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Full Length Research Paper

Effect of cooking methods on available and unavailable carbohydrates of some tropical grain legumes

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The available and unavailable carbohydrate contents of eleven tropical legumes from different seed lines were investigated in raw, cooked and autoclaved forms. Raw legumes contained small amounts of glucose and fructose which ranged from 0.05 to 0.22 g/100 g and 0.24 to 0.90 g/100 g, respectively, sucrose varied between 1.49 g/100 g and 3.76 g/100 g. Reducing sugars were higher in bambara groundnut than other legumes. Starch was the principal carbohydrate, ranging from 35.4 to 50.0 g/100 g. African yam beans, lima beans and kidney beans had fairly high levels of oligosaccharides (raffinose + stachyose) than bambara groundnuts. Non-cellulosic polysaccharides and cellulose contents were highest in jack bean followed by pigeon pea TUc5537-1 and least in bambara groundnut KAB-3. Lignin was low and fairly uniform in all the legumes. The available carbohydrates were reduced to various extents by cooking, whereas the unavailable carbohydrates were not affected appreciably by heat treatment.

Key words: Legume grains, available and unavailable carbohydrates, cooking, autoclaving.

INTRODUCTION

Grain legumes are foodstuffs of great nutritional significance to people in tropical developing countries. In Nigeria and other African countries, a large number of species and varieties of legumes are consumed by the teaming population, as they are inexpensive and important sources of protein (20-40%), carbohydrates (50-60%), along with various other nutrients which have beneficial effects on human health and well-being (Borget, 1992; Ofuya and Akhidue, 2005). However, some legume species are not widely acceptable to the consumers and often under-utilized as human food due to undesirable characteristics such as the presence of flatulence producing factors as well as other anti-nutritive constituents (Olson et al*.,* 1981; Liener, 1994).

The legume carbohydrates, especially the indigestible oligosaccharides raffinose, stachyose and verbascose represent an important proportion of sugars (Knudsen, 1997) and are well known to produce flatulence or ejection of rectal gas in humans and this can be a social problem (Calloway et al., 1971; Rackis, 1981; Saini, 1989). They contain α-galactosidic linkages which are indigestible by human digestive enzymes as the appropriate endogenous enzyme is lacking. As a consequence, the intact oligosaccharides reach the lower intestines where they are metabolized by the micro flora, producing short chain fatty acids (SCFA), carbon dioxide, hydrogen and, to a lesser extent, methane as flatulence products (Hellendoorn, 1969; Savitri and Desikachar, 1985; Bravo, Siddhuraju and Saura-Calixto, 1999). In addition to these flatulent active factors, other carbohydrate fractions of legume seeds include the cell wall polysaccharides which constitute the unavailable carbohydrates that are not only resistant to processes of digestion in man (Kamath and Belavady, 1980; Rashid et al., 2003), but also produce SCFA in the colon from fermentation thereby causing an intensified motility of the gut, reduction in transit time of food passage and minor digestive upsets (Goodlad and Mathers, 1992; Annison, 1993).

A variety of treatments such as milling and steaming, cooking, roasting or fermentation are used in traditional preparation of legume sources for human food (Apata and Ologhobo, 1997; Oboh et al., 2000; Seena et al., 2006). These domestic processing methods have been reported to have varying efficiencies in causing loss of flatus producing carbohydrates in cowpea (Nwinuka et al., 1997). Little information is available on the losses of the available carbohydrates in under-exploited African legumes after heat processes. This paper describes the

Table 1. Available and unavailable carbohydrate contents of raw and heat processed African yam bean (g/100 g dry matter).

Carbohystrate	Variety					
	Sumunu-Iseyin I			Sumunu-Iseyin II		
	Raw	Cooked	Autoclaved	Raw	Cooked	Autoclaved
Available carbohydrates						
Glucose	0.14	0.10	0.12	0.22	0.19	0.23
Fructose	0.31	0.23	0.30	0.38	0.29	0.34
Sucrose	2.60	1.84	1.98	1.97	1.30	1.49
Reducing sugars	0.57	0.45	0.51	0.60	0.42	0.57
Starch	43.9	42.1	43.2	48.1	47.9	47.8
Raffinose	0.73	0.64	0.71	0.81	0.79	0.78
Stachyose	3.30	2.86	3.20	2.90	2.10	2.90
Unavailable carbohydrates						
Non-cellulosic polysaccharides	7.31	6.95	7.30	8.94	8.32	8.60
Cellulose	4.34	3.98	4.06	4.12	3.78	3.89
Lignin	1.35	1.30	1.34	1.74	1.66	1.68

content of the available and unavailable carbohydrates of some legume seeds grown in Nigeria and the effects of cooking and autoclaving on them.

MATERIALS AND METHODS

Mature dry seeds of eleven legumes were used for the investigation. These included two varieties each from African yam bean (*Sphenostylis stenocarpa*), bambara groundnut (*Voandzeia subterranea* (L.) Thouars), kidney bean (*Phaseolus vulgaris* L.), lima bean (*Phaseolus lunatus* L.), pigeon pea (*Cajanus cajan* (L) Millsp) and one variety of jack bean (*Canavalia ensiformis* (L) DC). The seed samples were purchased from local farm centre and the legume breeding unit of the National Cereals Research Institute, Ibadan, Nigeria. Legumes of each type (1 kg) were subjected to cooking and autoclaving treatments. Preliminary investigations were carried out to establish the cooking time for the individual varieties of legumes, i.e., the time required to achieve no further increase in weight of the strained legumes after holding in either cold or boiling water. The cooking times ranged from 1.84 to 2.76 h (mean = 2.30 h), and by then, the weight of the legumes had more than doubled. Cooking was done by adding dry seeds to boiling water (five times the volume of dry seeds), in a cooking pot and heated for their required cooking time. The cooked samples were drained and dried at 55°C for 20 h. For autoclaving, the raw legumes were milled and then autoclaved at 121°C and 1.05 kg/cm^2 pressure for 30 min.

The raw and cooked seeds were milled in a Willey press to pass through a 0.5 mm sieve and, along with the milled autoclaved samples were separately stored in sealed Kilner jars and kept at 4°C until required for analysis.

The extraction of total ethanol soluble sugars from raw and heat processed legume seed flours was done by repeated shaking with 80% ethanol (w/v) at 60°C and the extracts thus obtained were pooled. Extractions were repeated until the final extract showed a negative test for sugar. Absence of sugar was detected qualitatively by spraying with *p*-anisidine hydrochloride reagent (Cerning and Guilbot, 1973). The ethanol was separated from the pooled extracts in a rotatory vacuum evaporator at 40°C and quantitative determinations of individual sugars (glucose, fructose and sucrose) were performed using a combination of enzymatic and chemical methods (Johnson et al., 1964). Reducing sugars were estimated colorimetrically (Solomonsson et al., 1984). The enzymatic method (Capital and Kabanus, 1987) was used to determine starch content. Oligosaccharides were separated on Whatman No.1 (5 x 45 cm) by descending chromatography using propanol-ethanol-water (7:1:2) and constituent sugars (raffinose + stachyose) were located by the end-strip method (Ologhobo and Fetuga, 1988) and their concentrations were quantified according to the method of Dubois et al. (1956). Unavailable carbohydrates (cell wall contents) were estimated by acid hydrolysis (Southgate, 1969). All the quantitative analyses were done in duplicate and expressed in g/100 g on a dry matter basis.

RESULTS

The available and unavailable carbohydrate contents of the six legume species studied are presented in separate tables which compared the raw, cooked, and autoclaved varieties of individual legume. Table 1 shows the data for African yam bean. In the raw seed, glucose, fructose and reducing sugars were present in small amounts while sucrose fraction represents 2.60 g/100 g dry matter of the grain. Starch was the major component, ranging from 43.9 to 48.1 g/100 g. The oligosaccharide content had more of stachyose than raffinose, occurring in ratio 4.4:1 in Sumunu-Iseyin I variety. The legume contained fairly high level of non-cellulosic polysaccharides (8.94 g/100 g). The available carbohydrates were reduced to various extents; between 4.1- 29.2% as a result of cooking and smaller reductions were observed with autoclaving process. Values of the unavailable carbohydrates were not appreciably affected by heat treatment.

Bambara groundnut (Table 2) had low concentrations of monosaccharide (glucose + fructose) and oligosaccharides while reducing sugars represent 1.29g/100 g dry matter. Oturkpo local variety contained appreciable amount of disaccharide sucrose, accounting for 3.76 g/100

Table 2. Available and unavailable carbohydrate contents of raw and heat processed bambara groundnut (g/100 g dry matter).

Carbohystrate	Variety					
	KAB-3			Oturkpo local		
	Raw	Cooked	Autoclaved	Raw	Cooked	Autoclaved
Available carbohydrates						
Glucose	0.13	0.10	0.11	0.09	0.07	0.08
Fructose	0.90	0.72	0.74	0.84	0.65	0.74
Sucrose	3.02	2.52	2.71	3.76	2.89	3.10
Reducing sugars	1.13	0.91	1.06	1.29	1.10	1.21
Starch	50.0	48.1	49.7	47.8	45.6	47.4
Raffinose	0.27	0.26	0.24	0.22	0.23	0.30
Stachyose	1.00	0.90	0.85	0.75	0.80	0.67
Unavailable carbohydrates						
Non-cellulosic polysaccharides	4.57	4.28	4.35	5.18	4.30	5.06
Cellulose	2.82	2.59	2.76	3.15	2.22	2.89
Lignin	1.01	0.98	1.03	0.87	0.85	0.87

Table 3. Available and unavailable carbohydrate contents of raw and heat processed kidney bean (g/100 g dry matter).

Carbohystrate	Variety					
	Pondo-6			Yara-1		
	Raw	Cooked	Autoclaved	Raw	Cooked	Autoclaved
Available carbohydrates						
Glucose	0.08	0.05	0.07	0.05	0.04	0.05
Fructose	0.47	0.36	0.39	0.64	0.49	0.55
Sucrose	1.66	1.42	1.78	2.07	1.74	2.00
Reducing sugars	0.79	0.62	0.75	0.88	0.65	0.84
Starch	41.5	40.0	40.6	45.0	41.20	43.8
Raffinose	0.62	0.53	0.59	0.60	0.61	0.59
Stachyose	3.10	2.97	3.00	2.48	2.60	2.50
Unavailable carbohydrates						
Non-cellulosic polysaccharides	7.35	6.59	6.85	8.17	7.54	7.92
Cellulose	5.47	4.96	5.28	4.73	4.41	4.60
Lignin	1.32	1.30	1.32	1.50	1.46	1.48

dry matter. Starch was abundant, amounting to 50 g/100 g in KAB-3. The cell wall constituents are low, ranging from 0.89 to 5.18 g/100 g dry matter. The available carbohydrate content of the cooked KAB-3 seed exhibited maximum reduction (23%) in glucose and minimum reduction (3.7%) in trisaccharide raffinose relative to the raw form.

In kidney bean (Table 3), content of available carbohydrates were also low, except starch (45 g/100 g) in Yara-1 and tetrasaccharide stachyose (3.10 g/100 g), in Pondo-6. The legume contained fairly high levels of non- cellulosic polysaccharides (8.17 g/100 g) and cellulose (5.47 g/100 g). Autoclaving brought an average of about 5 and 3% reduction in the available and unavailable carbohydrates of Pondo- 6, respectively.

The data of the lima bean (Table 4) showed that the monosaccharide and reducing sugars were present in small amounts (0.07 to 0.81 g/100 g) and sucrose in higher amounts (1.49 to 1.58 g/100 g), while starch content was up to 47. 6 g/100 g in TPL 88. Like in other legumes, oligosaccharides also contained more of stachyose than raffinose, occurring in ratio 5.6:1 in TPL 249. Non-cellulosic polysaccharides and cellulose constitute 9.12 and 5.36 g/100 g of the dry matter, respectively. Lignin was in lesser amount (1.49 g/100g).

The results of the pigeon pea (Table 5) showed that monosaccharides are minor in the two varieties. TUC 5537-1 variety contained high amount of non-cellulosic polysaccharides (11.40 g/100 g) and Ex-Ibadan had fairly high level of cellulose (4.40 g/100 g) and only 2.04 g/100 g

Table 4. Available and unavailable carbohydrate contents of raw and heat processed lima bean (g/100 g dry matter).

Carbohystrate	Variety					
	TPL 88			TPL 249		
	Raw	Cooked	Autoclaved	Raw	Cooked	Autoclaved
Available carbohydrates						
Glucose	0.07	0.05	0.06	0.09	0.06	0.08
Fructose	0.75	0.53	0.68	0.56	0.37	0.45
Sucrose	1.58	1.19	1.53	1.49	1.21	1.37
Reducing sugars	0.81	0.63	0.80	0.76	0.52	0.74
Starch	47.6	42.8	45.1	43.8	40.3	41.2
Raffinose	0.75	0.68	0.71	0.61	0.56	0.60
Stachyose	2.95	2.94	2.57	3.40	3.30	3.29
Unavailable carbohydrates						
Non-cellulosic polysaccharides	9.12	8.90	9.03	8.26	7.54	8.10
Cellulose	4.81	4.32	4.58	5.36	4.86	5.07
Lignin	1.49	1.51	1.38	1.54	1.50	1.51

Table 5. Available and unavailable carbohydrate contents of raw and heat processed pigeon pea (g/100 g dry matter).

Carbohystrate	Variety					
	Ex-Ibadan			TUC 5537-1		
	Raw	Cooked	Autoclaved	Raw	Cooked	Autoclaved
Available carbohydrates						
Glucose	0.14	0.09	0.12	0.09	0.05	0.07
Fructose	0.40	0.28	0.30	0.29	0.18	0.20
Sucrose	2.01	1.75	1.96	2.25	1.82	1.83
Reducing sugars	0.52	0.39	0.55	0.46	0.30	0.43
Starch	42.7	39.5	41.9	44.4	41.7	43.8
Raffinose	0.50	0.45	0.49	0.46	0.40	0.44
Stachyose	2.90	2.81	2.83	2.07	1.97	1.89
Unavailable carbohydrates						
Non-cellulosic polysaccharides	10.31	10.10	10.20	11.40	10.90	11.20
Cellulose	5.40	5.01	5.19	4.87	4.29	4.61
Lignin	2.04	1.98	2.00	1.36	1.28	1.32

lignin.

Jack bean (Table 6) showed that the starch content was smaller (35.4 g/100 g) than that of the other legume species. It is rich in non-cellulosic polysaccharides (14.0 g/100 g) and cellulose (9.84 g/100 g) but contains less of lignin (3.40 g/100 g). The reduction in carbohydrate contents of the heat processed jack bean followed the same trend as observed in other legumes with loss of 20% in glucose as a result of cooking and 1.7% in cellulose consequent upon autoclaving.

DISCUSSION

The values obtained for simple sugars and starch in the legumes compare reasonably well with the levels reported earlier for other varieties of pigeon pea (Rao and Belavady, 1978), kidney bean (Tanusi et al., 1972), bambara groundnut (Doku et al., 1978), lima bean (Dibofori et al., 1994) and several legume species such as the cowpea, chickpea, black gram, broad bean and *Pisum sativum* (Onigbinde and Akinyele, 1983; Jood et al.,1985; Canibel et al., 1997; Rehman, 2007) but differ appreciably from reported values for soybean, particularly in its sucrose and starch contents of 4.61 and 16.1 g/100g, respectively (Ologhobo and Fetuga, 1984; Trugo, et al., 1995) and also from groundnut with starch value of 12.5 g/100 g (Tharanathan, Wankhede and Rao, 1979). In the present investigation, substantial amounts of starch (> 40 g/100 g dry matter) were found in most of the legumes. Starch provides the major source of physiological energy in human and monogastric diets; its

Table 6. Available and unavailable carbohydrate contents of raw and heat processed jack bean (g/100 g dry matter).

Carbohystrate	Jack bean		
	Raw	Cooked	Autoclaved
Available carbohydrates			
Glucose	0.10	0.08	0.09
Fructose	0.24	0.13	0.19
Sucrose	2.20	1.87	2.14
Reducing sugars	0.38	0.25	0.38
Starch	35.4	32.8	34.6
Raffinose	0.60	0.51	0.58
Stachyose	2.26	1.95	2.23
Unavailable carbohydrates			
Non-cellulosic polysaccharides	14.00	13.43	13.89
Cellulose	9.84	9.46	9.47
Lignin	3.40	3.36	3.40

occurrence in high amounts in these grains underscores their potential energy supply. Apart from its energy contribution, starch in most of the processed food systems is known to contribute to the texture, and as a result, to the organoleptic properties of food (Tharanathan and Mahadevamma, 2003).

The presence of fairly high levels of oligosaccharides evidenced in lima bean TPL 249, African yam bean sumunu-Iseyin I and kidney bean pondo-6 relative to other legumes reflects the possible existence of species and varietal differences in the individual legume studied. These higher levels are indicative of the role these legumes might play in inducing flatulence upon ingestion. Dibofori et al. (1994) have shown that an average consumption of 500 g of lima beans containing 620 mg raffinose/100 g would produce 186 ml/h flatus volume which is enough to cause discomfort in humans. In comparison to other legume species, bambara groundnuts contained considerably less of the raffinose and stachyose which tends to suggest lesser flatus production potential in this grain legume. Also, the low occurrence of these components may be of relevance in making bambara groundnut more acceptable for incorporation into weaning foods.

The values of available carbohydrates in each of the autoclaved legumes were similar to those of the raw form while the cooked had lower values which may be a consequence of the leaching out of soluble starch portion and the soluble sugars, by boiling water during the cooking process. A similar observation has been reported by Rehman (2007) for black gram and chickpea. However, it is important to note that cooking or boiling has been implicated in gelatinization of starch and this tends to increase the availability of starch for digestion by amlylolytic enzymes (Haralampu, 2000).

The values for the unavailable carbohydrates in the grain legumes, except jack bean, were in the range of the results reported for a number of common tropical legumes such as black gram, cowpea and green gram (Kamath and Belavady, 1980). The unavailable carbohydrate constituents in the legumes studied were low except in jack bean. The higher occurrence of unavailable carbohydrates in jack bean than other legumes investigated suggests that the digestion and absorption of associated nutrients in the former by monogastric digestive systems are likely to be comparatively lower than in other legumes. In the present work, normal cooking and autoclaving did not effect appreciable changes in the composition of non-cellulosic polysaccharides, cellulose and lignin; a similar observation was made by Tharanathan et al. (1979) with processed groundnut meal. In contrast, Rehman et al. (2004) reported losses in unavailable carbohydrate contents in black gram and chick pea as a result of cooking. Such discrepancy may probably be due to distinct cooking process used by the investigators. From this study, it seems that the legume cell walls have relatively strong linkage as evidenced by their stability property under the conditions of heat treatment employed.

In conclusion, the carbohydrate components of the eleven tropical grain legumes under study showed small quantities of monosaccharide, and the dominant component was starch. African yam bean, lima bean and kidney bean had higher concentrations of oligosaccha-rides than other legumes investigated. The cooking methods employed brought about slight decrease in the content of the oligosaccharides, making effective processing essential to increase consumer acceptance of the legume types.

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