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CHARACTERIZATION, QUALIFICATION AND COMPARISON OF IRRIGATED BARLEY GROWN IN THE CERRADO FOR BREWING MALT PRODUCTION: PART 1

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Abstract: Brazil imports about 60% of all malt used for beer production, which is carried out throughout the national territory. Aiming to meet the growing demand, reduce the country's dependence on foreign malt, and also reduce logistics costs, malting industries and genetic improvement companies began to focus on adapting barley to the Brazilian cerrado. Aiming at the application of these barleys in the malting process, studies are needed for the development of cultivars with adequate malting quality, which are adapted to the region and which still have productive potential. In this work, the objective was to characterize and qualify ten barley cultivars produced in two locations in the Cerrado: Perdizes-MG and in the region surrounding Brasília-DF. The barleys were cultivated in 2017 and their characteristics were established from the analysis of moisture content, classification, pre-germinated, weight of a thousand grains, germination power (PG), germination energy (EG), sensitivity to water (SA), germination index (IG), β-glucans and protein content. Based on these results, the C8 cultivar was selected as the most promising for malt production, among the materials presented, in both locations, mainly due to the results of the germination analyzes – PG of 99% and 97%; EG of 98% for both and SA of 1.0% and 4.0%, respectively for CC8 and CP8. The processing was carried out and the products were submitted to analysis of classification, moisture content, friability, diastatic power (PD), congress must, saccharification time, extract, pH, viscosity, β-glucans, soluble nitrogen, FAN and protein content (TP). The latter was one of the most relevant characters for the qualification of the materials, as it exhibited highly significant differences between the values, with variations from 12.81% to 17.73%, revealing the interference of the environment in the expression of these genotypes. The malts produced did not meet the Pilsen-type malt specifications, but have characteristics of special malts, such as: soluble TP between 3.2% and 6.5%, PG reaching borderline values of 304 WK and extract contents consistent with this class, with values between 74.5% and 79.4% – which promote sensory changes for the beer. Finally, it is concluded that field research must continue, as the promising results of this work indicate that with more development time, several barley genotypes will be adapted to the region, thus expanding the national production of malt and beer.
Keywords: *Hordeum vulgare*L., malting, beer, cultivar, genotype.

INTRODUCTION

Producing 140 million hectoliters per year, Brazil is the third largest beer producer in the world, according to CervBrasil (Associação Brasileira da Indústria da Cerveja, 2016) and the Ministry of Agriculture, Livestock and Supply (MAPA), behind only China (460 mi hL) and United States (221 mi hL). The productive chain of the brewing sector employs around 2.2 million people, being one of the largest employers in Brazil, and is still responsible for 1.6% of the country's PIB. The south and southeast regions account for 85.8% of beer production, which may be a reflection of the country's economic concentration in these regions (CERVBRASIL, 2016; BRAZIL 2021).

In 2020, the number of registered breweries in the country was 1,383, and the following year, the calculation already determined more than 1,549(BRAZIL 2021). Thus, cith the growing participation of microbreweries and the expansion of large breweries in the national market, it is necessary to have a wide supply of raw materials. However, most of the inputs used for brewing are imported, including barley

malt (VALENTE; ALVES, 2016; PINHEIRO, 2016). The country imports about 60% of all malt used (MULLER, 2018).

The import of malt by Brazil is approximately 800 tons per year, with the main suppliers being Uruguay, Argentina and France (MULLER, 2018). In order to meet the growing demand, and also reduce the country's dependence on foreign malt, malting industries and genetic improvement companies began to focus on adapting barley to the Brazilian cerrado (PORTAL BRASIL, 2015). For (AMABILE, 2013a), the region has high potential for the production of the crop, giving opportunity and supply to the agricultural business, in order to include new commercial opportunities. On the other hand, it also promotes the reduction of logistics costs, since the country's large malting plants are located in the states of RS, PR and SP, while the breweries are found throughout the national territory. Therefore, the costs of transporting and storing malt end up raising the value of the final product (MARTINS 2005; BASTOS, 2019).

Barley is considered the oldest cereal in the world, in cultivation, and is the fourth most produced cereal in the world (United States Department of Agriculture – USDA 2018). In Brazil, barley grains are used for animal feed (7%), for the production of malt (86%) and for other purposes (7%) (AMABILE, 2013a). First quality seeds (thickness greater than 2.5 mm) are intended for malting (AMABILE, 2013 b), on the other hand, those that do not meet industry requirements are intended for animal feed (LIZARAZO, 2003).

This crop, due to its physiological characteristics, needs mild air temperatures and corrected soils, conditions generally present in cropsof winter in the Cerrado (AMABILE; FALEIRO, 2014). Cultivation is carried out in the off-season, allowing harvesting in the absence of rain, resulting in high-quality, clean seeds without the presence of fungi and dormancy (MONTEIRO, 2012). However, for the production of malt, its insertion in the agricultural system in question requires studies aimed at its adaptation to this environment, involving several areas of technical-scientific knowledge, mainly in relation to plant breeding, aiming to develop cultivars of better industrial and agronomic quality. for cultivation in the region (AMABILE, 2013a).

The Cerrado region, located in the central plateau of Brazil, has potential for food production, being considered the largest pproducer of grains in Brazil and accounts for 42% of all cereal production (PORTAL BRASIL, 2015). Species previously considered unfit or marginal are fully adapted to the region, such as soy, wheat, sunflower, quinoa, among others (AMABILE, 2013a). Barley was introduced in the Midwest in the 1970s, to compose the irrigated system due to its economy in terms of water consumption and its ability to adapt to the edaphoclimatic conditions of this region (AMABILE, 2007, 2013a; MONTEIRO, 2012). However, it is known that this barley does not express the desired quality for malting aimed at the brewing market. This fact is due to the high content of protein and β-glucans found in the cereal (PINHEIRO, 2016), which exceed the recommended values: 12.0% (BRASIL, 1996) and 200 mg L-1 (KREISZ, 2009) respectively.

The high protein content together with the high content of β-glucans cause an increase in the viscosity of the beer, a decrease in the productive yield and also promotes a negative effect on its physical-chemical stability (MOLINA-CANO, 1997). Faced with this scenario, the research group at the ''Universidade de Brasilia", LaBCCERva (Laboratory of Brewing Bioprocesses and Catalysis in Renewable Energy), develops research and promotes the brewing

culture, whose main emphasis is related to the solution and promotion of value to the economic sector of region through technologies and analysis of raw materials grown in the Brazilian Cerrado.

In the Cerrado there are few studies on genetic diversityof barley (MONTEIRO, 2012). It is extremely important to characterize and evaluate genetic diversity, enabling an expansion of the existing work collection to obtain superior genotypes (SAYD, 2014). It is also important to identify and quantify genetic and environmental effects, as well as effects of the interaction of the genotype with the environment (MONTEIRO, 2012; AMABILE, 2013a; SAYD, 2014).

Given the above, the objective was to characterize and qualify the barley grown in two regions of the Brazilian Cerrado, Cristalina (GO) and Perdizes (MG), performing a comparison between them, to assess the differences caused by the edaphoclimatic characteristics of the environments. Finally, verify the viability of malt production with the analyzed barley.

MATERIAL AND METHODS

The barley samples used to develop the project were donated by the Agrária Foundation for Agricultural Research (FAPA) which is one of the productive chains of Cooperativa Agrária (Agroindustrial Cooperative located in the district of Entre Rios, in Guarapuava – PR). In total, there were 20 samples, with ten different cultivars: BRS Brau, BRS Korbel, BRS Itanema, BRS Manduri, BRS Cauê, BRS Quaranta, Danielle, Abi Voyager, Anag 01, Ana 02. The genotypes were sown in two locations, (Figure 1), the first being in the area of the Directed Settlement Plan of the Federal District (PAD – DF), at Fazenda Nativa, located in the rural area of Buriti Vermelho (coordinates: 15°54'17.917"S, 47°23'53.866"W and 892 meters altitude); and the other at Grupo Rocheto in the municipality of Perdizes – MG (coordinates:19°21'17.77"S, 47°22'7.292"W and 1,034 meters altitude). THE Table 1displays the nomenclature assigned to the samples.

Figure 1 -Locations of experiments carried out by FAPA visualized on Google maps. The northernmost marking is Fazenda Nativa and the southern marking is Grupo Rocheto.

Source: Google Maps.

Sowing was carried out on May 10, 2017, in Perdizes, and between May 12 and 14, 2017, at PAD - DF. 100 kg ha-1 of potassium chloride (KCl) and 137 kg ha-1 of formula 11-32-00 were used in the fertilization[1]. Subsequently, nitrogen fertilization was carried out in coverage, using urea as a source, at a dose of 50 kg ha-1.The harvest was carried out on September 8th and 9th, 2018, in Perdizes, and between September 17th and 18th, 2018, at PAD - DF.

METHODS – BARLEY ANALYSIS

Prepared by the authors Barley analyzes were carried out in accordance with the methods manual of the European Brewing Convention (Analytica EBC, 2018) and the collection of brewing analysis methods

1. Concentration expressed in percentage of nutrients: nitrogen, phosphorus and potassium – NPK – in the granules

Genotype	Assigned nomenclature	Place	Assigned nomenclature
BRS Brau	C1	crystal clear	CC1
		partridges	CP1
BRS Korbel	C2	crystal clear	CC2
		partridges	CP2
BRS Itanema	C3	crystal clear	CC3
		partridges	CP3
BRS Manduri	C4	crystal clear	CC4
		partridges	CP4
BRS Caue	C5	crystal clear	CC5
		partridges	CP5
BRS Quaranta	C6	crystal clear	CC6
		partridges	CP6
Danielle	C7	crystal clear	CC7
		partridges	CP7
Abi Voyager	C8	crystal clear	CC8
		partridges	CP8
Anag 01	C9	crystal clear	CC9
		partridges	CP9
Ana 02	C10	crystal clear	CC10
		partridges	CP10

Table 1 -Genotypes used and nomenclature assigned according to the place of cultivation.

Prepared by the authors.

(MEBAK, 2011). The tests carried out were: classification of barley, pre-germinated, moisture content, germination power, germination energy, weight of a thousand grains, sensitivity to water, germination index. The procedures are found in the chemical and physical analysis section of the EBC manual and the MEBAK raw material book, and were adapted to be carried out in the LaBCCERva laboratory of the Institute of Chemistry of the ''Universidade de Brasília" (UnB), and in the laboratories of Embrapa Closed.

- Classification of barley.

Barley grading was performed at Embrapa Cerrados according to method 3.1 of the 2005 EBC Manual (Analytica EBC, 2018) with adaptations. The analysisof each genotype triplicates were made.

- Moisture Content.

Barley moisture content was measured on the LaBCCERva according to method 3.2 of the 1997 EBC Manual (Analytica EBC, 2018), with adaptations. The analysis of each cultivar was carried out in triplicates.

- Weight of a thousand grains.

The thousand-grain weight analysis was performed in the LaBCCERva according to method 3.4 EBC Manual of 1997(Analytica EBC, 2018), with adaptations. For each barley, triplicates were made.

- Pre-germinated.

The analysis of pre-germinated seedlings was carried out in the LaBCCERva according to method 1.4.5.1 of the MEBAK manual (2011), with adaptations. For each sample triplicates were made. Germinal power.

Germination power analysis was performed on the LaBCCERva from toaccording to method 1.4.1.1 of the MEBAK manual (2011), with adaptations.

- Germinal energy and sensitivity to water (brf 4 and 8ml).

Germination energy and barley water sensitivity analyzes were carried out at LaBCCERva according to method 3.6.2 of the 1997 EBC manual (Analytica EBC, 2018), with adaptations. For each sample, triplicates were made.

- Index of germination.

The germination index (GI) is calculated with the results of the germination energy analysis and the average germination time (MGT), respectively by equations 1 and 2.

$$MGT = \frac{(n_{24}+2n_{48}+3n_{72})}{(n_{24}+n_{48}+n_{72})} \text{(equation 1)}$$

$$IG = \frac{10}{MGT} \text{ (equation 2)}$$

On what:

n_{24} = number of grains removed after 24 hours;

n_{48} = number of grains removed after 48 hours;

n_{72} = number of grains removed after 72 hours.

-Protein content.

The quantification through elemental analysis was carried out in the Elementary Analyzer of the Perkin Elmer 2400 Series II CHN/S of the Analytical Center of the Institute of Chemistry of the ''Universidade de Brasília" (UnB). Conversion to dry basis was performed with equation 3, and conversion to protein content used the factor 6.25, as shown in equation 4.

$$Ntotal\ \% = \frac{total\ nitrogen\ (\%)\ x\ 100}{dry\ basis\ (\%)} \text{(equation 3)}$$

$$total\ protein\ \% = Ntotal\ \%\ x\ 6{,}25 \text{(equation 4)}$$

Where:

100 = conversion to percentage;

Total nitrogen % (m/m) = nitrogen content for wet samples;

Total N % (m/m) = nitrogen content for

dry samples;

Dry basis % = sample mass minus moisture content;

Total protein % = sample protein content.

-Content of β-glucans.

The analysis of β-glucans from samples of barley cultivars was performed in the LaBCCERva according to the McCleary method (MCCLEARY; CODD, 1991), which is reported by the AACC through the 32-23 methodology (AACC, 1999) and is equivalent to method 3.10.1 of the 1997 EBC manual (Analytica EBC, 2018). Therefore, the enzymatic kit from Megazyme International Ireland Ltd was used to prepare the samples and quantify the β-glucans, which were taken to the spectrophotometer (VARIAN) for reading at 510 nm.

RESULTS AND DISCUSSIONS.

The barley analyzes were intended to characterize each of the genotypes and verify their quality for malt production. The results of the classification of the samples are expressed in Tables 2 and 3.

The values were expressed only in terms of the first quality portion, as the FAO (*Food and Agriculture Organization of the United Nations*) (FAO, 2009) guarantees to be the most relevant for malt production. This organization also defines the minimum retention in the sum of the two sieves, 2.5 and 2.8 mm, which must be greater than 90%, however, this value may vary according to the legislation of the country or the requirement of the company (FAO, 2009). In Australia, the minimum retention specification for the production of first quality malt is 70%, stipulated by the *Northern Barley Improvement Program* (GTA, 2013), while, in Brazil, the legislation does not specify a value (BRASIL, 1996).

Analyzing the results of cultivation in Partridges in Table 3, it is possible to see that all materials reached at least 80% of the grains in the first quality, with CP10 barley having the highest percentage (95.48%). The lowest percentage (84.96%) was obtained by the CP5 variety. In turn, from Cristalina's results, in Table 2, only three cultivars reached the minimum retention of 70%: CC7 (72.45%), CC8 (80.99%) and CC9 (72.20%). Even if the uncertainties associated with the analyzes were high, considering the CVs, the evaluation of experimental quality through precision was good for most samples, because – according to (Pimentel-Gomes, 1990) – the smaller the estimate of the CV, the greater the precision of the experiment and the smaller the significance between the mean estimates. According to the author, the experimental error is considered low when the CV is less than 10%. Thus, samples CC1 (11.40%), CC4 (12.23%) and CC6 (15.60%) were the ones that showed the highest experimental error[2].

Comparing the manifestation of the varieties in the two places by the joint analysis, it is possible to notice that the genotype and environment interaction was different and significant at 1%. This statement is confirmed by the high F test values shown in Table 4. Due to this fact, the analysis of each environment was carried out individually and the results were expressed in Tables 4 and 5. This interaction is responsible for the phenotypic variability of cultivars, since it is the expression of the genotype influenced by environmental factors, that is, differences in the performance of genotypes are revealed in response to changes in the environment (MOLINA-CANO, 1997; SAYD, 2014; MAGALHÃES, 2018). The interaction of the different genotypes with the environment is due to two conditions.

2. Experimental errors are attributed to the propagation of errors that exist during the analysis, starting from the choice of seeds for the cultivation that are not exactly the same, until the performance of the analysis, which depends on sampling errors and the method itself, for example.

Sample	Average (g)*	s	CV (%)
CC1	37.31 ± 10.56 d	4.25	11.40
CC2	51.07 ± 12.05 c	4.85	9.50
CC3	61.26 ± 6.37 b	2.57	4.19
CC4	55.58 ± 16.88 c	6.80	12.23
CC5	43.09 ± 2.50 d	1.01	2.34
CC6	42.32 ± 16.40 d	6.60	15.60
CC7	72.45 ± 6.15 a	2.48	3.42
CC8	81.82 ± 3.99 a	1.60	1.96
CC9	72.20 ± 8.23 a	3.31	4.59
CC10	66.80 ± 1.45 b	0.58	0.87

Table 2 – Classification of barley plants in Cristalina expressed in terms of first quality.

Table prepared by the authors. Note: *The means (do not refer to the deviations) followed by the same letter in the column, do not differ from each other by the Scott-Knott test at 1% significance.

Sample	Average (g)*	s	CV (%)
CP1	95.17 ± 1.13 a	0.45	0.48
CP2	90.44 ± 3.00 c	1.21	1.33
CP3	93.58 ± 1.27 a	0.51	0.55
CP4	91.24 ± 2.90 c	1.17	1.28
CP5	84.96 ± 2.52 d	1.01	1.19
CP6	92.87 ± 2.86 b	1.15	1.24
CP7	95.10 ± 1.89 a	0.76	0.80
CP8	95.19 ± 2.65 a	1.07	1.12
CP9	94.67 ± 0.58 a	0.23	0.25
CP10	95.48 ± 0.69 a	0.28	0.29

Table 3 -Classification of barley plants in Partridges expressed in terms of first quality.

Table prepared by the authors. Note: *means (does not refer to deviations) followed by the same letter in the column, do not differ from each other by the Scott-Knott test at 1% significance.

Joint Analysis				
FV	GL	QM	E (QM)	F
Environments (A)	1	QMa	17832.02	51.48**
Genotypes (G)	9	QMg	428.44	2142.65**
G x A	9	QMga	275.43	33.010**
Mistake	40	Who is	8.32	BR

Individual Analysis						
Common factors			crystal clear		partridges	
FV	GL	QM	E (QM)	F	E (QM)	F
Repetitions (R)	two	QMr	1.13		2.38	
Genotypes (G)	9	QMg	671.40	39.29**	32,48	57.28**
Mistake	18	Who is	17.54		0,57	

Table 4 -Analysis of variance of the model in randomized blocks.

Table prepared by the authors. Note: ** significant at 1% probability by F-test.

parameters	crystal clear	partridges
$\hat{\sigma}^2_f$	223.80	10.83
$\hat{\sigma}^2_e$	5.85	0.19
CV (%)	7.17	0.81

Table 5 - Pstatistical parameters.

Table prepared by the authors.

The first is the predictable variation that occurs from one location to another, such as soil and management, also called biotic. The second, in turn, is unpredictable or abiotic variation – as examples, we have air and soil temperature, nutrient availability and rainfall distribution (HOLOPAINEN-MANTILA,2015).

Taking into account the F test shown in Table 4, in addition to the difference in the interaction between environment and genotype, it is possible to notice significant differences between genotypes, traitrizing a high variability between them, which was expected, since, as previously described, they have different origins. The F test is also used to estimate experimental precision. For Resende and Duarte (2007) its value must be greater than 2.0 for the evaluation of cultivars. Therefore, the test carried out in Perdizes demonstrated greater experimental precision.

As previously reported, the management was the same in both places, so this variation in the result, for the same cultivar, dit depends on the environment. By the estimates of environmental variance ($\hat{\sigma}_e^2$) and the experimental variation coefficients (also known as environmental variation coefficient, CVe) obtained for the two environments, it is possible to perceive the intensity of the environmental effect on the genotypes, which were relevant in Cristalina (5.85% and 7.17% respectively, against 0.19% and 0.81% obtained for Partridges), affecting the phenotypic variance ($\hat{\sigma}_f^2$) in that location (223.80 against 10.83 in Perdizes). As a result for classification in first quality, taking variety 1 as an example, its cultivation in Cristalina (CC1) obtained the percentage of 37.31%, being the lowest result among the twenty samples. Comparatively, for the same parameter, its cultivation in Partridges (CP1) obtained the percentage of 95.17%, being the third best result (behind only samples CP8, with 95.19% and CP10, with 95.48%).

Due to the facts mentioned and mainly due to the Scott-Knott test, the classification analysis was used as a selection factor. the groupingof the averages, by the Scott-Knott test, showed, for both environments, four groups of similarities, and the first (group a) registered three cultivars in common, C7, C8 and C9. Therefore, these cultivars can be considered stable in both locations, as they boast first quality grains that reached the proposed standard of 70%, confirmed by the Scott-Knott analysis at 1% significance, in unfavorable environments (LORENCETTI, 2004; MARTINS ; DDO, 2016).

This way, taking into accountConsidering the statistical results, the cultivars that appeared in one of the last two groups by the Scott-Knott test (groups d and d) – C1, C2, C4, C5, C6 – were discarded for not showing results relevant to the purpose of malt production. Cultivars C7, C8 and C9 showed the best results, and were sent for further analyses. Finally, the C3 and C10 cultivars were evaluated. Despite being in the same group ("a" in Perdizes, and "b" in Cristalina), it is possible to conclude that the results of the C10 variety were better in both places, with 95.48% and 66.48% of the grains in first quality in Perdizes and Cristalina, respectively. While C3 denoted values of 93.58% and 61.26%, therefore being discarded. The C10 variety, in turn, was submitted to the other analyses.

The moisture content is important for the determination of the other constituents of barley (protein, carbohydrates, among others), as they are estimated based on the dry matter content (KUNZE, 2004). The moisture content of the barley samples used were collected in 2017 and therefore submitted to storage. Therefore, it was expected that the moisture content would be less than 13% as stipulated in Ordinance

Sample	Average (%)	s	CV (%)
CC7	10.87 ± 0.60	0.24	2.22
CC8	10.63 ± 0.33	0.13	1.25
CC9	11.88 ± 0.65	0.26	2.20
CC10	7.98 ± 0.57	0.23	2.88
CP7	9.01 ± 0.85	0.34	3.80
CP8	10.54 ± 0.35	0.14	1.34
CP9	9.78 ± 0.82	0.33	3.38
CP10	10.51 ± 1.39	0.56	5.32

Table 6 -Moisture content.

Table prepared by the authors.

Sample	GMP (g)*	s	CV (%)
CC7	36.26 ± 0.60 b	0.24	0.66
CC8	39.84 ± 0.16 a	0.07	0.16
CC9	35.62 ± 3.15 b	1.27	3.56
CC10	36.48 ± 0.42 b	0.17	0.47
CP7	46.23 ± 1.60 b	0.65	1.40
CP8	46.05 ± 0.24 b	0.10	0.21
CP9	47.83 ± 0.56 a	0.23	0.47
CP10	46.50 ± 1.01 b	0.41	0.88

Table 7 -Thousand grain weight analysis results.

Table prepared by the authors. Note: * grouping letters refer only to means and not to standard deviations (s).

691/96. This was confirmed by the results indicated in Table 6. The results ranged from 7.98% to 11.88%, and had low CVs (less than 10%), considered ideal according to the Pimentel-Gomes classification (1990).

With regard to the weight of a thousand grains, Piacentini (2015), admits that barley cultivars with a high weight of a thousand grains (PMG) have a higher starch content, that is, they provide a higher yield. The PMG analysis is complementary to the classification, allowing a (subjective) estimate of the density and size of the grains (NEWMA; NEWMAN, 2008; ASBC, 2011). Thus, the PMG results were observed, as shown in Table 7, performing a correlation with Tables 2 and 3. For the Cristalina environment, it can be seen that the C8 cultivar was the one that had the highest amount of first-class grains. quality, in addition to having demonstrated the highest PMG, that is, they are homologous results. However, the other results are very close in both analyses, so that when ordering them, the two procedures do not have the same classification. This is due to the uncertainties associated with the analyses. Briggs (1998) guarantees that counting a thousand grains at random to perform the PMG can generate an error of up to 12% of the true value. The Scott-Knott test was then performed at 5% significance and the formation of two similarity groups was observed for both cases. The first group (a) presented only an average higher than the others: for Cristalina, the C8 cultivate and for Perdizes, the C9.

Briggs (1998) states that BMP values between 32 g and 44 g are normal for thebarley. Ullrich (2011), in turn, states that more bulky barleys have weights ranging from approximately 40 g to 50 g. Therefore, samples cultivated in Perdizes fit the PMG standard for malt production. However, of the Cristalina samples, only the C8 cultivar is suitable for processing. Amabile (2013a), obtained results that varied from 32.50 g to 52.75 g for 39 elite genotypes of barley cultivated in the Federal District, some samples thus indicating values higher and lower than those of this work.

When analyzing the quality of a batch of barley, it is important to check for the presence of grains that have already shown signs of germination, as they can compromise storage and processing (BRIGGS, 1998). From the data depicted in Table 8, it is possible to say that, by analyzing the pre-germinated grains, the genotypes have quality for malting, as they contain less than 5% of pre-germinated grains. The highest percentage provided by the CP7 sample, with a content of 3%. The Scott-Knott test at 5% significance did not generate different groupings for Cristalina, but the formation of two similarity groups for Perdizes was observed, for which – in the first group (group a) – only the average of C10 was higher the rest.

The evaluation of germination is done through tests of germination power (PG), germination energy (EG), germination index (IG) and sensitivity to water. The responses obtained from the germination analyzes were reported in Tables 9 and 10, for the cultivations in Cristalina and Perdizes, respectively.

Germination performance is the most important quality criterion for brewing barley. Barleys that showed irregular germination produce malts with low modification and, consequently, reduced quality (FRANCAKOVA, 2012). The germination power determines the minimum tolerance limit admitted by Ordinance 691/96 is 95% for the germination power (BRASIL, 1996). The data obtained show, as a minimum, the value of 96%. Therefore, the tested cultivars can be used for brewing purposes. However, it is extremely important to verify the ability

Sample	M (%)	M*	s	CV(%)
CC7	98	1.43 ± 0.09 a	0.04	2.59
CC8	98	1.43 to	0.00	0.00
CC9	98	1.44 ± 0.06 a	0.02	1.67
CC10	98	1.47 ± 0.23 a	0.09	6.32
CP7	97	1.40 ± 0.07 b	0.03	2.13
CP8	98	1.43b	0.00	0.00
CP9	98	1.45 ± 0.11 b	0.04	2.95
CP10	100	1.54 ± 0.14 a	0.06	3.76

Table 8 -Analysis of pre-germinated.

Table prepared by the authors. Note: *data transformed into arcsen((x/100)0.5), where x = the value, in %, of the mean. Grouping letters refer only to means, not to standard deviations (s).

Samples		CC7	CC8	CC9	CC10
PG	Average (%)	96	99	96	97
	Average*	1.38 ± 0.04 b	1.50 ± 0.14 to	1.36 ± 0.09 b	1.41 ± 0.09 b
	s	0.02	0.06	0.04	0.03
	CV (%)	1.14	3.85	2.72	2.44
BRF 4mL	Average (%)	96	98	99	98
	Average*	1.39 ± 0.24 a	1.44 ± 0.06 a	1.46 ± 0.06 a	1.44 ± 0.06 a
	s	0.10	0.02	0.02	0.02
	CV (%)	7.02	1.67	1.65	1.67
BRF 8 mL	Average (%)	93	97	92	97
	Average*	1.31 ± 0.13 b	1.41 ± 0.05 a	1.29 ± 0.14 b	1.41 ± 0.05 a
	s	0.05	0.02	0.06	0.02
	CV (%)	1.86	1.32	4.89	1.32
IG		9.4	9.0	9.0	9.5
SA (%)		3.0	1.0	7.0	1.0

Table 9 -Analysis of germination power (PG), BRF 4 mL (germinal energy), BRF 8 mL, germination index (GI) and water sensitivity (SA) for barley grown in Cristalina.

Table prepared by the authors. Note: *data transformed into arcsen((x/100)0.5), where x = the value, in %, of the mean. Grouping letters refer only to means and not to standard deviations (s).

Samples		CP7	CP8	CP9	CP10
PG	Average (%)	96	97	96	96
	Average*	1.38 ± 0.04 a	1.39 ± 0.05 a	1.37 ± 0.05 a	1.36 ± 0.03 a
	s	0.01	0.02	0.02	0.01
	CV (%)	1.08	1.53	1.40	1.02
BRF 4 mL	Average (%)	92	98	97	97
	Average*	1.30 ± 0.21 a	1.47 ± 0.25 a	1.40 ± 0.16 a	1.40 ± 0.16 a
	s	0.09	0.10	0.06	0.06
	CV (%)	6.66	6.85	4.49	4.49
BRF 8 mL	Average (%)	89	94	89	92
	Average*	1.24 ± 0.15 a	1.32 ± 0.11 a	1.24 ± 0.06 a	1.28 ± 0.10 a
	s	0.06	0.04	0.03	0.04
	CV (%)	4.80	3.40	2.02	3.04
IG		7.4	8.1	9.3	8.1
SA (%)		3.0	4.0	8.0	5.0

Table 10 -Analysis of germination power (PG), BRF 4 mL (germinal energy), BRF 8 mL, germination index (GI) and water sensitivity (SA) for barley grown in Partridges.

Table prepared by the authors. Note: *data transformed into arcsen((x/100)0.5), where x = the value, in %, of the mean. Grouping letters refer only to means and not to standard deviations (s).

Sample	N (%)	PM (%)*	s	CV (%)
CC7	2.63 ± 0.22	16.44 ± 1.36 a	0.55	3.32
CC8	2.84 ± 0.10	17.73 ± 0.61 a	0.25	1.39
CC9	2.73 ± 0.10	17.06 ± 0.62 a	0.25	1.47
CC10	2.50 ± 0.46	15.62 ± 2.86 a	1.15	7.38
CP7	2.05 ± 0.29	12.81 ± 1.81 a	0.73	5.69
CP8	2.49 ± 0.27	15.58 ± 1.72 a	0.69	4.44
CP9	2.45 ± 0.16	15.31 ± 0.97 a	0.39	2.56
CP10	2.27 ± 0.02	14.21 ± 0.12 a	0.05	0.35

Table 11 -Total nitrogen and protein results.

Table prepared by the authors. Note: * grouping letters refer only to means and not to standard deviations (s).

of the material to germinate at the time in question, that is, without using any type of induction to germination, as in PG.

Considering that the PG results were satisfactory, the result of the EG analysis was then observed. Only one sample expressed a value lower than thereference value, which is CP7, with 92%. However, all results were inferior to those of PG.

The FAO specification (2009) stated that the minimum value for the germination index is 6.0, and all the results obtained were higher than this level (7.4 to 9.5), confirming the theory that there was an inhibition of germination due to the long period of storage, and not due to dormancy.

The results obtained for water sensitivity were less than 10%. According to Kunze (2004), a barley with an SA of up to 10% is not sensitive. From the statistical analyses, it is possible to notice that the coefficient of variation (CV) for all analyzes was less than 10% (1.0% to 7.02%), being then classified as low for the analyzes of agronomic materials by the classification of Pimentel-Gomes (1990). The results of grouping means by the Scott-Knott test at 5% significance did not show formation of more than one group for Partridges. However, the formation of two similarity groups was observed for Cristalina in the PG and BRF 8 mL analyses. The first group (group a) has only an average higher than the others for PG (C8). For BRF 8 mL, the grouping was two means for each of the groups, being C8 and C10 belonging to the first group. Therefore, vitality analyzes indicate that the cultivars with the greatest brewing potential are C8 and C10.

In order to verify whether the protein composition was within the normality standards, whose values are between 10 and 12%, the total nitrogen content of the samples was determined, which were converted into protein content, using the conversion factor of 6.25 (BRIGGS, 1998; KUNZE, 2004; SRIPERM, 2011). All values obtained for barley were above the expected range, as shown in Table 11. The lowest results were obtained for Perdizes, ranging from 12.81% to 15.58%. On the other hand, the lowest value obtained in Cristalina was 15.62%, that is, higher than any of the results in Perdizes. Furthermore, analyzing the responses obtained by the cultivars in both environments, the greatest variation was obtained in the C7 genotype, with a 3.63% difference. The lowest variation was obtained by the C10 variety, with 1.41%. Taking into account that the genotypes showed values above expectations, and were susceptible to environmental variations, due to oscillations in the results, they cannot, therefore, be pointed out as stable (LORENCETTI, 2004; MARTINS; DDO, 2016). Statistical analysis, however, did not identify significant differences for both environments (forming only one group) using the Scott-Knott test at 5% significance. In addition, low values of CVs (less than 10%). for both environments (formation of only one group) by the Scott-Knott test at 5% significance. In addition, low values of CVs (less than 10%). for both environments (formation of only one group) by the Scott-Knott test at 5% significance. In addition, low values of CVs (less than 10%).

Different environmental conditions of crop growth can affect grain filling and, consequently, its composition, which compromises the final quality (HOLTEKJØLEN, 2008). Many studies pointam that the responses of the genotypes were influenced by environmental conditions, causing a decrease in grain size and starch content, in addition to an increase in β-glucans and proteins, mainly (MOLINA-CANO, 1997; JIN, 2004; BRENNAN; CLEARY, 2005; CATWALK, 2005; QI, 2006; HOLTEKJØLEN, 2008). The interaction of the different genotypes with

the environment is due to two conditions. The first is the predictable variation that occurs from one location to another, such as soil and management, also called biotic. The second, in turn, is the unpredictable or abiotic variation, such as air and soil temperature, nutrient availability and rainfall distribution (HOLOPAINEN-MANTILA, 2015).

Nitrogenous compounds, on the other hand, have different functionalities being highly influenced by the raw materials and by the conduction of the process. These materials make up about 5% of the wort, which are soluble derivatives of the total malt protein, with different molecular weights. Among them are amino acids, peptides and proteins, obtained from the hydrolysis of malt. High molecular weight proteins are responsible for the texture and foam of beer, while those of medium molecular weight favor the stability of this foam, in addition to contributing to freshness and CO2 retention. Free amino acids (FAN) and peptides, in turn, are responsible for the organoleptic characteristics of beer, in addition to being fundamental in the metabolism of yeasts during fermentation (MATHIAS, 2014). Thus, low-protein barley is also not used for malt production.

The high results for protein content are one of the great problems of the Cerrado (GUERRA, 1995). Amabile (2008; 2014) observed thefluctuations in protein content for barley cultivated in different locations in the Cerrado, obtaining results of up to 14.7%. According to them, during the grain filling period there were high temperatures and low relative humidity of the air, which caused this increase. However, the values are significantly higher than those reported in the literature presented, which are related to the year of cultivation, and the genotypes used. Zale (2000) reports in his research that in all seven barley chromosomes there are regions related to its protein content, being then a hereditary characteristic that depends on the growth environment (EMEBIRI, 2005).

Pinheiro (2016) obtained a high result of the protein content for the barley used in its malting, reaching the value of 13.2%. However, this result does not represent a negative point for the author, on the contrary, he states that the high protein content provides foam creaminess and differentiated color. In addition, the high protein content provides high diastatic power, that is, greater production of enzymes (BRIGGS, 1998; EMEBIRI, 2004), which can then be used in mashing with adjuncts or even replacing part of the conventional malt used, aiming at greater extract production. The proposed considerations can be used to justify the use of these barleys for the production of special malts, which, in addition to adding certain peculiarities, also add value to the product.

The levels of β-glucans in barley depend on genetic factors, variety, along with environmental influences (BRAZIL, 2015). According to Brennan and Cleary (2005), the levels of β-glucans are influenced by the amount of water supplied to the seeds during maturation.

In this work, values between 3.33% and 4.35% were obtained for the content of β-glucans, which are within the acceptable range, which varies from 3.0% to 4.5% under normal conditions (KUUSELA, 2004; SA; PALMER, 2004; FOX, 2008). Furthermore, analyzing the responses obtained by the cultivars in both environments, a variation of 0.15% to 0.51% was obtained between them. Such arguments refer to the low susceptibility to environmental variations and satisfactory results in unfavorable environments (LORENCETTI, 2004; MARTINS, DDO, 2016). Zhang (2001) carried out studies with ten genotypes cultivated in eight different environments, reaching values between 3.31% and 5.46% and variations between

Sample	M (%)*	s	CV (%)
CC7	3.84 ± 1.32 a	0.53	13.83
CC8	4.17 ± 1.09 a	0.44	10.51
CC9	4.23 ± 1.30 a	0.52	12.37
CC10	3.73 ± 1.34 a	0.54	14.41
CP7	3.33 ± 0.04 b	0.01	0.42
CP8	4.35 ± 0.24 a	0.10	2.20
CP9	4.08 ± 0.27 a	0.11	2.69
CP10	3.33 ± 0.07 b	0.03	0.85

Table 12 -Analysis ofβ-glucans.

Table prepared by the authors. Note: * grouping letters refer only to means and not to standard deviations (s).

0.01% and 1.58%. An even wider range was obtained by Holtekjølen, (2006) – from 2.4% to 8.3% – but Andersson, (1999) reported values of up to 14.9%.

Analyzing the statistical results, it is noticed that the variationstions were higher for Cristalina than for Perdizes. The CVs for Partridges, from 0.42% to 2.69%, are considered low according to the Pimentel-Gomes classification (1990). On the other hand, all values for Cristalina were high, from 10.51% to 14.41%, as they are greater than 10%. The explanation for this difference between environments is due to the difference in protein content, which presented higher levels in Cristalina. It was previously stated that high protein content is related to increased wort turbidity (JAMAR, 2011). The measurement of β-glucans is carried out using a UV-VIS spectrophotometer and strongly depends on turbidity, as the radiation can be absorbed or refracted by the particles present in the solution, causing variation in the detector responses (SKOOG, 2002). The Scott-Knott test at 5% significance did not group separately for Cristalina, but two similarity groups were formed for Perdizes, for which the second group, group b, presented only two lower means, C7 and C10.

Thus, considering only the results of β-glucans, the evaluated cultivars can be used for malt production. However, it is important to remember that adequate values of these components do not guarantee the necessary quality. During malting, the hydrolysis of the cell wall is the first of the transformations that occur during germination (JAMAR, 2011), that is, the quality of the malt is more directly associated with the degradation of the β-glucan content than with the composition in yes.

CONCLUSION

Barley characterization and qualification analyzes are important to estimate the final malt quality and establish standards to optimize the malting process according to the available cultivar. The procedures carried out allowed observing the interference of the environment in the expression of the genotypes, which can compromise the brewing quality of the barley. High protein content (greater than 12%, with values between 12.81% and 17.73%) and variation in grain size (ideally 90% greater than 2.5 mm thick, of which results between 37.31% and 95.17%) negatively affect the extract content, causing heterogeneity in the modification of the endosperm during malting, in addition to low yield in the brewing process. Therefore, the C8 cultivar was selected as the most suitable for the malting process.

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