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Technological quality of common bean landraces from organic cropping system

Qualidade tecnológica de grãos de cultivares crioulas de feijão produzidas sob sistema orgânico

Kali Simioni (ORCID 0009-0001-1115-7551), **Cileide Maria Medeiros Coelho** (ORCID 0000-0001-9528-7371), **Giselle Regina Rodolfo** * (ORCID 0000-0002-5530-6037), **Clovis Arruda de Souza** (ORCID 0000-0003-0037-1509)

Universidade do Estado de Santa Catarina, Lages, SC, Brasil. * Author for correspondence: gisellerodolfo@hotmail.com

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ABSTRACT

Beans are an important constituent of the Brazilian diet, and the search for cultivars with good culinary characteristics and adapted to the place of cultivation is necessary. It is known that there is a wide genetic diversity for common bean landrace cultivars. Still, little is known experimentally about the behavior of these cultivars when produced under organic cultivation. This work aimed to evaluate the technological quality of common bean landraces produced under organic cropping system. Twenty-six cultivars were used, four commercial and twenty-two landraces, originating from the Active Bean Germplasm Bank (BAF) of Santa Catarina State University – Agroveterinary Sciences Center (UDESC/CAV), produced in organic and conventional cultivation, in two crops. Cooking time and resistance, percentage of water absorption and broken grains and total soluble solids were evaluated. The shortest cooking time for the grains cultivated in the organic system (18 to 22 minutes) was obtained. The cultivars that had a percentage of unbroken grains between 60 and 80% showed a higher content of total soluble solids in the broth. Based on the genetic diversity for technological quality in organic cropping system, the use of cultivars, BAFs: 60, 23, 81, 13, 68, 55, 75 and 36 are indicated to integrate genetic improvement programs or to be used by small farmers for bean production.

KEYWORDS: agroecology; cooking quality; genetic diversity; *Phaseolus vulgaris* L.

RESUMO

O feijão é um constituinte importante da dieta alimentar brasileira, sendo necessária a busca por cultivares com boas características culinárias e adaptadas ao local de cultivo. Sabe-se que existe uma ampla diversidade genética para as cultivares crioulas de feijão, mas pouco ainda se conhece experimentalmente sobre o comportamento dessas cultivares quando produzidas sob cultivo orgânico. O objetivo deste trabalho foi avaliar a qualidade tecnológica dos grãos de cultivares crioulas de feijão produzidas em cultivo orgânico. Foram utilizadas 26 cultivares sendo quatro comerciais e 22 crioulas, com origem do Banco Ativo de Germoplasma de Feijão (BAF) da Universidade do Estado de Santa Catarina – Centro de Ciências Agroveterinárias (UDESC/CAV), produzidas em cultivo orgânico e convencional, em duas safras. Tempo de cozimento e resistência, porcentagem de absorção de água e grãos quebrados e sólidos solúveis totais foram avaliados. O menor tempo de cozimento foi obtido nos grãos produzidos no sistema orgânico (18 a 22 min). As cultivares que tiveram percentual de grãos inteiros entre 60 a 80% apresentaram maior teor de sólidos solúveis totais no caldo. A partir da diversidade genética para a qualidade tecnológica sob cultivo orgânico, indica-se o uso das cultivares, BAFs: 60, 23, 81, 13, 68, 55, 75 e 36, para integrar programas de melhoramento genético ou serem utilizadas por pequenos agricultores para a produção de feijão.

PALAVRAS-CHAVE: agroecologia; qualidade para cozimento; diversidade genética; *Phaseolus vulgaris* L.

INTRODUCTION

Common bean is grown and consumed in several countries, and Brazil is the largest producer and consumer of this staple grain, an excellent source of proteins and minerals present in most Brazilians' daily meals (KLÄSENER et al. 2020). Because of the little time available for preparing meals, research efforts have been increasingly focused on exploring cultivars with good cooking traits, which are fundamental for cultivar acceptance in the consumer market. Demand is for cultivars that, in addition to high yields, have technological properties that meet the consumer preference, such as size, shape, color stability, fast imbibition time, short cooking time, and production of broth with thick consistency and predominantly unbroken grains after cooking (BARROS & PRUDENCIO 2016, SANTIS et al. 2019, SILVA et al. 2019).

These attributes are determined by the genotype and influenced by the environmental conditions during the development of the plant and grains (PERINA et al. 2014, VANIER et al. 2019). There is a great variation in cooking time, which is related to the water absorption capacity of the grains (VANIER et al. 2019), and environmental conditions influence a wide genetic variability (KATUURAMU et al. 2020). Therefore, researchers need to further investigate such interaction in order to generate information that contributes to genetic improvement programs.

Common bean landraces cultivation has historically and traditionally been a typical component of rural economies, cultivated by small-scale farmers using low-input production systems. Although landraces are an important component of agrobiodiversity, most of them are now in danger of genetic erosion since old farmers cultivate them and are gradually being substituted by modern cultivars (CATARCIONE et al. 2023). Due to and because the landraces cultivars provide more socioeconomic and food autonomy for small farmers (KAUFMANN et al. 2018), is really important that there is a rescue of this cultivation form.

There is a wide genetic diversity among common bean landraces (GINDRI et al. 2017), and the selection of the most promising cultivars to achieve better technological quality can be done directly, which has already been reported by previous works using the conventional farming system (COELHO et al. 2008). Few studies have analyzed genetic divergence in common bean cultivars based on technological quality traits (RIBEIRO et al. 2021). The results obtained in this work experimentally demonstrate the importance of genetic diversity for the organic cultivation system, despite the fact that historically landrace cultivars have been grown in the absence of synthetic inputs.

The pursuit of organic cropping systems aimed to maximize profits by adding value to the products has increased considerably (FERREIRA et al. 2019). However, more studies characterizing landraces in ecologically-based cropping systems are necessary, considering that they are more beneficial to the environment and biodiversity than the conventional systems (CAPRONI et al. 2018). In this context, it is confirmed that the present work is unprecedented because it considers the genetic diversity and the organic cropping system.

Currently, production and consumption of organic products have increased, mainly due to consumers' concern with quality foods, without chemical residues, and that ensure food security and sustainability in farming systems (EBERLE et al. 2019, ANDREATTA et al. 2020). Given that, this work aimed to evaluate the technological quality of common bean landraces produced under organic cropping system.

MATERIAL AND METHODS

The experiment was carried out in the experimental farm station of the Epagri (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina) Campos Novos, located in Campos Novos / SC state, in an area of organic farming. The beans were produced in two growing seasons, at the same place. The first one (2012/2013) is considered as crop 1, with production between Oct/2012 and Feb/2013, employing both organic and conventional cropping systems, and the second one (2013/2014) as crop 2, with production from Nov/2013 to Feb/2014 in the traditional system and from Dec/2013 to March/2014 in the organic cropping system. Data on rainfall, average and maximum temperature in the experimental period were obtained from Epagri and correspond to organic and conventional cropping systems in the crop 1 (Figure 1a) and traditional and organic cropping systems in crop 2 (Figure 1b and 1c).

The experimental design consisted of randomized blocks with four replications and the treatments consisted in a simple combination of cultivars and cropping system. The plots comprised four 4 m long rows, spaced 0.5 m apart, at a density of 15 seeds.m^{-1}. The net area of each plot consisted of the two central rows, excluding 0.5 m from each end of the rows.

For organic cropping, seeds of common oat (*Avena sativa*) and vetch (*Vicia sativa*) were scattered over the area to implement the winter cover at densities of 50 kg.ha^{-1} and 30 kg.ha$^{-1,}$ respectively. As fertilizer, 5.000 kg.ha^{-1} of poultry manure was used, 1/3 at the base and 2/3 on the cover. For the control of pests and diseases, 0.5% of Neem oil was applied at the early developmental stage and then 1% until the end of the cycle. Together with Neem oil, 40 mL.20L^{-1} of pepper extract (Plantil Plus) and 1% diatomaceous earth were applied when necessary as insect repellents. Hoeing was done four times during the crop growth cycle for weed control.

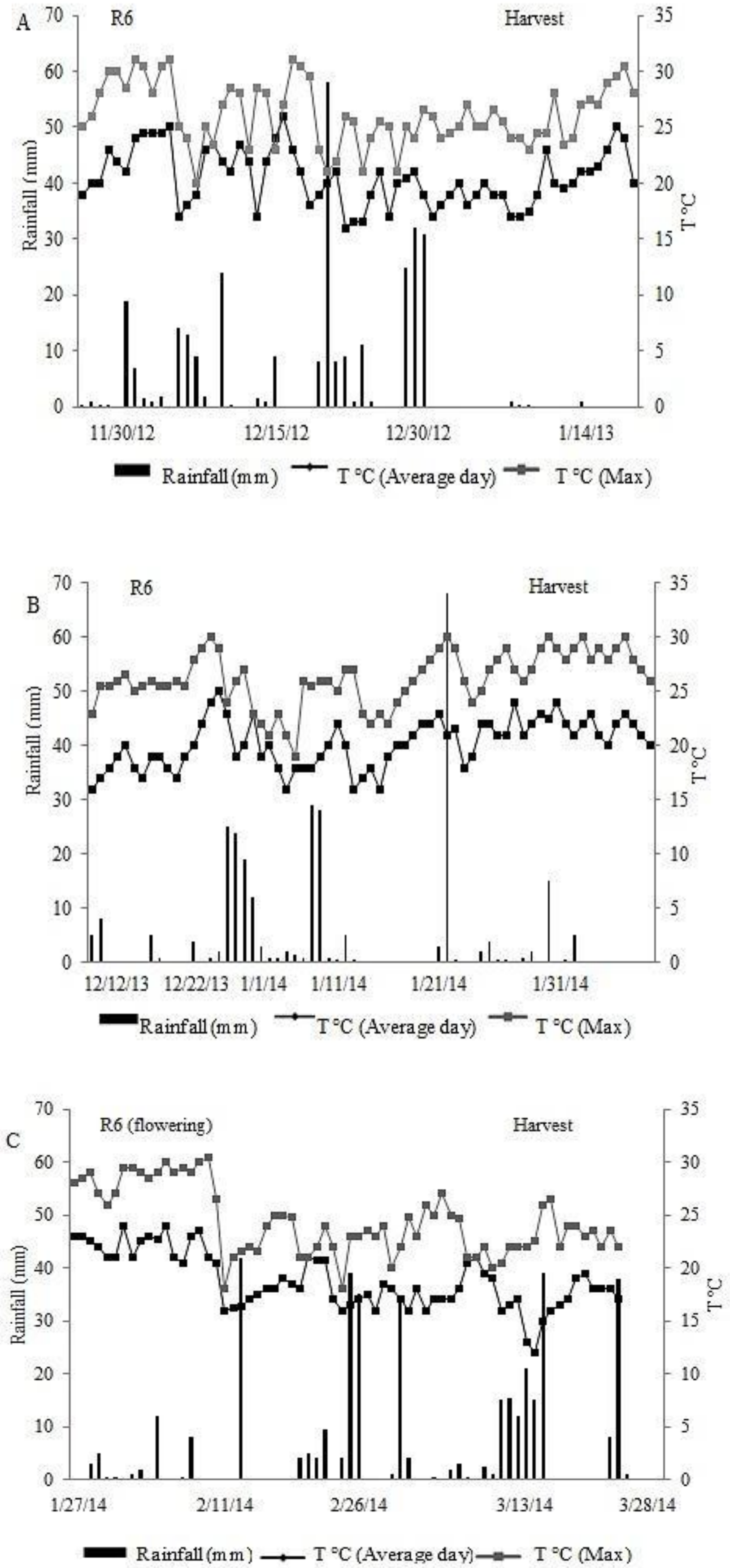


Figure 1. Rainfall, average and maximum accumulated temperatures from flowering to harvest. A) crop 1 - organic and conventional cropping systems. B) crop 2 - conventional cropping system. C) crop 2 - organic cropping n system, in Campos Novos / SC.

In the conventional area, the same plant species and densities were used for the winter cover. For fertilization, N-P_2O_5-K_2O (5-25-25) soluble chemical fertilizer was applied at the sowing time at the rate of 400 kg.ha^{-1}, and 15 days after the plants emergence, cover fertilization was done with urea (45-00-00) at the rate 80 kg.ha^{-1}, divided into two application times (phenological stages V3 and R5 of bean).

A total of 26 common bean cultivars were used, 22 being landraces, originating from the Active Bean Germplasm Bank (BAF) of Santa Catarina State University – Agroveterinary Sciences Center (UDESC/CAV), and four commercial varieties. Cultivars BAFs 03 (Manchinha), 04 (Amendoim Lages), 07 (Preto Lages), 13 (Taquara), 23 (Preto Chapecó), 36 (Rasga), 42 (Vagem Branca), 44 (Vermelho), 46 (without name), 47 (Preto precoce), 50 (Carioca Brilhante), 55 (Preto), 57 (Preto), 60 (Preto 60 dias), 68 (Vermelho), 75 (Serrano), 81 (Preto 70 dias), 84 (Carioca Rosado), 97 (Charque), 102 (México 309), 108 (Branco) and 120 (Roxinho) are landraces and cultivars BAF 110 (SC 202 Guará), 112 (IPR 88 Uirapuru), 115 (BRS Valente) and 121 (IAPAR 81) are commercial. These were selected previously based on genetic diversity characteristics related to morphoagronomic components and physiological potential of the seeds over seven self-fertilizing seasons (COELHO et al. 2008, ZILIO et al. 2014).

After reaching the physiological maturity, bean pods were harvested with water content close to 12% (measured by samplings made for all cultivars) and then dehulled manually. The grains were packed in paper bags and kept in a dry chamber (± 10 ºC and 45% relative air humidity) until the time of analyses, which were carried out at the laboratory of seed analysis of Santa Catarina State University, Lages / SC.

The percentage of water absorption (PWA) was determined using three repetitions of 16 g of grains immersed in 100 mL of distilled water at 25 °C, for 8 h (COELHO et al. 2008). The percentage of imbibition before cooking was determined according to the equation of BERRIOS et al. (1999). Previously soaked bean grains were subjected to the cooking test using the Mattson bean cooker modified by PROCTOR & WATTS (1987), where 25 grains were placed into the cooker filled with distilled water at boiling temperature (± 100 °C) for cooking, and the cooking time was recorded when the 13th plunger perforated the grains, totaling 52% of cooked grains.

Analyses of the percentage of imbibition after cooking (PIAC) and the percentage of unbroken grains after cooking (PUG) were carried out based on the adapted method described by CARBONELL et al. (2003), where previously soaked grains were placed in an autoclave at 110 °C during 15 min for cooking. After cooking, the percentage of imbibition was determined by weighing the beans (unbroken and split grains). The PUG was determined according to the method proposed by CARBONELL et al. (2003), according to which cooked beans were counted and separated into two portions: unbroken and split grains. To determine the content of total soluble solids (TSS) which consisted of filtering the broth after imbibition and cooking with subsequent drying by the oven-drying method.

The data were subjected to analysis of variance by F-test and the Scott-Knott compared the means of the different genotypes at each cropping system. The Tukey's test was used for each genotype of different system. For statistical analysis, the crop seasons were not considered as factors and were used for data reliability, therefore no comparisons were made. Pearson's simple correlation analysis was also used for all variables to identify possible correlations between them. Significance was considered at the level of $p < 0.01$ and $p < 0.05$. All analyses were performed using SAS® 9.1.3 and GENES software.

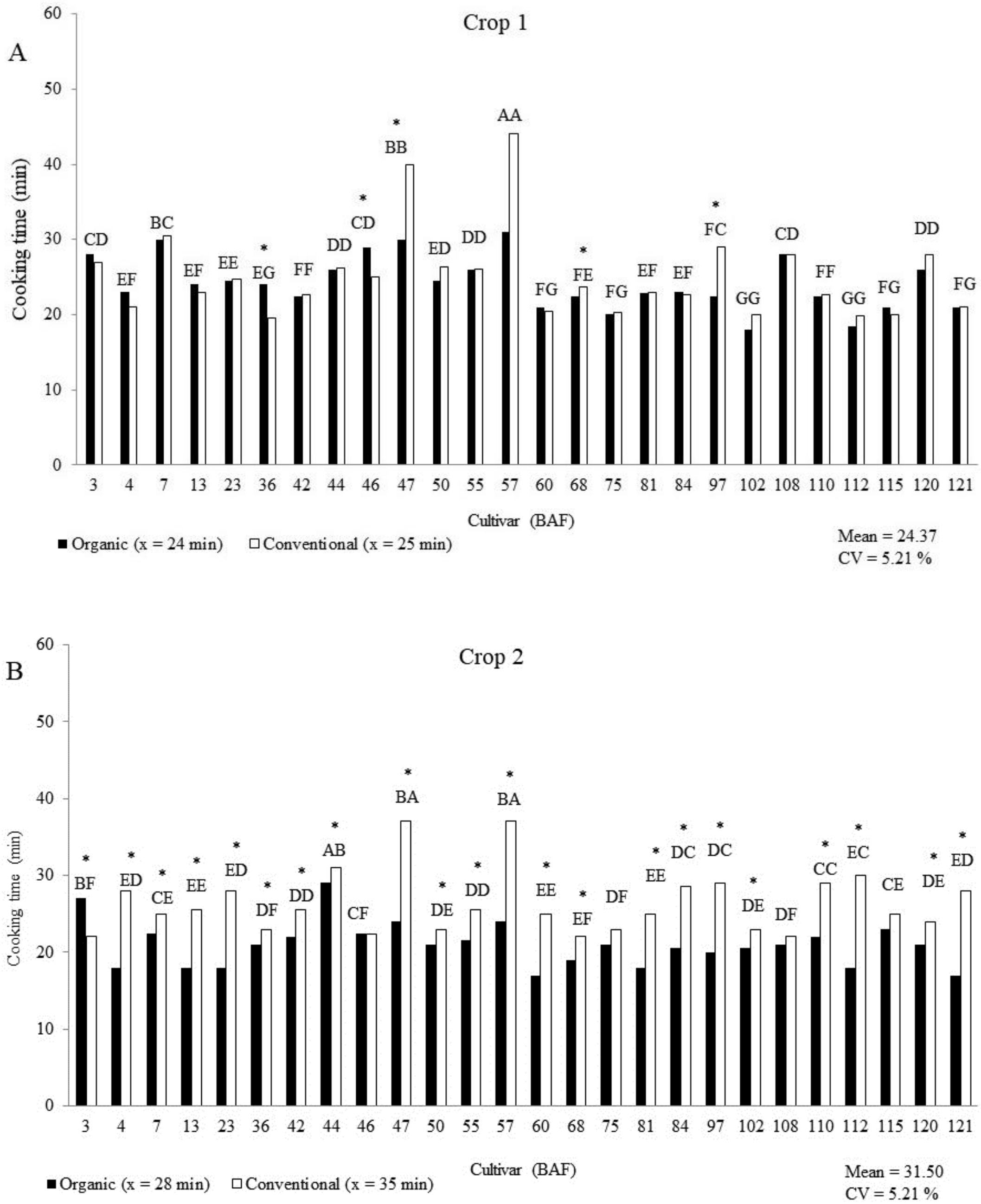
RESULTS AND DISCUSSION

In the crop 1, an average cooking time (CT) of 24.5 min was achieved, and in the crop 2, CT was of 31.5 min, and an increase of this characteristic was observed in both cultivation systems (Figure 2a and 2b). According to SILVA et al. (2016) and SANTOS et al. (2016), CT below 30 min is desirable for bean cultivars because of the time and energy that can be saved. In this study, the cultivars that accounted for the highest increases of CT were the landraces BAF 84, 97, 44, 47 and 57 (increase of 11 min) and the commercial varieties BAF 112, 121 and 110 (increase of 18 min). It can be seen that, on average, the organic cultivars had a shorter CT when compared to the commercial varieties. It is important to highlight that according to PERERA et al. (2023), why some varieties have shorter cooking times is still not well understood.

This occurrence may be related to the higher precipitation accumulated during the physiological maturation stage until harvest (Figure 1b and 1c), and the genetic diversity contributed to these results due to pre-harvest stress condition. This result can also be associated with the sources of nutrients with the application of organic fertilizers, which could be better studied in future works. In a study conducted by

OLIVEIRA et al. (2012), the cultivar also influenced CT. For CARBONELL et al. (2003), a longer CT occurred for cultivars grown under the highest rainfall volumes recorded during pre-harvest.

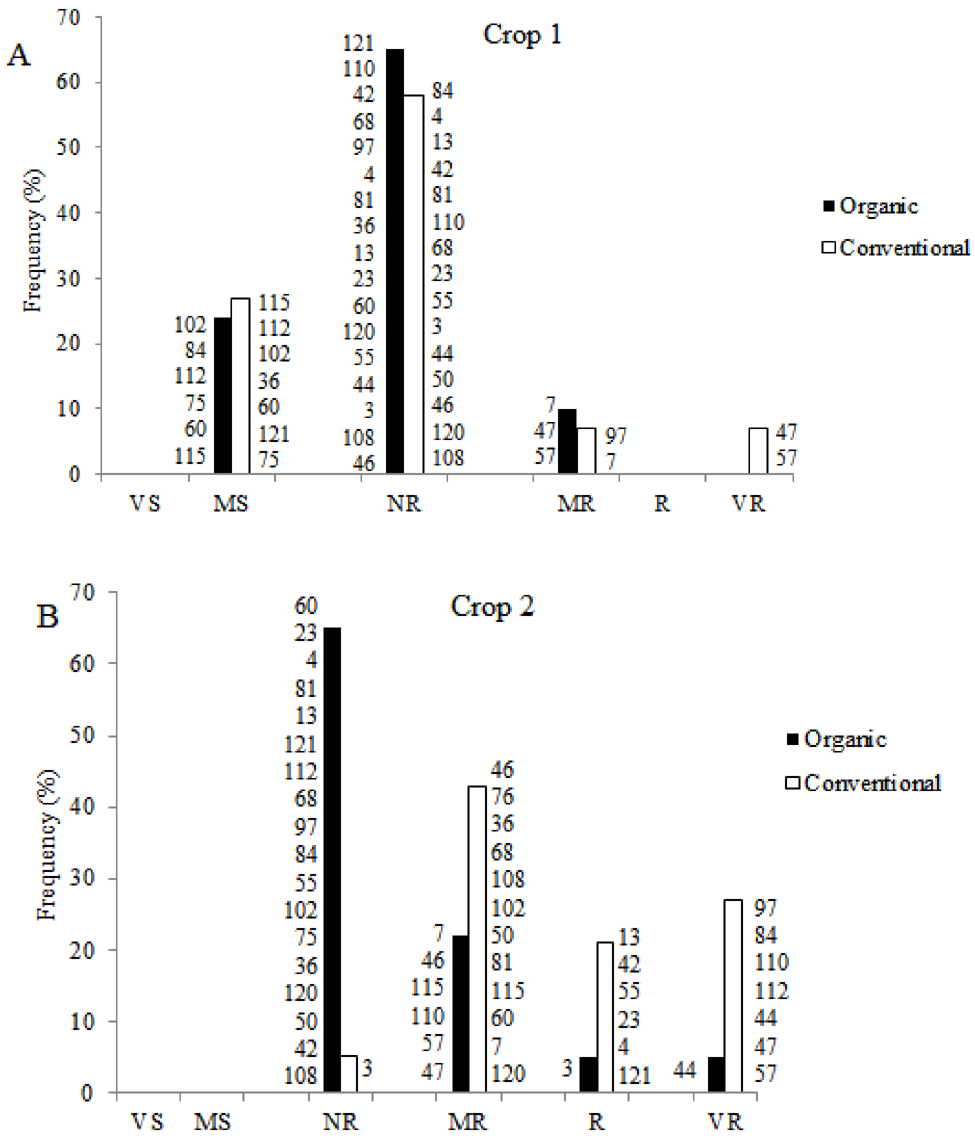
The CT variation found in crop 1 was between 18.33 (BAF 102) and 47.33 min (BAF 57). In crop 2, where precipitation was higher in both cropping systems, the CT varied from 22.69 (BAF 60) to 48.55 min (BAF 57) (Figure 2b). When ZILIO et al. (2014) evaluated the same genotypes at different cultivation sites, they found an even greater variation, from 43 to 77.5 min (Anchieta/SC); 26 to 51 min (Joaçaba/SC), and in Lages/SC variation was between 28.5 and 49.5 min. In a study conducted by SILVA et al. (2019), CT varied from 20.5 to 31.8 min, confirming the occurrence of genotype and environment interaction. In the same way, RIBEIRO et al. (2021) assert that the quality traits in common beans vary according to genotype and environment interaction.



Means followed by the same letter do not differ between cultivar by the Scott Knott test. *: Significant difference between the cropping systems for each cultivar, by the Tukey test (p <0.05).

Figure 2. Cooking time (min) of beans. A) Crop 1 - to organic and conventional cropping systems. B) Crop 2 – to organic and conventional cropping systems.

With regard to the cooking resistance classes proposed by PROCTOR & WATTS (1987), in general the beans produced in the organic system fell predominantly into the class of normal resistance in both crops, which meets consumers' requirements (Figure 3a and 3b). This result corroborates those found by SANTIS et al. (2019), who obtained a variation between 21 and 32 min, considered normal cooking resistance. In the conventional cropping system, a higher incidence of cultivars classified as resistant and very resistant to cooking were found, which is considered as undesirable to consumers, requiring more time and energy to cook, especially in crop 2, which received more rain and, consequently, produced more resistant beans (Figure 3b).



VS (very susceptible), MS (medium susceptibility), NR (normal resistance), MR (medium resistance), R (resistant), VR (very resistant).

Figure 3. Resistance to cooking of bean grains. A) Crop 1 - to organic and conventional cropping systems; B) Crop 2 – to organic and conventional cropping systems.

For the PWA variable, in crop 1 it varied from 72.01% (BAF 44) to 108.54% (BAF 97), and in crop 2 from 65.02% (BAF 97) to 109.50% (BAF 23) (Table 1). Higher variations were found by ZILIO et al. (2014), who examined the same cultivars of this work in different locations and found values ranging from 59.3% (BAF 13) to 103% (BAF 120) in the beans produced in Joaçaba, and from 44.7% (BAF 84) to 109.9% (BAF 112) in the beans produced in Lages. In other studies, such as those by OLIVEIRA et al. (2012) and PERINA et al. (2014), PWA values of up to 94% and between 97 to 109%, respectively, were found. In work by RIBEIRO et al. (2019), PWA varied from 84.37 to 94.59%.

Table 1. Percentage of water absorption before (PWA) and after (PIAC) cooking grains beans from organic (Org) or conventional (Conv) systems, in two crops.

BAF	PWA				PIAC			
	Crop 1		Crop 2		Crop 1		Crop 2	
	Org	Conv	Org	Conv	Org	Conv	Org	Conv
03	78.27 d*	85.21 e	82.52 e*	94.16 d	119.82 d	124.61 d	122.05 d	128.61 d
04	93.96 b	95.91 c	94.17 c	96.85 c	148.60 a	155.63 a	146.68 a	151.19 a
07	74.90 e	63.10 g*	80.12 e*	92.19 d	130.89 c	116.43 e*	134.13 c	140.44 b
13	93.55 b	91.48 d	99.14 b	100.83 c	138.33 b	136.59 c	141.97 b	140.41 b
23	84.82 c*	101.56 b	97.15 c*	109.50 a	138.36 b	139.76 c	148.91 a	142.34 b
36	96.69 b	95.20 c	104.70 a	98.44 c*	124.74 c*	146.85 b	130.75 c*	145.33 b
42	93.96 b*	102.68 b	96.19 c	99.96 c	122.58 c	129.70 d	122.85 d	121.95 d
44	72.01 e	73.67 f	69.80 f	71.68 f	119.33 d	110.23 e*	115.10 d	103.29 f*
46	102.20 a*	106.25 a	96.34 c	100.19 c	127.76 c	134.80 c	119.97 d	123.24 d
47	93.27 b	95.93 c	78.52 e*	83.86 e	122.55 c	123.05 d	105.77 e	105.56 f
50	83.38 c	85.77 e	73.58 f*	90.63 d	122.97 c*	132.31 c	111.27 e*	132.44 c
55	96.00 b	96.46 c	101.00 b	98.68 c	113.95 d*	135.23 c	116.95 d*	132.66 c
57	99.34 a	89.50 d*	83.58 e	75.53 f*	111.83 d	114.55 e	94.87 e	95.30 g
60	95.71 b*	99.69 b	95.43 c*	103.16 b	125.62 c*	143.56 c	123.79 d*	142.61 b
68	92.79 b	94.04 c	97.56 c	96.80 c	124.15 c*	115.51 d	126.83 d*	149.38 a
75	94.11 b*	98.70 b	103.05 a*	108.42 a	151.51 a	139.74 c	122.61 d*	144.52 b
81	96.21 b	98.05 b	92.53 d	85.22 e*	109.30 d*	135.29 c	103.24 e*	117.28 e
84	82.86 c*	101.32 b	69.10 f	71.57 f	118.11 d*	146.47 b	102.35 e	111.27 e
97	103.83 a*	108.54 a	65.02 g	67.24 g	141.62 b	137.84 c	100.78 e	91.77 g
102	90.72 b	90.60 d	90.13 d	91.20 d	139.93 b	140.51 c	137.78 c	136.62 c
108	93.67 b	94.59 c	96.74 c	97.40 c	147.11 a	153.90 a	148.67 a	151.34 a
110	92.26 b	95.77 c	89.44 d	92.57 d	135.03 b	138.20 c	130.22 c	130.53 c
112	93.55 b	94.80 c	95.53 c	98.93 c	154.05 a	137.65 c*	154.09 a	136.87 c*
115	93.52 b	95.66 c	94.46 c	98.25 c	143.47 b	129.32 d*	142.43 b	126.85 d*
120	102.28 a	99.92 b	105.86 a	103.67 b	125.07 c	133.15 c	126.55 d	131.47 c
121	96.34 b	97.44 b	93.44 d*	98.60 c	145.29 a	135.27 c*	140.48 b	131.36 c
Mean	91.93	94.3	90.2	93.29	130.84	134.08	125.81	129.41

Same letters in the column do not differ by Scott Knott's test. *: significant difference between the cropping systems for each cultivar, using the Tukey test ($p < 0.05$).

In the present work, 70% of the cultivars did not exhibit a significant difference for the water absorption capacity between the cropping systems in both crops, indicating that the cropping system did not influence the water absorption capacity by the grains, and that this trait seems to be more likely associated with the genotype and crop during the pre-harvest stage of the cultivars susceptible to water stress (Table 1). For PIAC, a behavior similar to the PWA was observed, with a relative increase of approximately 70 and 72% of PWA for crops 1 and 2, respectively, in both cropping systems (Table 1). For PWA, OLIVEIRA et al. (2012) found mean values of 104.77%.

In general, for PUG, the main effect was due to cultivars exhibiting similar behavior in both cropping systems (Table 2). This outcome may be related to the duration of the cooking time and the grains morphological and physical characteristics, such as the grain integument impermeability (cell walls more rigid), that can influence the hydration and cooking capacity (PERERA et al. 2023). So, this effect can be related to genetic diversity. In the work conducted by OLIVEIRA et al. (2012), more than 98% of PUG was found, and in PERINA et al. (2014), more than 50% of the grains split lengthwise during cooking. This result impairs quality, since the industry and consumers prefer grains that do not split after cooking. BARROS & PRUDENCIO (2016) reported that PUG was up to 85.5% in their study.

In both cropping systems, there was a variation in TSS of approximately 5 to 12.5% and 43 to 11.2% for the crops 1 and 2, respectively (Table 2). A variation of TSS in 25 cultivars was also found by SILVA et al.

(2016), with values ranging from 1.6 to 13.6%, and PERINA et al. (2014) found a mean value of 11.5%. In this work, 54% of the cultivars did not differ in TSS between cropping systems in both crops, indicating that this trait depends more on the genotype than in the crop.

Table 2. Percentage of unbroken grains (PUG) and content of total soluble solids (TSS) of bean grains from organic (Org) or conventional (Conv.) systems, in two crops.

BAF	PUG				TSS			
	Crop 1		Crop 2		Crop 1		Crop 2	
	Org	Conv	Org	Conv	Org	Conv	Org	Conv
03	83.37 a	81.58 c	90.11 a	93.01 b	5.07 m	5.40 i	3.89 j*	4.72 i
04	76.47 b	75.55 d	77.70 c	81.21 d	8.09 h	8.33 f	6.76 g*	7.42 f
07	84.14 a	84.70 c	83.46 b	85.44 d	7.63 l	7.70 g	6.47 g	6.62 g
13	68.27 d	66.36 e	69.23 d*	75.13 e	11.59 b	11.12 b*	10.27 b	10.19 b
23	76.49 b	76.49 d	76.18 c	77.56 e	9.25 f	8.50 f*	8.76 d	7.09 f*
36	73.93 c	70.44 e	77.44 c*	88.39 c	11.47 b	10.35 c*	10.68 b	9.21 c*
42	69.45 d	69.73 e	76.33 c	80.25 e	10.54 d	9.30 d*	9.54 c	8.59 d*
44	78.87 b	79.74 c	92.32 a*	99.12 a	8.11 h	7.43 g*	6.85 g	6.68 g
46	81.47 a	79.33 c	82.09 b	85.66 d	8.77 g	9.04 e	7.36 f	7.46 f
47	83.58 a	92.74 b	85.53 b*	93.14 b	9.34 f	9.61 d	8.40 e	8.41 d
50	78.61 b	81.67 c	83.08 b*	89.53 c	6.78 j	6.74 h	5.17 h	5.48 h
55	69.50 d	70.60 e	71.40 d*	77.51 e	11.76 b	10.18 c*	10.41 b	9.60 c*
57	86.30 a*	97.54 a	86.31 b*	91.62 c	11.48 b	10.11 c*	10.34 b	9.28 c*
60	73.15 c	72.86 d	75.38 c*	87.55 c	9.33 f	9.65 d	8.20 e*	8.74 d
68	74.82 c	76.46 d	78.61 c*	84.15 d	8.80 g	8.78 e	7.79 f	7.55 f
75	71.12 d	71.73 e	78.34 c*	88.23 c	10.43 d	10.48 c	9.50 c	9.39 c
81	69.38 d	69.49 e	70.28 d*	79.79 e	10.41 d	10.40 c	9.64 c	9.22 c
84	73.11 c	73.41 d	77.12 c*	84.30 d	10.90 c	10.19 c*	9.84 c	8.70 d*
97	74.65 c*	82.42 c	79.50 c*	88.19 c	9.09 f*	9.71 d	7.70 f	7.51 f
102	55.72 e	57.50 f	64.51 e*	76.33 e	12.47 a	12.69 a	11.27 a	11.25 a
108	83.90 a	83.59 c	84.87 b	88.30 c	5.67 l	5.41 i	4.57 i	4.87 i
110	72.90 c	74.62 d	82.20 b*	98.47 a	10.32 d	9.58 d*	9.61 c	8.15 e*
112	69.89 d	70.40 e	76.49 c*	97.32 a	10.38 d	10.63 c	9.65 c	9.32 c
115	70.57 d	69.28 e	80.52 b*	94.95 b	11.64 b	11.11 b*	10.00 c	9.40 c*
120	78.58 b	80.94 c	81.60 b*	87.31 c	7.90 h	7.27 g*	6.98 g	6.30 g*
121	70.46 d	69.82 e	73.47 c	76.16 e	9.67 e	8.91 e*	8.15 e	7.91 e
Mean	74.95	76.12	86.49	86.49	9.50	9.18	8.38	8.04

Same letters in the column do not differ by Scott Knott's test. *: significant difference between the cropping systems for each cultivar, using the Tukey test (p <0.05).

Pearson's simple correlation showed that between the CT and PUG, the higher the cooking time the higher is the percentage of unbroken grains, irrespective of the crop and cropping system (Table 3). A similar result was found by CARBONELL et al. (2003), who also reported a significant correlation between these two characteristics. According to BARROS & PRUDENCIO (2016), the higher the PUG, the lower the broth's TSS content. The results of this study corroborate those found by the authors cited here, and a significant negative correlation between PUG and TSS can be observed (Table 3). It was also found that most of the cultivars studied that exhibited 60 to 80% of unbroken grains had more TSS in broth. Literature does not recommend an ideal PUG to express good technological quality, but it is known that most consumers prefer a broth with thick consistency and that the TSS influences this trait in broth.

The PWA showed a significant correlation with the CT only for the crop 2; therefore, one cannot infer that PWA can be used as an estimate for assessment of CT in different cultivars (Table 3). ZILIO et al. (2014) found a similar result, who observed a low and negative correlation between the imbibition capacity and CT. Thus, the use of the imbibition capacity for the initial selection of genotypes with low CT should be applied only for crops grown under regular weather (temperature and rainfall), which was not observed in this study. On the other hand, a significant negative correlation between PIAC and CT was observed for both cultivation systems and crops. This result showed that the shorter the cooking time the higher is the percentage of imbibition after cooking (Table 3).

Table 3. Pearson's simple correlation of the technological quality beans variables of organic and conventional systems, in two crops.

System/Variables		Crop 1				Crop 2			
		PWA	PIAC	PUG	TSS	PWA	PIAC	PUG	TSS
Organic	CT	-0.13	-0.36*	0.84**	-0.37	-0.44*	-0.33*	0.78**	-0.26
	PWA		0.12	-0.19	0.36		0.55**	-0.42*	0.28
	PIAC			-0.2	-0.07			-0.25	-0.04
	PUG				-0.67**				-0.64**
Convencional	CT	-0.21	-0.53**	0.89**	-0.24	-0.56**	-0.65**	0.54**	0.17
	PWA		0.55**	-0.22	0.31		0.81**	-0.3	0.03
	PIAC			-0.43*	0.1			-0.31	-0.07
	PUG				-0.54**				-0.59**

* and **: significant at the level of p <0.01 and p <0.05, using the "t" test. PWA: percentage of water absorption before and after (PIAC) cooking grains beans; PUG: percentage of unbroken grains; TSS: content of total soluble solids; CT: cooking time.

It is important highlight that the characteristics evaluated showed variation in different landrace cultivars results, which is related to genetic diversity. Other authors observed variations in landrace cultivars variables results analyzed, such as morpho-agronomic traits (COELHO et al. 2010), nutrient content (PEREIRA et al. 2011), physiological quality of seeds (GINDRI et al. 2017, GINDRI & COELHO 2019). This genetic variability contributes to the maintenance of biodiversity and resistance/tolerance to biotic and abiotic stresses (ADHIKARI et al. 2022). When studying the seed quality of landrace bean cultivated in organic and conventional systems, GINDRI et al. (2017), did not observe differences in the results between the cropping systems. Similarly in this work, for some traits evaluated such as PWA, PIAC, PUG and TSS, no differences were observed between the systems either, reinforcing that these traits depend more on the genotype than on the cropping system

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CONCLUSION

Common beans grown in organic cropping systems present a better or similar grain technological quality compared to the conventional system. The cultivars identified as BAF 60, 23, 81, 13, 68, 55, 75 and 36 were the ones that achieved the best technological quality, which meet the quality standards required by consumers. This is due to the cooking time, which was shorter than 28 minutes. The percentage of imbibition before and after cooking, which was higher than 90 and 120%, respectively; the percentage of unbroken grains, between 60 and 80%; and total soluble solids in broth, between 9 and 12%. It is possible to categorize the common bean landraces according to the technological quality traits and recommend them to genetic improvement in breeding programs or to farmers to produce common bean in organic cropping system.

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