Journal of Food Composition and Analysis 22 (2009) 678–683

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Original Article

Changes in carbohydrate fraction during dehydration process of common legumes

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A R T I C L E I N F O

Article history:
Received 31 January 2008
Received in revised form 30 October 2008
Accepted 21 February 2009

Keywords:
Bean
Lentil
Grain legumes
Legume flour
Dietary fibre
Starch
α-Galactosides
Dehydration
Food processing
Food analysis
Food composition

A B S T R A C T

The effect of thermal dehydration on carbohydrate fraction of legumes (chickpea and two cultivars of beans) was evaluated. The legumes showed important contents of total dietary fibre (TDF), with insoluble dietary fibre (IDF) as the main fraction (75–96%). The level of dietary fibre (DF) in legumes was affected by processing; dehydration was the process that exhibited a significant increase in soluble dietary fibre (SDF). The extent of DF changes depended on the type of legume and the process. Starch was also affected by processing which improved its digestibility, although this depends on the type of legume and treatment (soaking, cooking and dehydration). Legumes exhibited important levels of raffinose family oligosaccharides (RFOs), but the profile differed according to the seed. The dehydration process produced significant reductions of these soluble compounds: 76% for white bean, 57% for chickpea and 41% for pink-mottled cream bean. Therefore, dehydration was an efficient process to reduce flatulence compounds, and legume flours can be proposed as functional ingredients for their beneficial health effects.

1. Introduction

The nutritional value of legumes is gaining considerable interest in developed countries because of the demand for healthy foods. Grain legumes are a good source of protein, minerals and available carbohydrates (starch and oligosaccharides). They also provide a large amount of structural carbohydrates due mainly to a high content of dietary fibre (DF) compared to other fibre-rich plant food (Tharanathan and Mahadevamma, 2003), although DF content depends on the species, varieties and processing of legumes. The chemical structure and physico-chemical properties of fibre are important for functional behaviours in food use and for diet-related health effects. Starch represents the major carbohydrate in the legume seed (22–45%), although the rate of starch digestion is, both *in vitro* and *in vivo*, lower than that for cereals. A proportion of starch called resistant starch escapes complete digestion and has properties similar to fermentable fibres (Tovar and Melito, 1996; Hoover and Zhou, 2003). Common seeds such as bean (*Phaseolus vulgaris*), lentil (*Lens culinaris*), pea (*Pisum sativum*), chickpea (*Cicer arietinum*) and faba bean (*Vicia faba*, also broad bean or fava bean) are the most widely consumed legume throughout Spain. In Europe, legume consumption has increased in the last decade (average of 3.9 kg/capita per year), with differences between countries—Greece, Portugal and Spain (6 kg/capita per year) consume the most legumes.

Although legumes are considered to be one of the most nutritious plant foods, the presence of certain antinutritional factors limits their biological value and acceptance as food. This is the reason why the seeds have to be processed before being consumed (Chavan et al., 1989). Some antinutrients such as α-galactosides are heat stable and are not removed by the heating process (Somiari and Balogh, 1993). The main α-galactosides, also called raffinose family oligosaccharides (RFOs), are widely distributed in the leguminose family. RFOs contain 1–3 units of galactose linked to sucrose by α-1,6 linkages (Dey, 1985). These linkages are not hydrolyzed in the upper part of the gastro-intestinal tract, due to absence of the enzyme α-galactosidase. These sugars are fermented by colonic microflora, producing flatus gases (H_2, CO_2, and small amounts of CH_4), abdominal pain and diarrhoea. Flatus production is considered to be the single most important factor that deters people from eating these grain legumes. However, recent research shows that α-galactosides may also have a beneficial effect by increasing the bifidobacteria population in the colon (Alles et al., 1999; Bouhnik et al., 2004).

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0889-1575/$ – see front matter
doi:10.1016/j.jfca.2009.02.012

Most studies have examined different processes for levels reduction of these oligosaccharides, such as germination and fermentation process, low dose radiation-processed, extrusion, cooking, and so on (Vidal-Valverde et al., 1998; Ibrahim et al., 2002), but there have not been many studies concerning dehydration as a thermal treatment (Martín-Cabrejas et al., 2006, 2009). The industrial process of dehydration may affect α-galactoside content by reducing the medium or/and transformations in the carbohydrate fraction which may include hydrolysis of α-galactosides.

The present study was thus carried out to evaluate the influence of the dehydration process on the carbohydrate fraction, including dietary fibre fractions, starch and the profile of oligosaccharides, in common Spanish legumes (chickpea and bean) so as to obtain nutritious flours for people with digestive problems.

2. Materials and methods

2.1. Samples

Seeds of chickpea and two cultivars of beans (white bean and pink-mottled cream bean) were used in the present study. They were obtained from the agri-food industry Vegenat SA (Badajoz, Spain). From each cultivar three batches of 250 g of raw and processed samples were prepared.

2.2. Processing conditions

Legumes were subjected to an industrial dehydration process carried out in Vegenat SA. The processing consisted of the following steps: raw material was soaked in tap water (1:10; w/v) for 16 h at 20 °C. After draining the soaking water, the soaked legumes were cooked by boiling for 20 min (for the white beans), 30 min (for the pink-mottled cream beans) or 70 min (for chickpeas). The soaked-cooked seeds were dehydrated in a forced-air tunnel at 75 ± 3 °C for 6 h. Samples were taken at each step and they were named as follows: S (soaked legumes), S + C (soaked and cooked legumes) and S + C + D (soaked, cooked and dehydrated legumes). The seeds were freeze-dried and were milled to flour and passed through a 250 μm sieve.

2.3. Dietary fibre determination

Mes-Tris AOAC method 991.43 was used for DF determination (AOAC, 1995). Two replicates of each sample were taken to complete the six-sample analysis method. The principle of the method was based on the use of three enzymes (heat-stable α-amylase, protease and amyloglucosidase) under different incubation conditions in order to remove starch and protein components. Dietary fibre fractions were obtained as indigestible residues after enzymatic digestion of nondietary fibre components; the insoluble residues were isolated by filtration and soluble fibre was precipitated with ethanol. Dried residues correspond to insoluble dietary fibre (IDF) and soluble dietary fibre (SDF), respectively. Determination of residual ash and proteins (as Kjeldahl N × 5.40) was carried out in the residues for corresponding corrections. Total dietary fibre (TDF) was calculated as the sum of IDF and SDF. Kjeldahl nitrogen and ash contents were assayed according to standard procedures (AOAC, 1995).

2.4. Starch determination

Starch was analysed from the residue obtained after soluble carbohydrate extraction using a procedure based on the total enzymatic digestion to glucose (Vidal-Valverde et al., 1998). The glucose content was measured by the method of glucose-oxidase peroxidase (Dahlqvist, 1964). The available starch was estimated according to the method of Li et al. (1985).

2.5. Determination of soluble carbohydrates

The extraction method of soluble carbohydrates was carried out in legume flour according to a procedure described previously by Sánchez-Mata et al. (1998). The sample extract was vacuum evaporated at 30 °C to dryness, the concentrated sugars were redissolved in deionised water and sonicated for five minutes, and finally filtered using Whatman 41 paper. MilliQ water was added to bring the volume up to10 mL. Samples were passed through a Sep pak® C_{18} cartridge (Waters, Midford, MA, USA), then 2 mL of filtrate was mixed with 8 mL of acetonitrile and filtered through a 0.54 μm Millex membrane prior to injection. The soluble carbohydrates were determined by HPLC using an amino bonded column (3.9 mm × 300 mm column, Waters, Midford, MA, USA), isocrate pump and refractive index detector. The mobile phase was acetonitrile:water (65:35; v/v), at a flow rate of 1 mL min^{-1} at room temperature.

Quantification of peaks was performed using the external standard method. An approach to the amount of ciceritol (with no commercial standard available) was made, using the calibration curve of the previous peak (raffinose), corrected by molecular weight. Standard sugars were obtained from Merck (Darmstadt, Germany).

2.6. Statistical analysis

Results were analysed using Duncan's multiple range test (DMRT) (Bender et al., 1989). Differences were considered significant at $p \leq 0.05$.

3. Results and discussion

Although different studies have been carried out on the effect of different thermal methods and chemical and mechanical processes upon DF components in legumes (Esteban et al., 1998; Li et al., 2002; Martín-Cabrejas et al., 2004), few data have been documented about the influence of industrial dehydration on DF fractions (Martín-Cabrejas et al., 2006). Table 1 illustrates the contents of insoluble (IDF), soluble (SDF) and total dietary fibre (TDF) and distribution in raw and processed legume flours. The TDF levels in raw legume seeds were relatively high, and were similar or higher than those found in other common legumes and much

Table 1
Content of insoluble, soluble and total dietary fibre and its distribution in raw and processed legume flours (g kg^{-1} DM).

Sample	IDF	SDF	TDF	IDF:SDF
Chickpea				
Raw	204.8 ± 2.7^a	9.6 ± 0.1^a	214.4	21:1
S	197.6 ± 3.3^a	12.8 ± 0.8^b	210.4	15:1
S + C	235.1 ± 1.1^b	15.0 ± 0.8^c	250.0	16:1
S + C + D	252.9 ± 1.2^c	19.6 ± 0.6^d	272.5	13:1
White bean				
Raw	211.4 ± 2.8^a	58.2 ± 1.2^a	269.6	4:1
S	212.0 ± 0.9^a	65.8 ± 0.5^b	277.8	3:1
S + C	218.9 ± 1.1^b	77.6 ± 1.4^c	296.5	3:1
S + C + D	230.8 ± 1.6^c	79.1 ± 3.1^c	309.9	3:1
Pink-mottled cream bean				
Raw	163.7 ± 2.4^b	54.3 ± 0.9^a	218.1	3:1
S	147.6 ± 1.3^a	64.4 ± 1.3^b	212.0	2:1
S + C	171.0 ± 0.9^c	73.7 ± 2.5^c	244.9	2:1
S + C + D	189.5 ± 2.3^d	75.2 ± 1.0^c	264.7	3:1

Mean values of each column followed by different superscript letter significantly differ when subjected to Duncan's multiple range test ($p < 0.05$). [Mean ± SD ($n = 6$)].