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Standardization of imbibition time of Common bean grains to evaluate cooking quality

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ABSTRACT *- The objective of this study was to standardize the imbibition time of common bean grains for an evaluation of the capacity of water uptake and determination of the cooking time, aiming at the identification of genotypes with high cooking quality. The completely randomized design was used in a 19 x 4 factorial arrangement with three replications. Grains of 19 cultivars were set to imbibe during four periods at room temperature. A significant interaction between cultivars and imbibition times was observed in relation to the evaluated variables. The correlation coefficients differed in magnitude and signal for the different cultivars. For an evaluation of the uptake capacity and the determination of the cooking time eight hours of imbibition of common bean grains are effective to differentiate normal from hard grains and to identify fast-cooking cultivars.*

Key words: *Phaseolus vulgaris* L., water uptake, cooking time, genetic variability.

INTRODUCTION

The development of more productive and disease and pest-resistant cultivars with superior agronomical traits has been main objective of improvement in common bean. On the other hand, the technological characteristics that are also important for the evaluation of the new cultivars are still poorly investigated. In this sense, the cooking quality (fast water uptake and shorter cooking time), a determinant factor for the acceptance of the product by consumers as much as by the food industry, must be evaluated.

The cooking of common bean grains is indispensable for consumption as it warrants the inactivation of antinutritional elements and establishes the taste and texture the consumer demands (Yokoyama and Stone 2000). Besides, it is possible to avoid nutritional losses caused by cell alterations that may occur in long cooking periods (Wassimi et al. 1988). In these premises, the development of common bean cultivars that cook in less than 30 minutes is desirable for saving energy, expenses, and time (Costa et al. 2001).

The cooking time of a common bean cultivar that is being included in the Serviço Nacional de Protetion de Cultivars - SNPC (National Service of Cultivar Protection) of the Ministério da Agricultura, Pecuária e Abastecimento - MAPA (Ministry of Agriculture, Husbandry, and Supply) must actually be evaluated by a Mattson's cooking device (Proctor and Watts 1987). The official methodology is precise, although very slow and permits the

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evaluation of few samples a time, which restricts its use for initial generations of improvement programs, when a great number of populations is being evaluated.

The development of methodologies that allow the early identification of lines with shorter cooking time is indispensable. The test of grain water uptake prior to cooking has therefore been used since the cooking capacity is related to the quick water uptake by grains and depends on the characteristics of the grain tegument (Garcia-Vela and Stanley 1989, Phlak et al. 1989, Scholz and Fonseca Júnior 1999a, b). The determination of the water uptake capacity is simple and can be obtained quickly for a great number of samples, allowing the disposal of undesirable genotypes already in the first segregant generations (Ramalho et al. 1993, Costa et al. 2001).

A positive and significant correlation between the quantity of absorbed water and the cooking capacity have been described (Scholz and Fonseca Júnior 1999a, b, Dalla Corte et al. 2003). On the other hand, a negative and significant correlation between these parameters is also reported in literature (Jacinto et al. 1999). Moreover, the utilization of the water uptake test as indicator of the cooking time has been questioned due to the low correlation observed (Carbonell et al. 2003).

The imbibition time of common bean grains for an evaluation of the water uptake test recommended by the official methodology of the SNPC is 18 hours (Garcia-Vela and Stanley 1989). However, 16 hours (Carbonell et al. 2003, Dalla Corte et al. 2003), 12 hours (Lemos et al. 2004), and even 4 hours of imbibition have been used (Costa et al. 2001). These results point to the need of standardizing the imbibition time of common bean grains in distilled water for water uptake and cooking tests as the maximal grain hydration time varies according to the considered genotype and may oscillate from 8h 08min (IAC Carioca Aruã) up to 15h 44min (IAC Carioca Pyatã) (Lemos et al. 2004).

Taking these aspects into consideration, the objective of this study was a standardization of the imbibition time of common bean grains of different cultivars for the evaluation of the water uptake test by the grains and for the determination of the cooking time, aiming at the identification of genotypes with high cooking quality.

MATERIAL AND METHODS

The experiments were conducted at the Plant Science Department of the University Federal of Santa Maria (UFSM), Santa Maria, RS, Brazil. The grains used were provided by a field experiment of the Common Bean Improvement Program of this institution.

The experimental design was of complete randomized blocks with 3 replications and the plots consisted in four 4m-long rows spaced 0.50m, with a useful area of $3m^2$. The evaluated treatments were the 19 common bean cultivars registered in the SNPC-MAPA for cultivation in the state of Rio Grande do Sul.

The soil was prepared by conventional tillage and the fertilization based on the chemical soil analysis. The sowing density was adjusted according to the recommendation of Cepef (2001) for the different cultivars. Top dressing nitrogen fertilization was split in two applications of 40 kg ha^{-1} nitrogen at the growth stages of the first (V3) and the third (V4) threefold leaves. Insects and weeds were controlled whenever necessary to avoid that the crop suffered competition.

The manual harvest and the threshing of the plants were realized in January 2003 and the grains dried on a cement square after the separation of the impurities by machines of air and sieves, and dried in a stove to a mean humidity of 12%. At once, samples of 2kg of grain were wrapped in paper bags and stored in a cold chamber (at 0 °C and 80% relative humidity) for 10 months before the evaluations of the grain quality for cooking.

The experimental design was completely randomized in a 19 x 4 factorial arrangement for the laboratory evaluations with three replications of 25 grains. For the water uptake test, the grains of the different cultivars were put in plastic cups with 50ml distilled water for four imbibition periods (8, 11, 14, and 17 hours) at room temperature (23 °C). After the set time, the grains were taken out and partially dried with a paper towel to retire the excess of water that remained externally in the teguments. The water uptake was determined by the difference of weight of the grains before and after imbibition, according to the methodologies of Garcia-Vela and Stanley (1989) and of Phlak et al. (1989). The percentage of normal grains (with normal water uptake) and the percentage of hard grains (without the capacity of absorbing water) were also quantified in relation to the total number of evaluated grains through manual counting.

The grain cooking time was determined by Mattson's cooking device with 25 pegs (Proctor and Watts 1987). After the set time of imbibition, the water was eliminated and the grains were arranged on the tray of the device, each peg set above a grain. The appliance was put in a pan with boiling distilled water and heated on a gas stove. As the cooking proceeded, the pegs dropped and penetrated the grains. The time from the moment when the cooker was placed in the boiling water until the dropping of the peg was marked, measuring the time of dropping of each peg or the cooking time for each grain. The time required until 13 pegs (half + 1) had dropped was used to determine the mean cooking time of each sample.

The obtained data were subjected to analysis of variance, using the test F at a level of 5% of probability, to test the hypothesis of the principal and the interaction effects. The analysis of regression of time within a cultivar was carried out for the variables with cultivar-imbibition time interaction. Pearson's analysis of correlation between the variables was also realized.

RESULTS AND DISCUSSION

The analysis of variance (Table 1) revealed the presence of significant interaction between cultivars and imbibition times in relation to the percentage of normal grains, percentage of hard grains, water uptake test by the grains and cooking time, indicating a differentiated response of the common bean cultivars in function of the grain imbibition time.

The variation coefficients obtained for the considered variables oscillated from 2.02% to 5.48% and are considered low, attributing good experimental precision to the estimates of this trial. However, a variation coefficient of 188.29% was verified for hard grains, probably due to near-to-inexistence of grains with no hydration capacity (mean of 1.06%) even after the shortest imbibition period (eight hours). It is believed that the prevailing environmental conditions from the period of physiological maturation to the grain harvest favored the non-occurrence of hard grains in the evaluated cultivars since this characteristic is largely influenced by the genetic and environmental effects and the interactions between these factors (Carbonell et al. 2003, Lemos et al. 2004). Thus, values of low or reduced intensity for hard grains were observed, representing a favorable performance of the cultivars for this characteristic.

Table 1. Mean squares for the percentage of normal grains (NG), and of hard grains (HG), water uptake test (uptake), and cooking time (cookability) for 19 cultivars of common bean

		Mean squares			
Causes of variation	df	NG %	HG %	Uptake %	cookability seconds
Cultivar (C)	18	72.78*	72.78*	562.14*	195985.75*
Time (T)	3	39.62*	39.62*	575.53*	6775.40
C x T	54	11.47*	11.47*	41.97*	10686.29*
Error	152	3.99	3.99	12.35	3471.40
Mean		98.94	1.06	96.52	1075.50
VC (%)		2.02	188.29	3.64	5.48

* Significant at 1% of probability level by the test F

In relation to the percentage of normal grains it was observed that, independently of the time in which the common bean grains remained immersed in distilled water, there was no increase in the number of grains with normal water uptake for most of the evaluated cultivars since no regression equation was adjusted (Table 2). However, an increase in the percentage of normal grains up to 14h 34min and 14h 39min was observed for the cultivars Diamante Negro and IAPAR 44, respectively. It is worth emphasizing that these cultivars presented the smallest means of normal grains, 90.33% (Diamante Negro) and 94.33% (IAPAR 44), which suggests problems of impermeability of the tegument, influencing the grain hydration capacity. It was not possible to estimate the ideal imbibition time for BRS Expedito, since even after 17h of immersion the grains were still taking up water; however, it should be pointed out that the mean percentage of normal grains was 98.94%.

A differentiated performance of grains was observed in the water uptake test. For eight cultivars, the time of imbibition did not influence this variable since no regression effect was significant (Table 2). However, a linear equation was adjusted for eight cultivars and only for two (TPS Bionobre and TPS Nobre) it was possible to estimate the time of maximal hydration. The result obtained for IAPAR 44 was unexpected and difficult to explain, since it had been expected that the common bean grains that remained immersed for a longer time would have a greater uptake. Thus, it is possible to affirm that the time of maximal hydration of the grains is variable according to the evaluated genotype, similarly to what Lemos et al. (2004) had also observed. However, these authors were able to quantify the time of maximum hydration since equations of second degree were adjusted for each one of the evaluated genotypes. It is believed that the different time intervals, as well as the prevalent environmental conditions at achieving the grains, the grain processing techniques, and the imbibition temperature contributed to the observed differences, since these factors influenced the integrity of the tegument of the common bean grains and, consequently, water uptake and cooking (Scholz and Fonseca Júnior 1999a, b).

Eight hours of imbibition can therefore be used for the water uptake test by the grains. This period was efficient for the differentiation of normal from hard grains for the majority of the evaluated common bean cultivars, with values close to 100% of normal grains. It is believed that longer periods of immersion are not necessary, since even for those cultivars that needed a longer imbibition time (Diamante Negro and IAPAR 44) it was possible to attain indices considered satisfactory.

The cooking time showed that eight hours of imbibition were effective to identify cultivars with a high cookability for 12 evaluated cultivars, which corresponds to 63% of the total (Table 2). This result allows the conclusion that the imbibition of common bean grains in distilled water for 8 or for 17 hours does not stretch or reduce the cooking time for these cultivars. However, the cooking time diminished with the increase of the time the grains were imbibed up to 10h 33min (IAPAR 31) and 15h 54min (IAPAR 44). In this sense, a longer imbibition time of the grains in distilled water became necessary for these two cultivars to reduce the cooking time. However, the result obtained for cultivars BRS Expedito and TPS Nobre was unexpected and difficult to explain, since a longer imbibition period led to an increased cooking time of up to 12h 58min (BRS Expedito) and 14h 52min (TPS Nobre).

The 19 common bean cultivars were cooked in less than 25 minutes (Table 2). A similar result was observed for common bean cultivars of the group carioca evaluated in São Paulo (Lemos et al. 2004), which reflects the attempts of improvement programs to develop fast-cooking cultivars adapted to the needs

of the present-day common bean consumer who does not have a lot of time to prepare meals and who appreciates the quality of a consumed product.

Besides, it is important to mention that if the imbibition time of the cultivar that required the longest time (IAPAR 44) were adequate, it would be at a level with the cultivars of fast uptake (desirable) to those of slow uptake (longer cooking time). We also note that the grains of the evaluated commercial cultivars were stored for 10 months in a cold chamber prior to evaluation, representing an extreme condition, since the cooking quality is normally evaluated right after the harvest. Thus too long time periods of imbibition are unnecessary, since they benefit the cultivars that need a longer time for the tegument hydration.

The correlation coefficients obtained between the analyzed variables differed in magnitude and in signal for the different cultivars (Table 3). In most combinations, the coefficients were not significant since linear regression was not adjusted. When the mean of the 19 common bean cultivars is considered, it was observed that significant correlation and of low magnitude was found between the water uptake test and the cooking time, confirming what Carbonell et al. (2003) had observed. However, other authors observed a positive and significant correlation between these variables (Scholz and Fonseca Júnior 1999a, b, Dalla Corte et al. 2003). On the other hand, a negative and significant correlation between water uptake and the cooking time is also reported in literature (Jacinto et al. 1999). The use of the water uptake test as indicator of the cooking time should therefore be further evaluated by common bean improvement programs, in view of the divergent responses found in literature and the effect of the interaction genotype x environment under these characteristics (Scholz and Fonseca Júnior 1999a, b, Carbonell et al. 2003, Dalla Corte et al. 2003, Lemos et al. 2004).

Thus, it can be affirmed that the imbibition time of eight hours in common bean grains is sufficient for the realization of the cooking test, since it allowed the differentiation of normal from hard grains in the test of grain water uptake and the identification of fast-cooking cultivar. This indicates that the imbibition time recommended by the official methodologies (Brasil 2001) can be reduced since a too long imbibition time may lead to wrong information on the superiority of the common bean grain quality for cooking.

CONCLUSIONS

Eight hours of imbibition of the common bean grains for the evaluation of the water uptake test and for the quantification of the cooking time is efficient for the differentiation of normal from hard grains and for the identification of cultivars with fast cooking.

Table 2. Linear (LR), square (SR) and cubic (CR) effects, equation, coefficient of determination (R^2), mean and point of maximal and/or minimal technique efficiency (PMTE) of 19 cultivars of common bean evaluated in four times of imbibition, in relation to the percentage of normal grains (NG), the water uptake test (uptake) and cooking time (cookability)

Cultivar	LR	SR	CR	Equation of regression = function t	R^2 (%)	Mean	PMTE
				Y: NG (%); t: time (h)			
Carioca	ns	ns	ns	-	-	99.99	-
Diamante Negro	*	*	ns	$Y = 24.792 + 9.709t - 0.333t^2$	99	90.33	14h 34min(1)
BRS Expedito	*	ns	ns	$Y = 94 + 0.399t$	60	98.99	-
FTS Magnífico	ns	ns	ns	-	-	99.99	-
FTS Soberano	ns	ns	ns	-	-	99.99	-
Guapo Brilhante	ns	ns	ns	-	-	99.66	-
Guateian 6662	ns	ns	ns	-	-	99.99	-
Iapar 31	ns	ns	ns	-	-	99.99	-
Iapar 44	*	*	ns	$Y = 42.849 + 7.593t - 0.259t^2$	97	94.33	14h 39min(1)
Irai	ns	ns	ns	-	-	99.99	-
Macanudo	ns	ns	ns	-	-	99.66	-
Macotaco	ns	ns	ns	-	-	99.33	-
Minuano	ns	ns	ns	-	-	99.33	-
Pérola	ns	ns	ns	-	-	99.99	-
Rio Tibagi	ns	ns	ns	-	-	99.99	
TPS Bionobre	ns	ns	* (3)	-	-	98.33	-
TPS Bonito	ns	ns	ns	-	-	99.99	-
TPS Nobre	ns	ns	ns	-	-	99.99	-
Valente	ns	ns	ns	-	-	99.99	-

To be continued

Cultivar	LR	SR	CR	Equation of regression = function t	R^2 (%)	Mean	PMTE
				Y: UPTAKE(%); t: time (h)			
Carioca	*	ns	ns	Y = 85.984 + 0.773t	72	95.65	-
Diamante Negro	*	ns	* (3)	Y = 46.781 + 2.791t	89	81.67	-
BRS Expedito	*	ns	ns	Y = 106.685 + 0.818t	71	116.91	
FTS Magnífico	ns	ns	ns	-	-	99.51	-
FTS Soberano	*	ns	ns	Y = 86.367 + 0.769t	57	95.98	-
Guapo Brilhante	*	ns	ns	Y = 75.658 + 1.013t	84	88.33	-
Guateian 6662	ns	ns	ns	-	-	98.28	-
Iapar 31	ns	ns	ns	-	-	95.97	-
Iapar 44	*	*	ns	$Y = 132.183 - 9.179t + 0.429t^2$	99	89.34	10h 41min(2)
Irai	ns	ns	ns	-	-	98.01	-
Macanudo	ns	ns	ns	-	-	96.64	-
Macotaco	ns	ns	ns	-	-	95.22	-
Minuano	*	ns	ns	Y = 85.289 + 0.654t	81	93.47	-
Pérola	ns	ns	ns	-	-	100.43	-
Rio Tibagi	*	ns	ns	Y = 85.931 + 0.901t	84	97.19	
TPS Bionobre	*	*	ns	$Y = 38.129 + 7.829t - 0.242t^2$	98	95.49	16h 11min(1)
TPS Bonito	*	ns	* (3)	Y = 76.114 + 2.163t	91	103.15	-
TPS Nobre	ns	*	ns	$Y = 59.129 + 6.719t - 0.276t^2$	74	96.90	12h 10min(1)
Valente	ns	ns	ns	-	-	95.70	-
				Y: COOKABILITY (seconds); t: time (h)			
Carioca	ns	ns	ns		-	17min 24s	-
Diamante Negro	ns	ns	ns	-	-	19min 48s	-
BRS Expedito	ns	*	* (3)	-	71	20min 24s	12h 58min(1)
FTS Magnífico	*	ns	ns	$Y = 2.148 + 202.219t - 7.796t^2$	91	19min 20s	-
FTS Soberano	ns	ns	ns	Y = 928.056 + 18.522t	-	16min 54s	-
Guapo Brilhante	*	ns	ns	-	86	14min 14s	-
Guateian 6662	ns	ns	ns	Y = 983.833 - 10.400t	-	18min 10s	-
Iapar 31	*	*	ns	-	95	15min 24s	10h 33min(2)
Iapar 44	*	*	* (3)	$Y = 1452.296 - 115.441t + 5.463t^2$	81	18min 20s	15h 54min(2)
Irai	*	ns	ns	$Y = 1987.806 - 122.783t + 3.861t^2$	81	22min 35s	-
Macanudo	ns	ns	ns	Y = 1148.667 + 16.500t	-	13min 51s	-
Macotaco	ns	ns	ns	-	-	16min 27s	-
Minuano	ns	ns	ns	-	-	17min 05s	-
Pérola	ns	ns	ns	-	-	19min 24s	-
Rio Tibagi	ns	ns	* (3)	-	-	16min 52s	-
TPS Bionobre	ns	ns	ns	-	-	18min 02s	-
TPS Bonito	ns	ns	Ns	-	-	18min 27s	-
TPS Nobre	*	*	Ns	-	94	19min 49s	14h 52min(1)
Valente	ns	ns	Ns	$Y = 391.769 + 116.020t - 3.898t^2$	-	18min 06s	-

* = Significant at the level of 5% of probability by the test F; ns = non-significant by the test F

(1) point of Maximal Technique Efficiency (2) Point of Minimal Technique Efficiency (3) Regression for third degree not adjusted for being of difficult biological explanation

Table 3. Correlation coefficients of Pearson[1] among the characteristics percentage of normal grains (ng), water uptake test (uptake), cooking time (cookability), and imbibition time (time) of 19 common bean cultivars

Characteristics	time (h)	ng (%)	uptake(%)	time (h)	ng (%)	uptake(%)
		Carioca			Diamante Negro	
ng (%)	0.0000ns			0.7198*		
uptake(%)	0.6611*	-0.0000ns		0.9081*	0.8537*	
cookability (seg)	-0.2680ns	0.0000ns	-0.5450ns	-0.3879ns	-0.1805ns	-0.2947ns
		BRS Expedito			FTS Magnífico	
ng (%)	0.5635ns			0.0000ns		
uptake(%)	0.5460ns	0.0464ns		0.0246ns	0.0000ns	
cookability (seg)	0.2664ns	0.5840*	-0.1346ns	0.8518*	-0.0000ns	-0.1006ns
		FTS Soberano			Guapo Brilhante	
ng (%)	0.0000ns			0.4045ns		
uptake(%)	0.6579*	-0.0000ns		0.8962*	0.4361ns	
cookability (seg)	0.3048ns	0.0000ns	-0.1184ns	-0.7908*	-0.1447ns	-0.8306*
		Guateian 6662			Iapar 31	
ng (%)	0.0000ns			0.0000ns		
uptake(%)	0.6785*	0.0000ns		0.5426ns	0.0000ns	
cookability (seg)	-0.0449ns	0.0000ns	-0.0182ns	0.7067*	-0.0000ns	0.4123ns
		Iapar 44			Iraí	
ng (%)	0.5314ns			0.0000ns		
uptake(%)	0.6238*	0.6008*		0.7974*	-0.0000ns	
cookability (seg)	-0.8001*	-0.5403ns	-0.3822ns	0.5253ns	0.0000ns	0.3156ns
		Macanudo			Macotaco	
ng (%)	0.1348ns			0.2000ns		
uptake(%)	0.0215ns	0.0279ns		0.4690ns	0.3626ns	
cookability (seg)	0.0561ns	0.4136ns	0.4185ns	0.3623ns	0.2866ns	0.6206*
		Minuano			Pérola	
ng (%)	0.6000*			0.0000ns		
uptake(%)	0.8373*	0.6888*		0.7745*	0.0000ns	
cookability (seg)	-0.0835ns	0.0343ns	-0.3251ns	0.6668*	0.0000ns	0.5129ns
		Rio Tibagi			TPS Bionobre	
ng (%)	0.0000ns			0.3435ns		
uptake(%)	0.4633ns	0.0000ns		0.8688*	0.3586ns	
cookability (seg)	-0.1089ns	0.0000ns	0.0332ns	-0.2755ns	-0.4140ns	-0.1702ns
		TPS Bonito			TPS Nobre	
ng (%)	0.0000ns			0.0000ns		
uptake(%)	0.8006*	0.0000ns		-0.1511ns	-0.0000ns	
cookability (seg)	-0.3546ns	0.0000ns	-0.1012ns	0.5944*	0.0000ns	-0.1605ns
		Valente			all cultivars [2]	
ng (%)	0.0000ns			0.1930*		
uptake(%)	0.6113*	0.0000ns		0.3270*	0.5093*	
cookability (seg)	0.4534ns	0.0000ns	0.6263*	0.0544ns	-0.1652*	0.1708*

[1] * Significant at 5% of probability by test t, with 10 degrees of freedom, ns = insignificant
[2] * Significant at 5% of probability by test t, with 226 degrees of freedom, ns = insignificant

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Padronização do tempo de embebição de grãos de feijão para avaliar qualidade de cozimento

RESUMO - *O objetivo deste trabalho foi padronizar o tempo de embebição dos grãos de feijão para a avaliação da capacidade de absorção de água e a determinação do tempo de cozimento, visando a identificação de genótipos com alta qualidade de cozimento. Adotou-se o delineamento experimental inteiramente casualizado, arranjado em fatorial 19 x 4, com três repetições. Os grãos das 19 cultivares foram colocados em embebição em quatro diferentes tempos, à temperatura ambiente. Presença de interação significativa entre cultivares e tempos de embebição em relação às variáveis avaliadas foi observada. Os coeficientes de correlação diferiram em magnitude e em sinal para as diferentes cultivares. Oito horas de embebição dos grãos de feijão para a avaliação da capacidade de absorção e para a determinação do tempo de cozimento é eficiente na diferenciação de grãos normais de duros e na identificação de cultivares com cozimento rápido.*

Palavras-chave: *Phaseolus vulgaris* L., absorção de água, tempo de cozimento, variabilidade genética.

REFERENCES

Brasil (2001) Ministério da Agricultura, Pecuária e Abastecimento. Anexo IV. Requisitos mínimos para determinação do valor de cultivo e uso de feijão (*Phaseolus vulgaris*), para a inscrição no registro nacional de cultivares - RCN.

Carbonell SAM, Carvalho CRL and Pereira VR (2003) Qualidade tecnológica de grãos de genótipos de feijoeiro cultivados em diferentes ambientes. **Bragantia 62**: 369-379.

Cepef (2001) **Recomendações técnicas para cultivo de feijão no Rio Grande do Sul**. São Cristóvão, Erechim, 112p.

Costa GR, Ramalho MAP and Abreu AFB (2001) Variabilidade para absorção de água nos grãos de feijão do germoplasma da UFLA. **Ciência e Agrotecnologia 25**: 1017-1021.

Dalla Corte A, Moda-Cirino V, Scholz MBS and Destro D (2003) Enviroment effect on grain quality in early common bean cultivars and lines. **Crop Breeding and Applied Biotechnology 3**: 193-202.

Garcia-Vela LA and Stanley DW (1989) Water-holding capacity in hard-to-cook bean (*P. vulgaris* L.): effect of pH and ionic strength. **Journal of Food Science 54**: 1080-1081.

Jacinto CH, Azpíroz SR, Acosta JAG, Hernández HS, Baltazar BM and Bernal-Lugo I (1999) Seed physical traits and inheritance of cooking time in recombinant bean inbred lines. **Bean Improvement Cooperative 42**: 125-126.

Lemos LB, Oliveira RS, Palomino EC and Silva TRB (2004) Característica agronômicas e tecnológicas de genótipos de feijão do grupo comercial Carioca. **Pesquisa Agropecuária Brasileira 39**: 319-326.

Phlak LC, Caldwell KB and Stanley DW (1989) Comparison of methods used to characterize water imbibition in hard-to-cook beans. **Journal of Food Science 54**: 326-336.

Proctor JR and Watts BM (1987) Development of a modified Mattson bean cooker procedure based on sensory panel cookability evaluation. **Canadian Institute of Food Science and Technology Journal 20**: 9-14.

Ramalho MAP, Santos JB and Zimmermann MJO (1993) **Genética quantitativa em plantas autógamas: aplicações ao melhoramento do feijoeiro**. UFG, Goiânia, 271p.

Scholz MBS and Fonseca Júnior NS (1999) Efeito de ambientes, dos genótipos e da interação genótipos x ambientes na qualidade tecnológica de feijão do grupo de cores no estado do Paraná. In: **Anais da VI Reunião Nacional de Pesquisa do Feijão**. Embrapa, Goiânia, p. 339-342.

Scholz MBS and Fonseca Júnior NS (1999) Influência ambiental, genotípica e sua interação na qualidade tecnológica de feijão do grupo preto no Paraná. In: **Anais da VI Reunião Nacional de Pesquisa do Feijão**. Embrapa, Goiânia, p. 389-392.

Wassimi NN, Hosfield FD and Uebersax MA (1988) Combining ability of tannin content and protein characteristics of raw and cooked dry beans. **Crop Science 28**: 452-458.

Yokoyama LP and Stone LF (2000) **Cultura do feijoeiro no Brasil: características da produção**. Embrapa Arroz e Feijão, Santo Antônio de Goiás, 75p.