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Water Absorption, Hard Shell and Cooking Time of Common Beans (*Phaseolus vulgaris* L.)

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Legumes play an important role in human nutrition, especially among low-income human groups in developing countries. Beans are particularly important in Brazil for two reasons: Brazil is the largest producer and consumer of grain legumes in the world and the fact that beans are a major source of protein for many people. The objective of this study was to evaluate the hard-shell percentage in seven common beans (*Phaseolus vulgaris* L) cultivars, by using the Burr cooking method before and after soaking. The following cultivars developed by Embrapa Rice and Beans, in Santo Antônio de Goiás – GO, obtained from the same area and planting time (winter) were used: BRS Vereda (rosinha); BRS Timbó (roxinho); BRS Grafite (preto); BRS Radiante (rajado); BRS – Pontal (carioca); BRS Marfim (mulatinho) and Jalo Precoce (jalo). The results revealed significant differences ($p < 0.05$) among the cultivars in relation to hard-shell and cooking time (before and after soaking). The cultivar Jalo Precoce (jalo) presented the highest percentage of hard-shell (42%) and cooking time (67.5 minutes) without previous soaking. The cultivars BRS Timbó (roxinho); BRS Grafite (preto); BRS Pontal (carioca), and BRS Marfim (mulatinho) did not present hard-shell grains.

Keywords: Common bean, hard-shell, cooking time, water absorption.

INTRODUCTION

Beans are a staple food, both in the rural and urban areas in Brazil (Costa de Oliveira et al., 2001) supplying significant amounts of protein, calories, unsaturated fatty acid (linoleic acid), food fiber, mainly soluble fiber, besides being an excellent source of some minerals (iron and zinc) and vitamins (Coelho, 1991; Berríos et al., 1999; Villavicencio et al. 2000; Kutos et al. 2003). Despite these advantages, bean grains have some undesirable characteristics that limit their acceptability or nutritional value, such as: hard-to-cook phenomenon, antinutrients or antinutritional factors or limitation in some amino acids of high biological value (Jood et al., 1986; De-Leon et al., 1992; Vidal-Valverde et al., 1993; Barampama and Simard, 1994; Costa de Oliveira et al., 2001).

The development of bean cultivars adapted to the cultivation site and with yield potential has been the major

goal of bean breeding. However, for a new bean cultivar to be registered, certain market requirements must be met, such as yield, resistance to diseases, and product cooking quality (grain) (Carbonell et al., 2003; Lemos et al., 2004). Thus, it is important for these bean cultivars to have grains with desirable cooking characteristics, such as lower cooking time and high water absorption capacity.

Beans have been extensively cultivated under different climatic conditions and by producers with different technology levels. Thus, to obtain higher profitability, it would be necessary to search for varieties adapted to the cultivation conditions and with high grain yield to meet consumer demands (Carneiro et al., 2005).

Prior grain soaking and cooking are fundamental for bean preparation and consumption, guaranteeing inactivation of antinutrients to provide the sensorial and color characteristics, flavor and texture desired by consumers (Adams and Bedford, 1973; Costa and Vieira, 2000; Costa de Oliveira et al, 2001; Costa et al., 2006; Toledo and Canniatti-Brazaca, 2008). These are the main

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factors that farmers consider before adopting a bean cultivar.

According to some authors, soaking time is directly related to cooking time, which tends to decrease, as beans remain immersed (Rodrigues et al., 2005a and 2005b).

In Brazil, the recommendation of new bean cultivars has been made based on their agronomical characteristics (EMBRAPA, 1994; Carneiro, 2002; Lemos et al., 2004). Despite the fact that Brazil is the largest bean producer in the world, few studies have been conducted to characterize appearance, texture and flavor of the several bean varieties that are available in this country. In most cases, the sensorial profiles of the grains, mainly those genetically improved, remain unknown (Carneiro et al., 2005).

Water-holding capacity and cooking time of beans were evaluated by Rodrigues et al. (2005a and 2005b) and these showed that cooking time decreased as soaking time increased. Romano et al. (2005a) studying the hydration curve and cooking time, verified that after three hours of soaking, the cooking time of the cultivars Pérola and Guapo Brilhante was reduced to half.

Cooking can be conducted not only at different times and temperatures, but also at different pressure conditions. It is important to point out that cooking time could be shorter under pressure, without jeopardizing the sensorial properties of the bean (Della Modesta and Garruti, 1981).

The most common used temperature for cooking under pressure is approximately 121°C and between 97 and 100°C for conventional cooking (Burr, 1971; Proctor and Watts, 1987).

Grain soaking time necessary to evaluate water-holding capacity is 16 hours, as suggested by The National Bean Cultivar Registry to determine Cultivar Value and Use (CVU), according to SNP-C-MAPA (Ruling no. 294/98 – Annex IV). This procedure utilizes one part of grain to four parts of water at room temperature (Garcia-Vela and Stanley, 1989). However, some authors have reported that soaking time may be reduced to 4 hours (Costa de Oliveira et al., 2001; Esteves et al., 2002; Carbonell et al., 2003; Dalla Corte et al., 2003).

For home cooking, the raw and washed beans are soaked in water for 12 to 16 hours (overnight). Such procedure is based only on everyday experience, as to its effect on cooking time (Romano et al., 2005a).

During hydration, however, grain respiration and metabolism intensify, and may provoke nutrient loss through dissolution. Thus, the water used for soaking must be re-used for bean preparation (Romano et al., 2005b). Discarding the soaking water is sometimes done in home cooking.

Studying the cultivars Guapo Brilhante and Pérola, previously soaked in water for 16 hours, Romano et al. (2005b) observed total solid losses of 2 and 2.5 %, respectively, and soluble protein of 1.51 and 2% ,

respectively.

On the other hand, Oliveira et al. (2001) concluded that home cooking of beans previously soaked for 5 hours, followed by discarding the water not absorbed by the grains would be sufficient to reduce antinutrients and flatulence, as well as starch loss.

Other factors that may influence bean grain cooking time were humidity higher than 10%, high temperature and prolonged storage time (above 32°C and storage longer than 24 months), as reported by Burr and Morris (1968). Such conditions can increase cooking time from 240 to 340 minutes.

One of the main factors in the adoption of a bean cultivar by consumers and, consequently, by producers, is related to cooking time. As most women work outside the house, less time is available for cooking. On the other hand, for the low-income human groups, the reduction in energy costs (cooking gas), is a defining purchase factor. Hence, cooking time evaluation is a priority before recommendation of a given cultivar (Costa and Vieira, 2000).

The hard-shell percentage is the ratio of grains that did not absorb water after soaking in relation to its total number (Rodrigues et al., 2005a and 2005b).

Traditional legume processing and cooking methods have been improving to enhance flavor, nutritive value and consumer acceptance.

Cooking is known to be fundamental for bean consumption, as it increases digestibility, inactivates antinutritional factors or antinutrients, increases nutrient biological value and confers the sensorial quality that consumers demand to improve acceptance (Tharanathan and Mahadevamma, 2003).

The objective of this study was not only to evaluate the culinary quality of seven bean cultivars from different commercial groups, but also to test their water-holding capacity, number of hard-shell grains and cooking time, using an experimental cooker.

MATERIAL AND METHODS

Materials

The bean cultivars used in this study were developed by Embrapa Rice and Beans, and were grown at Capivara Farm, located in Santo Antônio de Goiás–GO, during the same growing season. The following seed samples were sent in polyethylene bags to Embrapa Food Technology: 1) BRS Vereda (rosinha); 2) BRS Timbó (roxinho); 3) BRS Grafite (preto); 4) BRS Radiante (rajado); 5) BRS Pontal (carioca); 6) BRS Marfim (mulatinho) and 7) Jalo Precoce (jalo). The seed samples were maintained under refrigeration (5°C ± 2) until analyses.

Water-holding capacity and absorption peak

Water-holding capacity was determined by the method described by Garcia-Vela and Stanley (1989) and Plhak et al. (1989),

indicated by Bean Cultivars National Registry Norms to determine the CUV (Cultivation Use and Value), and according to SNPC-MAPA (Ruling no. 294/98 – Annex IV), which takes into account weight differences before and after water soaking. Small-grain seed samples (8g) of each bean cultivar were soaked in a 500 mL beaker containing 100 mL of distilled water at room temperature (23 to 25°C) for 16 hours. Every hour, the soaking water was drained for 3 minutes and then the beans were weighed. The hydration rate was obtained by the following formula:

$$CA = (P_f - P_i / P_i) \times 100, \text{ where:}$$

CA = Water-holding capacity;

P_i = sample initial weight;

P_f = sample final weight.

Water-holding capacity and maximum water-holding peaks were statistically analyzed using models including the cultivar and random error effects, with three repetitions.

Regression analysis was also carried out for the % of water absorbed by the seven bean cultivars as a function of soaking time (linear and quadratic effect), and the water-holding peak (P_iA) was characterized by the result of the regression equation derivative for each cultivar. Water-holding capacity was estimated by regression of each repetition, replacing the variable x by the value found for P_iA . Variance analysis (F test) and the mean comparison test (Tukey test at 5% significance) were applied.

Hard-shell grain percentage

Bean grains were sieved through a no. 12 sieve (10 mesh) with 100 being selected from those retained, based on their integrity. The samples were washed and immersed for 8 hours in distilled water and the seeds that did not absorb water were counted. These grains were visually verified for shell wrinkage. The result was expressed as hard-shell percentage (without water-holding capacity). Data were statistically analyzed by ANOVA Variance Analysis (F test) and mean comparison (Tukey test at 5% significance).

Experimental cooking time

Bean cooking time was measured in an experimental JAB-77 cooker, minor type, with 25 blades, each weighing 90g, manufactured by Universidade do Estado de São Paulo (UNESP) – Jaboticabal – SP, based on the Mattson cooker principle (31). The cooker consists of metal receptors that maintain the grains in a static position, with two small openings (superior and inferior), and vertical blades placed on the extremities of each grain, where they penetrate after cooking. Each receptor is vertically penetrated by a blade when the grain becomes sufficiently soft. Twenty-five beans were positioned in the receptors, and the cooker was placed into a 10 L stainless steel pot, containing 5 L of distilled water, with the inferior part of the cooker being kept immersed in water maintained at temperature ranging from 102 to 104 °C.

Cooking time was recorded as each bean was penetrated by its respective blade, this being the time needed to penetrate 50% of the beans, conventionally adopted as the falling time of the 13th blade on the bean. Experiments were conducted using beans soaked for 16 hours as well as those without previous soaking. Cooking time was statistically analyzed using the following model:

$$Y_{ijk} = \mu + C_i + T_j + CT_{ij} + E_{ijk}, \text{ where}$$

Y_{ijk} = observation on bean k sample of cultivar j , submitted to treatment i ,

μ = mean effect

C_i = cultivar i effect with $i = 1$ BRS Vereda, 2 BRS Timbó, 3 BRS Grafite, 4 BRS Radiante, 5 BRS Pontal, 6 BRS Marfim, and 7 Jalo Precoces;

T_j = treatment j effect, with $j = 1$ without soaking and 2, with soaking;

CT_{ij} = effect of the interaction of cultivar i with treatment

j ; E_{ijk} = random error.

Correlations of the physical analysis results were conducted using the means.

RESULTS AND DISCUSSION

Water-holding capacity

The water absorption curves of the 7 cultivars presented a quadratic effect (Figure 1). The water volume absorbed by the grains increased with the soaking time, but the cultivars presented distinct behaviors.

The cultivar BRS Grafite held the highest water percentage (70.21%) in the first soaking hour, but after 16 hours, its absorption was similar to the other cultivars. On the other hand, the cultivar Jalo Precoces, which, in the first hour, held the lowest percentage of water (5.80%), took a longer time to reach the maximum water holding peak (14.33min). However, absorption was similar to the others, being relatively constant from the beginning of the soaking process, not differing statistically from cultivars BRS Grafite and BRS Marfim.

On the other hand, Rodrigues et al. (2005a and 2005b) reported that bean soaking time over 13 hours may not affect the water-holding capacity by the grains, due to their stabilization to absorb water.

Cultivar BRS Radiante absorbed 55.61% in the first hour, being the cultivar that absorbed the highest amount of water at its maximum holding peak (120.33%), but did not differ from the other cultivars ($p < 0.05$). Despite the distinct behavior of the cultivars, water-holding capacities were statistically similar, as shown in Table 1.

The F test revealed no significant difference ($p < 0.05$) among the cultivars regarding water-holding capacity. However, there was a significant difference ($p < 0.05$) when the cultivars were compared regarding their maximum water-holding peak.

The water volume absorbed by the beans increased with soaking time, reaching their respective holding peaks between 11.33 and 14.33 hours. This interval can be considered satisfactory, as it simulates the habit of soaking the beans overnight before cooking.

Similar results were previously reported by Rodrigues et al. (2005a and 2005b) with maximum hydration values of 13.12 and 13.20 hours for varieties TPS Nobre (black group) and Pérola (carioca group), respectively. However, Ramos Junior et al. (2002) found higher values for the black bean varieties, which presented an average time of 19.20 hours, and lower values for the carioca group (8.17 to 12.2 hours), according to the genotype evaluated.

Considering the interference of the characteristics of the grain tegument, such as thickness, weight, adherence

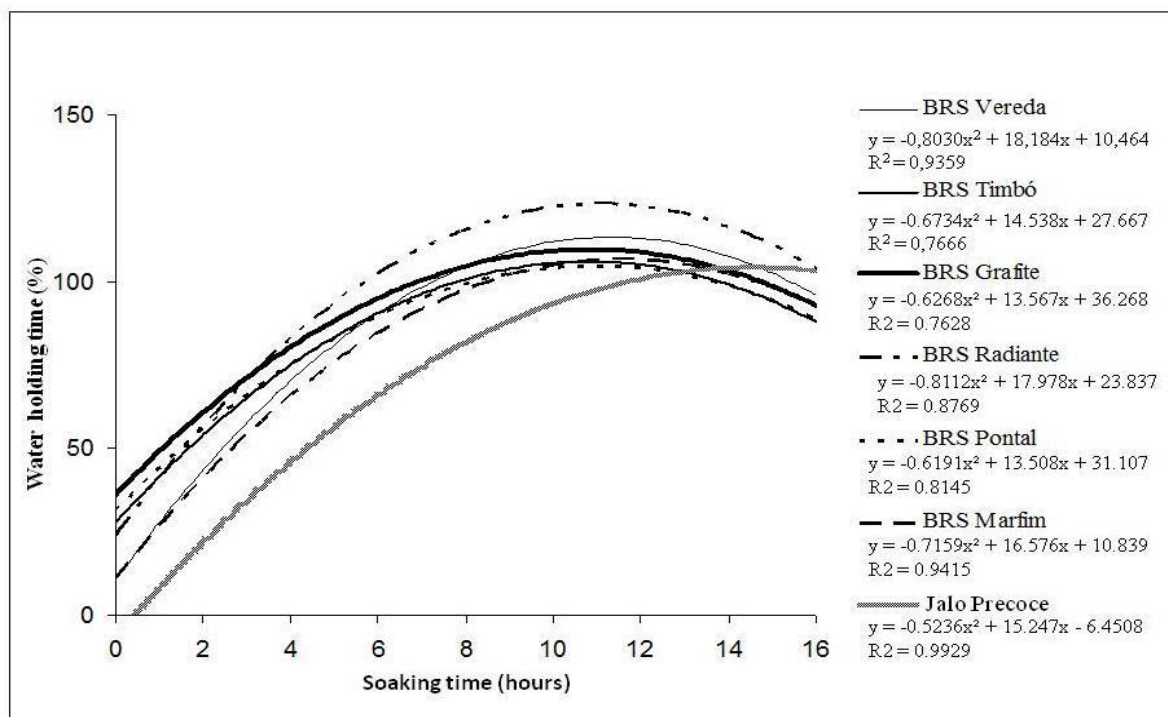


Figure 1. Relation between water holding capacity and soaking time in the seven cultivars of common bean (*Phaseolus vulgaris* L.): brs vereda, brs timbó, brs grafite, brs radiante, brs pontal, brs marfim and jalo precoce.

Table 1. Mean of the minimum square and respective standard errors of the water holding capacity and absorption peak in seven cultivars of common bean (*Phaseolus vulgaris* L.): brs vereda, brs timbó, brs grafite, brs radiante, brs pontal, brs marfim and jalo precoce, and coefficient of variation (cv)

Cultivars	Water Holding Capacity (%)	Absorption Peak (hours)
BRS Vereda	112.00 ^a ± 4.86	11.33 ^b ± 0.52
BRS Timbó	102.33 ^a ± 4.86	11.33 ^b ± 0.52
BRS Grafite	105.33 ^a ± 4.86	12.00 ^{ab} ± 0.52
BRS Radiante	120.33 ^a ± 4.86	11.67 ^b ± 0.52
BRS Pontal	100.33 ^a ± 4.86	11.67 ^b ± 0.52
BRS Marfim	105.67 ^a ± 4.86	12.00 ^{ab} ± 0.52
Jalo Precoce	106.67 ^a ± 4.86	14.33 ^a ± 0.52
Mean	107.52	12.05
CV (%)	7.83	7.47

Means with the same letters did not differ significantly ($p < 0.05$) and but those with different letters differed significantly ($p < 0.05$).

Table 2. Percentage of hard-shell, cooking time of the grains with and without previous soaking, and time reducing after cooking with previous soaking in the seven common bean cultivars (*phaseolus vulgaris* l)

Cultivars	Hard-shell (%)	Cooking Time (min.)		Time Reduction (%)
		With soaking	Without soaking	
BRS Vereda	1.67 ^{bc} ± 0.55	14.31 ^{bc} ± 0.65	52.18 ^{ab} ± 3.77	72.49 ^a ± 2.26
BRS Timbó	0.00 ^c ± 0.55	13.33 ^c ± 0.65	47.18 ^b ± 3.77	71.66 ^a ± 2.26
BRS Grafite	0.00 ^c ± 0.55	13.81 ^{bc} ± 0.65	49.98 ^{ab} ± 3.77	72.13 ^a ± 2.26
BRS Radiante	4.00 ^b ± 0.55	19.75 ^a ± 0.65	59.18 ^{ab} ± 3.77	65.87 ^a ± 2.26
BRS Pontal	0.00 ^c ± 0.55	15.08 ^{bc} ± 0.65	46.95 ^b ± 3.77	67.59 ^a ± 2.26
BRS Marfim	0.00 ^c ± 0.55	14.33 ^{bc} ± 0.65	53.37 ^{ab} ± 3.77	73.04 ^a ± 2.26
Jalo Precoce	42.00 ^a ± 0.55	16.55 ^b ± 0.65	67.50 ^a ± 3.77	75.25 ^a ± 2.26
Mean	6.81	15.31	53.76	71.15
CV (%)	13.97	7.33	12.16	5.50

Means with the same letters did not differ significantly ($p < 0.05$) and but those with different letters differed significantly ($p < 0.05$).

to cotyledons, elasticity, porosity and colloidal properties in water absorption by beans (Esteves et al., 2002), it can be observed that there is a variation of maximum hydration time of the grains as a function of the genotype and environmental conditions that these beans are submitted throughout their development (Carneiro et al., 1999a and 1999b; Kigel, 1999; Scholz and Fonseca Júnior, 1999a and 1999b; Carbonell et al., 2003; Dalla Corte et al., 2003; Coelho et al., 2008).

Esteves et al. (2002) studied six bean cultivars and concluded that there is an inverse relation among polyphenol and lignin content and peroxide activity with water-holding capacity, showing that chemical characteristics and endogenous enzymatic activities can also influence the water-holding capacity.

Percentage of hard-to-cook beans and experimental cooking time

Cultivar Jalo Precoce (Table 2) presented the highest percentage of hard-shell grains (42%) without absorbing the highest amount of water (106.67%), after 16 hours of soaking (Table 1), followed by cultivars BRS Radiante (4% of hard-shell grains and 120.33% of absorbed water) and by BRS Vereda (1.67% and 112%), respectively.

Concomitantly, Jalo Precoce's cooking time, without previous soaking (67.50 min), was much higher than those of the other cultivars analyzed (Table 2).

There was a significant difference among the cultivars with grains without hydration capacity (hard-shell), showing distinct values with a mean of 6.81%. Cultivars BRS Vereda, BRS Timbó, BRS Grafite, BRS Pontal and

BRS Marfim did not present a significant difference ($p < 0.05$) and revealed absence of this characteristic, being thus favorable.

Cooking times were different when the previously soaked grains were compared to those not soaked in water at room temperature. These results were expected and similar to those reported by Coelho et al. (2008) who evaluated bean cultivars soaked in water at different temperatures (5 to 35°C), verifying that these variations influence the cooking time of each cultivar differently.

The cooking mean time values for the seven cultivars without previous soaking decreased as follows: 67.50 (Jalo Precoce); 59.18 (BRS Radiante); 53.37 (BRS Marfim); 52.18 (BRS Vereda); 49.98 (BRS Grafite); 47.18 (BRS Timbó) and 46.95 minutes (BRS Pontal).

There was a reduction in the cooking time as a result of previous soaking time, though with different values for each sample. Jalo Precoce presented the highest cooking time reduction after soaking, followed by BRS Marfim, BRS Vereda, BRS Grafite, BRS Timbó, BRS Pontal and BRS Radiante, respectively. However, no statistically significant difference ($p < 0.05$) was found among them.

Cooking time average was reduced (from 53.76 to 15.31 min) after soaking, which is a desirable and, often, a determining factor in consumer acceptance of a bean cultivar.

Cultivar BRS Timbó presented the lowest cooking time (13.33min), but did not differ statistically ($p < 0.05$) from cultivars BRS Vereda, BRS Grafite, BRS Pontal and BRS Marfim.

Cultivar BRS Timbó was initially introduced in the Distrito Federal and northwest of Minas Gerais Brazilian

states by Embrapa Rice and Bean in 2002, and was confirmed to present a potentially better cooking performance, being recommended for cultivation in the states of Goiás, Mato Grosso do Sul, Minas Gerais and Distrito Federal (Del Peloso et al., 2004).

On the other hand, Rava et al. (2004) reported cooking times of 21 and 26 min for cultivars of the same group (roxinho) which were higher than those found in this study.

Considering a decrease in cooking gas costs, previous soaking must be recommended, as studies previously conducted did not reveal any nutritional loss, besides offering the advantage of eliminating antinutritional factors (Oliveira et al., 2001).

Mean cooking times of 15.52 min and 19.47 min, respectively, which were similar and slightly higher than that found for cultivar BRS Pontal (carioca) were reported by Rodrigues et al. (2005a and 2005b) and Carbonell et al. (2003) for cultivars of the same group and sowing time (winter). However, a mean cooking time of 37 min was observed for the same commercial group in a different sowing time (rainy season) (Ramos Junior & Lemos, 2002).

Sowing time interference was also evident in this study for the black commercial group cultivar, which presented values close to those found by other authors studying black bean varieties sown at the same time, with average values of 15.24min (Rodrigues et al., 2005a and 2005b) and 20.87min (Carbonell et al., 2003). However, when sown at a different time (rainy season), these cultivars presented longer cooking times.

Ramos Junior et al. (2002) found mean values of 46.72min for 11 cultivars analyzed during the rainy season and Carbonell et al. (2003) also found for the same time, higher averages (24.25 min) than those found in the winter (20.87 min) for the same cultivars.

Rodrigues et al. (2005a and 2005b) evaluated the effect of sowing time on grain quality for the varieties TPS Nobre (preto) and Pérola (carioca), reporting a shorter cooking time for both varieties, sown in autumn between April and June (Vieira and Vieira, 1995).

Carbonell et al. (2003) observed the influence of sowing time on 19 cultivars which, during drought, summer sowing (Vieira and Vieira, 1995) obtained a shorter cooking mean time.

Reduced mean cooking times found in this study (Table 2) may also be related to a short grain storage period, as corroborated by Ribeiro et al. (2005), who reported that aged common beans (black), stored at ambient temperature, had a cooking time of 50.50 min after 30 days, and of 139.50 min after 60 days, while the control sample (fresh beans stored at 5°C) presented a cooking time of 21.50 min. This confirms that cooking time could be influenced by sowing conditions, processing and storage conditions. Bean storage under high temperature and relative humidity led to the development of the hard-to-cook phenomenon, increasing cooking time (Ribeiro

et al., 2005).

Brackmann et al. (2002) reported that both grain type and storage time affect cooking time and that refrigeration was the type of storage that best maintained the bean quality up to 19 months.

Shimelis and Rakshit (2005) evaluated the effect of cooking time on different bean varieties after 24 hours of soaking. They found out that cooking times varied from 19.50min (*Awash*) to 41.70min (*Gofta*), with water absorption percentages between 227.29 and 124.94%, respectively. These values are much higher than those found for the Brazilian varieties evaluated in this study.

Other authors verified a negative correlation between the variables water-holding capacity and cooking time in bean cultivars (*Phaseolus vulgaris* L.) (Goycoolea et al., 1990; Rodrigues et al., 2005a and 2005b; Romano et al., 2005a). However, the water-holding capacity test used as an indicator of cooking time has been questioned due to the low correlation found by Carbonell et al. (2003).

The local conditions under which grains are obtained for cooking quality analysis also affect the results, indicating a high interaction between genotype and environment (Carbonell et al., 2003).

The high percentage of hard-shell grains did not show any relation when the grains were cooked after soaking. Rodrigues et al. (2005a and 2005b) found a positive and significant relation between water-holding capacity by the grains and percentage of regular grains (not hard) in the two cultivars studied.

These results showed different grain behaviors, even when similar samples were used, with substantial variations lower than 10% of the average being observed. However, Burr (1968), evaluating 6 bean cultivars from different regions, found that 90g blade experimental cookers present the time required for the grain to be considered cooked, with inter-sample differences not higher than 10% in several tests.

A positive correlation between water-holding capacity by the grains and cooking time was reported in genotypes developed in breeding programs in Brazil (Scholz and Fonseca Júnior, 1999a and 1999b; Dalla Corte et al., 2003).

Conclusions

In conclusion, the previous soaking of the bean grains for all cultivars reduced the cooking time, gas consumption and this practice must be recommended for low-income populations.

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