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Effect of processing on available carbohydrate content and starch digestibility of kidney beans (*Phaseolus vulgaris* L.)

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Abstract

The effects of different soaking and cooking methods were investigated on available carbohydrate content and starch digestibility of red and white kidney beans. Total soluble sugars, reducing sugars, non-reducing sugars and starch contents of red and white kidney beans were 9.95 and 11.3%, 0.82 and 0.96%, 9.13 and 10.3%, and 44.4 and 47.8%, respectively. All these available carbohydrate components decreased to various extents as a result of soaking and cooking. From 2.51 to 13.6% and 7.03 to 28.0% of total soluble sugars were lost on soaking kidney beans in tap water and sodium bicarbonate solution, respectively. However, losses in total soluble sugars were maximum (19.9–60.9%) on cooking pre-soaked kidney beans. Losses in starch contents were 4.27 to 24.7% and 30.4 to 70.7% as a result of the soaking and cooking processes, respectively. Besides these losses, starch digestibility of kidney beans was also markedly improved as a result of cooking. However, no appreciable improvement in starch digestibility was observed after soaking kidney beans in water or alkaline solution.

Keywords: Kidney beans; Soaking; Cooking; Available carbohydrates; Starch digestibility

1. Introduction

Beans (*Phaseolus vulgaris* L.), widely grown and consumed throughout the world, are excellent sources of proteins (20–25%) and carbohydrates (50–60%) and fairly good sources of minerals and vitamins (Aykroyd & Doughty, 1977). However, their wide acceptability is adversely affected by the presence of tannins, saponins and other anti-nutritional substances (Hentges, Weaver & Nielson, 1991; Morrow, 1991; Stanley, 1992). Therefore, many attempts have been made to reduce the levels of the antinutritional substances and improve the nutritive value. Soaking of beans before cooking is a common practice to soften texture and hasten the cooking process. Soaking has also been suggested for reducing antinutritional substances and improving cooking quality (De-Leon, Elias & Bressani, 1992; Wah, Sharma & Jackson, 1997). Germination and cooking are known to improve the nutritional quality and protein digestibility of beans (Khokhar & Chauhan, 1986; Rehman & Shah, 1996). On the other hand, most of the macro and micro nutrients, particularly vitamins and minerals, are lost during these soaking and cooking processes (Addy, Salami, Ibocli & Remawa, 1995; Rincon, Ros & Collins, 1993). Losses in protein contents have also been ascribed to different processing treatments of beans (Phirke, Chavan, Jadha & Salunkhe, 1982). However, very little information is available about the losses of available carbohydrates and improvement in starch digestibility after soaking and cooking. Therefore, the present work was undertaken to study the effect of different soaking and cooking methods on the losses of available carbohydrates in red and white kidney beans. Digestibility of starch was also studied after soaking and cooking of kidney beans.

2. Materials and methods

Red and white kidney beans were obtained from Ayub Agricultural Research Institute, Resalewala, Faisalabad, Pakistan. The beans were cleaned to remove broken seeds, dust and other foreign materials and then subjected to soaking treatments prior to cooking.

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2.1. Soaking treatments

Fifty gram samples of kidney beans were soaked in 250 ml of tap water and sodium bicarbonate solution (1% w/v), separately at 30° and 100°C for 1–2 h. The soaking solution was drained off, rinsed twice with distilled water and then dried in a hot air oven (Horizontal Forced Air Drier, Proctor and Schwartz Inc. Philadelphia, PA) at 55°C for 24 h.

2.2. Cooking treatments

Pre-soaked kidney beans were cooked by ordinary cooking and pressure cooking methods. Details of each cooking method are given below.

2.2.1. Ordinary cooking (without pressure cooker)

Pre-soaked kidney beans were put in a round-bottom flask fitted with a condenser. Tap water (5 ml/g) was added and the samples were cooked on a hot plate until they became soft. After cooking, excess water was drained off, and the sample was dried in a hot air oven at 55°C for 24 h.

2.2.2. Pressure cooking

Pre-soaked kidney beans were placed in 1-l beakers containing tap water (5 ml/g). Tops of the beakers were covered with aluminium foil. After cooking in a pressure cooker at 15 lbs/inch^2 for 15 min, excess water was drained off and the sample was dried in a hot air oven at 55°C for 24 h. Raw and processed kidney beans were ground in a Wiley mill to pass through a 40-mesh sieve.

2.3. Chemical analysis

The total water-soluble sugars were extracted according to the method of Cerning and Guilbot (1973). Starch was extracted from the sugar-free pellet by the method of Clegg (1956). Quantitative determinations of total soluble sugars and starch were carried out according to the method of Yemm and Willis (1954). Reducing sugars were estimated by Somogyi's modified method (Somogyi, 1945), and non-reducing sugars were estimated by calculating the difference between total soluble sugars and reducing sugars. Starch digestibility in vitro was determined after digestion with pancreatic α amylase in 0.1 M phosphate buffer at 37°C for 2 h (Costas, 1982). All determinations were carried out in triplicate and standard deviations (S.D.) were calculated according to the method of Steel and Torrie (1980). Duncan's multiple range test was used to determine significant differences ($P<0.05$).

3. Results and discussion

Table 1 summarizes the available carbohydrate contents of raw and soaked kidney beans. Total soluble sugars, reducing sugars, non-reducing sugars and starch contents in red and white kidney beans were 9.95 and 11.3%, 0.82 and 0.96%, 9.13 and 10.3% and 44.4 and 47.8%, respectively. Table 1 shows that the soaking of red and white kidney beans decreased the quantity of available carbohydrates, i.e. total soluble sugars, reducing sugars, and non-reducing sugars. When the soaking temperatures and times were increased, the extent of decrease in all these carbohydrates became more pronounced. In sodium bicarbonate soaking solution, the extent of loss was significantly ($P<0.05$) higher than that observed when kidney beans were soaked in tap water. Raw unsoaked red and white kidney beans contained 9.95 and 11.3% total soluble sugars, respectively. The values of total soluble sugars in red and white kidney beans became 8.70 and 9.75% due to water soaking, whereas these values were found to be 7.25 and 8.13% on soaking in sodium bicarbonate solution (1% w/v). However, starch contents in red and white kidney beans became 44.4–39.50% and 47.8–38.8%, respectively as a result of water-soaking. Also, the amounts of starch in red and white kidney beans were 37.0 and 36.0%, respectively, after soaking in sodium bicarbonate solution. Therefore, on the basis of these results (Table 1), it is concluded that the water-soaking process reduced total soluble sugars and starch contents from 2.51–13.6% and 4.27–19.0%, respectively, whereas 7.03–28.0% of total soluble sugars and 7.67–24.7% of starch were lost from the kidney beans after soaking in sodium bicarbonate solution. In fact, reduction in the levels of available carbohydrates with these treatments occurred mainly because of their solubility in water, and sodium bicarbonate solution as has already been observed by earlier workers in other dry beans (Silva & Braga, 1982; Sudesh, Usha & Tandhir, 1986). Generally, legume starch is composed of soluble and insoluble portions and, on soaking, the soluble portion is extracted and consequently causes significant reduction in starch contents.

Available carbohydrate contents of red and white kidney beans were further decreased as a result of cooking (Table 2). Total soluble sugars and starch contents were 5.77 and 28.5% for red kidney bean and 6.63 and 29.0% for white kidney beans on cooking the water-presoaked kidney bean by an ordinary method. These values became 5.08 and 23.2% for red kidney beans, 6.16 and 23.0% for white kidney beans after cooking in a pressure cooker. On cooking alkali-soaked kidney beans by an ordinary method, total soluble sugars and starch contents were 4.94 and 18.0% for red kidney beans and 5.61 and 19.0% for white kidney beans. After cooking alkali-soaked kidney beans in a pressure cooker, total soluble sugars and starch contents were found to be 3.89 and 15.0% for red kidney beans, whereas 5.16% total soluble sugars and 14.0% starch were present in white kidney beans. In fact, the ordinary cooking method caused a reduction in total

Table 1
Effect of soaking on available carbohydrate contents (%) of kidney beans[a]

Soaking conditions			Red kidney beans				White kidney beans			
Soaking solution	Temperature (°C)	Time (h)	Reducing sugars	Non-reducing sugars	Total soluble sugars	Starch	Reducing sugars	Non-reducing sugars	Total soluble sugars	Starch
Raw	–	–	0.82a±0.06	9.13a±0.36	9.95a±0.61	44.4a±3.6	0.96a±0.05	10.3a±0.39	11.3a±0.50	47.8a±1.87
Tap water	30	1	0.70a±0.05	9.00a±0.39	9.70a±0.50	42.5a±2.44	0.84a±0.06	9.90a±0.29	10.7a±0.60	44.8a±1.29
	30	2	0.59b±0.07	8.88a±0.40	9.47a±0.56	41.7b±2.05	0.76b±0.04	9.68a±0.28	10.4a±0.60	43.0a±1.36
	100	1	0.55b±0.06	8.65a±0.35	9.20a±0.47	41.0b±3.00	0.70b±0.05	9.52a±0.18	10.2a±0.57	40.0b±1.45
	100	2	0.40c±0.08	8.30b±0.29	8.70b±0.41	39.5c±3.2	0.50c±0.03	9.25b±0.27	9.75b±0.60	38.7b±1.60
Sodium bicarbonate solution	30	1	0.55b±0.09	8.70a±0.28	9.25a±0.50	41.0b±2.69	0.60c±0.06	9.60a±0.30	10.2a±0.50	43.0a±1.60
	30	2	0.45c±0.05	8.10b±0.45	8.55b±0.52	39.3c±2.00	0.55c±0.07	8.50b±0.37	9.05b±0.58	41.5a±1.40
	100	1	0.40c±0.05	7.25b±0.49	7.65b±0.53	40.3b±2.37	0.45d±0.05	8.00b±0.33	8.45c±0.63	40.0b±1.45
	100	2	0.35c±0.04	6.90c±0.63	7.25c±0.64	37.0c±2.39	0.38d±0.05	7.75c±0.40	8.13c±0.55	36.0c±1.37

[a] Mean values±S.D. Triplicate determinations. Mean values within a column with different letters are significantly different at $P<0.05$.

Table 2
Effect of cooking on available carbohydrates contents (%) of soaked kidney beans[a]

Soaking conditions			Red kidney beans				White kidney beans			
Soaking solution	Temperature (°C)	Time (h)	Reducing sugars	Non reducing sugars	Total soluble sugars	Starch	Reducing sugars	Non-reducing sugars	Total soluble sugars	Starch
Raw (Uncooked)			0.82a±0.06	9.13a±0.36	9.95a±0.61	44.4a±3.6	0.96a±0.05	10.4a±0.39	11.3a±0.50	47.8a±1.87
Soaking and ordinary cooking										
Tap water	30	2	0.33b±0.01	6.75b±0.25	7.08b±0.36	30.9b±1.26	0.47b±0.06	7.80b±0.36	8.27b±0.41	31.8b±1.27
	100	2	0.27b±0.03	5.50b±0.30	5.77b±0.40	28.5b±1.30	0.38b±0.04	6.25b±0.27	6.63b±0.40	29.0b±1.30
Sodium bicarbonate solution	30	2	0.25b±0.03	5.80b±0.41	6.05b±0.40	22.1c±1.72	0.40b±0.02	6.60b±0.22	7.00c±0.29	23.2c±1.69
	100	2	0.19c±0.02	4.75c±0.29	4.94c±0.35	18.0d±1.37	0.31c±0.02	5.30c±0.40	5.61b±0.36	19.0c±1.20
Soaking and pressure cooking										
Tap water	30	2	0.27b±0.02	5.70b±0.33	5.97b±0.37	26.7b±1.29	0.35b±0.03	6.60b±0.39	6.95b±0.33	24.4b±1.30
	100	2	0.18c±0.03	4.90b±0.30	5.08c±0.30	23.2c±1.44	0.26c±0.01	5.90b±0.33	6.16b±0.36	23.0b±1.33
Sodium bicarbonate solution	30	2	0.20b±0.03	4.00c±0.27	4.20d±0.40	18.9d±1.50	0.30c±0.02	5.80b±0.37	6.10b±0.37	18.0c±1.20
	100	2	0.14c±0.04	3.75c±0.24	3.89d±0.42	15.0d±1.36	0.21d±0.01	4.95c±0.29	5.16c±0.40	14.0c±1.21

[a] Mean values±S.D. Triplicate determinations. Mean values within a column with different letters are significantly different at $P<0.05$.

Table 3
Effect of soaking and cooking on starch digestibility (%) of kidney beans[a]

Soaking conditions			Red kidney beans			White kidney beans		
Soaking solution	Temperature (°C)	Time (h)	Without cooking	Ordinary cooking	Pressure cooking	Without cooking	Ordinary cooking	Pressure cooking
Raw	–	–	38.0a±2.35	50.7b±1.61	55.8b±3.00	39.6a±1.61	52.0b±2.00	56.7b±2.89
Tap water	30	2	40.7a±2.49	63.2b±2.72	66.0b±3.09	40.0a±2.71	64.0b±2.11	68.4c±2.67
	100	2	41.2a±2.20	66.0b±2.80	68.1b±2.89	40.8a±2.80	67.3b±2.12	69.5c±2.47
Sodium bicarbonate solution	30	2	41.8a±2.40	65.4b±2.41	72.8c±2.90	40.9a±2.81	66.8b±2.67	74.0c±2.40
	100	2	42.3a±2.30	69.7b±2.40	80.0c±2.99	43.0a±2.80	71.9b±2.02	81.3c±2.08

[a] Mean values±S.D. Triplicate determinations. Mean values within a row with different letters are significantly different at $P<0.05$.

soluble sugars of 19.9–50.4% and, in starch contents of 30.4–60.3%. On the other hand, 37.3–60.9% of total soluble sugars and 40.0–70.7% of starch were lost from kidney beans due to pressure cooking. It is evident from these findings that when soaking in water or sodium bicarbonate solution was combined with cooking, the extent of losses of available carbohydrates from these beans was significantly ($P<0.05$) higher than after a simple soaking treatment. This is understandable, again because, in boiling water during cooking, the solubility of sugars will be much higher than at room temperature. Contrary to these observations, Rao and Belavady (1978) reported that cooking brought about a significant increase in soluble sugars. This could be explained by the fact that the cooking water was not discarded in that study whereas both soaking and cooking water were rejected and beans alone were analyzed for various carbohydrates during the present study.

Besides losses in available carbohydrates, starch digestibility was affected significantly ($P<0.05$) on cooking, whereas it remained almost unchanged after soaking in water or sodium bicarbonate solution (Table 3). Initially, starch digestibility of uncooked red kidney beans was 38.0% which became 55.8% after cooking in a pressure cooker. Maximum increase in starch digestibility was found to be 111% (38.0–80.0%) on cooking water-soaked kidney beans in a pressure cooker, whereas the increase was 79.0% (38.0–68.1%) after cooking beans by the ordinary method. Similar observations were also made on cooking white kidney beans. Better improvement in starch digestibility after pressure cooking could be attributed due to hydrolysis of starch under the drastic conditions of heating under pressure. However, no appreciable difference in digestibility of starch was observed when water- or alkali-soaked kidney beans were cooked by either cooking method. These results are in agreement with those obtained by Mbofung, Rigby and Waldron (1999) who reported distinct improvement in starch digestibility of cowpeas after cooking. In this study, uncooked kidney beans were markedly resistant to pancreatic amylase attack but cooking led to a dramatic increase in susceptibility to digestion by this enzyme. In fact, cooking improves the digestibility of starch through gelatinization and destruction of anti-nutrients (Yu - Hui, 1991).

4. Conclusion

Different soaking and cooking methods extracted nutrients, including available carbohydrates, from kidney beans to various extents. Soaking temperature and time affected the extraction of available carbohydrates. Sodium bicarbonate solution extracted about twice as much carbohydrates as did water. Similarly, pressure cooking extracted comparatively more carbohydrates from kidney beans than the ordinary cooking method. Therefore, the soaking and cooking liquors of beans may be used for soup and dessert preparations, due to their contents of different nutrients, particularly available carbohydrates.

References

Addy, E. O. H., Salami, L. I., Ibocli, L. C., & Remawa, H. S. (1995). Effect of processing on nutrient composition and anti-nutrientive substances of African locust bean and baobale seed. *Plant Foods Hum. Nutri., 48*(2), 113–117.

Aykroyd, W. R., & Doughty, T. (1977). *Legumes in human nutrition.* Italy: Food and Agriculture Organization of the United Nations.

Cerning, J., & Guilbot, J. (1973). Specific method for the determination of pentosans in cereals and cereal products. *Cereal Chemistry, 50*(2), 176–184.

Clegg, K. M. (1956). The application of the anthrone reagent to the estimation of starch in cereals. *Journal of the Science of Food and Agriculture, 7*, 40–44.

Costas, G. B. (1982). Physical characteristics, enzymatic digestibility and structure of chemically modified smooth pea and waxy maize starches. *J. Agri. Food Chem., 30*, 925–930.

De-Leon, L. F., Elias, L. G., & Bressani, R. (1992). Effect of salt solutions on the cooking time, nutritional and sensory characteristics of common beans. *Food Research International, 25*, 131–136.

Hentges, D. L., Weaver, C. M., & Nielson, S. S. (1991). Changes of physical and chemical components in the development of the hard-to-cook defect. *Journal of Food Science, 56*, 436–442.

Khokhar, S., & Chauhan, B. M. (1986). Anti-nutritional factors in moth bean. Varietal differences and effects of methods of domestic processing and cooking. *Journal of Food Science, 51*, 591–594.

Mbofung, C. M. F., Rigby, N., & Waldron (1999). Use of two varieties and hard-to-cook beans (*Phaseolus vulgaris*) in the processing of koki (a steamed legume product). *Plant Food Hum. Nutri., 54*, 131–150.

Morrow, B. (1991). The rebirth of legumes. *Food Tech., 45*, 96–121.

Phirke, A. V., Chavan, J. K., Jadha, S. J., & Salunkhe (1982). Physical properties, chemical composition, cookability and solubilization of proteins of dry beans (*Phaseolus vulgaris* L.). *J. Legumes Res., 5*(2), 91–96.

Rao, P. U., & Belavady, B. (1978). Oligosaccharides in pulses; varietal differences and effects of cooking and germination. *J. Agric. Food Chem., 26*, 316–319.

Rehman, Z. U., & Shah, W. H. (1996). Effects of soaking and cooking on physical characteristics, tannins contents and protein digestibility of kidney beans. *Pak. J. Sci. Ind. Res., 39*, 195–199.

Rincon, F., Ros, G., & Collins, J. L. (1993). Mineral loss in cowpeas (*Vigna unguiculate* L.) by pressure heating in water. *Journal of Food Science, 58*, 856–859.

Silva, H. C., & Braga, G. L. (1982). Effect of soaking and cooking on the oligosaccharide content of dry beans (*Phaseolus vulgaris* L.). *Journal of Food Science, 47*, 924–925.

Somogyi, M. (1945). A new reagent for the determination of sugars. *Journal of Biological Chemistry, 160*, 61–68.

Stanley, D. M. (1992). Hard beans. A problem for growers, processors and consumers. *Hort. Technol., 2*, 370–378.

Steel, R. G. D., & Torrie, J. H. (1980). *Principles and procedures of slatistics*. London: McGraw Hill.

Sudesh, J., Usha, M., & Randhir, S. (1986). Effect of processing on available carbohydrates in legumes. *J. Agric. Food Chem., 34*, 417–420.

Wah, C. S., Sharma, K., & Jackson, M. G. (1997). Studies on various chemical treatments of seed meal to improve or inactivate tannins. *Ind. Anim. Sci., 47*, 8–11.

Yemm, E. W., & Willis, A. J. (1954). The estimation of carbohydrates in plant extracts by anthrone. *Biochemical Journal, 57*, 508–514.

Yu - Hui, T. (1991). Effect of the hard-to-cook defect and processing on protein and starch digestibility of cowpeas. *Cereal Chemistry, 68*(4), 413–418.