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; Ramirez-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.

However, Ramirez-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; Ramirez-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.
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 (NaHCO₃) and mixed (NaCl + NaHCO₃) (*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, polyphen-
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; Pujolá 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., 2008); starch (total, available starch and resistant starch, amylose) (Carmona-García et al., 2008); fibril (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

<table>
<thead>
<tr>
<th>Study</th>
<th>Preparation methods</th>
<th>Ashes</th>
<th>Protein digestibility</th>
<th>Carbohydrates</th>
<th>Fibres</th>
<th>Lipids</th>
<th>Minerals</th>
<th>Mineral extractability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toledo &amp; Canniatti-Brazaca, 2008</td>
<td>NS CWS COS</td>
<td>CWS</td>
<td>CWS = COS</td>
<td>NS = CWS</td>
<td>Total: NS = CWS</td>
<td>NS = COS = CWS</td>
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<td></td>
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<td></td>
<td>Soluble: CWS</td>
<td>Insoluble: NS = COS</td>
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<td></td>
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<tr>
<td>Oliveira et al., 2008</td>
<td>RAW CWS COS</td>
<td>CWS</td>
<td></td>
<td></td>
<td>Total CWS</td>
<td>CWS Fe &amp; Zn: NS</td>
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<td></td>
<td>Soluble: COS</td>
<td>Ca &amp; Cu: CWS</td>
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<tr>
<td>Carmona-Garcia et al., 2007</td>
<td>NS CWS COS</td>
<td>CWS</td>
<td></td>
<td></td>
<td>Total, available and resistant starch: COS</td>
<td></td>
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<tr>
<td>Elmaki et al., 2007</td>
<td>RAW CWS COS</td>
<td>NS</td>
<td></td>
<td></td>
<td>&lt;content with &gt;extractability</td>
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<td>&gt;CL &amp; COS &gt;CL &amp; COS</td>
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<tr>
<td>Pujola et al., 2007</td>
<td>RAW MC COS</td>
<td>COS</td>
<td></td>
<td>Amylopectin, total and resistant starch: RAW Amylose: MC</td>
<td></td>
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<tr>
<td>Rehman &amp; Shah, 2004</td>
<td>COS(H2O/NaHCO3)</td>
<td></td>
<td></td>
<td></td>
<td>Cellulose, lignin and hemicellulose: NaHCO3, MCC</td>
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<td></td>
<td>Cooking (CC, PC, MC)</td>
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</tbody>
</table>

NS, not soaked; CWS, cooked with soaking water; COS, cooked without the soaking water; H2O, water; NaHCO3, sodium bicarbonate solution; CC, cooking in common pot or Mattson cooker; PC, cooking in pressure cooker or autoclave; MC, microwave cooking.
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. uns soaked 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 uns soaked 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

<table>
<thead>
<tr>
<th>Study</th>
<th>Preparation Methods</th>
<th>Phytates</th>
<th>Tannins</th>
<th>Oligosaccharides</th>
<th>Total phenolic compounds</th>
<th>Phytic acid</th>
<th>Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toledo &amp; Canniatti-Brazaca, 2008</td>
<td>NS</td>
<td>For author: Soaked = NS table: COS</td>
<td>NS</td>
<td>COS &gt; CWS</td>
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<tr>
<td>Xu &amp; Chang, 2008</td>
<td>COS</td>
<td>Soaking length (SL)</td>
<td>COS</td>
<td>Greatest content: NS</td>
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<tr>
<td>Ramírez-Cárdenas et al., 2008</td>
<td>RAW</td>
<td>COS</td>
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<tr>
<td>Nergiz &amp; Gökgöz, 2007</td>
<td>NS</td>
<td>CWS</td>
<td></td>
<td>CWS</td>
<td>CWS</td>
<td>CWS</td>
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<tr>
<td>Shimelis &amp; Rakshit, 2007</td>
<td>COS (H2O; NaHCO3)</td>
<td>Germination (G)</td>
<td>G &gt; NaHCO3 &gt; H2O</td>
<td>PC &gt; CC</td>
<td></td>
<td></td>
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<tr>
<td>Pujola et al., 2007</td>
<td>RAW</td>
<td>S</td>
<td></td>
<td>COS</td>
<td>S</td>
<td></td>
<td></td>
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<tr>
<td>Elmaki et al., 2007</td>
<td>COS</td>
<td>Soaking length (SL)</td>
<td>Longer SL</td>
<td>COS</td>
<td>Longer SL</td>
<td></td>
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<tr>
<td>Luthria &amp; Pastor-Corrales, 2006</td>
<td>RAW</td>
<td>2% in the soaking water</td>
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</tbody>
</table>

NS, not soaked; CWS, cooked with soaking water; COS, cooked without the soaking water; H2O, water; NaHCO3, sodium bicarbonate solution; CC, cooking in common pot or Mattson cooker; PC, cooking in pressure cooker or autoclave; S, only soaked.

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

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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 (NaHCO₃) 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 NaHCO₃ 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, Ramirez-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 & Gökgoz (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-Cabrera 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 harticot 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 (Ramirez-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 lixiviation 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. Ramirez-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 (NaHCO₃) solution. In both cases, the beans were cooked without the soaking water. The starch, amyllopectin 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. Kutos 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 (Kutos 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 (Ramirez-Cardenas et al., 2008; Toledo &
ied soaked beans cooked without the soaking water and
found that the cellulose, hemicellulose and lignin con-
tents were higher when the beans were soaked in a
sodium bicarbonate solution (NaHCO3) and cooked in
a microwave oven or regular pot.

According to Kutos et al. (2003), soaking and cook-
ing 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, Kutos et al.
(2003) believe that it is better not to soak beans to
maintain total fibre content. It is important to empha-
sise that resistant starch content, which resembles
soluble fibre, was similar between unsoaked, cooked
beans and cooked beans without the soaking water
(Kutos et al., 2003).

Chopra et al. (2009) studied five different types of
uncooked legumes where the soaking water was dis-
carded 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 antinutri-
ents covered in the studies, the different effects of
preparation 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 antinutri-
tional 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 com-
pounds and tannins. Even though mineral content was
also reduced, the bioavailability of most studied min-
derals 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 sub-
stances, so cooking is mandatory. Finally, the contents
of the analysed compounds in beans can be affected by
bean variety, crop location and stocking and distribu-
tion 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.

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**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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