Original

Environment is crucial to the cooking time of beans

Ambiente é decisivo no tempo de cocção em grãos de feijão

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Abstract

The objectives of this study were to understand how genotype, storage time, and storage conditions affect cooking time of beans and to indicate storage techniques that do not affect the cooking time. The grains were subjected to five different storage periods and six different storage conditions. The cooking time was estimated using the Mattson Cooker. The data were subjected to analysis of variance and a subsequent adjustment of simple linear regression for deployment of the interactions between the factors. Contrasts were used to determine the best levels of the factor storage condition. Genotype did not impact cooking time when the storage time and storage conditions were considered. Time and storage conditions affect the cooking time of beans in a dependent manner, but time of storage had the biggest influence. The best conditions for long-term storage of beans ensuring a smaller increase in cooking time is plastic storage at low temperatures. Thus, plastic freezer storage is a practical alternative for consumers.

Keywords: *Phaseolus vulgaris L.; cooking; conservation of grain.*

Resumo

O objetivo deste trabalho foi compreender como os fatores genótipo, tempo e condição de armazenamento impactam no tempo de cocção de grãos de feijão, bem como indicar formas de armazenamento que não afetam o tempo de cocção. Os grãos foram submetidos a cinco diferentes tempos de armazenamento e a seis condições de armazenamento. Estimou-se o tempo de cocção utilizando-se o Cozedor de Mattson. Os dados foram submetidos à análise de variância, com posterior ajuste de regressão linear simples para desdobramento das interações entre fatores. Para a determinação dos melhores níveis do fator condição de armazenamento, foram utilizados contrastes. Genótipo não é decisivo para o tempo de cocção quando são considerados tempo e condição de armazenamento. Tempo e condição de armazenamento afetam de maneira dependente o tempo de cocção dos grãos de feijão; no entanto, o fator tempo tem maior influência. A melhor condição de armazenamento de grãos de feijão em longo prazo, com menor incremento no tempo de cozimento, é o armazenamento em plástico em baixas temperaturas. Assim, o armazenamento em plástico no freezer é uma alternativa prática para os consumidores.

Palavras-chave: *Phaseolus vulgaris L.; cocção; conservação dos grãos.*

1 Introduction

The bean (*Phaseolus vulgaris* L.) is cultivated by small and large producers in diverse production systems in all regions of Brazil. It is considered one of the traditional foods and a staple diet of Brazilians (LEMOS et al., 2004).

Studies conducted between 1975 and 2002 show that per capita Brazilian consumption of beans dropped by 12% (WANDER, 2005), mainly due to the reduced time available to prepare meals since cooking the grain is essential for the inactivation of anti-nutritional factors of beans (KHOKHAR; CHAUHAN, 1986).

In order to be registered in the National Register of Cultivars, cultivars are submitted to technological and industrial quality evaluations, which involve assessment of the average cooking time using the Mattson Cooker (PROCTOR; WATTS, 1987; BRASIL, 2001).

There are many factors that affect the cooking quality of beans. Among them, time of storage, water content in which the seed was stored, packaging in which the seed was stored, temperature, and relative air humidity during storage are the most important (TOLEDO et al., 2009).

After storage, the genotypes available in the market show changes in taste, broth, and color of the beans (BRAGANTINI, 2005). With the reduction in bean cooking quality, there is a decrease in its commercial value (SAWAZAKI et al., 1985).

There are regions where harvesting takes place only once a year, for example in the Plateau region of Santa Catarina, where the harvest period is from October to February (BRASIL, 2005). In these regions, due to the large consumption, the harvested grain needs to be stored during the offseason to enable its consumption at other times of the year. High quality products obtained during harvesting may suffer damage due to improper storage reducing the consumers' preference (RIOS; ABREU; CORREA, 2003).

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Seeds are usually stored under uncontrolled environmental conditions thus being subject to variations of temperature, relative humidity, and moisture content (VIEIRA; YOKOYAMA, 2000). The grains sold in supermarkets are stored in plastic bags ensuring long shelf life.

Packaging is classified into three categories according to the degree of permeability: *i*) permeable *ii*) semi-permeable and *iii*) impermeable (TOLEDO; MARCOS FILHO, 1977). When seeds are stored in permeable packages, their moisture content will vary with changes in the environment moisture. Semi-permeable packages offer some resistance to changes, but moisture is still lost. In airtight containers, there is no influence of external moisture on the seed, but it is influenced by oxygen deficiency (POPINIGIS, 1985). Seed moisture content tends to vary during storage due to fluctuations in environmental humidity and temperature (SILVA et al., 2010).

The objective of this study was to elucidate the influence of genotype, storage time, and storage conditions on the cooking time of beans and to indicate storage methods that do not affect the cooking time.

2 Materials and methods

The seeds used were obtained from the Study of Lineages and Cultivars Bean, conducted in Lages, in the state of Santa Catarina, Brazil. The geographic coordinates of Lages are 27° 52' 30" South latitude and 50° 18' 20" West longitude. After harvesting, the beans were stored for different periods under different conditions. A factorial design of 2 × 5 × 6 with three replications was used. The bean genotypes used were IPR Uirapuru (black) and IPR Juriti (carioca). They were submitted to five periods of storage of 0, 45, 120, 240, and 360 days after harvest; the zero day of storage refers to cooking the grain immediately after harvest. The storage conditions were the following: *i*) transparent and semi-permeable plastic package in uncontrolled ambient ; *ii*) transparent and semi-permeable plastic package in a dry chamber; *iii*) transparent and semi-permeable plastic package in the freezer; *iv*) kraft paper package in uncontrolled ambient ; *v*) kraft paper package in a dry chamber, and *vi*) kraft paper package in the freezer.

The average data of temperature and humidity during storage were collected from a Agro-weather Station as follows: *i*) 0 days (20 mar. 2010), 21.1 °C and 78%; *ii*) 45 days (20 mar. 2010 to 05 apr. 2010), 17.6 °C and 85%; *iii*) 120 days (20 mar. 2010 to 18 jul. 2010), 14.2 °C and 88%; *iv*) 240 days (20 mar. 2010 to 15 nov. 2010), 14.2 °C and 89%; *v*) 360 days (20 mar. 2010 to 15 mar. 2011), 19.1 °C and 83%. The freezer temperature was kept at –18.0 °C, and humidity was 44%; the dry chamber temperature was lower than 10 °C and humidity was lower than 60%, which was maintained by low temperatures.

Before cooking, the samples (16 g of beans) were hydrated with 50 mL of distilled water and maintained at 25 °C for 12 hours. A Mattson Cooker that consisted of 25 plungers of 90 g and 2 mm tip diameter was used for cooking the beans. The grains were cooked in 2.5 L of boiling distilled water. The time interval from the introduction of grains in the boiling distilled water until the fall of the 13th plunger was recorded, characterizing 52% of cooked beans (DALLA CORTE et al., 2003).

The statistical model used for data analysis was (Equation 1):

$$y_{ijk} = \mu + g_i + t_j + c_k + gt_{ij} + gc_{ik} + tc_{jk} + gtc_{ijk} + e_{ijk} \quad (1)$$

where: μ: mean; g_i: genotype effect; t_j: storage time effect; c_k: storage condition effect; gt_{ij}: effect of genotype X time of storage interaction; gc_{ik}: effect of genotype X storage condition interaction; tc_{jk}: effect of storage time X storage condition interaction gtc_{ijk}: effect of genotype X storage period X storage condition; and e_{ijk}: experimental error.

The data were subjected to analysis of variance at 0.05 probability error by the F test. Nine contrasts were tested for each storage period (Table 1). In the contrasts tested, one of the components of a set of combinations of each of the six storage conditions was fixed in order to isolate the other component.

3 Results and discussion

The main effect due to genotype factor shows difference ($p \leq 0.05$) by the F test (Table 2). The IPR Uirapuru (black trade group) had, on average, shorter cooking time showing more satisfactory results in relation to IPR Juriti (carioca trade group), which had a longer cooking time on average.

When using scheme factorial, the objective is not to estimate only the error, but also the greater number of freedom degrees assigned to the model due to main effects and interactions among the factors. The interactions involving the genotype factor ($p > 0.05$) shows the low magnitude of the mean squared in relation to the factors time and storage condition. This means that the differences between the environmental conditions are larger than the other experimental factors (ROCHA et al., 2009).

The quality of the bean seeds, and therefore the cooking time, are affected by both the genotype and the environmental conditions to which they are submitted (DALLA CORTE et al., 2003). In general, the presence of genotype *vs.* environment interactions affects the cooking time, and the environmental factors have greater influence than that of genetic causes (BERTOLDO et al., 2009). Similarly, in the present study, genotype showed very little contribution to variations in cooking time compared to that of storage conditions and time. Little contribution of genotype to the cooking time and major contributions related to the effects of storage time and storage conditions were observed by other authors (MORAIS et al., 2010). This lack of genotypic variation could be a consequence of the narrowing of the genetic base by bean breeding programs in Brazil; especially at the end of the highly productive genotypes selection process (COIMBRA et al., 2009) resulting in low contribution of the genotype to characteristics such as cooking time regardless of the commercial group to which the seeds belong.

Storage time and storage condition ($p \leq 0.05$) were of fundamental importance in determining the cooking time for beans. These factors indicate that the cooking time works differently for each interaction, and therefore it is more

Table 1. Contrasts tested for each storage time involving the storage conditions.

Contrast	Storage condition		
C_1	Plastic package in uncontrolled ambient	*vs.*	Plastic package in a dry chamber
C_2	Plastic package in a dry chamber	*vs.*	Plastic package in freezer
C_3	Plastic package in uncontrolled ambient	*vs.*	Plastic package in freezer
C_4	Paper package in uncontrolled ambient	*vs.*	Paper package in a dry chamber
C_5	Paper package in a dry chamber	*vs.*	Paper package in freezer
C_6	Paper package in uncontrolled ambient	*vs.*	Paper package in freezer
C_7	Plastic package in uncontrolled ambient	*vs.*	Paper package in uncontrolled ambient
C_8	Plastic package in a dry chamber	*vs.*	Paper package in a dry chamber
C_9	Plastic package in freezer	*vs.*	Paper package in freezer

Table 2. Analysis of variance for genotype, storage time, and storage condition.

Source	Degrees of feedom	Mean square	F value
Genotype (GEN)	1	*55.3	5.05
Time Storage (TS)	4	*1135.5	103.62
Conditional Storage (CS)	5	*649.0	59.23
GEN*TS	4	10.9	0.99
GEN*CS	5	14.4	1.31
TS*CS	20	*190.7	17.41
GEN*TS*CS	20	4.5	0.41
Error	119	11.0	
CV (%)	9.78		
Total	178		

valuable to study the mutual influence of these factors. When this happens, there is evidence that the behavior of a factor depends on the levels of another factor; thus, there is the need to assess the unfolding of the interaction (BERTOLDO et al., 2008).

For the unfolding of the interaction, the behavior of the storage condition factor in each level of the factor time of storage was evaluated using regression adjustment**.** For each one of the six combinations of storage conditions a regression curve was adjusted according to the degree of the polynomial given by the statistical analysis, and there was similar behavior among them.

Paper and plastic storage in ambient conditions showed quadratic behavior ($p \leq 0.05$). However, the angular coefficient of these regressions ($p > 0.05$) does not provide information of the minimum cooking time for the storage times tested. Hence, all curves adjusted to cooking time as a function of time of storage for the six conditions were of first degree. The linear fit to four cultivars of beans for cooking time during storage, combined with P_2O_5, was also observed by Bertoldo et al. (2009). The parameters of quadratic and cubic functions have difficult interpretation, which restricts the fitting of curves of higher degrees (SOUZA et al., 2000).

With increasing storage time there was an increase in cooking time for all conditions (Figure 1). Grain stored in uncontrolled ambient, both in paper and plastic packages, were the conditions that most influenced the cooking time. In these conditions, there is a great variation in temperature and humidity without any control of the factors affecting the grains.

The storage condition that produced the longest cooking time (60 minutes) ($p \leq 0.05$) after 360 days of storage was the paper package in ambient conditions. This condition reflects a poor control of gas exchange between the grains and the environment, and it is highly unstable in relation to temperature and humidity. Therefore, this storage condition should be avoided to maintain the quality of the grains.

With regard to the plastic packages in ambient, the variation in the cooking time ranged from 27 minutes ($p \leq 0.05$) in 0 days of storage to 53 minutes after one year of storage. This is the most common type of grain storage during marketing. It is necessary to seek an alternative form of bean preservation to avoid a sharp increase in cooking time because of the storage.

Comparing the results obtained under ambient conditions with those obtained in the dry chamber and freezer, both in plastic and paper packages, low temperature show a smaller increase in cooking time (Figure 1). This result is similar to that found by other authors (RIGUEIRA; LACERDA FILHO; VOLK, 2009). They found that the storage of bean grains in a controlled environment showed a greater conservation of physiological and technological quality of grains with less reduction in the cooking time.

The storage conditions must be checked to prevent seeds from consuming their own reserves due to increased respiration rates under increased temperature and humidity (VIEIRA; YOKOYAMA, 2000). The beans stored in inappropriate conditions become hardened and resistant to cooking mainly due to two factors: *i*) hardening of the integument (hard shell), which becomes waterproof, *ii*) hard-to-cook or HTC phenomenon, when the grains can absorb water, but the cotyledons do not soften during cooking, even when fully hydrated (VINDIOLA; SEIB; HOSENEY, 1986).

The beans stored in plastic containers in a dry chamber showed an increase ($p \leq 0.05$) of 0.0120 minutes in cooking time for each day of storage. Whereas, when stored in plastic in the freezer, the cooking time increased ($p \leq 0.05$) 0.0130 minutes for each day of storage resulting in an increase of 5.0 minutes in one year of storage. There was an increase ($p \leq 0.05$) of

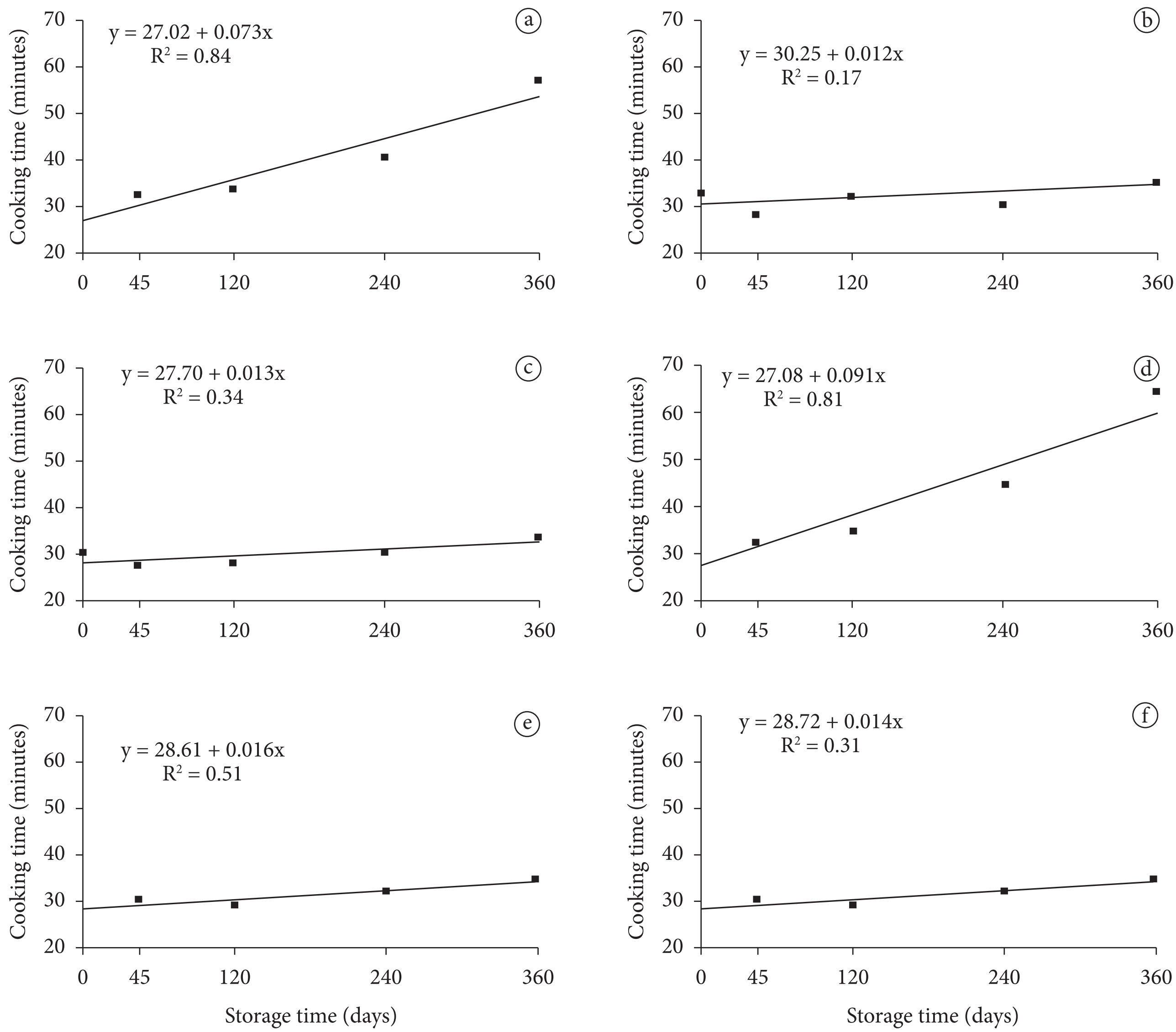

Figure 1. Effect of storage time on the cooking time for the different storage conditions: a) plastic package in uncontrolled ambient; b) plastic package in a dry chamber; c) plastic package in the freezer, d) paper package in uncontrolled ambient; e) paper package in a dry chamber; and f) paper package in the freezer.

0.0160 minutes in the cooking time in relation to each day of storage for the beans stored in paper package in the dry chamber. This results in an increase of more than 6.0 minutes in cooking time when stored for one year. Finally, for the beans stored in paper package in the freezer, there was an increase ($p \leq 0.05$) of 0.0140 minutes per day of storage, or 5.0 minutes of increase in cooking time after one year of storage. These results show that the increase in cooking time for these four storage conditions was small indicating grain storage alternatives.

With the regression adjustments, it is possible to make inferences about the cooking times for the genotypes in question within the range of storage time tested, from 0 to 360 days for each storage condition. The drawback of the curve fitting with linear behavior is that the inferences are limited to this time interval. To obtain results that go beyond this range, it is recommended to perform experiments with storage times greater than 360 days. The time tested is equivalent to one year, representing the period between two crops. Storage times greater than this value are not feasible since preference is given to newly harvested beans.

When analyzing the levels of the factor storage condition considered together, it is not possible to infer the magnitude of the influence of the package (plastic and paper) and local storage (ambient, dry chamber and freezer) on the grains.

Based on estimates of means, depending on storage time, the condition in which the grains are stored have a greater importance (Table 3). The differences ($p \leq 0.05$) between storage conditions are greater with increasing storage time and magnitude. In the storage time of 45 days, only two contrasts were significant ($p \leq 0.05$), where the largest difference was observed in: plastic package in ambient conditions *vs.* plastic package in the freezer (–5.13 cooking time). At 360 days of storage, there was a difference between five contrasts ($p \leq 0.05$), and the biggest difference was between paper package at ambient conditions *vs.* paper package in the freezer (–30.17 minutes cooking time).

Table 3 shows the different values ($p \leq 0.05$) for the nine contrasts tested for each storage time. For storage times of 45, 120, and 240 days, the material in which the grains were stored did not influence the cooking time, but the storage temperature did ($p < 0.05$). However, when the grains were stored for 360 days, there was a difference ($p \leq 0.05$) between the storage conditions in plastic and paper packages at uncontrolled ambient. This result indicates that for prolonged periods of storage, it is necessary special attention to the materials in which the grains are stored in order to maintain their technological quality.

Overall, there was difference ($p \leq 0.05$) between the storage conditions for plastic package in ambient conditions when compared with plastic package in a dry chamber and plastic in the freezer. However, the conditions for plastic package in a dry chamber and plastic package in the freezer, in general, were not different ($p > 0.05$). This result indicates that when the grains were stored in plastic packages with controlled conditions and at low temperatures, there was no difference ($p > 0.05$) in the cooking time. Nevertheless, when the grains were stored in plastic packages in ambient conditions, there was an increase in the cooking time due to the temperature. A difference ($p \leq 0.05$) was also observed between the grains stored in paper package in ambient conditions and those stored in the dry chamber and freezer, with no difference ($p > 0.05$) between the dry chamber and freezer. Temperatures below 5 °C drastically reduced the respiratory rate because the CO_2 does not spread efficiently at low temperatures, while around 30 °C there is a considerable increase in respiratory rates (BUCKERIDGE et al., 2004).

Table 3. Contrasts ($p \leq 0.05$) for each storage time between the storage conditions for the cooking time of the beans.

Storage time	Contrast[1]	Mean square	Estimate
			Minutes
0	C_1	*56 .25	4.33
0	C_8	*44.58	–3.86
45	C_1	*54.66	–4.27
45	C_3	*78.80	–5.13
120	C_2	*52.00	–4.16
120	C_3	*103.31	–5.87
120	C_4	*88.08	–5.42
120	C_6	*55.21	–4.29
240	C_1	*167.93	–7.48
240	C_3	*291.56	–9.86
240	C_4	*381.70	–11.85
240	C_6	*469.50	–12.51
360	C_1	*1448.92	–21.98
360	C_3	*1653.93	–23.48
360	C_4	*2632.33	–29.62
360	C_6	*2730.08	–30.17
360	C_7	*175.03	7.64
Error		10.96	4.33

*The differences ($p \leq 0.05$) rejecting the null hypothesis (H_0: $\mu_1 = \mu_2 = ... = \mu_n$). [1]Contrasts listed in Table 1.

Respiration is a physiological process that generates heat, carbon dioxide, and water vapor that influence the hardening of the grains (CANNIATTI-BRAZACA et al., 1998). Water vapor, when accumulated, increases the relative humidity inside the grain, which favors the process of hardening (AGUILERA; RIVERA, 1992). The suppression of respiration due to reduction in temperature may be a strategy to be used to minimize post-harvest respiration rates during storage of food products (TAIZ; ZEIGER, 2004).

To make sure that the increase in cooking time is due to increased respiration rates, experiments are needed to test the influence of the respiration of grains on cooking time using the strategy of controlled atmosphere. Controlled atmosphere is based on reducing the concentration of oxygen and high concentrations of nitrogen and carbon dioxide, directly interfering with breathing (SANTOS et al., 2006). In a study on storage at environment temperature with controlled atmosphere through the continuous flow of N_2 and refrigerated storage for bean genotypes, the cooking time for beans stored in controlled atmosphere and cold storage was shorter (BRACKMANN et al., 2002).

4 Conclusion

Genotypic variation has small influence compared to time storage and storage conditions on the cooking time of beans. Thus, further experiments should concentrate on storage time and conditions to improve the cooking time of stored beans.

The best condition for storing beans in the long term, with a smaller increase in cooking time is plastic package storage at low temperatures. Therefore, plastic package storage in the freezer is a practical alternative and should be implemented to encourage consumers to increase use and consumption of beans.

References

AGUILERA, J. M.; RIVERA, R. Hard - to - cook defect in black beans hardening rates, water inhibition and multiple mechanism hypothesis. **Food Research International**, v. 25, n. 2, p. 101-108, 1992. http://dx.doi.org/10.1016/0963-9969(92)90150-4

BERTOLDO, J. G. et al. Difficulties related to the use of tests of comparison of averages in scientific articles. **Revista Biotemas**, v. 21, n. 2, p. 145-153, 2008.

BERTOLDO, J. G. et al. Effects of different doses of phosphorus during cultivation and length of subsequent storage on the cooking time of beans. **Revista Biotemas**, v. 22, n. 1, p. 39-47, 2009.

BRACKMANN, A. et al. Conservation of three bean genotypes (*Phaseolus vulgaris* L.) of the group carioca in cold storage and controlled atmosphere. **Ciência Rural**, v. 32, n. 6, p. 911-915, 2002. http://dx.doi.org/10.1590/S0103-84782002000600001

BRAGANTINI, C. **Alguns aspectos do armazenamento de sementes e grãos de feijão**. Santo Antônio de Goiás: Embrapa Arroz e Feijão, 2005. 28 p.

BRASIL. **Serviço Nacional de Proteção de Cultivares**. Brasília, 2001. Anexo IV. Requisitos mínimos para determinação do valor de cultivo e uso de feijão (*Phaseolus vulgaris*) para inscrição no Registro Nacional de Cultivares – RNC. 8 p.

BRASIL. Instrução normativa nº 12, de 28 de março de 2008. Estabelece o Regulamento Técnico do Feijão, definindo o seu padrão oficial de classificação, com os requisitos de identidade e qualidade, a amostragem, o modo de apresentação e a marcação ou rotulagem. **Diário Oficial da República Federativa do Brasil**, Brasília, DF, 31 mar. 2005. Seção 1, p.11.

BUCKERIDGE, M. S. et al. Respiração. In: KERBAUY, G. B. **Fisiologia Vegetal**. Rio de Janeiro: Editora Guanabara, 2004. cap. 7, p.198-216.

CANNIATTI-BRAZACA, S. G. et al. Influence of storage time at 11 °C on some physical characteristics of guandu beans (*Cajans cajan L.*) cultivars. **Ciência e Tecnologia de Alimentos**, v. 18, n. 1, p. 53-59, 1998.

COIMBRA, J. L. M. et al. Mining of genotype x environment interaction in *Phaseolus vulgaris* L. to the State of Santa Catarina. **Ciência Rural**, v. 39, n. 2, p. 355-363, 2009. http://dx.doi.org/10.1590/S0103-84782008005000069

DALLA CORTE, A. et al. Enviroment effect on grain quality in early common bean cultivars and lines. **Crop Breeding and Applied Biotechnology**, v. 3, n. 3, p. 193-202, 2003.

KHOKHAR, S.; CHAUHAN, B. M. Antinutritional factors in Moth Bean (Vigna aconitifolia): Varietal Differences and Effects of Methods of Domestic Processing and Cooking. **Journal of Food Science**, v. 51, p. 591-594, 1986. http://dx.doi.org/10.1111/j.1365-2621.1986.tb13887.x

LEMOS, L. B. et al. Agronomic and technologic characteristics of common bean genotypes from Carioca commercial group. **Pesquisa Agropecuária Brasileira**, v. 39, n. 4, p. 319-326, 2004. http://dx.doi.org/10.1590/S0100-204X2004000400004

MORAIS, P. P. P. et al. Influence of the period and storage conditions of beans at the time of cooking. **Revista Ciência Agronômica**, v. 41, n. 4, p. 593-598, 2010.

POPINIGIS, F. **Fisiologia da semente**. 2. ed. Brasília: AGIPLAN, 1985. 289 p.

PROCTOR J. R.; WATTS, B. M. Development of a modified Mattson bean cooker procedure based on sensory panel cookability evaluation. **Institute of Food Science and Technology**, v. 20, n. 1, p. 9-14, 1987.

RIGUEIRA, R. J. A.; LACERDA FILHO, A. F.; VOLK, M. B. S. Evaluation of the quality beans stored in a refrigerated environment. **Alimentos e Nutrição**, v. 20, n. 4, p. 649-655, 2009.

RIOS, A. O.; ABREU, C. M. P.; CORREA, A. D. Effect of storage and harvest conditions on some physical, chemical and nutritious properties of three bean cultivars (Phaseolus vulgaris L.). **Ciência e Tecnologia de Alimentos**, v. 23, p. 39-45, 2003. Suplemento.

ROCHA, F. et al. Environmental effects on yield of carioca bean in Santa Catarina state. **Bragantia**, v. 68, n. 3, p. 621-627, 2009. http://dx.doi.org/10.1590/S0006-87052009000300008

SANTOS, C. M. S. et al. Effect of controlled atmosphere on postharvest life and quality of 'Prata Anã' banana. **Ciência e Agrotecnologia**, v. 30, n. 2, p. 317-322, 2006. http://dx.doi.org/10.1590/S1413-70542006000200018

SAWAZAKI, H. E. et al. Biochemical and physical modifications of bean seeds during storage. **Bragantia**, v. 44, n. 1, p. 375-390, 1985. http://dx.doi.org/10.1590/S0006-87051985000100033

SILVA, F. S. et al. Viabilidade do armazenamento de sementes em Diferentes embalagens para pequenas propriedades Rurais. **Revista de Ciências Agro-Ambientais**, v. 8, n. 1, p. 45-56, 2010.

SOUZA, A. P. et al. Logistic equation use in studying the dose-response of glyphosate and imazapyr by using bioassays. **Planta daninha**, v. 18, n. 1, p. 17-28, 2000. http://dx.doi.org/10.1590/S0100-83582000000100002

TAIZ, L.; ZEIGER, E. **Fisiologia Vegetal**. 3. ed. Porto Alegre: Artmed, 2004. 719 p.

TOLEDO, M. Z. et al. Qualidade fisiológica e armazenamento de sementes de feijão em função da aplicação tardia de Nitrogênio em cobertura. **Pesquisa Agropecuária Tropical**, v. 39, n. 2, p. 124-133, 2009.

TOLEDO, F. F.; MARCOS FILHO, J. Embalagens das sementes. In: TOLEDO, F. F.; MARCOS FILHO, J. **Manual das sementes, tecnologia da produção**. São Paulo: Agronômica Ceres, 1977. cap. 14, p. 187-193.

VINDIOLA, O. L, SEIB, P. A, HOSENEY, R. C. Accelerate development of the hard-to-cook state in beans. **Cereal Foods Word**, v. 31, p. 538, 1986

VIEIRA, E. H. N.; YOKOYAMA, M. Processamento, colheita e armazenamento. In: VIEIRA, E. H. N.; RAVA, C. A. **Sementes de feijão**: produção e tecnologia. Santo Antonio de Goiás: Embrapa Arroz e Feijão, 2000. p. 233-248.

WANDER, A. E. Perspectivas de mercado interno e externo para o feijão. In: CONGRESSO NACIONAL DE PESQUISA DE FEIJÃO, 8., 2005, Goiânia. **Anais**... Goiânia: Embrapa Arroz e Feijão, 2005. v. 2, p. 892-895.