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Chemical composition and starch digestibility in flours from Polish processed legume seeds

Małgorzata Piecyk *, Rafał Wołosiak, Beata Drużynska, Elwira Worobiej

Division of Food Quality Evaluation, Department of Biotechnology, Microbiology and Food Evaluation, Faculty of Food Sciences, Warsaw University of Life Sciences – SGGW, 159 Nowoursynowska Str., 02-787 Warszawa, Poland

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ABSTRACT

The study was undertaken to determine the effect of various treatments, i.e. cooking after soaking, freezing after cooking and storage at a low temperature (−18 °C, 21 days), and autoclaving, of Polish cultivars of bean, pea and lentil seeds on the chemical composition and starch digestibility of the resultant flours. The cooking of seeds caused a significant decrease in contents of ash (by 11–48%), polyphenols (by 10–70%) and protein (to 19%) in flours made of bean. In addition, analyses demonstrated significantly decreased contents of resistant starch, RS (by 61–71%) and slowly digestible starch, SDS (by 56–84%). Storage of frozen seeds resulted in insignificant changes in the chemical composition, and in increased contents of both RS and SDS. The flours produced upon the autoclaving process were characterized by similar changes in the contents of ash and protein as in cooked seeds, yet losses of polyphenols were lower and, simultaneously, contents of RS and SDS were higher. All the analyzed flours were shown to be characterized by a reduced content of amylose in starch, which might have affected its digestibility. This was indicated by a strict negative correlation reported between the value of the starch digestion index (SDRI) and amylose content of starch ($r = 0.84$, $p > 0.05$).

1. Introduction

Dry legume seeds are a valuable source of many nutrients, including proteins or starch, and compounds with a high biological activity, e.g. dietary fibre, oligosaccharides, minerals and vitamins. Ample epidemiological surveys point to a relationship between their consumption and a reduced risk of the incidence of some metabolic diseases, including diabetes and cardiovascular diseases, as well as neoplasms (Englyst, Veenstra, & Hudson, 1996; Jenkins et al., 2002; Xu, Yuan, & Chang, 2007). This corroborated effect contributed to inclusion of the legumes into the list of dietary constituents recommended by many organisations fighting with civilization diseases, e.g. The American Heart Association (Duranti, 2006).

Carbohydrates constitute the major fraction of seeds, where their content fits within the range of 24–68% d.m. This fraction is predominated by starch, the content of which ranges from 22% to 45% depending on seed species (Hoover & Sosulski, 1991). Dietary starch is foremost a source of energy, though in recent years special attention has been paid to its nutritive value linked with its susceptibility to being digested in the small intestine. The nutritive value of starch is determined by the content of resistant starch (RS) as well as contents of rapidly digestible starch (RDS) and slowly digestible starch (SDS). Resistant starch is defined as starch and products of its degradation that escape absorption in the small intestine of a healthy man (Englyst & Hudson, 1996). The presence of RS in the diet has been shown to exert positive effects on a human body, for it stimulates the growth of beneficial microflora, increases contents of SCFAs, as well as reduces colonic pH, postprandial blood level of glucose, and blood level of cholesterol (Sajilata, Singhal, & Kulkarni, 2006).

In turn, SDS is a starch fraction that is subject to slow, but complete, hydrolysis in the small intestine (Englyst & Hudson, 1996). Its physiological preponderance over RDS is due to its stabilizing effect on glucose level in blood. Advantages resulting from SDS intake include, among other things, prophylaxis and treatment of type II diabetes, because it affects the sensation of satiety through the metabolic response, namely the postprandial low level of glucose and insulin in blood (Jenkins et al., 2002).

Starch of leguminous plants is referred to as starch with good nutritional value owing to relatively high contents of SDS and RS, and it is characterized by a low glycemic index (GI) (Chung et al., 2008a). The low availability of starch in the seeds results from the presence of intact tissue structures surrounding starch grains, a high content of amylose (25–65%), high contents of the soluble fractions of dietary fibre with high viscosity, the presence of digestibility-reducing components, e.g. α-amylase inhibitor or phytic

* Corresponding author. Fax: +48 22 5937682.
E-mail address: malgorzata_piecyk@sggw.pl (M. Piecyk).

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acid, C-type crystallinity, and strong interactions between amylose chains (Chung et al., 2008a; Hoover & Sosulski, 1985; Hoover & Zhou, 2003).

Despite advantages stemming from legume seeds intake, their exploitation for consumption purposes in Europe is not high; their annual consumption accounts for 2.7 kg per capita, compared to the world average of 6.5 kg per capita (FAOSTAT, 2009), which results from, for example, the necessity of their time-consuming preparation for consumption. Hence, investigations have been conducted into the feasibility of enriching other food products, e.g. pasta, with flour of legume seeds, which would enable decreasing their GI (Goni & Valenitn-Gamazo, 2003; Petitot & Micard, 2010). An alternative may be the use of flour produced from seeds subjected to hydrothermal treatment, e.g. in soup concentrates. However, contents of SDS and RS are determined by multiple factors, including seed variety and environmental conditions during seeds cultivation, the presence of other nutrients and, most of all, by the type of hydrothermal treatment (Escarpa, González, Morales, & Saura-Calixto, 1997; Marconi, Ruggeri, Cappelloni, Leonardi, & Caenoval, 2000; Osorio-Diaz et al., 2002; Rosin, Lajolo, & Menezes, 2002). SDS is particularly thermally unstable, thus production of food rich in this fraction is difficult. In addition, recent studies addressing the effect of technological processes on RS content do not involve the evaluation of their impact on polyphenols content.

In view of the above, the objective of this study was to determine the effect of traditional cooking after soaking, storage of cooked and frozen seeds, and autoclaving of Polish varieties of bean, pea and lentil on the chemical composition of flours, and especially on the content of polyphenols and starch digestibility.

2. Materials and methods

2.1. Materials

The experimental materials were seeds of bean (*Phaseolus vulgaris*) var. Raba and var. Warta, and seeds of pea (*Pisum sativum*) var. Milwa and var. Medal, originating from the Institute of Plant Breeding and Acclimatisation, as well as seeds of lentil (*Lens culinaris*) var. Anita and var. Tina, originating from the Plant Breeding and Seed Production Centre "Spójnia" in Nochów.

2.2. Hydrothermal processing

2.2.1. Cooking

The seeds were soaked in distilled water in a ratio of 1:3 (w/w) for 16 h, then water was decanted and the seeds were again poured with distilled water in a ratio of 1:5 (w/w) to dry seeds. Afterwards, the seeds were cooked for a period of time determined for each seed variety in preliminary analyses, so that most of the seeds could be crushed with fingers. The time of cooking was affected, to a great extent, by the size of seeds, and was presented in Table 1. Once cooked, the seeds were drained and cooled.

2.2.2. Freezing

Part of the cooked seeds was packed in bags and, after freezing at −18 °C, stored at this temperature for 21 days. Afterwards, the seeds were defrosted for 2 h at a room temperature.

2.2.3. Autoclaving

The seeds were poured with distilled water in a ratio of 1:5 (w/w) in glass bottles, and the closed bottles were fixed in a laboratory autoclave. Preliminary analyses enabled determining the optimal conditions of the process, i.e. conditions under which only a small fraction of seeds disintegrated, which could contribute to greater losses of dry matter components (Table 1).

Table 1
Characteristics of seeds and conditions of thermal treatment.

Variety	Colour of coats	Thousand-seeds weight (g)	Cooking time (min)	Autoclaving	
				Temperature (°C)	Time (min)
Bean					
Raba	White	178	30	121	7
Warta	White	414	40	121	12
Pea					
Medal	Yellow	300	40	121	12
Milwa	Brown	269	40	121	12
Lentil					
Anita	Green and brown	45	20	121	7
Tina	Green and brown	46	20	121	7

2.3. Production of flour from seeds after treatments

After the treatments, the seeds were dried in a vacuum dryer at a temperature of 40 °C for 18 h. Dried processed seeds and crude seeds were ground in a laboratory mill (IKA M20), sieved through a screen with a mesh diameter of 125 μm, and stored in tightly closed plastic containers at a temperature of 4 °C until chemical analyses. In turn, analyses of digestibility were carried out immediately after seed grinding, because storage of flours, especially these from legume seeds, resulted in an increasing content of RS (Yadav, Sharma, & Yadav, 2010a).

2.4. Chemical composition of flour

Moisture content was determined by gravimetry heating (130 °C for 2 h), using 5 g of sample. Ash and total nitrogen content were determinated in accordance with AOAC methods 923.03 and 991.20, respectively (AOAC, 1990). The percentage of crude protein was estimated by multiplying the total nitrogen content by a factor of 6.25. Fat content was determined by extraction with hexane for 3 h using a Soxhlet apparatus according to the AOCS (1998) method Ba 3-38.

2.5. Determination of total phenolics content (TPC)

The amount of total phenolics in 70% acetone extracts was determined with the Folin–Ciocalteu's reagent (Naczk & Shahidi, 1989; Singleton & Rossi, 1965). Absorption at 700 nm was measured (Shimadzu UV-160A). The content of total phenolics was expressed as gallic acid (Sigma Chemicals Co., Germany) equivalents in mg of GAE/100 g d.m.

2.6. Total starch (TS) and apparent amylose content

A total starch assay kit (Megazyme International, Ireland) was used to determine the starch content. Samples (100 mg) were wetted with aqueous ethanol (80% v/v), and starch was pre-dissolved in 2 M KOH at 4 °C. pH was then adjusted with acetate buffer and starch was hydrolysed with thermostable α-amylase and amyloglucosidase in a water bath at 50 °C. Liberated glucose was quantified using the glucose oxidase–peroxidase assay kit (K-GLUC, Megazyme), and TS was calculated as glucose × 0.9. Apparent amylose content was determined using the method of Williams, Kuzina, and Hlynka (1970).