ELSEVIER

Food Chemistry 80 (2003) 231–235

Food Chemistry

www.elsevier.com/locate/foodchem

Dietary fibre content of dry and processed beans

Tatjana Kutoš, Terezija Golob*, Milica Kač, Anamarija Plestenjak

Department of Food Science and Technology, Biotechnical Faculty, University of Ljubljana, 1111 Ljubljana, Jamnikarjeva 101, Slovenia

Received 8 January 2002; accepted 31 May 2002

Abstract

Common beans (*Phaseolus vulgaris* L.) are a good source of protein, vitamins, minerals and especially dietary fibre. As beans are never eaten raw, the effects of soaking, cooking, soaking–cooking and canning on soluble, insoluble and total dietary fibre contents of beans are studied. Total dietary fibre content was determined by enzyme-gravimetric method. The fraction of insoluble dietary fibre was corrected for the content of resistant starch, determined as part of the total starch in insoluble fibre. The results indicate that thermal processing decreased the insoluble fibre content, and consequently the total dietary fibre content of beans. Soaking and cooking of beans significantly ($P \leqslant 0.05$) increased the resistant starch content. The data on dietary fibre content of processed food are much more relevant than those of raw food. Thus food composition tables should contain as much data on processed food as possible.

Keywords: Beans; Dietary fibre; Processing; Resistant starch

1. Introduction

Common beans (*Phaseolus vulgaris* L.), grain legumes belonging to the family *Fabaceae* (*Leguminosae*), are used by humans world-wide. They are an important source of protein (16–33%), vitamins (thiamine, riboflavin, niacin, vitamin B_6, folic acid), dietray fibre (14–19%), especially soluble dietary fibre, minerals (Ca, Fe, Cu, Zn, P, K, Mg), and free unsaturated fatty acids. They contain very little sodium, and no cholesterol (Reyes-Moreno & Paredes-López, 1993).

Recent studies indicate that dietary fibre may be protective against cardiovascular diseases, diabetes, obesity, colon cancer, and other diverticular diseases (Lee, Prosky, & DeVries, 1992). The current physiological definition of dietary fibre [the remnants of plant cells resistant to digestion by the alimentary enzymes of the human (Prosky & DeVries, 1991)] has been extended to include all the polysaccharides in the diet that are resistant to endogenous secretions of the human digestive tract. Accordingly, the term dietary fibre refers to nonstarch polysaccharides, resistant starch and lignin (Lee et al., 1992). Since each dietary fibre component exerts a different physiological effect, it is important to obtain data on both the total dietary fibre content and its profile (Vidal-Valverde, Fries, & Esteban, 1992). As recommended by Prosky, Asp, Schweizer, DeVries, and Furda, (1988), the daily intake of total dietary fibre should be 20–35 g with approximately one third of that as soluble dietary fibre.

Dietary fibre is determined gravimetrically as total dietary fibre (TDF) after hydrolytic degradation of foods. TDF consists of soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) and its importance in nutrition has been widely studied (Prosky & DeVries, 1991; Robertfroid, 1993). Asp, Johansson, Hallmer, and Siljeström (1983) reported that, in addition to the soluble and insoluble fractions, partly-soluble fractions also exist. Data on SDF and IDF contents of common beans vary, depending on the analytical method applied and on the previous treatments of the beans, SDF content being more sensitive to these changes (Aman & Westerlund, 1996). According to Mongeau and Brassard (1995), the method for TDF determination of Prosky et al. (1988) gives high values. They suggest that the 1DF value may contain, also some starch which can be resistant (resistant starch—RS) and/or residual. Residual starch can be used by the human organism as a source of energy, while resistant starch is non-digestible.

* Corresponding author. Tel.: +386-61-4231161; fax: +386-61-2566296.

E-mail address: terezija.golob@bf.uni-1j.si (T. Golob).

0308-8146/02/$ - see front matter
PII: S0308-8146(02)00258-3

Beans are never eaten raw and are processed before consumption. Processing can change dietary fibre content, especially its composition and its physico chemical properties. These may have different physiological influences on the organism (Asp, 1986; Carnovale & Lintas, 1995). Most investigations on dietary fibre content were performed on raw beans and only a few on processed beans. The objective of this work was to determine and compare SDF, IDF and TDF in raw, soaked and cooked beans, before and after the correction for the RS portion.

2. Materials and methods

2.1. Bean samples analyzed—preparation and processing of beans

Grains of brown beans of the Pinto variety, imported from China in the year of harvesting were processed and analyzed during the following year. Prior to treatment, beans were stored in a dry and cool place (under standard conditions in a vegetable processing plant). Seeds that were too small, molded, mechanically damaged or wrinkled, were excluded.

Beans were prepared in six different ways; additionally canned beans of the same variety were analyzed for comparison. The details of sample preparation are given below.

2.1.1. Raw dry beans (RB)

Raw dry beans (RB) refers to beans as such, the samples were ground for 3 min in a coffee mill and stored in polyethylene bags at room temperature prior to analyses.

2.1.2. Soaked beans (SB)

Soaked beans (*SB*) refers to beans soaked in tap water overnight at room temperature (300 ml of tap water were added to 100 g of bean seeds; soaking took place for 18 h at 20 °C); the soaked seeds were drained, dried on a paper towel, lyophilized, ground for 3 min in a coffee mill and stored in polyethylene bags at room temperature prior to analyses.

2.1.3. Soaked-S beans (SSB)

Soaked-S beans (SSB) refers to beans soaked overnight in a solution of baking soda in tap water at room temperature, (300 ml of tap water containing 5.0 g of baking soda were added to 100 g of bean seeds, soaking took place for 18 h at 20 °C), the soaked seeds were drained, and then treated in the same way as SB.

2.1.4. Cooked soaked beans (CSB)

Cooked soaked beans (CSB) refers to beans soaked in tap water overnight at room temperature (300 ml of tap water were added to 100 g of bean seeds, soaking took place 18 h at 20 °C) then drained and dried on a paper towel and consequently cooked in fresh tap water (volume ratio beans to water being 1–6) boiling in a covered pot (98–100 °C) until they became suitable for consumption (approx. 40 min). Cooked seeds were drained, and treated in the same way as SB.

2.1.5. Cooked soaked-S beans (CSSB)

Cooked soaked-S beans (CSSB) refers to beans soaked in a solution of baking soda in tap water overnight at room temperature (300 ml of tap water containing 5.0 g of baking soda were added to 100 g of bean seeds and soaked for 18 h at 20 °C) then drained and dried on a paper towel and consequently cooked in fresh tap water (volume ratio beans to water being 1–6) boiling in a covered pot (98–100 °C) until they became suitable for consumption (approx. 40 min). Cooked seeds were drained, and treated in the same way as SB.

2.1.6. Cooked nonsoaked beans (CNSB)

Cooked nonsoaked beans (CNSB) refers to nonsoaked beans directly cooked in boiling water until they became suitable to consumption. Nonsoaked beans (50 g) were cooked in 400 ml of tap water boiling in a covered pot (98–100 °C) until they became suitable for consumption (approx. 2 h). Cooked seeds were drained, and treated in the same way as SB;

2.1.7. Canned beans

Canned beans (CnB) refers to beans directly from a commercial can, which have been drained, and treated in the same way as SB. .

2.2. Chemical assessment of parameters

Beside water content' (which is indispensible for evaluation of results) the following categories of dietary fibre have been determined: insoluble dietary fibre content (IDF) (which was additionally modified for the resistant starch (RS) in it) and soluble dietary fibre content (SDF). The sum of soluble and insoluble dietary fibre fractions (IDF + SDF) is referred to as total dietary fibre content (TDF).

Water content was determined according to AOAC (1999) by drying the samples to constant weight at 95–100 °C.

Dietary fibre content (DF) was determined by an enzyme-gravimetric method according to Prosky et al. (1988). The method gives the sum of insoluble (IDF) and soluble dietary fibre (SDF) contents. The fraction of insoluble dietary fibre (IDF) has been corrected for the content of resistant starch (RS) which has been determined as the part of total starch in insoluble dietary fibre (IDF) as proposed by Champ (1992). The suitability of the methods has been extensively reviewed by Asp (1995).

Table 1
Water, soluble dietary fibre (SDF), insoluble dietary fibre (IDF), total dietary fibre (TDF), resistant starch (RS), corrected IDF and corrected TDF in raw and processed beans (g/100 g dry matter except for water which is g/100 g as is)

Samples	Water[a]	SDF[b]	IDF[b]	TDF[b]	RS[a]	Corrected IDF[b,c]	Corrected TDF[c,d]
RB	11.3±0.7	3.5±2.0	19.8±1.4	23.3±1.5	9.1±2.6	10.7±3,0	14.2±3.2
Processed samples							
SB	57.5±0.6	4.9±1.1	15.2±1.8	20.1±1.9	3.1±1.2	12.1±2.3	17.0±2.7
SSB	57.1±1.0	6.0±1.1	13.8±2.0	19.8±1.7	2.9±0.9	10.9±1.9	16.9±1.8
CSB	63.1±0.6	4.7±3.4	17.5±1.9	22.2±2.4	5.7±1.2	11.8±1.6	16.5±2.9
CSSB	66.0±3.9	2.7±1.8	18.2±1.3	20.9±2.0	7.4±1.6	10.8±2.1	13.5±2.6
CNSB	60.5±1,1	5.9±2.5	16.7±2.3	22.6±2.9	5.4±1.5	11.3±2.7	17.2±2.9
CnB	73.9±0.8	2.3±0.9	17.2±1.7	19.5±2.2	7.8±2.1	9.4±1.6	11.7±1.6
Analysis of variance							
Processing among all samples	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$
Processing among processed samples	$P \leqslant 0.01$	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$	$P \leqslant 0.001$

SB, soaked beans; SSB, soaked-S beans; CSB, cooked soaked beans; CSSB, cooked soaked-S beans; CNSB, cooked nonsoaked beans; CnB, canned beans.

[a] Mean±S.D. for six repetitions in two determinations.

[b] Mean±S.D. for six repetitions in four determinations.

[c] Corrected IDF = IDF −RS.

[d] Corrected TDF = SDF + IDF −RS.

2.3. Statistical analysis

The data were statistically analyzed using the GLM procedure in the SAS statistical program (SAS, 1990). The following model was used:

$$Y_{ijk} = \mu + S_i + R_j + D_k + e_{ijk}$$

Y_{ijk} = observation, μ = general mean, S_i = effect of samples (i = 1,2,3,4,5,6,7), R_j = effect of repetitions (j = 1,2,3,4,5,6), D_k = effect of determinations (k = 1,2,3,4), e_{ijk} = residual random term with variance $\sigma^2_{enf>}$.

Least square means for experimental groups were obtained using the LSM procedure (SAS, 1990) and were compared at the 5% probability level.

3. Results and discussion

Water, SDF, IDF, TDF, RS, and corrected IDF and TDF in raw beans and in six samples of processed beans are presented in Table 1. Processing of beans significantly affected ($P \leqslant 0.001$) all the parameters analyzed, except water content ($P \leqslant 0.01$). These results confirmed previous findings by different authors (Aman & Westerlund, 1996; Almazan & Zhou, 1995; Asp, 1995; Prosky et al., 1988).

Raw beans contained 11.3 g water in 100 g. The water content changed significantly due to soaking and cooking (Table 1). Most water was absorbed during soaking (46.2 g/100 g for SB and 45.8 g/100 g for SSB). Additional absorption took place during cooking (5.6 g/100 g for CSB and 8.9 g/100 g for CSSB). Compared to nonsoaked beans (49.2 g of water per 100 g of sample), both soaked cooked beans samples absorbed significantly more water (51.8 and 54.7 g/100 g). The water content was the highest in canned beans (73.9 g/100 g). Generally, final water content of beans was significantly affected by processing and treatment ($P \leqslant 0.01$).

Table 1 also indicates that soaking of the beans increased the SDF content. The highest value of SDF was determined in SSB (6.0 g/100 g). Cooking of soaked beans decreased the SDF, the same being true for canning. The lowest content of SDF was determined in CnB (2.3 g/100 g) and CSSB (2.7 g/100 g). Both differed significantly ($P \leqslant 0.05$) from all other samples as is evident from Table 2.

IDF content of the beans decreased during soaking, from 19.8 g/100 g in RB to 15.2 g/100 g in SB and 13.8 g/100 g in SSB. However, the IDF content was slightly higher in cooked beans i.e. 16.7 g/100 g in CNSB and 18.2 g/100 g in CSSB. In IDF content, CSB, CNSB and CnB differed significantly ($P \leqslant 0.05$) from other samples (Table 2).

Similar observations are true for the TDF content. The highest value of TDF was determined in RB (23.3 g/100 g), while all processed beans contained less TDF from 19.5 g/100 g in CnB to 22.6 g/l00 g in CNSB). It is evident from Table 2 that both soaked samples and CnB differed from CSSB and also from CSB and CNSB.

The RS content was the highest for RB (9.1 g/100 g), which may account for its high IDF content. It is probable that the major part of RS is the inaccessible starch in the cells which suffered no damage during the grinding of beans. Soaking decreased the RS content to 3.1 g/100 g in SB and to 2.9 g/100 g in SSB, but cooking

Table 2
Least square means and standard errors for SDF, RS and corrected IDF and TDF in processed beans (g/100 g dry matter)

Processed samples	SDF		IDF		TDF		RS		Corrected IDF[a]		Corrected TDF[b]	
	LSM	SEM	LSM	SEM	LSM	SEM	LSM	SEM	LSM	SEM	LSM	SEM
SB	4.9a	0.6	15.2c	0.3	20.1c	0.4	3.1c	0.4	12.1a	0.4	17.0a	0.5
SSB	6.0a	0.6	13.8d	0.3	19.8c	0.4	2.9c	0.4	10.9b	0.4	16.9a	0.5
CSB	4.7a	0.6	17.5b	0.3	22.2a	0.4	5.7b	0.4	11.8b	0.4	16.5a	0.5
CSSB	2.7b	0.6	18.2a	0.3	20.9b	0.4	7.4a	0.4	10.8b	0.4	13.5b	0.5
CNSB	5.9a	0.6	16.7b	0.3	22.6a	0.4	5.4b	0.4	11.3b	0.4	17.2a	0.5
CnB	2.3b	0.6	17.2b	0.3	19.5c	0.4	7.8a	0.4	9.4c	0.4	11.7c	0.5

LSM, least square means; SEM, standard error; SB, soaked beans; SSB, soaked-S beans; CSB, cooked soaked beans; CSSB, cooked soaked-S beans; CNSB, cooked non-soaked beans; CnB, canned beans. Values in the same column, followed by different letters, are significantly different ($P<0.05$).

[a] Corrected IDF = IDF − RS.

[b] Corrected TDF = SDF + IDF − RS.

increased it. The highest values were determined in CSSB (7.4 g/100 g) and CnB (7.8 g/100 g). According to Aman and Westerlund (1996) and Raben et al. (1994) the increase of RS content after cooking is a consequence of starch retrogradation after gelatinization. According to the results in Table 2, there were three groups of processed beans which differed statistically significantly in RS content.

By subtraction the content of RS from the IDF content, the corrected values for IDF and TDF were calculated and are presented in the last two columns of Table 1. The corrected values showed a 54.0–79.6% decrease in IDF and a 60.0–85.4% decrease in TDF. The differences among processed samples were significant ($P \leqslant 0.05$; Table 2).

In Table 3, the portion of RS in IDF and the portion of SDF and IDF in TDF, before and after correction with RS, are presented. Processing methods affected the portion of RS and also the ratio of SDF to IDF in TDF. A relatively high content of RS (more than 20%) was observed. In all thermally processed beans the values ranged from 32.3% (in CNSB) to 45.3% (in CnB). These results can best be explained by the arguments of Tovar (1992), who emphasized that all legume starches are characterized by high amylose content, generally above 29%. The amylose fraction of starch undergoes an irreversible swelling during soaking and heating in water, leading to disappearance of structural order; the process is known as gelatinization. According to Aman and Westerlund (1996) and Raben et al. (1994), thc increase of the RS content is a consequence of starch gelatinization during heating and its retrogradation after cooling.

Table 3
Resistant starch (RS), soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) before and after correction with RS in raw and processed beans

Samples	RS[a]	Before correction[b]		After correction[b]	
		SDF	IDF	SDF	IDF
RB	46.0	25.0	85.0	24.6	71.4
Processed beans					
SB	20.4	24.4	75.6	28.8	71.2
SSB	21.0	30.3	69.7.	35.5	64.5
CSB	32.6	21.2	78.8	28.5	71.5
CSSB	40.7	12.9	87.1	20.0	80.0
CNSB	32.3	26.1	73.9	34.3	65.7
CnB	45.3	11.8	88.2	19.7	80.3

SB, Soaked beans; SSB, soaked-S beans; CSB, cooked soaked beans; CSSB, cooked soaked-S beans; CNSB, cooked nonsoaked beans; CnB, canned beans.

[a] % in IDF.

[b] 9% in TDF.

The IDF fraction formed the majority of TDF and ranged from 69.7% (in SSB) to 88.2% (in CnB), while the fraction of SDF ranged from 11.8% in CnB to 30.3% (in SSB; Table 3). These results agree with data of Su and Chang (1995) who reported that the IDF fraction in raw dry beans is 72–90% of the TDF. From the nutrition point of view, only thermally processed beans are important, because the beans are never eaten raw or soaked. The ratios of soluble fraction in these samples were from 11.8% (in CnB) to 26.1% (in CNSB). The value for CNSB is within the range of SDF in food products recommended by Prosky and DeVries (1991). According to them, the TDF intake should contain approximately one third of SDF. In the CNSB, the SDF/TDF ratio was 1/3. Therefore, to maintain a high SDF in cooked beans, we should avoid soaking before cooking.

If RS is not considered a part of IDF, the portion of SDF after correction is higher (Table 3): approximately 4.8% in both soaked beans and 7.6% in thermally treated beans. The increase in the soluble fraction is higher for the samples with higher RS contents. For thermally treated samples, the average ratio of SDF to IDF is close to the recommended value for food products.

4. Conclusions

Processing, cooking, and pretreatment of pinto beans resulted in significantly ($P \leqslant 0.001$) different water, TDF, SDF, IDF, and RS contents.

Considerable decreases of IDF and, consequently, TDF contents for all thermally processed samples, were observed.

Processing (soaking and cooking) significantly increases the resistant starch content ($P \leqslant 0.05$).

Among treatments studied, cooked nonsoaked beans are the most interesting from the nutritional point of view (34.6% of SDF in TDF is a value very close to the recommendation by Prosky et al., 1988).

Changes observed in dietary fibre content due to thermal processing of beans are very complex. The changes depend on the type of beans, the processing method and its duration. In addition, the results obtained also vary with the analytical method applied.

For foods that are not eaten raw, such as beans, the data on dietary fibre content of cooked (processed) foods are much more relevant than those of raw foods. Thus food composition tables should contain as much data on cooked (processed) foods as possible.

References

Almazan, A. M., & Zhou, X. (1995). Total dietary fibre content of some green and root vegetables obtained at different ethanol concentrations. *Food Chemistry*, *53*, 215–218.

Aman, P., & Westerlund, E. (1996). Cell wall polysaccharides: structural, chemical, and analytical aspects. In A. C. Eliasson (Ed.), *Carbohydrates in food* (pp. 191–226). New York: Marcel Dekker.

AOAC official method 934.01. (1999). Moisture in animal feed. In *Official methods of analysis of AOAC International* (16th ed.) (pp. 4–1). Gaithsburg, USA: AOAC INTERNATIONAL.

Asp, N. G. (1986). Physiology of dietary fibre in the upper intestinal tract. In R. Amadó, & T. F. Schweizer (Eds.), *Nahrungsfasern. Dietary fibers* (pp. 105–113). London: Academic Press.

Asp, N. G. (1995). Dietary fibre analysis—an overview. *European Journal of Clinical Nutrition*, *49*, 42–47.

Asp, N. G., Johansson, C. G., Hallmer, H., & Siljeström, M. (1983). Rapid enzymatic assay of insoluble and soluble dietary fibre. *Journal of Agricultural and Food Chemistry*, *31*, 476–482.

Carnovale, E., & Lintas, C. (1995). Dietary fibre: effect of processing and nutrient interactions. *European Journal of clinical Nutrition*, *49*, 307–311.

Champ, M. (1992). Determination of resistant starch in foods and food products: interlaboratory study. *European Journal of Clinical Nutrition*, *46*, 51–62.

Lee, S. C., Prosky, L., & DeVries, J. W. (1992). Determination of total, soluble, and insoluble dietary fibre in foods–enzymatic–gravimetric method, MES–TRIS buffer: collaborative study. *Journal of AOAC International*, *75*, 395–416.

Mongeau, R., & Brassard, R. (1995). Importance of cooking temperature and pancreatic amylase in determination of dietary fibre in dried legumes. *Journal of AOAC International*, *78*, 1444–1449.

Prosky, L., & DeVries, J. W. (1991). *Controlling dietary fiber in food products*. New York: Van Nostrand Reinhold.

Prosky, L., Asp, N. G., Schweizer, T. F., DeVries, J. W., & Furda, I. (1988). Determination of insoluble, soluble, and total dietary fibre in foods and food products: interlaboratory study. *Journal of the Association of Official Analytical Chemists*, *71*, 1017–1023.

Raben, A., Tagliaube, A., Christensen, N. J., Madsen, J., HoIst, J. J., & Astrup, A. (1994). Resistant starch: the effect on postprandial glycemia, hormonal response, and satiety. *American Journal of Clinical Nutrition*, *60*, 511–544.

Reyes-Moreno, C., & Paredes-López, O. (1993). Hard-to-cook phenomenon in common beans—a review. *Critical Reviews in Food Science and Nutrition*, *33*, 227–286.

Robertfroid, M. (1993). Dietary fibre, inulin and oligofructose: a review comparing their physiological effect. *Critical Reviews in Food Science and Nutrition*, *33*, 103–148.

SAS. (1990). *SAS/STAT User's Guide,* 4th ed., Cary, SAS Inst., pp. 891–1230.

Su, H. L., & Chang, K. C. (1995). Physicochemical and sensory properties of dehydrated bean paste products as related to bean varieties. *Journal of Food Science*, *60*, 794–797.

Tovar, J. (1992). *Bioavaibility of starch in processed legumes* (pp. 1–51). Doctoral thesis. University of Lund, Norwich.

Vidal-Valverde, C., Frias, J., & Esteban, R. (1992). Dietary fibre in processed lentils. *Journal of Food Science*, *57*, 1161–1163.