Nutritional characterization and productivity evaluation of landrace maize cultivars

Patrícia Medianeira Grigoletto Londero[1]
Camila Somavilla Kelling[2]
Jamila dos Santos Alves[3]
Anelise Pigatto Bissacotti[4]
Lia Rejane Silveira Reiniger[5]
Marlove Fátima Brião Muniz[6]

Ideias centrais

- O milho (*Zea mays* L.) é cereal amplamente produzido e consumido em todo o mundo.

- Em relação aos parâmetros biométricos, as testemunhas melhoradas de milho apresentaram desempenho semelhante ao da maioria das cultivares crioulas.

- A cultivar híbrida BRS 1002 destacou-se, em relação às demais variedades de milho analisadas, por ter apresentado a maior produtividade, apesar de não ter atingido a sua capacidade máxima.

- As cultivares crioulas de milho Cateto Amarelo, Ferro, Mato Grosso e Cinquentinha apresentaram teores significativos de cinzas, proteínas, lipídios, ácidos graxos mono e poli-insaturados e minerais.

- Houve eficiência na mensuração do valor genético verdadeiro em relação aos parâmetros biométricos, a composição química e ao perfil de ácidos graxos e minerais das cultivares de milho analisadas.

ABSTRACT

The objective of this work was to identify landrace maize cultivars with high nutritional contents and productivity. Biometric parameters, dry matter, ash, protein, and lipid contents, as well as fatty acid and mineral profiles of 15 landrace maize cultivars, and two improved controls ('BRS 1002' and 'BRS Missões') were determined. The maize cultivars were cultivated in the 2010/2011 growing season, in Ibarama, RS, Brazil. The improved maize controls showed similar performance to most landrace cultivars for the biometric parameters; however, 'BRS 1002' had the highest productivity. The landrace maize cultivars 'Cateto Amarelo', 'Ferro', 'Mato Grosso', and 'Cinquentinha' were more nutritious than the other cultivars. The measuring of the genetic values was effective for the analyzed characteristics in the cultivar grains. The studied cultivars, mainly those with higher-nutrient content, can be used in the food industry for food fortification and oil production.

Index terms: *Zea mays*, agrobiodiversity, grain productivity, landrace, nutritional quality.

Caracterização nutricional e avaliação da produtividade de cultivares crioulas de milho

RESUMO

O objetivo deste trabalho foi identificar cultivares crioulas de milho com altos teores nutricionais e produtividade. Determinaram-se os parâmetros biométricos, os teores de matéria seca, cinzas, proteínas e lipídios e o perfil de ácidos graxos e minerais dos grãos de 15 cultivares crioulas de milho e duas testemunhas melhoradas ('BRS 1002' e 'BRS Missões'). As cultivares de milho foram cultivadas na safra 2010/2011, em Ibarama, RS, Brasil. As testemunhas melhoradas de milho apresentaram desempenho similiar ao

[1] Agronomist, doctor in Agronomy, teacher of Department of Technology and Food Science of Universidade Federal de Santa Maria (UFSM), Santa Maria, RS, Brazil. E-mail: patricialondero@yahoo.com.br.

[2] Food technologist, laboratory technician of the Plant Analysis Laboratory, Associação Brasileira de Assistência Técnica e Extensão Rural do Rio Grande do Sul/Associação Sulina de Crédito e Assistência Rural (EMATER-RS/ASCAR), Porto Alegre, RS, Brazil. E-mail: camila_somavilla@hotmail.com.

[3] Food technologist, doctoral student in Food Science and Technology of Universidade Federal de Santa Maria, Santa Maria, RS, Brazil. E-mail: jamizinha_sm@hotmail.com.

[4] Food technologist, doctoral student in Food Science and Technology of Universidade Federal de Santa Maria, Santa Maria, RS, Brazil. E-mail: anelisebissacotti@yahoo.com.

[5] Agronomist, doctor in Seed Science and Technology, teacher of the Department of Phytotechnics, Universidade Federal de Santa Maria, Santa Maria, RS, Brazil. E-mail: liarsr@ufsm.br.

[6] Agronomist, doctor in Phytotechnics, teacher of Phytosanitary Defense, Universidade Federal de Santa Maria, Santa Maria, RS, Brazil. E-mail: marlove@smail.ufsm.br.

da maioria das cultivares crioulas quanto aos parâmetros biométricos; no entanto, a 'BRS 1002' mostrou a maior produtividade. As cultivares crioulas 'Cateto Amarelo', 'Ferro', 'Mato Grosso' e 'Cinquentinha' mostraram-se mais nutritivas do que as demais cultivares analisadas. A mensuração do valor genético foi eficiente para as características analisadas nos grãos das cultivares. As cultivares estudadas, em especial as crioulas que apresentam maiores quantidades de nutrientes, podem ser empregadas na indústria alimentícia para a fortificação de alimentos e a produção de óleos.

Termos para indexação: *Zea mays*, agrobiodiversidade, produtividade de grãos, cultivar crioula, qualidade nutricional.

INTRODUCTION

Maize (*Zea mays*) is a cereal member of the *Gramineae* family, whose origin is believed to be in the agriculture of the Aztec, Mayan, and Inca people (Araújo et al., 2015). From Mexico, cradle of maize, it spread throughout America (Cruz & Koblitz, 2011). In Europe, maize came to be known after Christopher Columbus returned to the continent, in 1492 (Cruz & Koblitz, 2011). After spreading around the world, maize began to be widely produced, significantly contributing to world economic development (Mussolini, 2009).

In Brazil, the estimated production of maize in the 2017/2018 harvest was 80,786,000 tonnes (Acompanhamento…, 2018). The continuous and high productivity of maize allowed of its insertion among the four main harvests produced in Brazil (Acompanhamento…, 2018), and gave the country the title of third largest producer of the cereal, behind the United States and China (Cruz & Koblitz, 2011). Paraná, Minas Gerais, and Rio Grande do Sul are the Brazilian states that stand out for maize harvest (Cruz & Koblitz, 2011).

Brazilian maize production has been used for diverse purposes. Maize is used for both animal feed and human consumption (Mussolini, 2009; Araújo et al., 2015), as well as raw material in high-technology industries (Paes, 2006). Because it is a source of energy attributed to the presence of carbohydrates (Araújo et al., 2015) and lipids (Paes, 2006), approximately 500 of the more than 600 existing maize products are part of human food (Araújo et al., 2015). Despite their significant amount, maize proteins are of poor quality (Paes, 2006) due to the small amount of the essential amino acids lysine and tryptophan (Cruz & Koblitz, 2011). The composition of maize micronutrients consists of vitamins A, B complex (Mussolini, 2009) and E, and the minerals phosphorus, sulfur, calcium (Paes, 2006), potassium, and magnesium (Cruz & Koblitz 2011).

There are several existing maize cultivars from which landrace ones are an important example. Preserved for generations by indigenous people and small farmers, landrace maize can also be called *landraces* (Coimbra et al., 2010). Although rustic (Araujo et al., 2013) and low yielding (Sandri & Tofanelli, 2008), landrace maize seed have several advantages for the farmer, such as: adaptation to the conditions of the cultivation place (Araujo et al., 2013), resistance, genetic variation (Sandri & Tofanelli, 2008), and use of seed in subsequent plantings, which results in lower costs. However, it has been observed that farmers have replaced the cultivation of landrace seed by genetically improved ones (Araujo et al., 2013), which is associated with the modernization suffered by agriculture in recent years. Although contributing to high productivity, hybrid cultivars require the heating of seeds for planting (Cruz & Koblitz, 2011), which entails high costs for the farmer, as well as high technological level to express their productive potential (Emygdio & Pereira, 2006). These facts show the need to rescue and preserve landrace maize seed, which play an important role in the conservation of species variability (Coimbra et al., 2010), providing information that can aid in the development of new genotypes and products. Landrace maize preserving could also increase the economic viability of domestic, commercial, and industrial areas (Sandri & Tofanelli, 2008; Araujo et al., 2013), as well as guarantee the food security and sovereignty, preventing and recovering cases of nutritional deficiencies.

The objective of this work was to identify the landrace maize cultivars with higher nutritional contents and produtivity.

MATERIALS AND METHODS

Fifteen landrace maize cultivars ('Brancão', 'Cunha', 'Cinquentinha', 'Pintado', 'Sertanejo', 'Oito Carreiras', 'Cateto Amarelo', 'Bico de Ouro', 'Cabo Roxo', 'Colorido', 'Amarelão', 'Mato Grosso', 'Ferro', 'Lombo Baio' e 'Palha Roxa') and two control – one simple hybrid ('BRS 1002') and one open-pollinated variety ('BRS Missões') – were grown in a field experiment in Ibarama (29º 25'10" S, 53º 08' 05" W, at 317 m altitude), in Rio Grande do Sul state, Brazil.

Maize sowing was performed with manual machines. For each cultivar, 50 maize seedlings were planted. The plots consisted of two 5 m rows, with 0.90 m row spacing, and 5 plants per linear meter were grown. Each plot corresponded to one cultivar.

Soil sampling for analysis, and fertilization and liming needs followed the guidelines of the Sociedade Brasileira de Ciência do Solo (Tedesco et al., 2004).

The experimental area was monitored for weeds and pests. Weeding was done by hand. For the biological control of caterpillars (*Spodoptera frugiperda*), 1% neem oil and 133 kg N ha^{-1} were applied to the hole in the form of urea, and wasps (*Trichogramma* spp.) were distributed in all experimental plots.

Harvesting was carried out manually in March 2011. Maize grains were dried to a 13% moisture content, cleaned and classified, to remove impurities and scraps. In a micromill MA-630, the grains were ground to obtain particles smaller than 1 mm. The cornmeal was stored in plastic bags and kept refrigerated until the beginning of the analyses.

The biometric parameters, thickness, length, and width of the grains were measured with a caliper. For this, in each performed analysis, 15 seed of each replicate were evaluated, totalizing 45 grains of each cultivar.

To calculate the productivity of each cultivar, the maize grain weight in grams per plot was transformed to kilogram per hectare.

Dry matter, crude protein, and ash were evaluated by AOAC methodologies (Cunniff, 1995). Lipid extraction was performed according to the method of Bligh & Dyer (1959).

For the determination of fatty acids, lipids were methylated after extraction, using the procedures suggested by Hartman & Lago (1973). Lipids were derivatized using methanolic solutions of KOH (0.4 mol L^{-1}) and H$_2$SO$_4$ (1 mol L^{-1}) and heating for 10 min in water bath at 100°C for each solution. Fatty acid methyl esters were dissolved with hexane, and determined using Varian gas chromatography (Star 3400 cx, Walnut Creek, California, USA), equipped with a flame ionization detector (GC-FID). The fatty acid methyl esters were injected manually (1 µL) and separated in a ZB Wax capillary column (Phenomenex, Torrance, California, USA) (30 m x 0.25 mm i.d. x 0.25 µm film thickness). Hydrogen was used as carrier gas at 10342 x 10^5 Pa constant pressure. The injector remained in separation mode with 1:50 ratio at 230°C. The column heating program began at 50°C with 2 min stop and then increased to 180°C with the heating rate of 20°C min^{-1}. Subsequently, 3°C min^{-1} rate was applied to reach 230°C and was maintained under isothermal conditions for 8 min. Ionization flame detector temperature was 230°C.

Fatty acids were identified by comparing the retention times of the analyses with the standard (FAME Mix-37, Sigma Aldrich). The quantification was performed by the normalization of fatty acid areas.

Maize samples were decomposed by wet digestion assisted by closed-range microwave radiation, using a commercial Multiwave microwave oven 3000 (Microwave Sample Preparation System, Anton Paar GmbH, Graz, Austria). The system was equipped with 8 quartz flasks with 80 mL

maximum capacity each. The maximum operating conditions for power, temperature, and pressure were 1400 W, 280°C and 80 bar respectively.

Samples of 500 mg of dried, homogenized ground maize kernels were mixed with 6 mL concentrated HNO_3 at 65% (Merck KGaA, Darmstadt, Hessen, Germany) in a decomposition flask. Subsequently, the flasks were closed and brought into the microwave oven cavity, following the microwave manufacturer's recommendation for the heating program. At the end of the digestion procedure, the resulting solutions were transferred to a polypropylene flask and checked to 30 mL with purified water (Millipore, with final resistivity of 18.2 MΩ cm).

Minerals were determined by inductively coupled plasma optical emission spectrometry (ICP OES) with axial view (Spectro Ciros CCD, Spectro Analytical Instruments GmbH, Kleve, North Rhine-Westphalia, Germany).

The results were subjected to the analysis of variance, at 5% probability. When the F value was significant, the cultivar means were compared to each other by the Scott-Knott test, at 5% probability, for which the statistical program SISVAR 5.3 was used (Ferreira, 2000).

The accuracy of the experiments was measured by selective accuracy (SA), considered as $SA=(1-1/F)^{1/2}$ and corresponding to the linear correlation between genotypic and phenotypic values (Resende & Duarte, 2007).

RESULTS AND DISCUSSION

The biometric parameters, thickness, length, width, and yield of the landrace cultivar grains showed significant difference due to the wide variability of the results (Table 1). The grains of the cultivar 'Cateto Amarelo' stood out, in relation to the others analyzed, for having the greatest thickness. As well the cutivar 'Oito Carreiras', it was observed that the 'Cateto Amarelo' had the greatest width. 'Bico de Ouro,' 'Amarelão', and 'Mato Grosso' produced longer grains than the other cultivars. When comparing the biometric parameters of the landrace cultivars and controls, it was found that controls do not differ significantly from most landrace maize.

The only cultivar that differed significantly from the others was the control cultivar 'BRS 1002' for to its high productivity. The landrace cultivars and 'BRS Missões' had a productivity less than 50% than that observed for 'BRS 1002'. However, despite being superior to the other cultivars for productivity, "BRS 1002" did not reach its maximum, which is approximately, 9,100 kg ha^{-1} (Emygdio et al., 2008). The same fact was observed for 'BRS Missões', which productivity much less than 6,262 kg ha^{-1} obtained by Emygdio & Pereira (2006) in Rio Grande do Sul, Brazil. Our result corroborates the widely accepted idea that the use of hybrid cultivars by low-technology farmers is not recommended due to the impossibility of expressing their productive potential (Emygdio & Pereira 2006). In addition to genetic factors, environmental factors may have interfered with the productivity obtained (Miranda et al., 2005).

The experimental precision through selective accuracy showed that the biometric parameters were between 0.93 and 0.97, proving to be very high according to the classification proposed by Resende & Duarte (2007). This result allowed of the inference on the efficiency of measuring the true genetic value of the characteristics of maize cultivars. The selective accuracy is considered adequate to classify the accuracy of experiments in general, as it depends on the magnitude of the experimental error, the number of repetitions and the proportion between variations of genetic and residual nature, associated with the character under evaluation (Cargnelutti Filho & Storck, 2007). The validity has been confirmed in the evaluation of experimental precision of competition tests for maize cultivars (Cargnelutti Filho & Storck, 2009).

Table 1. Biometric parameters of grains of different landrace maize cultivars and controls.[1]

Cultivar	Thickness (mm)	Length (mm)	Width (mm)	Productivity (kg ha^{-1})
Brancão	4.00c	11.80b	9.40c	1158b
Cunha	3.70c	12.60c	7.50d	1048b
Cinquentinha	3.70c	11.40c	8.70c	640b
Pintado	4.10b	11.90b	10.30b	1036b
Sertanejo	4.10b	11.30c	8.20d	1136b
Oito Carreiras	4.30b	11.00c	11.20a	718b
Cateto Amarelo	4.80a	11.80b	10.80a	816b
Bico de Ouro	4.10b	13.00a	9.80b	639b
Cabo Roxo	4.00c	12.30b	9.10c	1271b
Colorido	4.30b	10.70c	8.70c	620b
Amarelão	4.30b	13.10a	10.40b	875b
Mato Grosso	3.70c	12.90a	9.10c	968b
Ferro	4.20b	9.80c	8.50d	1428b
Lombo Baio	4.30b	11.10c	8.50d	1773b
Palha Roxa	4.10b	11.00c	9.10c	544b
BRS 1002	4.20b	11.30c	10.10b	3580a
BRS Missões	4.10b	10.80c	8.70c	1270b
Mean	4.10	11.60	9.30	1148
Maximum value	4.80	13.10	11.20	3580
Minimum value	3.70	9.80	7.50	544
Selective accuracy[2]	0.93	0.93	0.97	0.93

[1]Means with different letters, in the same column, are statistically different, according to the Scott-Knott´s test, at 5% probability. [2]Selective accuracy: very high, ≥0.90; high, ≥0.70 and <0.90; moderate, <0.70 and ≥0.50; low, <0.50).

The evaluated cultivars showed significant differences for the contents of dry matter, crude protein, ash, and lipid (Table 2). However, the improved control did not differ from most landrace cultivars for chemical composition. The selective accuracy obtained for dry matter, crude protein, and ash was high and very high for lipids.

The mean dry matter content in the analysed cultivars was 86.74% (Table 2), which agrees with the Instrução Normativa 60 of December 23, 2011, of the Ministério da Agricultura, Pecuária e Abastecimento (MAPA) (Brasil, 2011). The maximum moisture content in maize should be 14%, therefore the minimum dry matter content of this cereal should be 86%. Approximately 76.47% of the samples were in accordance with the MAPA recommendation (Brasil, 2011). The dry matter, identified in maize grains of the present study was higher than that observed by Sandri & Tofanelli (2008) in landrace maize (78.90%), and within the range identified by Santos et al. (2018) (86.25% and 88.47%).

The landrace cultivars 'Ferro', 'Cinquentinha', 'Mato Grosso', 'Bico de Ouro', and 'Cateto Amarelo' had the largest protein content, which makes them promising for commercial exploitation and direct insertion in alimentation (Table 2). However, maize has approximately 10% protein that is of low biological value (Cruz & Koblitz, 2011; Santos et al., 2018), due to the small amount of the essential amino acids lysine and tryptophan (Cruz & Koblitz, 2011). This fact was confirmed in this study, as the amount of crude protein present in maize grains ranged from 6.20% ('BRS 1002') to 8.75% ('Ferro'). Studies on landrace maize reported crude protein levels of approximately 7%, greater than 14% (Santos et al., 2018), and between 10.26% and 12.41% (Pinto et al., 2009), which are higher than those evidenced in the present study. The possible causes that led to low-protein levels identified in maize grains are the genetic variation among cultivars and the efficiency of soil-nitrogen utilization (Santos et al., 1998).

'Brancão', 'Sertanejo', 'Cateto Amarelo', 'Bico de Ouro', 'Amarelão', 'Mato Grosso', and 'Ferro' showed the higher ash contents among the cultivars (Table 2). Nevertheless, all maize cultivars in the present work had higher mineral contents than those described in the study by Mussolini (2009)

and Santos et al. (2018). Variations in the maize mineral composition may be influenced by soil nutrients and the type of management employed, according to Santos et al. (2018).

The highest values for lipids were observed for the 'Ferro' (6.53%) and 'Cateto Amarelo' (6.52%), which makes them important raw materials for the oil industry (Table 2). The average lipid contents in all cultivars were higher than those evidenced in other studies on landrace maize (Pinto et al., 2009; Santos et al., 2018), on hybrid (Mussolini, 2009), and on produced in agroecological system for maize (Kokuszka & Murate, 2007).

Table 2. Dry matter, crude protein, ash, and lipids (% dry matter) content of grains of different landrace maize cultivars and controls.[1]

Cultivar	Dry matter	Crude protein	Ash	Lipids
Brancão	85.82b	6.64b	1.43a	5.79c
Cunha	86.83a	7.13b	1.32b	6.12b
Cinquentinha	87.04a	8.18a	1.37b	5.95b
Pintado	86.95a	6.99b	1.37b	4.93d
Sertanejo	85.04b	6.73b	1.44a	5.28d
Oito Carreiras	85.54b	6.73b	1.33b	5.59c
Cateto Amarelo	86.47a	7.66a	1.55a	6.52a
Bico de Ouro	85.42b	7.73a	1.38a	5.09d
Cabo Roxo	87.61a	7.31b	1.37b	5.61c
Colorido	87.14a	6.96b	1.33b	5.19d
Amarelão	87.75a	7.31b	1.38a	5.36d
Mato Grosso	87.09a	8.12a	1.52a	5.59c
Ferro	86.52a	8.75a	1.52a	6.53a
Lombo Baio	86.69a	6.92b	1.35b	5.19d
Palha Roxa	88.08a	6.24b	1.37b	5.02d
BRS 1002	87.40a	6.20b	1.29b	5.63c
BRS Missões	87.19a	6.55b	1.30b	5.64c
Mean	86.74	7.19	1.39	5.59
Maximum value	88.08	8.75	1.55	6.53
Minimum value	85.04	6.20	1.29	4.93
Selective accuracy[2]	0.83	0.82	0.88	0.93

[1]Means with different letters, in the same column, are statistically different, according to the Scott-Knott´s test, at 5% probability. [2]Selective accuracy: very high, ≥0.90; high, ≥0.70 and <0.90; moderate, <0.70 and ≥0.50; low, <0.50.

Grains of the analysed maize cultivars have a fatty acid profile composed of 12 types, from which the main ones are unsaturated (81.22%) (Table 3); out of these, the polyunsaturated ones represent 47.43% of the total fatty acids. Among the polyunsaturated fatty acids, linoleic acid showed the highest quantification in maize grains (46.44%). Linoleic acid is not synthesized by the human organism, requiring a diet to be obtained, therefore, the high content of this fatty acid shows maize as an important source of it.

Monounsaturated fatty acids correspond to 33.79% of the total fatty acids of maize grains. The monounsaturated fatty acid that stands out in the studied maize cultivars was oleic fatty acid (33.32%).

Table 3. Identification and quantification of unsaturated fatty acids from grains of different landrace maize cultivars and controls.[1]

Cultivar	Unsaturated fatty acids[2]						
	16:1	18:1n9c	18:2n6c	18:3n3c	20:1	∑MUFAs	∑PUFAs
Brancão	0.18b	31.92c	48.40a	1.06a	0.32a	32.41	49.45
Cunha	0.16b	35.64a	43.64c	0.91b	0.30a	36.09	44.55
Cinquentinha	0.14b	37.76a	42.52c	0.75c	0.30a	38.19	43.27
Pintado	0.14b	33.49b	45.94b	0.93b	0.36a	33.98	46.27
Sertanejo	0.15b	33.59b	46.72a	0.96b	0.31a	34.05	47.69
Oito Carreiras	0.14b	32.32c	47.72a	1.14a	0.32a	32.78	48.86
Cateto Amarelo	0.16b	35.90a	44.35c	1.05a	0.30a	36.36	45.40
Bico de Ouro	0.14b	32.91b	47.69a	1.02a	0.32a	33.37	48.71
Cabo Roxo	0.15b	34.13b	45.35b	0.94b	0.32a	34.60	46.28
Colorido	0.15b	31.15c	47.45a	0.99b	0.29a	31.59	48.44
Amarelão	0.15b	35.70a	43.71c	0.97b	0.31a	36.15	44.68
Mato Grosso	0.15b	31.71c	48.56a	1.06a	0.31a	32.16	49.62
Ferro	0.16b	32.09c	48.12a	1.06a	0.30a	32.55	49.18
Lombo Baio	0.15b	31.95c	47.62a	1.06a	0.30a	32.41	48.68
Palha Roxa	0.18b	31.87c	46.89a	0.98b	0.31a	32.35	47.88
BRS 1002	0.14b	31.24c	48.99a	0.98b	0.31a	31.69	49.97
BRS Missões	0.25a	33.07b	45.74b	1.08a	0.29a	33.61	46.82
Mean	0.16	33.32	46.44	1.00	0.31	33.79	47.43
Maximum value	0.25	37.76	48.99	1.14	0.36	38.19	49.97
Minimum value	0.14	31.15	42.52	0.75	0.29	31.59	43.27
Selective accuracy[3]	0.75	0.93	0.91	0.94	0.30	-	-

[1]Means with different letters, in the same column, are statistically different, according to the Scott-Knott´s test, at 5% probability. [2]Unsaturated fatty acids:16:1, palmitoleic acid; 18:1n9c, oleic acid; 18:2n6c linoleic acid; 18:3n3c, linolenic acid; 20:1, elaidic acid; ∑MUFAs, sum of monounsaturated fatty acids; ∑PUFAs, sum of polyunsaturated fatty acids. [3]Selective accuracy: very high, ≥0.90; high, ≥0.70 and <0.90; moderate, <0.70 and ≥0.50; low, <0.50).

Saturated fatty acids were in small proportion in the maize cultivars (17.87%) (Table 4). Despite the low percentage of saturated fatty acids in maize grains, palmitic acid (C16: 0) showed a significant amount (13.83%). The variation of oleic acid, the variation was between 31.15% in 'Colorido', and 37.76% in 'Cinquentinha'; for linoleic acid contents was between 42.52 in 'Cinquentinha' and 48.99% in 'BRS 1002'; and for linolenic acid, the variation corresponded to 0.75 in 'Cinquentinha' and 1.14% in 'Oito Carreiras'.

Table 4. Identification and quantification of saturated fatty acids from grains of different landrace maize cultivars and controls.[1]

Cultivar	Saturated fatty acids[2]							
	14:0	16:0	17:0	18:0	20:0	22:0	24:0	∑SFA
Brancão	0.04a	13.36a	0.11b	2.55c	0.66b	0.25a	0.36a	17.34
Cunha	0.04a	13.97a	0.11b	3.00a	0.78a	0.28a	0.39a	18.56
Cinquentinha	0.03a	14.14a	0.09b	2.40c	0.65b	0.21a	0.27a	17.78
Pintado	0.04a	14.01a	0.12b	2.65b	0.78a	0.33a	0.47a	18.39
Sertanejo	0.04a	13.74a	0.10b	2.26c	0.65b	0.27a	0.37a	17.42
Oito Carreiras	0.04a	13.42a	0.12b	2.55c	0.73a	0.30a	0.43a	17.59
Cateto Amarelo	0.04a	13.67a	0.10b	2.33c	0.63b	0.25a	0.31a	17.33
Bico de Ouro	0.04a	13.03a	0.12b	2.51c	0.66b	0.26a	0.42a	17.04

Continua...

Continuação da Tabela 4

Cultivar	Saturated fatty acids[2]							
Cabo Roxo	0.04a	13.98a	0.13b	2.61b	0.72a	0.27a	0.38a	18.14
Colorido	0.04a	13.82a	0.15a	3.00a	0.75a	0.31a	0.52a	18.59
Amarelão	0.04a	13.68a	0.13a	2.84a	0.77a	0.28a	0.45a	18.19
Mato Grosso	0.03a	13.54a	0.15a	2.27c	0.66b	0.28a	0.35a	17.29
Ferro	0.04a	13.84a	0.15a	2.05c	0.63b	0.26a	0.36a	17.33
Lombo Baio	0.04a	13.93a	0.15a	2.50c	0.72a	0.27a	0.35a	17.95
Palha Roxa	0.05a	14.91a	0.12b	2.51c	0.68b	0.25a	0.33a	18.85
BRS 1002	0.04a	13.50a	0.13b	2.31c	0.69b	0.28a	0.38a	17.32
BRS Missões	0.06a	14.49a	0.13b	2.63b	0.72a	0.26a	0.34a	18.62
Mean	0.04	13.83	0.12	2.53	0.70	0.27	0.38	17.87
Maximum value	0.06	14.91	0.15	3.00	0.78	0.33	0.52	18.85
Minimum value	0.03	13.03	0.09	2.05	0.63	0.21	0.27	17.04
Selective accuracy[3]	0.63	0.76	0.88	0.88	0.78	0.68	0.68	-

[1]Means with different letters, in the same column, are statistically different, according to the Scott-Knott´s test, at 5% probability. [2]Saturated fatty acids:14:0, myristic acid; 16:0, palmitic acid; 17:0, heptadecanoic acid; 18:0, stearic acid; 20:0, arachidic acid; 22:0, behenic acid; 24:0, lignoceric acid; ∑SFA, sum of saturated fatty acids. [3]Selective accuracy: very high, ≥0.90; high, ≥0.70 and <0.90; moderate, <0.70 and ≥0.50; low, <0.50).

Selective accuracy showed very high values for oleic (0.93), linolenic (0.94) and linoleic (0.91) acids, and high values for heptadecanoic and stearic (0.88), arachidic (0.78), palmitic (0.76), palmitoleic acids (0.75) (Table 3).

Maize has approximately 3 to 6% minerals in its composition, which are mainly concentrated in the germ (Paes, 2006). Although considered the most abundant mineral in maize grains (Paes, 2006), phosphorus (282.75 to 355.80 mg 100 g^{-1}), after potassium (344.20 to 411.70 mg 100 g^{-1}), was the mineral present in higher amounts in the studied cultivars. The grain mineral profile of the analyzed maize cultivars was composed by potassium, phosphorus, magnesium (104.10 to 131.85 mg 100 g^{-1}), sulfur (103.30 to 120.50 mg 100 g^{-1}), calcium (2.79 to 3.95 mg 100 g^{-1}), zinc (1.78 to 2.24 mg 100 g^{-1}) and iron (1.63 to 2.18 mg 100 g^{-1}). The maize cultivars showed significant differences for calcium, potassium, and iron contents (Table 5).

Table 5. Characterization of mineral profile in grains of different landrace maize cultivars and controls (mg 100 g^{-1} dry matter).[1]

Cultivar	Mineral profile[2]							
	Mg	Ca	K	P	S	Fe	Zn	∑ minerals
Brancão	111.85a	3.12b	344.20b	329.05a	110.20a	2.03a	1.84a	902.29
Cunha	104.20a	3.87a	350.65b	282.75a	103.30a	1.63b	1.79a	848.19
Cinquentinha	112.80a	3.80a	391.60a	355.80a	120.50a	1.99a	2.19a	988.68
Pintado	105.10a	3.95a	376.45a	320.75a	108.90a	1.73b	1.99a	918.87
Sertanejo	109.10a	3.56a	371.35b	301.35a	106.10a	1.66b	1.91a	895.03
Oito Carreiras	104.10a	3.46a	348.00b	301.15a	104.80a	1.91a	1.91a	865.33
Cateto Amarelo	118.00a	3.17b	382.50a	334.50a	112.45a	1.81b	2.18a	954.61
Bico de Ouro	112.25a	2.80b	380.05a	319.80a	115.25a	1.94a	1.87a	933.96
Cabo Roxo	112.50a	3.88a	390.20a	351.25a	116.35a	1.89a	1.97a	978.04
Colorido	114.40a	3.69a	367.45b	338.95a	114.30a	1.77b	1.94a	942.50
Amarelão	108.05a	2.83b	391.25a	323.45a	113.30a	2.13a	2.12a	943.13
Mato Grosso	120.85a	3.24b	394.75a	350.00a	106.20a	1.79b	1.88a	978.71
Ferro	116.20a	3.42a	351.35b	317.90a	114.80a	2.11a	2.17a	907.95

Continua...

Continuação da Tabela 5

Cultivar	Mineral profile[2]						
Lombo Baio	119.75a	2.79b	411.70a	344.35a	111.65a	2.18a	2.24a	994.66
Palha Roxa	105.50a	3.09b	400.65a	332.10a	106.70a	2.13a	1.78a	951.95
BRS 1002	112.45a	3.11b	403.05a	305.95a	104.75a	1.71b	1.93a	932.95
BRS Missões	131.85a	3.37a	389.20a	335.10a	112.40a	1.93a	1.84a	975.69
Mean	112.88	3.36	379.08	326.13	110.70	1.90	1.97	936.03
Maximum value	131.85	3.95	411.7	355.8	120.5	2.18	2.24	848.19
Minimum value	104.1	2.79	344.2	282.75	103.3	1.63	1.78	994.66
Selective accuracy[3]	-	0.82	0.83	0.68	-	0.91	0.49	-

[1]Means with different letters, in the same column, are statistically different, according to the Scott-Knott´s test, at 5% probability. [2]Mineral profiles: Mg, magnesium; Ca, calcium; K, potassium; P, phosphorus; S, sulfur; Fe, iron; Zn, zinc. [3]Selective accuracy: very high, ≥0.90; high, ≥0.70 and <0.90; moderate, <0.70 and ≥0.50; low, <0.50).

The selective accuracy obtained for calcium (0.82) and potassium (0.83) was high, while for iron (0.91) it was very high. Given these results, it can be considered that there was a high precision in the measurement of the true genetic value of the studied characteristics.

All maize cultivars showed satisfactory total mineral concentrations. However, 'Lombo Baio' (994.66 mg 100 g^{-1}), 'Cinquentinha' (988.68 mg 100 g^{-1}), 'Mato Grosso' (978.71 mg 100 g^{-1}), 'Cabo Roxo' (978.04 mg 100 g^{-1}), and 'BRS Missões' (975.69 mg 100 g^{-1}) showed higher total mineral contents than the other cultivars. These results show that the studied cultivars, especially those with higher amounts of minerals, can be used in the food industry, aiming to fortify foods, mainly those intended for children.

It should be noted that mineral accumulation in maize may vary depending on the maturity stage, soil quality, cropping system, genetic diversity and nutrient interactions (Feil et al., 2005).

CONCLUSIONS

The improved maize controls show biometric parameters similar to that of most maize cultivars.

The landrace maize cultivars prove to be more nutritious than the improved controls.

'Cateto Amarelo', 'Ferro', 'Mato Grosso', and 'Cinquentinha' show significant contents for ash, proteins, lipids, mono- and polyunsaturated fatty acids, and minerals.

The landrace maize cultivars, especially those with higher-nutrient contents, can be used in the food industry for food fortification and oil production.

The measuring of true genetic value is effective in relation to biometric parameters, chemical composition, and fatty acids and mineral profiles of the studied maize cultivars.

'BRS 1002' is the control cultivar with the highest productivity.

There is no significant differences between several landrace maize cultivars and the controls 'BRS 1002' and 'BRS Missões'.

ACKNOWLEDGEMENTS

REFERENCES

ACOMPANHAMENTO DA SAFRA BRASILEIRA [DE] GRÃOS: safra 2018/19: terceiro levantamento, v.6, n.3, dez. 2018.

ARAUJO, A.V. de; BRANDÃO JUNIOR, D. da S.; FERREIRA, I.C.P.V.; COSTA, C.A. da; PORTO, B.B.A. Desempenho agronômico de variedades crioulas e híbridos de milho cultivados em diferentes sistemas de manejo. **Revista Ciência Agronômica**, v.44, p.885-892, 2013. DOI: https://doi.org/10.1590/S1806-66902013000400027.

ARAÚJO, H.M.C.; RAMOS, K.L.; MONTEBELLO, N.P.; BOTELHO, R.B.A.; ZANDONADI, R.P.; GINANI, V.C.; ARAÚJO, W.M.C. Transformação dos alimentos: cereais e leguminosas. In: ARAÚJO, W.M.C.; MONTEBELLO, N.P.; BOTELHO, R.B.A.; BORGO, L.A. (Org.). **Alquimia dos alimentos**. 3.ed. rev. e ampl. São Paulo: Senac, 2015. p.179-209.

BLIGH, E.G.; DYER, W.J. A rapid method of total lipid extraction and purification. **Canadian Journal of Biochemistry and Physiology**, v.37, p.911-917, 1959. DOI: https://doi.org/10.1139/o59-099.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **Instrução Normativa nº 60, de 23 de dezembro de 2011**. [Estabelece o Regulamento Técnico do Milho]. Brasília, 2011. Available at: <http://sistemasweb.agricultura.gov.br/sislegis/action/detalhaAto.do?method=visualizarAtoPortalMapa&chave=1739574738>. Accessed on: 5 jan. 2019.

CARGNELUTTI FILHO, A.; STORCK, L. Estatísticas de avaliação da precisão experimental em ensaios de cultivares de milho. **Pesquisa Agropecuária Brasileira**, v.42, p.17-24, 2007. DOI: https://doi.org/10.1590/S0100-204X2007000100003.

CARGNELUTTI FILHO, A.; STORCK, L. Medidas do grau de precisão experimental em ensaios de competição de cultivares de milho. **Pesquisa Agropecuária Brasileira**, v.44, p.111-117, 2009. DOI: https://doi.org/10.1590/S0100-204X2009000200001.

COIMBRA, R.R.; MIRANDA, G.V.; CRUZ, C.D.; MELO, A.V. de; ECKERT, F.R. Caracterização e divergência genética de populações de milho resgatadas do Sudeste de Minas Gerais. **Revista Ciência Agronômica**, v.41, p.159-166, 2010. DOI: https://doi.org/10.5935/1806-6690.20100021.

CRUZ, R.S.; KOBLITZ, M.G.B. Grãos: cereais e leguminosas. In: KOBLITZ, M.G.B. (Org.). **Matérias-primas alimentícias**: composição e controle de qualidade. Rio de Janeiro: Guanabara Koogan, 2011. p.43-119.

CUNNIFF, P. (Ed.). **Official methods of analysis of AOAC International**. 16th ed. Arlington: AOAC, 1995. 1018p. Official Methods 923.03, 925.10, 960.52.

EMYGDIO, B.M.; PEREIRA, L.R. BRS Missões: nova cultivar de milho para a região Sul do Brasil. **Pesquisa Agropecuária Brasileira**, v.41, p.545-547, 2006. DOI: https://doi.org/10.1590/S0100-204X2006000300025.

EMYGDIO, B.M.; TEIXEIRA, M.C.C.; ACOSTA, A. BRS 1002: nova cultivar de milho para o Sul do Brasil. **Pesquisa Agropecuária Brasileira**, v.43, p.1437-1440, 2008. DOI: https://doi.org/10.1590/S0100-204X2008001000025.

FEIL, B.; MOSER, S.B.; JAMPATONG, S.; STAMP, P. Mineral composition of the grains of tropical maize varieties as affected by pre-anthesis drought and rate of nitrogen fertilization. **Crop** Science, v.45, p.516-523, 2005. DOI: https://doi.org/10.2135/cropsci2005.0516.

FERREIRA, D.F. **Sistemas de análise estatística para dados balanceados**. Lavras: UFLA/DEX/SISVAR, 2000. 145p.

HARTMAN, L.; LAGO, R.C.A. Rapid preparation of fatty acid methyl esters from lipids. **Laboratory Practice**, v.22, p.475-476, 1973.

KOKUSZKA, R.; MURATE, E.H. Valor nutricional de milho produzido em sistemas de produção convencional e agroecológico. **Revista Brasileira de Agroecologia**, v.2, p.566-569, 2007.

MIRANDA, G.V.; SOUZA, L.V. de; COIMBRA, R.R.; GALVÃO, J.C.C.; MELO, A.V. de; GUIMARÃES, L.J.M.; VILELA, F.O. Comportamento de cultivares de milho em Minas Gerais – safras 1998/1999 e 1999/2000. **Revista Ceres**, v.52, p.401-419, 2005.

MUSSOLINI, R.C. **Caracterização físico-química e rendimento da moagem úmida de quatro híbridos de milho**. 2009. 58p. Dissertação (Mestrado) - Universidade Estadual Paulista "Júlio de Mesquita Filho", São José do Rio Preto.

PAES, M.C.D. **Aspectos físicos, químicos e tecnológicos do grão de milho**. Sete Lagoas: Embrapa Milho e Sorgo, 2006. 6p. (Embrapa Milho e Sorgo. Circular técnica, 75).

PINTO, A.T.B.; PEREIRA, J.; OLIVEIRA, T.R. de; PRESTES, R.A.; MATTIELO, R.R.; DEMIATE, I.M. Characterization of corn landraces planted grown in the Campos Gerais region (Paraná, Brazil) for industrial utilization. **Brazilian Archives of Biology and Technology**, v.52, p.17-28, 2009. Special number. DOI: https://doi.org/10.1590/S1516-89132009000700003.

RESENDE, M.D.V. de; DUARTE, J.B. Precisão e controle de qualidade em experimentos de avaliação de cultivares. **Pesquisa Agropecuária Tropical**, v.37, p.182-194, 2007.

SANDRI, C.A.; TOFANELLI, M.B.D. Milho crioulo: uma alternativa para rentabilidade no campo. **Pesquisa Agropecuária Tropical**, v.38, p.59-61, 2008.

SANTOS, D. da S.; MONTEIRO, S.S.; PEREIRA, E.M.; MARINI, F.S.; VASCONCELLOS, A.; LIMA, J.F. de. Composição centesimal de milho crioulo coletado em localidades do estado da Paraíba. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v.13, p.308-312, 2018. DOI: https://doi.org/10.18378/rvads.v13i3.5628.

SANTOS, M.X. dos; GUIMARÃES, P.E. de O.; PACHECO, C.A.P.; FRANÇA, G.E.; PARENTONI, S.N.; GAMA, E.E.G. e; LOPES, M.A. Melhoramento intrapopulacional no Sintético Elite NT para solos pobres em nitrogênio. I. Parâmetros genéticos de produção. **Pesquisa Agropecuária Brasileira**, v.33, p.55-61, 1998.

TEDESCO, M.J.; GIANELLO, C.; ANGHINONI, I.; BISSANI, C.A.; CAMARGO, F.A.O.; WIETHÖLTER, S. (Ed.). **Manual de adubação e de calagem para os estados do Rio Grande do Sul e de Santa Catarina**. 10.ed. Porto Alegre: Sociedade Brasileira de Ciência do Solo, Comissão de Química e Fertilidade do Solo- RS/SC, 2004. 400p.

―――――――――――――