 ± 0.04	1.06 ± 0.01	1.08 ± 0.04	2.14 ± 0.03
Glucose	6.31 ± 0.49	0.15 ± 0.04	6.45 ± 0.46	7.46 ± 0.53	0.11 ± 0.01	7.57 ± 0.52	7.40 ± 0.18	0.17 ± 0.05	7.57 ± 0.20
Total neutral sugars	11.01 ± 0.42	0.70 ± 0.09	11.70 ± 0.35	14.06 ± 0.78	0.60 ± 0.08	14.65 ± 0.73	14.88 ± 0.48	3.75 ± 0.24	18.63 ± 0.30
Uronic acids	1.75 ± 0.01	0.51 ± 0.00	2.26 ± 0.01	1.94 ± 0.10	0.26 ± 0.03	2.20 ± 0.08	4.75 ± 0.29	0.94 ± 0.07	5.69 ± 0.32
Klason lignin	4.57 ± 0.35	—	4.57 ± 0.35	5.61 ± 0.39	—	5.61 ± 0.39	6.60 ± 0.46	—	6.60 ± 0.46
Total dietary fibre	17.33 ± 0.39	1.21 ± 0.00	18.54 ± 0.39	21.61 ± 0.05	0.86 ± 0.03	22.47 ± 0.07	26.23 ± 0.24	4.69 ± 0.26	30.92 ± 0.21
	Green gram			Haricot bean			Chickpea		
	IDF	SDF	TDF	IDF	SDF	TDF	IDF	SDF	TDF
Fucose	nd	nd	nd	nd	0.17 ± 0.04	0.17 ± 0.04	0.07 ± 0.02	nd	0.07 ± 0.02
Arabinose	2.25 ± 0.14	0.17 ± 0.02	2.42 ± 0.12	4.23 ± 0.22	1.78 ± 0.07	5.84 ± 0.37	3.89 ± 0.28	0.28 ± 0.05	4.17 ± 0.26
Xylose	1.70 ± 0.06	nd	1.70 ± 0.06	1.51 ± 0.10	0.33 ± 0.03	1.84 ± 0.12	1.20 ± 0.07	0.08 ± 0.01	1.28 ± 0.08
Mannose	0.11 ± 0.03	0.26 ± 0.02	0.37 ± 0.05	nd	0.36 ± 0.02	0.36 ± 0.02	0.36 ± 0.04	0.26 ± 0.07	0.63 ± 0.07
Galactose	0.35 ± 0.02	0.17 ± 0.03	0.52 ± 0.04	0.47 ± 0.06	0.53 ± 0.05	1.00 ± 0.11	0.52 ± 0.06	0.29 ± 0.04	0.81 ± 0.03
Glucose	6.52 ± 0.16	0.14 ± 0.03	6.66 ± 0.20	5.24 ± 0.30	0.21 ± 0.02	5.45 ± 0.31	11.22 ± 0.20	0.39 ± 0.17	11.61 ± 0.35
Total neutral sugars	10.92 ± 0.28	0.74 ± 0.02	11.66 ± 0.30	11.45 ± 0.66	3.22 ± 0.22	14.67 ± 0.88	17.27 ± 0.47	1.30 ± 0.23	18.57 ± 0.79
Uronic acids	3.94 ± 0.07	0.48 ± 0.03	4.43 ± 0.09	2.30 ± 0.04	1.00 ± 0.07	3.29 ± 0.08	4.20 ± 0.18	0.75 ± 0.05	4.95 ± 0.14
Klason lignin	4.40 ± 0.35	—	4.40 ± 0.35	2.38 ± 0.28	—	2.38 ± 0.28	2.49 ± 0.72	—	2.49 ± 0.72
Total dietary fibre	19.26 ± 0.14	1.22 ± 0.03	20.49 ± 0.12	16.13 ± 0.76	4.22 ± 0.10	20.35 ± 0.83	23.95 ± 0.93	2.05 ± 0.05	26.00 ± 1.00

Mean values ± STD ($n = 3$); nd: not detected. IDF = Insoluble dietary fibre; SDF = Soluble dietary fibre; TDF = Total dietary fibre.

Table 4
Soluble sugar content of raw legumes (g/100 g dry matter)

	Moth bean	Horse gram	Black gram	Green gram	Haricot bean	Chickpea
Oligosaccharides[a]	5.07 ± 0.38	3.69 ± 0.24	3.15 ± 0.37	3.72 ± 0.28	2.32 ± 0.05	1.73 ± 0.06
Sucrose	1.52 ± 0.16	1.21 ± 0.12	1.28 ± 0.19	1.63 ± 0.12	3.70 ± 0.07	4.83 ± 0.37
Maltose	0.12 ± 0.03	0.53 ± 0.06	0.04 ± 0.02	0.12 ± 0.11	0.14 ± 0.02	0.44 ± 0.06
Glucose	0.80 ± 0.13	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.07 ± 0.03	0.00 ± 0.00
Xylose	0.00 ± 0.00	0.64 ± 0.09	0.25 ± 0.02	0.36 ± 0.02	0.00 ± 0.00	0.65 ± 0.07
Galactose	0.50 ± 0.08	0.08 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.01
Arabinose	0.17 ± 0.04	0.12 ± 0.03	0.05 ± 0.01	0.07 ± 0.01	0.03 ± 0.03	0.19 ± 0.02
Fructose	0.03 ± 0.01	0.03 ± 0.01	0.02 ± 0.00	0.02 ± 0.00	0.20 ± 0.11	0.05 ± 0.03
Inositol	0.08 ± 0.00	0.04 ± 0.00	0.03 ± 0.00	0.04 ± 0.00	0.01 ± 0.00	0.09 ± 0.01
Total	8.29	6.38	4.82	5.96	6.47	8.00

Mean values ± STD ($n = 3$).
[a] Oligosaccharides = inuline + raffinose + stachyose.

lowest value corresponded to black gram, with only 4.8% of the dry matter. However, in the saccharide composition of this fraction important differences could be noted, mainly with their oligosaccharide contents.

Since the column used in the HPLC analysis of soluble sugars was specific for mono and disaccharides, the peaks corresponding to oligosaccharides could not be effectively resolved. A good peak resolution was obtained for inulin, but not for stachyose or raffinose. Also ciceritol, which is present in raw chickpeas (Vidal-Valverde, 1993) could not be detected under the present analytical conditions.

Nevertheless, it can be seen from these analyses that oligosaccharides were the main constituent sugars of the soluble fraction in all the legumes except haricot beans and chickpeas (Table 4). The highest oligosaccharide contents corresponded to the little-known legumes (5.07 and 3.69% in moth bean and horse gram, respectively). Also, black gram and green gram showed significant amounts of oligosaccharides (3.15 and 3.72%, respectively). Haricot beans and chickpeas, whilst having the lowest oligosaccharide values, showed the highest sucrose content, up to 4.83% of the dry matter in chickpeas. Sucrose was present in all the other pulses as well. Small amounts of maltose could also be detected in all the samples. Monosaccharides (glucose, galactose, arabinose, fructose and inositol) were also detected in small amounts in the different samples.

The most common oligosaccharides in legume seeds are raffinose, stachyose and verbascose. They are comprised of one, two and three galactose units, respectively, joined together with sucrose through α-*D*-1,6 linkages. These oligosaccharides are not digested in the human small intestine due to the lack of α-galactosidases; they therefore reach the colon where they are fermented, like RS and SDF, with the production of short chain fatty acids (SCFA), CO_2, H_2 and, in some individuals, CH_4. It is precisely the production of these gases and the flatulence they induce which is related to their being considered as antinutritional factors (Vijayakumari et al., 1996). However, these oligosaccharides are soluble compounds that will be eliminated after food processing (soaking in salt water, sprouting, cooking, autoclaving, etc.) (Vijayakumari et al., 1995, 1996). On the other hand, as mentioned above for other compounds traditionally considered as antinutrients such as PP, beneficial effects of oligosaccharides related to the maintenance of a healthy colonic microflora or reducing the risk of dental caries have been described (Oku, 1996).

4. Conclusions

The study of the proximate composition of two underexploited Indian legumes, moth bean and horse gram, showed no apparent differences when compared to other legumes commonly consumed in Asian or Western countries, such as black gram, green gram, haricot beans and chickpeas. All of them were good sources of dietary carbohydrates and protein, yet they contained significant amounts of polyphenols, which have traditionally been considered as antinutrients. However, this assumption has changed in the last years since the discovery of the role of polyphenols as antioxidants and antimutagens (Okuda, 1993).

When the carbohydrate fraction of these legumes was studied in detail, the presence of high amounts of non-digestible carbohydrates such as resistant starch, dietary fibre and oligosaccharides was revealed. These non-digestible carbohydrates accounted for as much as 48.2% of the total carbohydrates in haricot beans, 46.4% in chickpeas, 46.1% in black gram, 43.4% in horse gram, 38.7% in green gram and 37.1% in moth beans. Therefore, the underexploited pulses contained more digestible carbohydrates than other legumes commonly consumed in India and world-wide, moth bean actually being the best of the studied seed legumes in terms of carbohydrate digestibility.

Although the little-used pulses showed higher amounts of oligosaccharides in comparison with common legumes, these antinutrients are easily lost during food processing (soaking, cooking, etc.).

In summary, the composition study of moth beans and horse gram showed that these little-used legumes are good sources of protein, carbohydrate and energy. The nutritional qualities of these pulses make them suitable for human consumption and a more extended culture could be recommended.

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