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Available and unavailable carbohydrates of some edible grain legumes

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ABSTRACT: The available and unavailable carbohydrate profiles of eleven legumes from different seed lines of African yam bean, bambara groundnut, kidney bean, lima bean, pigeon pea and jack bean in the raw, cooked and autoclaved forms were studied. Glucose, fructose and sucrose contents of all raw legumes varied from 0.05 to 0.22 g/100g, 0.24 – 0.90 g/100g and 1.49 – 3.25 g/100g dry matter, respectively. Raffinose ranged from 0.24 g/100g in bambara groundnut to 0.62 g/100g in African yam bean and stachyose from 0.75 g/100g in bambara groundnut to 3.00 g/100g in lima bean. Starch content was highest in the bambara groundnut and lowest in jack bean, with pigeon pea having intermediate value. Hemicellulose and cellulose contents were highest in jack bean, and lignin levels were similar in various legumes. Cooking resulted in a slight decrease in available carbohydrate levels whereas the unavailable carbohydrates were relatively unchanged by heat treatment.

Key Words: Available carbohydrates; Unavailable carbohydrates; Grain legumes; African yam bean; Bambara groundnut.

Introduction

Grain legumes are foodstuffs of great nutritional significance to people in developing countries. They are inexpensive and good sources of protein (20 – 40%), carbohydrates (50 – 60%) and various other nutrients which have beneficial effects on human health (Borget, 1992). However, legumes are not widely acceptable to the consumer and often underutilized 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 oligosaccharide raffinose, stachyose and verbescose are well known to produce flatulence or ejection of rectal gas in humans and it 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 enzyme is lacking. The intact oligosaccharides, therefore, enter the lower intestines where they are metabolised by the microflora, producing carbon dioxide, hydrogen and, to a lesser extent, methane as flatulence products (Hallendoorn, 1969; Savitri and Desikachar, 1985). 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) but also produce short-chain fatty acids in the colon from fermentation thereby causing an intensified motility of the gut, reduction in rate of food passage and minor digestive upsets (Goodlad and Mathers, 1992; Annison, 1993).

Information on the carbohydrate profile of grain legumes indigenous to the tropics are meagre. this study focussed on determining the available and unavailable carbohydrate contents of some legume seeds grown in Nigeria and the effect of cooking and autoclaving on them was also examined.

Materials and Methods

Eleven different types of grain legumes were used for the investigation. These included two varieties each of African yam bean (*Sphenostylis stenocarpa*), bambara groundnut (*Voandzeia subterranea* (L.) Thouars), kidney bean (*Phaseolus vulgaris* L.), lima beans (*Phaseolus lunatus* L.), pigeon pea (*Cajanus cajan* (L.) Millsp) and one variety of jack bean (*Canavalia ensiformis* (L) DC). the shape, colour and texture of these legume seeds have been reported (Apata and Ologhobo, 1994). They were obtained from local farm centres and the legume breeding unit of the National Cereal Research Institute, Moor Plantation, Ibadan, Nigeria. Legumes of each type was divided into three batches of 1 kg. Two such different batches were subjected to cooking and autoclaving treatments while the third batch was untreated. The procedure for both heat treatments and preparation of raw, cooked and autoclaved samples are the same as described previously (Apata and Ologhobo, 1997).

Analytical Procedure

The extraction of total ethanol soluble sugars from the legume flours was done by repeated shaking with 80% ethanol (w/v) at 60^{o}C and the extracts thus obtained were pooled. Extractions were repeated until the final extract showed a negative test for sugar. The ethanol was separated from the pooled extracts in a rotary vacuum evaporator at 40^{o}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 (Nelson, 1944). The glucoamylase method (Thivend *et al*., 1972) was used to determine starch content. Oligosaccharides were separated on Whatman No. 1 (15cm x 45cm) by descending chromatography using propanol-ethanol-water (70:10:20) and constituent sugars (raffinose and 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).

Results and Discussion

The available carbohydrate contents of the raw and processed legumes are presented in Table 1. All the raw samples contained trace amounts of glucose and fructose while sucrose is a major sugar with values ranging from 1.49 for pigeon pea Ex-Ibadan to 3.76 g/100g for bambara groundnut Oturkpo local. Reducing sugars were uniformly low in all legumes except for bambara groundnut types. Starch content was highest in bambara groundnut KAB-3 (50g/100g), followe by African yam bean sumunu Iseyin II (48.1 g/100g). Jack bean and pigeon pea contained smaller amounts of starch than that in the lima bean TPL88 and kidney bean Yara-1, but starch still constitute the dominant carbohydrate make-up for all the samples investigated. Raffinose highest concentration occurred inAfrican yam bean sumunu Iseyin I (0.81 g/100g) and lowest in bambara groundnut Oturkpo local (0.22 g/100g). Stachyose existed in highest concentrations in lima bean TPL249 (3.40 g/100g), African yam bean sumunu Iseyin I (3.20 g/100g) and kidney bean pondo-6 (3.00 g/100g) while fairly similar amounts of the tetrasaccharide were present in other legume types.

The values obtained for simple sugars and starch 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 including the cowpea, chickpea, blackgram, broad bean and *Pisum sativum* (Onogbinde and Akinyele,

Table 1. Available carbohydrate contents[a] of raw and processed legumes (g/100g dry matter)

Type of legume	Glucose	Fructose	Sucrose	Reducing Sugars	Starch	Raffinose	Stachyose
Raw							
African yam bean, Sumunu-Iseyin I	0.14	0.31	2.60	0.57	43.9	0.73	3.20
Sumunu-Iseyin II	0.22	0.38	1.97	0.60	48.1	0.81	2.90
Bambara groundnut, KAB-3	0.13	0.90	3.02	1.13	50.0	0.27	1.00
Oturkpo local	0.09	0.84	3.76	1.29	47.8	0.22	0.75
Kidney bean, Pondo-6	0.08	0.47	1.66	0.79	41.5	0.56	3.00
Yara-1	0.05	0.64	2.07	0.88	45.0	0.63	2.48
Lima bean, TPL 88	0.07	0.75	1.58	0.81	47.6	0.71	2.95
TPL 249	0.09	0.56	1.49	0.76	43.8	0.60	3.40
Pigeon pea, Ex-Ibadan	0.12	0.40	2.01	0.52	42.7	0.50	2.83
Tuc 5537-1	0.09	0.29	2.25	0.46	44.4	0.44	2.07
Jack bean	0.10	0.24	2.20	0.38	35.4	0.58	2.26
Mean	0.11	0.53	0.56	0.74	44.6	0.55	2.44
Standard deviation	0.04	0.22		0.28	4.0	0.18	0.87
Cooked			1.84				
African yam bean, Sumunu-Iseyin I	0.10	0.23	1.30	0.45	42.1	0.64	2.86
Sumunu-Iseyin II	0.19	0.29	2.52	0.42	47.9	0.79	2.10
Bambara groundnut, KAB-3	0.09	0.72	2.87	0.91	48.1	0.26	0.90
Oturkpo local	0.09	0.61	1.42	1.10	45.6	0.23	0.80
Kidney bean, Pondo-6	0.04	0.30	1.74	0.62	40.0	0.53	2.97
Yara-1	0.03	0.49	1.48	0.65	41.2	0.61	2.60
Lima bean, TPL 88	0.04	0.53	1.19	0.63	42.8	0.68	2.94
TPL 249	0.05	0.37	1.21	0.52	40.3	0.61	3.30
Pigeon pea, Ex-Ibadan	0.09	0.21	1.69	0.39	39.5	0.45	2.81
Tuc 5537-1	0.04	0.18	1.82	0.30	41.7	0.40	1.97
Jack bean	0.07	0.08	1.73	0.23	32.8	0.51	1.83
Mean	0.07	0.36	0.53	0.56	42.1	0.52	2.28
Standard deviation	0.04	0.19		0.25	3.73	0.15	0.80
Autoclaved							
African yam bean, Sumunu-Iseyin I	0.12	0.30	1.98	0.51	43.2	0.76	3.30
Sumunu-Iseyin II	0.23	0.34	1.49	0.57	47.8	0.78	2.90
Bambara groundnut, KAB-3	0.11	0.74	2.71	1.06	49.7	0.24	0.85
Oturkpo local	0.07	0.74	3.10	1.21	47.4	0.30	0.67
Kidney bean, Pondo-6	0.06	0.39	1.78	0.73	40.6	0.62	3.10
Yara-1	0.05	0.55	2.00	0.84	43.8	0.59	2.50
Lima bean, TPL 88	0.05	0.68	1.53	0.80	45.1	0.75	2.57
TPL 249	0.08	0.45	1.37	0.74	41.2	0.56	3.29
Pigeon pea, Ex-Ibadan	0.14	0.28	1.60	0.55	41.9	0.49	2.90
TUc 5537-1	0.07	0.20	1.83	0.43	43.8	0.46	1.89
Jack bean	0.09	0.19	2.14	0.38	34.6	0.60	2.23
Mean	0.09	0.44	1.96	0.71	43.1	0.56	2.40
Standard deviation	0.05	0.21	0.51	0.26	4.1	0.18	0.91

[a] **Average of duplicate analysis**

Table 2. Available carbohydrate contents[a] of raw and processed legumes (g/100g dry matter)

Type of legume	Hemicellulose	Cellulose	Lignin
Raw			
African yam bean, Sumunu-Iseyin I	7.31	4.34	1.35
Sumunu-Iseyin II	8.94	4.12	1.74
Bambara groundnut, KAB-3	4.57	2.82	1.01
Oturkpo local	5.18	3.15	0.87
Kidney bean, Pondo-6	7.35	5.47	1.32
Yara-1	8.17	4.73	1.50
Lima bean, TPL 88	9.03	4.81	1.49
TPL 249	8.26	5.36	1.54
Pigeon pea, Ex-Ibadan	10.10	5.40	2.04
TUc 5537-1	11.31	4.87	1.36
Jack bean	14.00	9.84	3.40
Mean	8.54	4.99	1.60
Standard deviation	3.83	1.51	0.90
Cooked			
African yam bean, Sumunu-Iseyin I	6.95	3.63	1.30
Sumunu-Iseyin II	8.12	3.48	1.66
Bambara groundnut, KAB-3	4.10	2.24	0.98
Oturkpo local	4.30	2.22	0.85
Kidney bean, Pondo-6	6.50	4.67	1.30
Yara-1	7.47	4.31	1.43
Lima bean, TPL 88	8.70	4.12	1.51
TPL 249	7.14	4.86	1.50
Pigeon pea, Ex-Ibadan	11.40	5.01	1.98
TUc 5537-1	10.70	4.29	1.28
Jack bean	13.30	9.17	3.43
Mean	6.87	4.36	1.56
Standard deviation	3.74	1.25	0.62
Autoclaved			
African yam bean, Sumunu-Iseyin I	7.35	4.06	1.34
Sumunu-Iseyin II	8.60	3.88	1.68
Bambara groundnut, KAB-3	4.35	2.76	1.03
Oturkpo local	5.04	2.89	0.89
Kidney bean, Pondo-6	6.72	5.18	1.34
Yara-1	7.90	4.49	1.47
Lima bean, TPL 88	9.12	4.38	1.38
TPL 249	8.10	5.07	1.51
Pigeon pea, Ex-Ibadan	10.20	5.19	2.00
TUc 5537-1	11.08	4.61	1.32
Jack bean	13.85	9.46	3.48
Mean	8.38	4.72	1.59
Standard deviation	2.79	1.05	0.87

[a] **Average of duplicate analysis**

1983; Jood *et al*., 1985; Canibel *et al*., 1997) but differed appreciably from soybean, particularly in sucrose and starch where contents are 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/100g (Tharanathan *et al*., 1979).

In the present study, substantial amounts of starch were found in all samples. This observation underscores the utilisation of these leguminous seeds as source of energy by man and monogastric animals. Oligosaccharide sugar contents were higher in lima bean TPL 249, African yam bean sumunu Iseyin I and kidney bean pondo-6 than other legumes under study. These high levels are likely indications of the roles these legume types might play in flatulence production. It has been shown that an average consumption of 500g of lima beans containing 620 mg raffinose/100g would produce 186 ml flatus volume which is enough to cause discomfort in humans (Dibofori *et al*., 1994). Bambara groundnuts, on the other hand, exhibited low quantities of raffinose and stachyose which suggests that lesser flatus production potential of this legume type relative to others investigated, and also it could make bambara groundnut more acceptable.

The level of available carbohydrate components in all the autoclaved samples were similar to values obtained for raw samples while cooked samples had slightly decreased values possibly due to the loss of water soluble sugars during the cooking process. Studies on other modes of processing which tend to be effective for removing oligosaccharides from the legumes are in progress.

Data obtained for unavailable carbohydrates are shown in Table 2. Among the raw samples, jack bean had the highest hemicellulose concentration of 14.00 g/100g, followed by pigeon pea TUc5537-1 (11.31g/100g), while the lowest was in bambara groundnut KAB-3 (4.37g/100g). Jack bean also contained higher cellulose (9.84 g/100g) than the other legume types where values were in the range of 2.82 – 5.40 g/100g. However, lignin levels were fairly uniform with values within the small range 1.60 ± 0.90g/100g. As in common tropical legumes such as blackgram, cowpea and green gram (Kamath and Belavady, 1980), the unavailable carbohydrate constituents in the samples studied were low except in jack bean, indicating that the digestibility of associated nutrients in the latter by monogastric digestive systems is likely to be comparatively lower than in other legumes. Cooking or autoclaving did not effect any appreciable changes in the contents of hemicellulose, cellulose and lignin, a finding also observed in the study of processed groundnut meal (Tharanathan *et al*., 1979). Thus, the cell wall constituents have unique stability property when subjected to heat treatment.

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