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Review article

Influence of soaking on the nutritional quality of common beans (*Phaseolus vulgaris* L.) cooked with or without the soaking water: a review

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Summary Bean soaking seems to be unanimously recommended by scientists; however, there is no consensus regarding the need to discard the soaking water before cooking. Thus, the present study proposes to review the influence of maceration on the nutritional quality of common beans (*Phaseolus vulgaris* L.) cooked with or without the soaking water, in an attempt to achieve agreement among scientists. The article search was done in a systematic way and eleven studies were found. Of these, three compared the use or not of the soaking water for cooking, seven of them discarded the soaking water and one used the soaking water. This review discusses each nutrient and antinutrient regarding the effects of soaking and compares them with other studies done with legumes. The results were not unanimous but there was a greater advantage to discarding the soaking water before cooking.

Keywords Antinutrients, bioavailability, cooking, dry beans, food quality, nutritional aspects, processing effects.

Introduction

The common bean (*Phaseolus vulgaris* L.) is consumed worldwide, especially in Latin America and Africa (FAO, 2009). Because of its cultural and nutritional importance, the Brazilian food pyramid shows beans in a group of their own (Philippi *et al*., 1999) and the Food Guide for the Brazilian Population recommends the consumption of at least one portion of beans per day (Vasconcellos *et al*., 2006).

However, beans contain compounds that can negatively affect their nutritional value, such as trypsin inhibitors, lectins, phytates, polyphenols (especially tannins in beans) and oligosaccharides (raffinose and stachyose). Some of these are thermolabile, disappearing after proper cooking, such as trypsin inhibitors and lectins. Others are thermostable, but their concentrations are reduced by dissolution in water (Haro, 1983; Silva & Silva, 1999, 2000).

Soaking the beans in water and discarding the water may eliminate a percentage of these compounds. Some studies (Oliveira *et al*., 2001a,b; Ramírez-Cárdenas *et al*., 2008) found a greater reduction in the content of tannins, phytates and oligosaccharides in beans that were soaked and cooked without the soaking water.

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However, Ramírez-Cárdenas *et al*. (2008) pointed out some studies that state that low concentrations of phytates and phenolic compounds can be protective against cancer and cardiovascular diseases. Meanwhile, oligosaccharide fermentation may have positive results such as production of short-chain fatty acids and decrease in intestinal pH (Muzquiz, 2008; Campos-Vega *et al*., 2009).

The positive or negative effects of these compounds seem to be more closely associated with their concentration in the beans, which varies according to type of bean, as well as their interaction with other components of the diet (Muzquiz, 2008; Ramírez-Cárdenas *et al*., 2008).

Bean soaking before cooking seems to be unanimously recommended by scientists; however, there is no consensus regarding the discarding of the soaking water. Although many authors recommend the soaking water to be discarded to eliminate antinutritional factors, others seek to prove the beneficial effects of these factors, which have been associated with the prevention of diseases. In this sense, it would be advantageous not to discard the soaking water. Yet, the published studies present contradicting and inconclusive results, which, according to Muzquiz (2008), can be attributed to the use of different methodologies and parameters. Therefore, a consensus regarding the fate of the soaking water is yet to be achieved.

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The objective of the present study is to perform a systematic review of the influence of soaking on the nutritional quality of common beans (*P. vulgaris* L.) cooked with or without the soaking water, to assess and compare the preparation methods and results and search for concordant recommendations among the studies.

Method

A systematic search of articles that discuss the influence of soaking on the nutritional quality of common beans (*P. vulgaris* L.) cooked with or without the soaking water, published between January 2004 and March 2009 was done. The following databases were searched: Scielo (Scientific Electronic Library Online), Lilacs (Latin American and Caribbean Centre on Health Sciences Information) and Scopus – which includes 100% of the publications of the Medline (National Library of Medicine) database. The keywords used for the search are listed in Table S1. The search was done separately for each language, using the keywords of the first line in combination with the keywords of the lower lines.

A total of twenty-two articles were found in Scielo, nine in Lilacs and 392 in Scopus. Nineteen repeated texts were removed, totalling 404 studies.

Based on the systematic search model, inclusion and exclusion criteria were established to meet the objectives of the research. The inclusion criteria of the articles were (i) original articles; (ii) articles in Portuguese, English or Spanish; (iii) studies with the common bean (*P. vulgaris* L.); (iv) studies that analysed the effects of soaking the beans on its composition, digestibility or bioavailability *in vitro* or *in vivo*. The exclusion criteria were (i) review articles; (ii) articles in languages other than the ones mentioned earlier; (iii) studies with coffee (called coffee *beans* in English); (iv) studies with only other types of legumes or with beans of different species; (v) studies that analysed the effect of soaking on the properties of the seeds, the bean plant or bean characteristics other than the nutritional and sensorial characteristics; (vi) studies that analysed the effects of soaking beans for preparations other than the traditional preparations (such as bean sweets, flours for supplements, animal feeds); (vii) studies that only compared bean varieties or cultivars, or compared different legumes, and did not compare different processing methods; (viii) studies that only covered the influence of different processing methods on the quality of the bean; (ix) articles that were not complete, even when they were ordered from the authors.

After the abstracts of all the articles were read, those that did not meet the inclusion criteria were excluded. Only eleven studies were specifically about the influence of soaking on the nutritional quality of common beans (*P. vulgaris* L.) cooked with or without the soaking water.

The studies were analysed according to their year of publication, country of origin, objectives, variables, preparation methods and analyses, results and conclusions and/or recommendations of the authors.

Characteristics of the analysed articles

The characteristics verified in the selected articles are described in Table S2. Most of these studies (27.3%) were done in Brazil (Oliveira *et al*., 2008; Ramírez-Cárdenas *et al*., 2008; Toledo & Canniatti-Brazaca, 2008), followed by the United States of America (18.2%) (Luthria & Pastor-Corrales, 2006; Xu & Chang, 2008); then came Mexico (Carmona-García *et al*., 2007); Spain (Pujolà *et al*., 2007); Turkey (Nergiz & Gökgöz, 2007); Ethiopia (Shimelis & Rakshit, 2007); Sudan (Elmaki *et al*., 2007); and Pakistan (Rehman & Shah, 2004), each with 9.1%.

Regarding the objectives and variables, three studies (Oliveira *et al*., 2008; Ramírez-Cárdenas *et al*., 2008; Toledo & Canniatti-Brazaca, 2008) assessed the effects of cooking the beans with or without the soaking water. The other studies analysed the effects of different bean processing methods (raw, soaked, soaked and cooked, cooked without soaking), but did not discuss the use of the soaking water for cooking. Of these eight studies, only one (Nergiz & Gökgöz, 2007) used the soaking water to cook the beans, while the other seven studies (Rehman & Shah, 2004; Luthria & Pastor-Corrales, 2006; Carmona-García *et al*., 2007; Elmaki *et al*., 2007; Pujolà *et al*., 2007; Shimelis & Rakshit, 2007; Xu & Chang, 2008) discarded the soaking water.

All articles analysed more than one variable. Thus, the studies also assessed the effects of different cooking methods (vapour, boiling, pressure cooking, microwave (Toledo & Canniatti-Brazaca, 2008; Xu & Chang, 2008; Shimelis & Rakshit, 2007; Nergiz & Gökgöz, 2007; Rehman & Shah, 2004); of different soaking solutions other than pure water – sodium chloride (NaCl), sodium bicarbonate ($NaHCO_3$) and mixed (NaCl + $NaHCO_3$) (Rehman & Shah, 2004; Carmona-García *et al*., 2007; Shimelis & Rakshit, 2007); of different types of beans, different varieties, colours and cultivars (Luthria & Pastor-Corrales, 2006; Elmaki *et al*., 2007; Pujolà *et al*., 2007; Oliveira *et al*., 2008; Ramírez-Cárdenas *et al*., 2008); of different soaking times (Elmaki *et al*., 2007; Xu & Chang, 2008) and of germinating the beans in the prepreparation phase (Shimelis & Rakshit, 2007).

All articles also had more than one outcome variable. The outcomes investigated most often were changes in phytate content (Elmaki *et al*., 2007; Nergiz & Gökgöz, 2007; Shimelis & Rakshit, 2007; Ramírez-Cárdenas *et al*., 2008; Toledo & Canniatti-Brazaca, 2008), followed by tannins content (Nergiz & Gökgöz, 2007; Shimelis & Rakshit, 2007; Ramírez-Cárdenas *et al*., 2008; Toledo & Canniatti-Brazaca, 2008), phenol content (total, polyphe-

nols – which also include tannins and phenolic acids) (Luthria & Pastor-Corrales, 2006; Elmaki *et al*., 2007; Nergiz & Gökgöz, 2007; Xu & Chang, 2008) and mineral content (Elmaki *et al*., 2007; Pujolà *et al*., 2007; Oliveira *et al*., 2008; Ramírez-Cárdenas *et al*., 2008); and *in vitro* protein digestibility (Nergiz & Gökgöz, 2007; Shimelis & Rakshit, 2007; Toledo & Canniatti-Brazaca, 2008). Other changes were also verified such as centesimal composition (Ramírez-Cárdenas *et al*., 2008; Toledo & Canniatti-Brazaca, 2008); starch (total, available starch and resistant starch, amylose) (Carmona-García *et al*., 2007; Pujolà *et al*., 2007); fibres (Rehman & Shah, 2004; Ramírez-Cárdenas *et al*., 2008); trypsin-inhibiting activity (Nergiz & Gökgöz, 2007; Shimelis & Rakshit, 2007); oligosaccharides (Shimelis & Rakshit, 2007); in addition to the capacity to extract minerals with HCl (Elmaki *et al*., 2007), among others. The outcome variables associated with the nutrients and antinutrients are shown separately in Tables 1 and 2, which also show the effects of different bean preparation methods on these variables.

Phytates and phytic acid

The authors of all studies that assessed phytates stated that a reduction of these compounds is desirable. The greatest reduction of phytates and phytic acid was achieved by soaking and cooking without the soaking water (Elmaki *et al*., 2007; Nergiz & Gökgöz, 2007; Ramírez-Cárdenas *et al*., 2008; Toledo & Canniatti-Brazaca, 2008). Toledo & Canniatti-Brazaca (2008) stated that phytate reduction was equal in samples with and without soaking, however, as shown in a table of their study, the phytate content varied according to cooking method. On average, the greatest phytate content was found in beans that were cooked with the soaking water, followed by beans cooked without soaking and finally beans cooked without the soaking water. Among soaked beans and for all cooking methods, beans cooked without the soaking water always had statistically lower phytate content than those cooked with the soaking water. Similar results were found by Oliveira *et al*. (2001b) in an older study with common beans, and by Boateng *et al*. (2007), who studied the phytate content in another species of bean.

However, phytic acid reduction may not be needed for the utilisation of some nutrients. A study done by Oliveira *et al*. (2003) showed that phytic acid in concentrations as high as eight times of that found in raw common bean did not compromise the utilisation of casein by rats during a 10-day period.

Studies found that soaking and cooking had different effects on different legumes. For example, Aranda *et al*. (2004) concluded that high consumption of phytate from beans (*Vicia faba* L.) had no negative effects on the digestion of calcium (Ca) and magnesium (Mg) by rats. However, through another mechanism, soaking and cooking increased the metabolic utilisation of Ca and Mg. Meanwhile, Chopra & Sankhala (2004) found a significant association between soaking and reduced phytate contents, concomitant with increased iron bioavailability in horse gram (*Dolichos biflorus*) and moth bean (*Phaseolus aconitifolius*).

The reduction of phytates and phytic acid (phytate salt) may not be necessary to improve the utilisation of all nutrients. However, their presence may impair the utilisation of some micronutrients, thus their reduction is desirable. In this sense, soaking, especially if the soaking water is discarded, can be recommended, as it proved to be an effective way to reduce phytates and phytic acid.

Total phenolic compounds

In all the studies that assessed total phenolic compounds (Luthria & Pastor-Corrales, 2006; Elmaki *et al*., 2007; Nergiz & Gökgöz, 2007; Toledo & Canniatti-Brazaca, 2008; Xu & Chang, 2008), the loss of these compounds was greater in soaked beans cooked without the soaking water and proportional to the length of soaking. A similar reduction was obtained for velvet beans (*Mucuna pruriens*) by Vadivel & Pugalenthi (2008, 2009), by soaking and discarding the water not absorbed by the beans, followed by autoclaving.

However, in the study by Luthria & Pastor-Corrales (2006), only 2% of the total phenolic compounds are lost in the soaking water, while 83% remain in the beans and 15% are probably lost during cooking. The effect of soaking on the total amount of phenolic compounds was also discussed by Anton *et al*. (2008) and Boateng *et al*. (2007). In the first study, there were no significant changes in the total content of phenolic compounds in soaked but uncooked navy and pinto beans. In the study by Boateng *et al*. (2007), there was a significant reduction only in the total content of phenolic compounds of pinto beans. The same was not observed for kidney beans after soaking and discarding the soaking water, without cook.

There is no consensus regarding the reduction of total phenolic compounds in beans when the inherent reduction of their antioxidant activity is assessed. Ranilla *et al*. (2009) found a relationship between the reduction of phenolic compounds and reduced antioxidant activity in soaked beans; however, the greatest loss was found in samples where the cooking water was discarded, which may indicate that great loss is because of cooking and may be avoided by consuming the beans with the cooking water.

Xu & Chang (2009) also found a relationship between the content of total phenolic compounds and antioxidant activity of beans. However, there was no association between total phenolic acids and antioxidant activity in black beans, only in pinto beans. The authors concluded that the greatest loss of phenolic compounds

Table 1 Selected studies, preparation methods and results regarding nutrients, indicating the methods that resulted in the greatest contents

Study	Preparation methods	Ashes	Protein	Protein digestibility	Carbohydrates	Fibres	Lipids	Minerals	Mineral extractability
Toledo & Canniatti-Brazaca, 2008	NS CWS COS	CWS	CWS = COS	NS = CWS		Total: NS = CWS Soluble: CWS Insoluble: NS = COS	NS = COS = CWS		
Oliveira *et al.*, 2008	RAW CWS COS							CWS = COS	
Ramírez-Cárdenas *et al.*, 2008	Raw NS CWS COS	CWS	CWS		NS	Total: CWS Soluble: COS Insoluble: CWS	CWS	Fe & Zn: NS Ca & Cu: CWS	
Nergiz & Gökgöz, 2007	NS CWS			CWS					
Carmona-García *et al.*, 2007	COS NS				Total, available and resistant starch: COS				
Elmaki *et al.*, 2007	RAW COS Cooking length (CL)							<content with >CL & COS	>extracta-bility >CL & COS
Pujolà *et al.*, 2007	RAW MC COS		COS		Amylopectin, total and resistant starch: RAW Amylose: MC				
Rehman & Shah, 2004	COS(H_2O/$NaHCO_3$) Cooking (CC, PC, MC)					Cellulose, lignin and hemicellulose: $NaHCO_3$, CC & MC			

NS, not soaked; CWS, cooked with soaking water; COS, cooked without the soaking water; H_2O, water; $NaHCO_3$, sodium bicarbonate solution; CC, cooking in common pot or Mattson cooker; PC, cooking in pressure cooker or autoclave; MC, microwave cooking.

Table 2 Selected studies, preparation methods and results regarding the antinutrients, indicating the methods that resulted in the greatest reductions

Study	Preparation Methods	Phytates	Tannins	Oligosaccharides	Total phenolic compounds	Phytic acid	Solids
Toledo & Canniatti-Brazaca, 2008	NS CWS COS	For author: Soaked = NS table: COS	NS COS > CWS				
Xu & Chang, 2008	COS Soaking length (SL)				COS Longer SL		
Ramírez-Cárdenas *et al.*, 2008	RAW NS CWS COS	COS	COS Greatest content: NS				
Nergiz & Gökgöz, 2007	NS CWS		CWS		CWS	CWS	
Shimelis & Rakshit, 2007	COS (H_2O; $NaHCO_3$) Germination (G) Cooking (CC, PC)			All ↓ G > $NaHCO_3$ > H_2O PC > CC			
Pujolà *et al.*, 2007	RAW S COS						S
Elmaki *et al.*, 2007	COS Soaking length (SL)				COS Longer SL	COS Longer SL	
Luthria & Pastor-Corrales, 2006	RAW COS				2% in the soaking water		

NS, not soaked; CWS, cooked with soaking water; COS, cooked without the soaking water; H_2O, water; $NaHCO_3$, sodium bicarbonate solution; CC, cooking in common pot or Mattson cooker; PC, cooking in pressure cooker or autoclave; S, only soaked.

and consequently, of the antioxidant activity of the studied beans, is because of heat. They also conclude that these changes depend upon the type of beans and processing conditions and that different phenolic contents might contribute to different degrees to the overall antioxidant activity.

The protective effect of beans against certain chronic diseases has been associated with the presence of phenolic compounds (Boateng *et al.*, 2007; Xu *et al.*, 2007). However, high levels may become undesirable when they impair digestion and protein absorption, inhibiting the activity of digestive enzymes such as α-amylase and trypsin (Vadivel & Pugalenthi, 2008).

In this context, associating a partial reduction of total phenolic compounds with better absorption of bean proteins, soaking and discarding the water not absorbed by the beans before cooking, seems to be more appropriate.

Tannins

Tannins are the most studied phenolic compounds of beans. Usually the studies assess total phenolic compounds or tannins. Among the selected articles, the reduction of tannins was considered desirable by all authors that analysed their content. In one of the studies (Ramírez-Cárdenas *et al.*, 2008), there was a greater tannin reduction in beans that were soaked and cooked without the soaking water. While comparing soaked beans cooked with the soaking water vs. unsoaked beans, Nergiz & Gökgöz (2007) found lower tannin content in soaked beans. On the other hand, Toledo & Canniatti-Brazaca (2008) found the lower tannin contents in all unsoaked samples and all cooking methods. The authors justify that the greater loss is because of a longer cooking period, required when the beans are not previously soaked. However, when the soaked beans are compared, the same study shows lower values for soaked beans cooked without the soaking water.

In the study by Oliveira *et al.* (2001b), for whom tannin reduction was desirable, a greater reduction in tannin content was also obtained by discarding the soaking water. In other studies with rojo bean (Mosha & Vicent, 2004), horse gram and moth bean (Chopra & Sankhala, 2004), soaking reduced the tannin levels significantly. However, such compounds did not affect the bioavailability of zinc and iron in the study done by Hemalatha *et al.* (2007).

Tannins are also considered bioactive compounds because of their antioxidant capacity (Xu *et al.*, 2007; Xu & Chang, 2009); however, they may have beneficial or adverse nutritional effects (Xu *et al.*, 2007).

In this sense, even though tannins do not always interfere with the utilisation of nutrients, their reduction was considered desirable by all authors as they are

primarily an antinutritional factor. Soaking and discarding the soaking water was the most effective way to reduce tannins. Thus, this procedure can be recommended in the preparation of beans, also because soaking does not completely eliminate tannins from beans, thus the antioxidant activity attributed to this compound is partially preserved. Thus, part of the antioxidant potential attributed to this compound can be preserved.

Oligosaccharides

Only one of the selected studies assessed the oligosaccharide content of beans and how it changed with different preparation methods. Shimelis & Rakshit (2007) studied the reduction of raffinose, stachyose and α-galactosides in two bean varieties (kidney bean) after soaking in water or a solution of sodium bicarbonate ($NaHCO_3$) and cooking without the soaking water in a pot or autoclave. The authors consider that reducing these oligosaccharides is desirable as they cause flatulence.

According to Shimelis & Rakshit (2007), both soaking solutions reduced the raffinose, stachyose and α-galactoside contents in both bean varieties. The germination process, also investigated by the study, was the most effective method to reduce these compounds. However, soaking also reduced their levels significantly, especially when a $NaHCO_3$ solution was used. Both soaking and cooking independently reduced the levels of all oligosaccharides. Consequently, when the two processes were associated, there was a greater reduction of these sugars, which was even more effective when the beans were cooked in an autoclave (Shimelis & Rakshit, 2007). According to Granito *et al*. (2007) in their study with *Phaseolus lunatus* beans, 1/3 of the raffinose content and 1/5 of the stachyose content are lost in the soaking water and the rest remained in the cooking water.

In another two studies that aimed to reduce stachyose and raffinose in bean-based processed products, soaking and cooking were effective for some bean varieties (Matella *et al*., 2005) or for some types of oligosaccharides (Siddiq *et al*., 2006).

Matella *et al*. (2005) found that soaking followed by discarding the soaking water reduced the oligosaccharide content of Michigan black beans and but did not affect the oligosaccharide contents of red and navy beans. The analysis was done only in raw beans.

On the other hand, Siddiq *et al*. (2006) found a significant reduction in the raffinose and stachyose contents of red kidney beans after soaking and discarding the soaking water. Cooking further reduced the raffinose content but did not affect the stachyose content.

Although there are differences in the effectiveness of bean processing to reduce oligosaccharides, which depend on the specific oligosaccharide or bean variety, soaking with subsequent discarding of the soaking water before cooking seems to reduce these compounds, something considered desirable in the reviewed studies.

Proteins and protein digestibility

Protein content depended on preparation method and varied from study to study. Toledo & Canniatti-Brazaca (2008) did not observe differences in the protein content of soaked beans cooked with or without the soaking water. Meanwhile, Ramírez-Cárdenas *et al*. (2008) found greater absolute protein contents in beans cooked with the soaking water; this difference was not confirmed statistically. Pujolà *et al*. (2007) found a greater protein content in soaked beans cooked without the soaking water than in raw beans or uncooked soaked beans.

Other studies with legumes investigated if different preparation methods, such as soaking, extrusion and especially thermal treatments, led to protein loss (Osman, 2007; Teguia & Fon Fru, 2007; Huma *et al*., 2008). Rehman & Shah (2005) found that the protein content of lentils, chick peas, red kidney beans, white kidney beans and black grams (*Vigna mungo*) may not be affected by soaking, discarding the soaking water and cooking.

Toledo & Canniatti-Brazaca (2008) found that protein digestibility was lowest in beans cooked without the soaking water, but there was no difference between unsoaked cooked beans and beans cooked with the soaking water. On the other hand, Nergiz & Gökgöz (2007) found that protein digestibility was greater in beans cooked with the soaking water than in unsoaked, cooked beans, but they did not investigate beans cooked without the soaking water.

A common observation is that bean processing reduces protein content but increases protein digestibility. While studying chick peas, lentils and different types of beans, Martín-Cabrejas *et al*. (2009) and Rehman & Shah (2005) found that protein digestibility increased after soaking and cooking without the soaking water. Soaking and cooking may reduce the contents of some antinutrients as, according to Shimelis & Rakshit (2005), tannins, trypsin inhibitors and some oligosaccharides correlate with lower protein digestibility in the haricot bean (*P. vulgaris* L.).

Although antinutritional factors are associated with lower protein digestibility, studies do not agree on whether the soaking water should be discarded. Preparation method does not seem to change protein content and digestibility.

Ashes, loss of solids, minerals and bioavailability

Beans cooked with the soaking water had the highest ash contents (Ramírez-Cárdenas *et al*., 2008; Toledo & Canniatti-Brazaca, 2008); however, soaking caused a

greater loss of total solids, regardless of cooking with or without the soaking water (Pujolà *et al*., 2007).

The lower ash content of soaked beans may be because of not only mineral lixiviation but also antinutritional factors. Shimelis & Rakshit (2005) found a positive correlation between ash content and zinc and phytic acid contents in haricot beans (*P. vulgaris* L.). Thus, a reduction of the ash content may be desirable. Cooking also seems to reduce ash content (Osman, 2007).

Mineral content varied from study to study. Oliveira *et al*. (2008) found that the mineral content of beans cooked with or without the soaking water were equal; Ramírez-Cárdenas *et al*. (2008) found higher contents of zinc and iron in unsoaked beans and calcium and copper in beans cooked with the soaking water. Elmaki *et al*. (2007) found that increasing the soaking length of beans or discarding the soaking water resulted in greater loss of minerals. However, these treatments were also associated with greater HCl-extractability. Thus, although minerals are lost in the soaking water, soaking and discarding the soaking water increases the bioavailability of the minerals that remained in the beans. This is probably caused by a reduction of antinutrients that chelate minerals, as they are also reduced when beans are soaked and the soaking water discarded.

Studies with other types of beans and legumes also found differing mineral contents. Huma *et al*. (2008) found that soaking and cooking can reduce the amount of minerals significantly. Granito *et al*. (2007) observed that there was a greater loss of calcium, magnesium, potassium, zinc and iron in cooked beans than in soaked beans cooked without the soaking water. However, minerals lost during cooking lixiviate to the cooking water; (Huma *et al*., 2008) consequently, bean preparations consumed with the cooking water retain those minerals.

Meanwhile, Chopra & Sankhala (2004) found that soaking decreases the tannin and phytate contents of horse gram (*D. biflorus*) and moth bean (*P. aconitifolius*), but calcium and magnesium contents are not reduced significantly by dissolution; the digestibility and metabolism of both minerals also increased with soaking. Aranda *et al*. (2004) also observed that soaking and discarding the soaking water decreases tannin and phytate contents, which improves iron bioavailability. Hence, studies with legumes in general and this review are concordant regarding mineral bioavailability: it increases with soaking, especially when the soaking water is discarded and is associated with a reduction of antinutritional factors.

Carbohydrates

As observed with proteins, studies are not concordant in relation to carbohydrate content. Ramírez-Cárdenas *et al*. (2008) found a greater carbohydrate content in unsoaked, cooked beans and lower content in beans cooked with the soaking water; however, statistical analyses were not done. In relation to starch fractions, Carmona-García *et al*. (2007) found greater proportions of total starch and available starch in beans cooked without the soaking water, considering the average found for samples soaked in different solutions. There were divergences regarding resistant starch: a sodium chloride (NaCl) solution was more effective in reducing resistant starch than a sodium bicarbonate ($NaHCO_3$) solution. In both cases, the beans were cooked without the soaking water. The starch, amylopectin and resistant starch contents of raw beans and the amylose content of soaked beans were higher than those of beans cooked without the soaking water (Pujolà *et al*., 2007). However, these results are not relevant because beans are not eaten raw, or soaked without subsequent cooking.

Different results were also obtained by other authors while studying the carbohydrate content of beans. Oliveira *et al*. (2001b) found that cooking soaked common beans without the soaking water reduced the starch content by 26.8%. Salgado *et al*. (2005) found a greater resistant starch content in macassar beans (*Vigna unguiculata* L. Walp) when they were soaked but cooked without the soaking water. Kutoš *et al*. (2003) found that unsoaked, cooked beans and soaked beans cooked without the soaking water had equal resistant starch contents. The authors of the two studies (Kutoš *et al*., 2003; Salgado *et al*., 2005) did not investigate beans cooked with the soaking water.

In agreement with Pujolà *et al*. (2007), Oliveira *et al*. (2001b) found that soaking associated or not with cooking, slightly reduced the starch content of beans. Additionally, Apata (2008) states that cooking reduces the carbohydrate content even if the beans are not previously soaked. Other authors second the influence of cooking on starch content and also mention other factors that influence starch content, such as postcooking handling, cooking method, bean variety, maturation stage of the seeds and length of time stocked frozen (Osorio-Díaz *et al*., 2002 and Salgado *et al*., 2005).

Most authors agree that cooking without the soaking water reduces the carbohydrate content of beans, but resistant starch content remains unchanged, which is desirable as resistant starch resembles soluble fibre (Salgado *et al*., 2005). If only starch is taken into account, it would not be recommended to cook soaked beans without the soaking water. However, when all carbohydrates are considered, it may be advantageous to discard the soaking water, as this reduces the contents of undesirable sugars, such as sucrose and the oligosaccharides that cause flatulence.

Fibres

Unsoaked beans and beans cooked with the soaking water seem to have more fibre than beans cooked

without the soaking water. However, when soluble and insoluble fibre fractions are analysed separately, their contents vary in beans cooked with or without the soaking water (Ramírez-Cárdenas *et al*., 2008; Toledo & Canniatti-Brazaca, 2008). Rehman & Shah (2004) studied soaked beans cooked without the soaking water and found that the cellulose, hemicellulose and lignin contents were higher when the beans were soaked in a sodium bicarbonate solution ($NaHCO_3$) and cooked in a microwave oven or regular pot.

According to Kutoš *et al*. (2003), soaking and cooking pinto beans increase soluble fibre content, but a higher increase was found in unsoaked, cooked beans. On the other hand, processing decreased the insoluble fibre content, which was less affected by cooking without the soaking water than by cooking without soaking. Total fibre content decreased discretely and was less affected by cooking without soaking, as found by Vidal-Valverde *et al*. (1998) in their study with faba beans (*V. faba L. major*). For this reason, Kutoš *et al*. (2003) believe that it is better not to soak beans to maintain total fibre content. It is important to emphasise that resistant starch content, which resembles soluble fibre, was similar between unsoaked, cooked beans and cooked beans without the soaking water (Kutoš *et al*., 2003).

Chopra *et al*. (2009) studied five different types of uncooked legumes where the soaking water was discarded and found that all fibre fractions increased with soaking, Thus, legume soaking is beneficial to health because it increases the dietary fibre content, especially soluble fibre content.

Considering the findings on nutrients and antinutrients covered in the studies, the different effects of prepreparation and preparation are summarised in Table S3.

Conclusion

The articles reviewed in this paper are based on studies that analyse the soaking of common beans (*P. vulgaris* L.) in water or other solutions (e.g. sodium bicarbonate, sodium chloride, acetic acid) to reduce the antinutritional and flatulence factors, as well as to increase nutrient availability. They also investigated if the losses were significant during the preparation processes. The results of these articles were systematically analysed by comparing the statistically analysed data.

Discarding the soaking water before cooking was found to be advantageous. This procedure seems to reduce some carbohydrate fractions of beans and can reduce, maintain or increase fibre content. Meanwhile, resistant starch content remains unchanged, whose function is similar to that of soluble fibres. This method also reduced phytates, phytic acid, total phenolic compounds and tannins. Even though mineral content was also reduced, the bioavailability of most studied minerals increased. Furthermore, the different preparation methods do not seem to affect the protein content and digestibility of the studied beans.

Soaking before cooking and discarding the soaking water also seems to be an effective way to reduce the amounts of oligosaccharides that cause flatulence. This is an important issue because an excess of these oligosaccharides can lead an individual to avoid eating beans altogether, because of the intestinal discomfort. So, despite the fact that these compounds do present some functional properties, if beans are not consumed to avoid intestinal discomfort, these compounds will also not be consumed and their benefits will not be enjoyed.

It should be emphasised that although thermal processing of beans is by far the factor that most reduces antinutrient and nutrient contents, beans are not eaten raw, especially because they contain toxic substances, so cooking is mandatory. Finally, the contents of the analysed compounds in beans can be affected by bean variety, crop location and stocking and distribution methods. As these factors will always be present, we suggest that beans should always be soaked and the soaking water discarded before cooking when preparing beans to improve their nutritional quality.

References

Anton, A.A., Ross, K.A., Beta, T., Gary Fulcher, R. & Arntfield, S.D. (2008). Effect of pre-dehulling treatments on some nutritional and physical properties of navy and pinto beans (*Phaseolus vulgaris* L.). *LWT – Food Science and Technology*, **41**, 771–778.

Apata, D.F. (2008). Effect of cooking methods on available and unavailable carbohydrates of some tropical grain legumes. *African Journal of Biotechnology*, **7**, 2940–2945.

Aranda, P., López-Jurado, M., Fernandéz, M., Moreu, M.D.C., Porres, J.M. & Urbano, G. (2004). Bioavailability of calcium and magnesium from faba beans (*Vicia faba* L var major), soaked in different pH solutions and cooked, in growing rats. *Journal of the Science of Food and Agriculture*, **84**, 1514–1520.

Boateng, J., Verghese, M., Walker, L.T. & Ogutu, S. (2007). Effect of processing on antioxidant contents in selected dry beans (*Phaseolus* spp. L.). *LWT – Food Science and Technology*, **41**, 1541–1547.

Campos-Vega, R., Reynoso-Camacho, R., Pedraza-Aboytes, G. *et al*. (2009). Chemical composition and in vitro polysaccharide fermentation of different beans (*Phaseolus vulgaris* L.). *Journal of Food Science*, **74**, T59–T65.

Carmona-García, R., Osorio-Díaz, P., Agama-Acevedol, E., Tovar, J. & Bello-Pérez, L.A. (2007). Composition and effect of soaking on starch digestibility of *Phaseolus vulgaris* (L.) cv. 'Mayocoba'. *International Journal of Food Science and Technology*, **42**, 296–302.

Chopra, S. & Sankhala, A. (2004). Effect of soaking and sprouting on tannin, phytate and *in vitro* iron in underutilized legumes – horse gram (*Dolichos biflorus*) and moth bean (*Phaseolus aconitifolius*). *Journal of Food Science and Technology*, **41**, 547–550.

Chopra, H., Sa, U. & Ghugre, P. (2009). Dietary fibre content of selected legumes: varietal differences and effect of processing. *Journal of Food Science and Technology*, **46**, 266–268.

Elmaki, H.B., Abdelrahaman, S.M., Idris, W.H., Hassan, A.B., Babiker, E.E. & El Tinay, A.H. (2007). Content of antinutritional

factors and HCl-extractability of minerals from white bean (*Phaseolus vulgaris*) cultivars: influence of soaking and/or cooking. *Food Chemistry*, **100**, 362–368.

FAO. FAOSTAT. (2009). *Consumption: Crops Primary Equivalent*, Food and Agriculture Organisation Statistics Division. Rome, Italy: FAO (Food and Agriculture Organisation of the United Nations). http://faostat.fao.org/site/609/default.aspx#ancor (last accessed 16 August 2010).

Granito, M., Brito, Y. & Torres, A. (2007). Chemical composition, antioxidant capacity and functionality of raw and processed *Phaseolus lunatus*. *Journal of the Science of Food and Agriculture*, **87**, 2801–2809.

Haro, A. (1983). La calidad nutritiva de las leguminosas: grano y su control genético. In: *Leguminosas de grano* (edited by J.I. Cubero & M.T. Moreno). Pp. 213–224. Madrid, Spain: Ediciones Mundi-Prensa.

Hemalatha, S., Platel, K. & Srinivasan, K. (2007). Zinc and iron contents and their bioaccessibility in cereals and pulses consumed in India. *Food Chemistry*, **102**, 1328–1336.

Huma, N., Anjum, F.M., Sehar, S., Khan, M.I. & Hussain, S. (2008). Effect of soaking and cooking on nutritional quality and safety of legumes. *Nutrition and Food Science*, **38**, 570–577.

Kutoš, T., Golob, T., Kač, M. & Plestenjak, A. (2003). Dietary fibre content of dry and processed beans. *Food Chemistry*, **80**, 231–235.

Luthria, D.L. & Pastor-Corrales, M.A. (2006). Phenolic acids content of fifteen dry edible bean (*Phaseolus vulgaris* L.) varieties. *Journal of Food Composition and Analysis*, **19**, 205–211.

Martín-Cabrejas, M.A., Aguilera, Y., Pedrosa, M.M. *et al*. (2009). The impact of dehydration process on antinutrients and protein digestibility of some legume flours. *Food Chemistry*, **114**, 1063–1068.

Matella, N.J., Dolan, K.D., Stoeckle, A.W., Bennink, M.R., Lee, Y.S. & Uebersax, M.A. (2005). Use of hydration, germination, and –galactosidase treatments to reduce oligosaccharides in dry beans. *Journal of Food Science*, **70**, C203–C207.

Mosha, T.C.E. & Vicent, M.M. (2004). Nutritional value and acceptability of homemade maize/sorghum-based weaning mixtures supplemented with rojo bean flour, ground sardines and peanut paste. *International Journal of Food Sciences and Nutrition*, **55**, 301–315.

Muzquiz, M. (2008). Conference: Componentes nutricionalmente activos en leguminosas: implicaciones en nutrición y salud. In: *Scientific memories – 1st International Scientific Congress and National Bean Fair* (edited by A.C. Hernández). ISBN: 978-970-43-0376-1. Pp. 226–227. Celaya, México: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuárias.

Nergiz, C. & Gökgöz, E. (2007). Effects of traditional cooking methods on some antinutrients and in vitro protein digestibility of dry bean varieties (*Phaseolus vulgaris* L.) grown in Turkey. *International Journal of Food Science and Technology*, **42**, 868–873.

Oliveira, A.C., Carraro, F., Reis, S.M.P.M. *et al*. (2001a). The elimination of the not absorved water during common bean soaking resulted in weight gain in rats. *Brazilian Journal of Nutrition*, **14**, 153–155.

Oliveira, A.C., Queiroz, K.S., Helbig, E., Reis, S.M.P.M. & Carraro, F. (2001b). The domestic processing of the common bean resulted in a reduction in the phytates and tannins antinutritional factors, in the starch content and in the raffinose, stachiose and verbascose flatulence factors. *Archivos Latinoamericanos de Nutrición*, **51**, 276–283.

Oliveira, A.C., Reis, S.M.P.M., Carvalho, E.M. *et al*. (2003). Increasing quantities of phytic acid in the diet did not affect casein digestibility and weight gain in rats. *Brazilian Journal of Nutrition*, **16**, 211–217.

Oliveira, V.R., Ribeiro, N.D., Jost, E. & Londero, P.M.G. (2008). Nutritional and microbiological quality of common beans (*Phaseolus vulgaris* L.) cooked with or without the use of soaking water. *Revista Ciência e Agrotecnologia*, **32**, 1912–1918.

Osman, M.A. (2007). Effect of different processing methods, on nutrient composition, antinutrional factors, and in vitro protein digestibility of Dolichos lablab bean [*Lablab purpuresus* (L) sweet]. *Pakistan Journal of Nutrition*, **6**, 299–303.

Osorio-Díaz, P., Bello-Pérez, L.A., Agama-Acevedo, E., Vargas-Torres, A., Tovar, J. & Paredes-López, O. (2002). In vitro digestibility and resistant starch content of some industrialized commercial beans (*Phaseolus vulgaris* L.). *Food Chemistry*, **78**, 333–337.

Philippi, S.T., Latterza, A.R., Cruz, A.T.R. & Ribeiro, L.C. (1999). Adapted food pyramid: a guide for a right food choice. *Brazilian Journal of Nutrition*, **12**, 65–80.

Pujolà, M., Farreras, A. & Casañas, F. (2007). Protein and starch content of raw, soaked and cooked beans (*Phaseolus vulgaris* L.). *Food Chemistry*, **102**, 1034–1041.

Ramírez-Cárdenas, L., Leonel, A.J. & Costa, N.M.B. (2008). Effect of domestic processing on nutrient and antinutritional factor content in different cultivars of common beans. *Ciência e Tecnologia de Alimentos*, **28**, 200–213.

Ranilla, L.G., Genovese, M.I. & Lajolo, F.M. (2009). Effect of different cooking conditions on phenolic compounds and antioxidant capacity of some selected Brazilian bean (*Phaseolus vulgaris* L.) cultivars. *Journal of Agricultural and Food Chemistry*, **57**, 5734–5742.

Rehman, Z.-U. & Shah, W.H. (2004). Domestic processing effects on some insoluble dietary fibre components of various food legumes. *Food Chemistry*, **87**, 613–617.

Rehman, Z.U. & Shah, W.H. (2005). Thermal heat processing effects on antinutrients, protein and starch digestibility of food legumes. *Food Chemistry*, **91**, 327–331.

Salgado, S.M., Melo Filho, A.B., Andrade, S.A.C., Maciel, G.R., Livera, A.V.S. & Guerra, N.B. (2005). Modification of the concentration of resistant starch in macassar bean (*Vigna unguiculata* L. Walp) hydrothermal process and freezing. *Ciência e Tecnologia de Alimentos*, **25**, 259–264.

Shimelis, E.A. & Rakshit, S.K. (2005). Antinutritional factors and in vitro protein digestibility of improved haricot bean (*Phaseolus vulgaris* L.) varieties grown in Ethiopia. *International Journal of Food Sciences and Nutrition*, **56**, 377–387.

Shimelis, E.A. & Rakshit, S.K. (2007). Effect of processing on antinutrients and in vitro protein digestibility of kidney bean (*Phaseolus vulgaris* L.) varieties grown in East Africa. *Food Chemistry*, **103**, 161–172.

Siddiq, M., Nyombaire, G., Dolan, K.D., Matella, N.J. & Harte, J.B. (2006). Processing of sugar-coated red kidney beans (*Phaseolus vulgaris*): fate of oligosaccharides and phytohemagglutinin (PHA), and evaluation of sensory quality. *Journal of Food Science*, **71**, C521–C526.

Silva, M.R. & Silva, M.A.A.P. (1999). Nutritional aspects of phytates and tannins. *Brazilian Journal of Nutrition*, **12**, 21–32.

Silva, M.R. & Silva, M.A.A.P. (2000). Antinutritional factors: protease inhibitors and lectins. *Brazilian Journal of Nutrition*, **13**, 3–9.

Teguia, A. & Fon Fru, S. (2007). The growth performances of broiler chickens as affected by diets containing common bean (*Phaseolus vulgaris*) treated by different methods. *Tropical Animal Health and Production*, **39**, 405–410.

Toledo, T.C.F. & Canniatti-Brazaca, S.G. (2008). Chemical and nutritional evaluation of Carioca beans (*Phaseolus vulgaris* L.) cooked by different methods. *Ciência e Tecnologia de Alimentos*, **28**, 355–360.

Vadivel, V. & Pugalenthi, M. (2008). Effect of various processing methods on the levels of antinutritional constituents and protein digestibility of *Mucuna pruriens* (L.) DC. var. *utilis* (Wall. ex Wight) Baker ex Burck (velvet bean) seeds. *Journal of Food Biochemistry*, **32**, 795–812.

Vadivel, V. & Pugalenthi, M. (2009). Effect of soaking in sodium bicarbonate solution followed by autoclaving on the nutritional and

antinutritional properties of velvet bean seeds. *Journal of Food Processing and Preservation*, **33**, 60–73.
Vasconcellos, A.B., Pinheiro, A.R.O., Recine, E. & Carvalho, M.F.C.C. (2006). *Dietary Guidelines for the Brazilian Population*. Pp. 61–64. Brasília, Brazil: Ministry of Health.
Vidal-Valverde, C., Frias, J., Sotomayor, C., Diaz-Pollan, C., Fernandez, M. & Urbano, G. (1998). Nutrients and antinutritional factors in faba beans as affected by processing. *Zeitschrift für Lebensmittel-Untersuchung und -Forschung*, **207**, 140–145.
Xu, B.J. & Chang, S.K.C. (2008). Total phenolic content and antioxidant properties of eclipse black beans (*Phaseolus vulgaris* L.) as affected by processing methods. *Journal of Food Science*, **73**, H19–H27.
Xu, B.J. & Chang, S.K.C. (2009). Total phenolic, phenolic acid, anthocyanin, flavan-3-ol, and flavonol profiles and antioxidant properties of pinto and black beans (*Phaseolus vulgaris* L.) as affected by thermal processing. *Journal of Agricultural and Food Chemistry*, **57**, 4754–4764.
Xu, B.J., Yuan, S.H. & Chang, S.K.C. (2007). Comparative analyses of phenolic composition, antioxidant capacity, and color of cool season legumes and other selected food legumes. *Journal of Food Science*, **72**, S167–S177.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1 Descriptors in Portuguese, English and Spanish used to search articles for the systematic research on the influence of soaking on the nutritional quality of common beans

Table S2 Author, year, country and predictor variables of the selected articles, according to the soaking and cooking methods used

Table S3 Summary of the results found by the systematic review on the influence of soaking on the nutritional quality of common beans (*Phaseolus vulgaris* L.) cooked with or without the soaking water

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