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Contents and Digestibility of Carbohydrates of Chickpea and Black Gram as Affected by Domestic Processing and Cooking

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ABSTRACT

*Starch digestibility (*in vitro*) and level of total soluble sugars, reducing sugars, non-reducing sugars and starch in cultivars of chickpea (*Cicer arietinum*), as well as black gram (*Vigna mungo*), varied significantly. The effects of different domestic processing and cooking methods on the contents of starch, sugars and starch digestibility (*in vitro*) of eight varieties of chickpea and four of black gram were investigated. Cooking, autoclaving and germination decreased the starch content and increased the level of total soluble sugars, reducing sugars, non-reducing sugars and starch digestibility of both the legumes. Soaking reduced the sugars considerably but starch only marginally. Autoclaving increased starch digestibility more than 4-fold and 5-fold in chickpea and black gram, respectively. Cooking and sprouting also improved starch digestibility appreciably.*

INTRODUCTION

Food legumes are an important dietary component for the majority of the population in India and several other developing countries. Besides being an inexpensive source of protein, the pulses are suppliers of dietary calories in the form of carbohydrates. The availability of energy from the dietary

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legumes is, therefore, dependent on the level and digestibility of available carbohydrates in these foods. Starch, a major constituent of available carbohydrates in food legumes, is known to possess low digestibility (Kumar & Venkatraman, 1976; Geervani & Theophilus, 1980; El Faki *et al.*, 1984). This may be ascribed to chain length and amount of amylose (Srinivasa, 1976) and the presence of amylase inhibitors (Singh et al., 1982), phytate and polyphenols (Thompson & Yoon, 1984) in these foods.

Legume grains are processed and cooked in a variety of ways depending on taste and cultural preferences. Antinutrients like phytates (Ologhobo & Fetuga, 1984; Khokhar & Chauhan, 1986), tannins (Rao & Deosthale, 1982) as well as starch and other available carbohydrates of some pulses (Gupta & Wagle, 1980; Jood *et al.*, 1986) have been reported to be affected by different processing and cooking treatments. Development of high-yielding crop varieties is one of the methods of increasing production for meeting the food requirements of growing populations in many developing countries. The newly evolved varieties may not only have different grain and quality characteristics but also may behave differently from existing cultivars after processing and cooking. This paper reports effects of various domestic processing and cooking treatments including soaking, cooking (ordinary and pressure cooking), sprouting and cooking of sprouts on the contents and digestibility (*in vitro*) of available carbohydrates of some important cultivars of two major Indian pulses, namely, chickpea and black gram.

MATERIALS AND METHODS

Materials

Seeds of eight high-yielding varieties of chickpea (*Cicer arietinum*); namely, C-235, H-208, H-78-65, H-77-66, H-76-67, H-75-35, H-81-73 and H-82-2 and four of black gram (*Vigna mungo*); namely, T-9, UH-80-7, Pant-U-30 and Pant-U-19, were obtained from the Department of Plant Breeding, Haryana Agricultural University, Hisar, India. Seeds were freed from dust, broken seeds and other foreign materials.

Processing and cooking treatments

Soaking

Seeds were soaked in plain water (1:5, w/v) for 12 h at room temperature The water left after soaking was discarded. The soaked seeds were washed twice with water and then dried in a hot air oven maintained at 55°C.

Cooking

The soaked seeds, after rinsing in water, were put in round mouthed tall beakers fitted with condensers connected to running water. After addition of water (three times the weight of dry seeds), the samples were cooked on a hot plate until they became soft (as felt between fingers). Similarly, unsoaked samples were also cooked in the same beakers, using seed to water ratio of 1:7 (w/v). For pressure cooking, the seeds were autoclaved at 1·05 kg cm^{-2} pressure for 15 min. For this, a dry seeds to cooking water ratio of 1:2 (w/v) was used. The cooked samples were mashed and then dried at 55°C.

Germination

The soaked seeds were germinated in sterile Petri dishes lined with damp filter papers at 25°C. In order to obtain a sprout measuring 1·5 to 2·5 cm, the usual size of sprouts generally consumed, the soaked seeds of chickpea and black gram varieties were germinated for 60 h and 48 h, respectively. The sprouts were rinsed in distilled water and dried at 55°C or rinsed sprouts were cooked until soft in the same way as the soaked samples above, mashed and dried at 55°C.

The dried samples were ground in an electric grinder to pass through a 100 mesh sieve and then stored in air-tight plastic bottles at room temperature until further analysis.

Chemical analysis

Total soluble sugars were extracted by refluxing in 80% ethanol (Cerning & Guilbot, 1973). Starch from the sugar-free pellet was extracted in 52% perchloric acid at room temperature (Clegg, 1956). Quantitative determination of total soluble sugars and starch was carried out according to the colorimetric method of Yemm & Willis (1954). Reducing sugars were estimated by Somogyi's modified method (Somogyi, 1945). Non-reducing sugars were determined by calculating the differences between total soluble sugars and reducing sugars. Starch digestibility (*in vitro*) was assessed by employing pancreatic amylase and then measuring maltose liberated by using dinitrosalicylic acid reagent (Singh *et al.*, 1982). For assaying *in vitro* starch digestibility, 25 mg defatted sample was dispersed in one ml of 0·2 M phosphate buffer (pH 6·9). After adding 0·5 ml pancreatic amylase (25 mg dissolved in 50 ml of the phosphate buffer; the enzyme obtained from M/s Sigma Chemical Company, St. Louis, USA) the sample suspension was incubated at 37°C in a waterbath for 2 h. Dinitrosalicylic acid reagent (2 ml) was quickly added and the mixture was heated for 5 min in a boiling waterbath. The contents were cooled and made to 25 ml with distilled water and filtered prior to measurement of its absorbance at 550 nm. A blank was run simultaneously by incubating the sample first and the dinitrosalicylic acid reagent was added before addition of enzyme solution. Maltose (E Merck, India) was used as standard and values (corresponding to absorbance obtained by subtracting the blank value from sample absorbance) were expressed as milligrams of maltose released per gram of sample. Each of the processing treatments and analyses for each variety of sample was carried out in four replicates.

Statistical analysis

The data were statistically analysed for analysis of variance to know the significant differences among various treatments (Snedecor & Cochran, 1967).

RESULTS AND DISCUSSION

The food legumes exhibited significant varietal differences in contents of carbohydrates (Table 1). Starch digestibility differed significantly only in chickpea varieties. Between the food legumes, black gram appeared to contain higher levels of total soluble sugars, non-reducing sugars and starch whereas chickpea had higher amounts of reducing sugars and starch digestibility. Among chickpea varieties the highest amounts of total soluble sugars, reducing sugars, non-reducing sugars and starch were present in H-75-35. H-82-2 had the highest starch digestibility. In black gram, UH-80-7 contained the maximum total soluble sugars and non-reducing sugars whereas the highest levels of reducing sugars and starch were found in T-9 and Pant-U-19, respectively. The range of carbohydrate contents in the pulses reported here is similar to that reported earlier (Pant & Tulsiani, 1968; Naivikul, 1978; Gupta & Wagle, 1980). Low starch digestibility of pulses may be ascribed to the content and chain length of the amylose constituent. Chickpea and black gram have been found to have an amylose with higher chain length than the amylose from green gram and red gram (Srinivasa, 1976). Legumes having a high content of long chain amylose are known to have poor digestibility of starch. The presence of various non-starchy carbohydrates may also influence the starch digestibility of raw legume seeds (El Faki *et al.*, 1984).

Effect of domestic processing and cooking

Sugar contents

Soaking of seeds of both the legumes significantly reduced the level of total soluble sugars, reducing sugars and non-reducing sugars (Tables 2 and 3).

TABLE 1
Carbohydrate Contents and *in vitro* Starch Digestibility (mg maltose released/g meal) of Chickpea and Black gram (on dry matter basis)[a]

Varieties	*Total sugars (g/100 g)*	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility*
Chickpea					
C-235	9·0	570	8·4	48·0	26·3
H-208	8·7	590	8·1	46·1	28·8
H-78-65	8·5	610	7·9	44·9	26·7
H-77-66	8·4	590	7·8	50·1	27·7
H-76-67	8·7	570	8·1	48·9	27·7
H-81-73	8·9	620	8·3	53·0	29·6
H-82-2	8·5	610	7·8	51·3	31·6
H-75-35	9·1	630	8·5	53·3	30·3
Mean	8·7	599	8·11	49·5	28·6
CD[b] ($P < 0{\cdot}05$)	0·2	20	0·2	1·7	0·9
Black gram					
T-9	9·3	430	8·9	53·9	22·2
UH-80-7	9·5	390	9·1	55·1	22·2
P-U-30	9·0	380	8·6	54·0	22·3
P-U-19	9·1	410	8·7	55·9	22·0
Mean	9·2	402	8·8	54·7	22·2
CD[b] ($P < 0{\cdot}05$)	0·2	10	0·2	0·7	0·8

[a] Values are averages of four replicates.
[b] Critical difference. Differences of two means between the varieties of the same legume exceeding this value are significant.

Total soluble sugars, reducing sugars and non-reducing sugars decreases ranged from 16 to 40%, 16 to 25% and 16 to 42% in chickpea varieties and 22 to 27%, 27 to 35% and 22 to 27% in black gram varieties, respectively. Losses of sugars during soaking could be on account of simple diffusion of sugars after being solubilised. The extent of diffusion of sugars from seed to soaking medium may be a function of structure of seed coat. Soaking has been known to reduce the level of sugars in various pulses (Silva & Braga, 1982; Jood *et al.*, 1986).

When the soaked seeds were cooked the losses in the sugar contents were reversed and consequently there was an increase in total soluble sugars, reducing sugars and non-reducing sugars of both the pulses (Tables 4 and 5). The extent of increase in total soluble sugars and non-reducing sugars was greater in chickpea varieties whereas reducing sugars increased to a greater extent in black gram varieties. When unsoaked seeds were cooked there was

TABLE 2
Effect of Soaking on Soluble Sugars, Starch and Starch Digestibility of Chickpea Cultivars (on Dry Matter Basis)[a]

Varieties	*Total soluble sugars (g/100 g)*	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/ g meal)*
C-235	6·08	430	5·6	45·4	31·5
	(−34)	(−25)	(−34)	(−6)	(+16)
H-208	5·5	450	5·0	40·7	31·7
	(−38)	(−24)	(−37)	(−12)	(+9)
H-78-65	5·1	470	4·7	42·0	31·1
	(−40)	(−23)	(−42)	(−7)	(+14)
H-77-66	6·3	460	5·9	45·0	29·5
	(−25)	(−22)	(−25)	(−10)	(+5)
H-76-67	6·9	480	6·5	43·0	31·3
	(−20)	(−16)	(−21)	(−12)	(+11)
H-75-35	7·1	500	6·6	46·3	32·7
	(−22)	(−21)	(−22)	(−13)	(+7)
H-82-2	7·1	510	6·8	45·8	33·1
	(−16)	(−18)	(−18)	(−14)	(+11)
H-81-73	7·3	490	6·6	45·2	34·8
	(−18)	(−20)	(−16)	(−12)	(+9)
Mean	6·5	474	6·0	44·2	31·9
CD[b] $P < 0.05$)	0·5	4·0	0·2	0·4	1·1

[a] Values are means of four replicates. Figures in parentheses indicate decrease (−) or increase (+) of soluble sugars, starch and starch digestibility expressed as percent of raw value.
[b] Critical difference. Differences of two means between the varieties of the same lugumes exceeding this value are significant.

an increase in the level of sugars in both the pulses (Tables 6 and 7). Increase in total soluble sugars and non-reducing sugars seemed to be higher in chickpea seeds whereas reducing sugars increased to a greater extent in black gram seeds.

Possible hydrolysis of starch to oligosaccharides and then to monosaccharides, resulting from cooking and autoclaving, may be responsible for increased concentration of sugars in the cooked pulses. In a similar study Rao & Belavady (1978) have observed increased levels of sugars in cooked pulses.

There was a contrast in the content of sugars after sprouting of the legume seeds (Tables 8 and 9). The level of sugars in chickpea sprouts was higher than in unprocessed seeds whereas, in black gram sprouts, it was considerably less than their unprocessed contents. When the sugar contents

TABLE 3
Effect of Soaking on Soluble Sugars, Starch and Starch Digestibility of Black gram Cultivars (on dry matter basis)[a]

Varieties	*Total soluble sugars (g/100 g)*	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/ g meal)*
T-9	7·0	280	6·8	49·9	28·4
	(−25)	(−35)	(−24)	(−8)	(+28)
UH-80-7	6·9	260	6·7	48·7	27·1
	(−27)	(−33)	(−27)	(−12)	(+21)
P-U-30	6·7	250	6·5	45·2	28·3
	(−25)	(−34)	(−25)	(−16)	(+27)
P-U-19	7·1	300	7·8	50·7	27·6
	(−22)	(−27)	(−22)	(−9)	(+26)
Mean	6·9	273	6·7	48·6	27·9
CD[b] ($P<0{\cdot}05$)	0·3	2·0	0·2	0·4	0·9

[a] Values are means of four replicates. Figures in parentheses indicate decrease (−) or increase (+) of soluble sugars, starch and starch digestibility expressed as percent of raw value.
[b] Critical difference. Differences of two means between the varieties of the same legume exceeding this value are significant.

of sprouts were compared with those of soaked seeds, as sprouting followed soaking, it seemed that sprouting resulted in appreciable gain in sugar concentration of soaked seeds. The increase in sugar during sprouting appeared to be more in chickpea than black gram varieties. This difference in concentration of sugars of sprouts may be attributed to the longer germination period in chickpea. As mentioned earlier, in order to have uniform desirable sprout length in both the pulses, chickpea was germinated for 60 h and blackgram for 48 h. The increase in sugar contents of soaked seeds during germination may be because of mobilisation and hydrolysis of seed polysaccharides, leading to more available sugars. A similar trend in sugar content of legume seed during germination has been observed earlier (Kumar & Venkataraman, 1976; Subbulakshmi *et al.*, 1976).

Cooking raised the level of sugar in the sprouts of both the pulses. As a result, there was a marginal increase in the level of sugars in chickpea and black gram over the control varieties. Gain in the level of sugars in black gram was notable.

Starch

On soaking for 12 h, the seeds of both the pulses contained significantly less

TABLE 4

Effect of Ordinary Cooking on Soluble Sugars, Starch and Starch Digestibility of Chickpea Cultivars (on dry matter basis)[a]

Varieties	Cooking of soaked seeds					Cooking of unsoaked seeds				
	Total soluble sugars (g/100 g)	Reducing sugars (mg/100 g)	Non-reducing sugars (g/100 g)	Starch (g/100 g)	Starch digestibility (mg maltose released/g meal	Total soluble sugars (g/100 g)	Reducing sugars (mg/100 g)	Non-reducing sugars (g/100 g)	Starch (g/100 g)	Starch digestibility (mg maltose released/g meal)
C-235	11·3	660	10·6	40·4	74·5	9·5	610	8·9	41·1	54·3
	(+26)	(+16)	(+26)	(−16)	(+183)	(+6)	(+7)	(+6)	(−14)	(+106)
H-208	11·1	670	10·4	39·9	75·9	9·3	620	8·7	42·3	57·5
	(+28)	(+14)	(+29)	(−13)	(+164)	(+7)	(+5)	(+7)	(−8)	(+100)
H-78-65	11·0	690	10·2	38·7	73·9	8·9	630	8·3	41·5	56·5
	(+28)	(+13)	(+29)	(−14)	(+177)	(+4)	(+3)	(+5)	(−8)	(+118)
H-77-66	11·4	640	10·7	41·6	73·0	8·8	600	8·2	43·1	53·6
	(+36)	(+9)	(+38)	(−17)	(+162)	(+6)	(+2)	(+6)	(−14)	(+92)
H-76-67	11·5	630	10·9	38·5	73·0	9·3	590	8·8	41·9	56·4
	(+33)	(+10)	(+34)	(−21)	(+164)	(+7)	(+4)	(+8)	(−15)	(+103)
H-75-35	11·8	700	11·1	42·0	74·6	9·6	660	9·0	43·9	58·8
	(+30)	(+11)	(+31)	(−21)	(+146)	(+6)	(+5)	(+6)	(−16)	(+94)
H-82-2	11·8	720	11·0	41·6	78·1	9·4	650	8·7	44·4	57·7
	(+32)	(+16)	(+34)	(−22)	(+164)	(+6)	(+5)	(+5)	(−17)	(+95)
H-81-73	11·4	660	10·8	40·7	77·1	8·8	680	8·2	43·0	59·8
	(+35)	(+8)	(+37)	(−21)	(+144)	(+4)	(+12)	(+4)	(−16)	(+89)
Mean	11·4	671	10·7	40·4	75·0	9·2	630	8·6	42·7	56·9
CD[b] ($P<0·05$)	0·5	4·0	0·2	0·4	1·1	0·5	4·0	0·2	0·4	1·1

[a] Values are means of four replicates. Figures in parentheses indicate decrease (−) or increase (+) of soluble sugars, starch and starch digestibility expressed as percent of raw value.

[b] Critical difference. Differences of two means between the varieties of the same legumes exceeding this value are significant.

TABLE 5

Effect of Ordinary Cooking on Soluble Sugars, Starch and Starch Digestibility of Black gram Cultivars (on dry matter basis)[a]

Varieties	*Cooking of soaked seeds*					*Cooking of unsoaked seeds*				
	Total soluble sugars (g/100 g)	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/g meal)*	*Total soluble sugars (g/100 g)*	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/g meal)*
T-9	10·9	610	10·3	22·5	65·1	9·8	460	9·4	43·4	53·6
	(+18)	(+42)	(+16)	(−21)	(+194)	(+5)	(+7)	(+5)	(−20)	(+142)
UH-80-7	11·0	590	10·4	44·6	69·2	9·7	470	9·2	45·5	54·9
	(+16)	(+51)	(+14)	(−19)	(+210)	(+2)	(+21)	(+2)	(−17)	(+146)
P-U-30	10·7	600	10·1	40·7	68·9	9·3	430	8·9	41·2	54·0
	(+18)	(+58)	(+17)	(−25)	(+209)	(+3)	(+13)	(+3)	(−24)	(+142)
P-U-19	10·5	620	9·8	42·1	69·3	9·4	490	8·9	47·5	54·7
	(+15)	(+51)	(+14)	(−25)	(+216)	(+3)	(+20)	(+3)	(−15)	(+149)
Mean	10·8	605	10·2	42·5	68·1	9·6	463	9·1	44·4	54·3
CD[b] ($P < 0·05$)	0·3	2·0	0·2	0·4	0·9	0·3	2·0	0·2	0·4	0·9

[a] Values are means of four replicates. Figures in parentheses indicate decrease (−) or increase (+) of soluble sugars, starch and starch digestibility expressed as percent of raw value.

[b] Critical difference. Differences of two means between the varieties of the same legume exceeding this value are significant.

TABLE 6

Effect of Autoclaving on Soluble Sugars, Starch and Starch Digestibility of Chickpea Cultivars (on dry matter basis)[a]

Varieties	*Total soluble sugars (g/100 g)*	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg of maltose released/g meal)*
C-235	12·1	690	11·4	28·7	157·5
	(+34)	(+21)	(+35)	(−40)	(+489)
H-208	12·1	700	11·5	29·6	157·5
	(+39)	(+19)	(+41)	(−36)	(+448)
H-78-65	11·8	710	11·1	28·1	157·7
	(+38)	(+16)	(+40)	(−39)	(+491)
H-77-66	11·4	730	10·6	30·5	156·9
	(+36)	(+24)	(+37)	(−39)	(+462)
H-76-67	11·9	750	11·3	26·0	155·8
	(+38)	(+32)	(+39)	(−47)	(+462)
H-75-35	11·0	720	11·3	27·2	159·4
	(+36)	(+14)	(+34)	(−9)	(+425)
H-82-2	12·3	740	11·6	28·4	160·2
	(+39)	(+19)	(+14)	(−47)	(+442)
H-81-73	11·7	700	11·0	31·5	159·4
	(+38)	(+15)	(+40)	(−39)	(+404)
Mean	11·9	718	11·2	28·8	158·1
CD[b] ($P<0·05$)	0·5	4·0	0·2	0·4	1·1

[a] Values are means of four replicates. Figures in parentheses indicate decrease (−) or increase (+) of soluble sugars, starch and starch digestibility expressed as percent of raw value.
[b] Critical difference. Differences of two means between the varieties of the same legume exceeding this value are significant.

starch than the unprocessed controls. A variation in loss ranged from 6% to 14% in chickpea and 8% to 16% in black gram varieties (Tables 2 and 3).

Cooking and autoclaving of soaked seeds further increased the loss of starch. Autoclaving had a more pronounced effect than ordinary cooking. Cooking of unsoaked seeds also reduced the starch content but the loss was relatively less as compared to cooking of soaked seeds. Sprouting also reduced the starch content of seeds, the reduction being more prominent in black gram seeds. Cooking after germination further reduced the starch content but to a very marginal extent.

Leaching out of soluble portion of starch from seed to soaking medium may, perhaps, explain the loss of starch during soaking. Cooking, ordinary as well as pressure cooking, may cause rupturing of starch granules followed by amylolysis. This may be responsible for the decreased amount of starch

TABLE 7
Effect of Autoclaving on Soluble Sugars, Starch, Starch Digestibility of Black gram Cultivars (on dry matter basis)[a]

Varieties	*Total soluble sugars (g/100 g)*	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/g meal)*
T-9	11·5	650	10·9	24·8	149·7
	(+24)	(+51)	(+22)	(−54)	(+576)
UH-80-7	11·7	670	11·1	32·7	149·7
	(+24)	(+72)	(+22)	(−41)	(+571)
P-U-30	11·2	700	10·5	31·5	151·3
	(+24)	(+84)	(+21)	(−42)	(+578)
P-U-19	10·8	640	10·2	31·0	152·3
	(+19)	(+56)	(+18)	(−45)	(+594)
Mean	11·3	665	10·7	30·0	150·8
CD[b] ($P<0{\cdot}05$)	0·3	2·0	0·2	0·4	0·9

[a] Values are means of four replicates. Figures in parentheses indicate decrease (−) or increase (+) of soluble sugars, starch and starch digestibility expressed as percent of raw value.
[b] Critical difference. Differences of two means between the varieties of the same legume exceeding this value are significant.

and an increased level of sugars in seeds after cooking. Starch may also be hydrolysed to oligosaccharides and ultimately to monosaccharides during germination. This may be required for energy production for various metabolic processes during germination. The hydrolysis of starch catalysed by phosphatases and amylases is probably responsible for the decreased amount of starch in the legume sprouts. The reduction in the starch content of pulses during soaking, cooking, autoclaving and germination (Kumar & Venkataraman, 1976; Sharma & Pant, 1979; Silva & Luh, 1979; Jood *et al.*, 1986) has also been reported earlier.

Starch digestibility

All domestic processing and cooking treatments improved the starch digestibility of chickpea as well as black gram varieties (Tables 2–8). Autoclaving was the most effective method of increasing starch digestibility of pulses followed by sprouting, cooking of soaked seeds, cooking of unsoaked seeds, cooking of sprouts and soaking. All the treatments, except soaking, appeared to influence the starch digestibility of black gram to a greater extent than that of chickpea. During soaking, there was not much difference in starch digestibility of both the pulses.

TABLE 8

Effect of Sprouting and Cooking of the Sprouts on Soluble Sugars, Starch and Starch Digestibility of Chickpea Cultivars (on dry matter basis)[a]

Varieties	*Sprouting*					*Cooking of sprouts*				
	Total soluble sugars (g/100 g)	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/g meal)*	*Total soluble sugars (g/100 g)*	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/g meal)*
C-235	9·5	580	8·9	39·2	74·6	9·9	600	9·3	39·0	93·3
	(+5)	(+2)	(+6)	(−19)	(+183)	(+10)	(+5)	(+10)	(−19)	(+254)
H-208	8·9	630	8·3	37·8	77·6	9·2	650	8·5	37·4	96·2
	(+2)	(+7)	(+2)	(−18)	(+170)	(+5)	(+10)	(+5)	(−19)	(+235)
H-78-65	8·9	620	8·3	36·7	75·9	9·0	640	8·4	35·7	97·7
	(+4)	(+2)	(+4)	(−18)	(+184)	(+5)	(+5)	(+5)	(−21)	(+266)
H-77-66	8·6	600	8·0	36·0	76·9	8·9	610	8·3	34·2	97·2
	(+3)	(+2)	(+3)	(−28)	(+176)	(+6)	(+3)	(+7)	(−32)	(+248)
H-76-67	9·1	590	8·5	33·6	77·1	9·1	620	8·5	33·1	96·2
	(+4)	(+4)	(+4)	(−31)	(+175)	(+5)	(+9)	(+5)	(−32)	(+247)
H-75-35	9·4	710	8·7	38·0	78·3	9·4	730	8·7	34·0	99·5
	(+4)	(+13)	(+3)	(−29)	(+158)	(+3)	(+16)	(+2)	(−36)	(+228)
H-82-2	9·5	670	8·8	40·1	77·8	9·8	700	9·1	36·0	98·8
	(+7)	(+8)	(+6)	(−25)	(+163)	(+10)	(+13)	(+10)	(−33)	(+233)
H-81-73	9·4	660	8·7	38·6	79·8	9·6	670	8·9	37·5	98·5
	(+11)	(+8)	(+11)	(−25)	(+152)	(+13)	(+10)	(+14)	(−27)	(+214)
Mean	9·2	632	8·5	37·5	77·1	9·4	652	8·7	35·9	97·2
CD[b] ($P<0·05$)	0·5	4·0	0·2	0·4	1·1	0·5	4·0	0·2	0·4	1·1

[a] Values are means of four replicates. Figures in parentheses indicate decrease (−) or increase (+) of soluble sugars, starch and starch digestibility expressed as percent of raw value.

[b] Critical difference. Differences of two means between the varieties of the same legume exceeding this value are significant.

TABLE 9

Effect of Sprouting and Cooking of the Sprout on Soluble Sugars, Starch and Starch Digestibility of Black gram Cultivars (on dry matter basis)[a]

Varieties	*Sprouting*					*Cooking of sprouts*				
	Total soluble sugars (g/100 g)	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/g meal)*	*Total soluble sugars (g/100 g)*	*Reducing sugars (mg/100 g)*	*Non-reducing sugars (g/100 g)*	*Starch (g/100 g)*	*Starch digestibility (mg maltose released/g meal)*
T-9	7·4	310	7·1	30·9	74·4	9·8	450	9·3	27·8	93·0
	(−21)	(−28)	(−21)	(−43)	(+236)	(+5)	(+5)	(+5)	(−48)	(+320)
UH-80-7	7·2	290	6·9	35·2	74·2	9·6	430	9·2	33·8	92·8
	(−24)	(−26)	(−24)	(−36)	(+233)	(+2)	(+10)	(+1)	(−39)	(+316)
P-U-30	7·1	280	6·8	33·6	71·4	9·1	420	8·7	32·3	90·0
	(−21)	(−26)	(−21)	(−38)	(+220)	(+1)	(+11)	(+1)	(−40)	(+300)
P-U-19	6·9	320	6·7	32·3	61·6	9·5	460	9·1	31·2	90·2
	(−24)	(−12)	(−24)	(−41)	(+226)	(+5)	(+12)	(+5)	(−44)	(+311)
Mean	7·2	300	6·9	33·1	72·9	9·5	440	9·1	31·3	91·5
CD[b] ($P<0·05$)	0·3	2·0	0·2	0·4	0·9	0·3	2·0	0·2	0·4	0·9

[a] Values are means of four replicates. Figures in parentheses indicate decrease (−) or increase (+) of soluble sugars, starch and starch digestibility expressed as percent of raw value.

[b] Critical difference. Differences of two means between the varieties of the same legume exceeding this value are significant.

Soaking and other treatments including cooking, autoclaving and sprouting of pulses are known to reduce the level of phytate, tannin and amylase inhibitors (Rao & Deosthale, 1982; Khokhar & Chauhan, 1986) which may, to some extent, be responsible for the increase in starch digestibility of processed and cooked legume grains.

Processing of legumes, involving heat treatment, may gelatinise starch which is readily attacked by α-amylase. Starch in untreated samples is ungelatinised and less readily hydrolysed. This may explain the partly better starch digestibility of cooked and autoclaved seeds. Differences in starch digestibility during different heat treatment may be due to differences in extent of starch gelatinisation. Significant differences in amylolysis rates in the processed legume seeds, as compared to the raw, have been reported (Subbulakshmi *et al.*, 1976; Geervani & Theophilus, 1980; El Faki *et al.*, 1984).

Chickpea and black gram, good sources of dietary carbohydrates like any other food legume, have relatively low starch digestibility. Different domestic processing and cooking treatments affect the carbohydrate content of pulses. Sugars are decreased during soaking whereas cooking, autoclaving and sprouting lead to increased starch hydrolysis, which may account for the increased level of sugars and decreased amount of starch during cooking and germination. The processing and cooking treatments improve the starch digestibility of legumes. Cooking may gelatinise starch and germination may mobilise starch, thereby resulting in improved digestibility of starch by α-amylase.

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