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CHARACTERIZATION, QUALIFICATION AND COMPARISON OF IRRIGATED BARLEYS CULTIVATED IN THE CERRADO FOR BREWING MALT PRODUCTION: PART 2

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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, the 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 cultivars of Barleys produced in two places in the Cerrado: Perdizes-MG and in the region surrounding Brasília-DF. The Barleys were grown 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 (S.A.), germination index (GI), β-glucans and protein content. The processing was carried out and the products were submitted to classification analyses, Moisture content, friability, Diastatic power (PD), congress must, saccharification time, extract, pH, viscosity, β-glucans, soluble nitrogen, FAN and content protein (PT). 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

Brewing depends on many factors that directly impact its quality. One of the crucial steps is the cleaning and asepsis control, together with the process adopted, mainly the procedures related to the raw materials used. Before being marketed, inputs must undergo rigorous analysis to determine the quality and characteristics of the materials. With malt, it is no different: malting must provide a quality material that fits the specifications of the desired type of malt (GHESTI, 2017).

In addition to providing results for quality control, malt analyzes provide an assessment of the malting process, allowing the brewer to predict its use in production. The data obtained before the process reveals information on how to conduct the process, allowing adjustments to be made when necessary. In the case of the brewing process, based on this information, recipes are created and the yield and characteristics of the final product are estimated (BRIGGS, 1998). Thus, obtaining a quality malt depends on the characteristics of the Barley used, which are crucial factors in establishing malting conditions.

In Brazil, Normative Instruction Number 11, of March 13, 2013, created by the Ministry of Agriculture, Livestock and Supply (MAPA), establishes the Technical Regulation for Barley malt. The Regulation in question determines the official classification

standard, sampling, presentation mode, marking or labeling, and malt quality requirements: Moisture, hectoliter weight, impurities, foreign matter and damaged grains (BRASIL, 2013). However, the quality requirements mentioned by the legislation are focused on commercialization, and not on the intrinsic characteristics of the malt destined for the production of beer. For the characterization of the industrial qualities of the malt (physical-chemical, sensory and physiological), official and standardized analytical methods are used, such as those established by the *European Brewery Convention* (EBC), by the American Society of Brewery (*American Society of Brewery Chemists* – ASBC), by the Commission for the Analysis of Beer Production in Central Europe (*Mitteleuropäische Brautechnische Analysen Kommission* – MEBAK) or by the Beer Institute (*Institute of Brewing* – IOB) (PORTO, 2011).

The manuals published by the aforementioned institutions have several analysis procedures for characterizing and qualifying the inputs used in brewing. Among the most used for malt evaluation, the following procedures are listed: classification, Moisture content, malt extract, saccharification time, protein content, total nitrogen, soluble nitrogen, soluble protein, Kolbach index, FAN (free amino nitrogen (free amino acids, in Portuguese), daystasic power, wort pH, wort viscosity, wort turbidity, wort β-glucans, malt friability and glassy grain content (MEBAK, 2011; PORTO, 2011; AMABILE, 2013; EBC, 2018). However, for more specific analyses, other procedures can still be performed.

After carrying out all analyzes and confirming the quality of the material, the malt is ready to be sold. Taking into account the presented review, this chapter addresses the malting of Barley cultivated in the Cerrado and the presentation of the analyzes of this malt. The aim is to study the viability of this Barley in order to justify the construction of a malting plant in the region, verifying whether the cultivation environment positively or negatively impacts this process and/or provides different characteristics for the product.

MATERIAL AND METHODS

SAMPLES

The Barley samples used to develop the project were selected from the results obtained from the Barley analyzes presented in "Characterization, qualification and comparison of irrigated Barleys cultivated in the Cerrado for brewing malt production: Part 1". Among the 10 cultivars previously analyzed – taking into account the interaction of the genotypes with the edaphoclimatic conditions of the two cultivation locations, Perdizes-MG and Cristalina-DF – the one that presented the best responses was the variety Abi Voyager (C8). The materials used were those previously called CC8 and CP8, referring to the cultivation in Cristalina and Perdizes, respectively.

METHODS

Micromalting

The micromaltings were carried out in the micromalting facilities of the LaBCCERva laboratory of the Institute of Chemistry of the ''Universidade de Brasília" (UnB). The two samples, CC8 and CP8, were lost and submitted to the same malting program developed from adaptations to the procedures used by Farzaneh (2017) and to the micromalting method 1.5.3 of the MEBAK manual (2011), aiming to adapt it to the results obtained. for the studied Barleys.

Initially, the samples were subjected to manual cleaning with the aid of a 2.2 mm wide oblong hole sieve (EAGRI). Then, 1,200

g of each sample were separated, which were immersed in 10 L of water at 13 ± 1 °C to reach a Moisture content between 42% and 26%. The maceration plan used interspersed wet and dry periods – plan in hours 8/12/6/10/6 –, totaling 42 hours (the first immersion was carried out at room temperature – 8 hours at 25 ± 1 ºC). To monitor the water absorption, the materials were weighed after the dry periods, that is, 20, 36 and 54 hours, and the determination of the degree of maceration (Moisture content) was obtained from equation 1.

$$\frac{(Weight\ after\ dry\ period - Initial\ weight\ A.I.)\ x\ 100}{Weight\ after\ dry\ period}$$

(Equation 1)

Then, the grains were transferred to the germination stage, whose temperature was maintained at 13 ± 1 °C. After three days, one-third of each material was transferred to drying, and the same procedure was performed after five and seven days. The drying plan used was the same in all stages, starting at 50 ± 1 °C and maintaining the temperature for 16 hours. Subsequently, the temperature was increased to 60 ± 1 °C for 60 min; in sequence, at 70 ± 1 °C for 60 min; and, finally, at 80 ± 1 °C for 150 min. These procedures were carried out in an oven (OLIDEF). To remove the rootlets, friction and manual sieving were carried out for three minutes.

Malt analysis

After malt production, the samples were sent to the central laboratory of Cooperativa Agrária Agroindustrial. Malt analyzes have been carried out, certified and accredited in accordance with the European Brewing Convention methods manual (Analytica EBC, 2018) and the collection of brewing analysis methods (MEBAK, 2011), which can be found in the chemical and physical analysis section. The tests carried out were: classification, Moisture, fine grinding extract, saccharification time, proteins, total nitrogen, soluble nitrogen, soluble protein, Kolbach index, FAN (free amino acids), daystasic power, wort pH, wort viscosity, β-glucans, malt friability and glassy grain content. From the results obtained for the same sample, that is, between the different germination days (three, five and seven days), the Average was determined.

RESULTS AND DISCUSSION

MALTING

Micromalting is the most widely used method to determine the malting potential and quality of a Barley sample. Based on the results obtained from Barley's analysis of the samples mentioned in 2.1.1 of this article. it is possible to evaluate the behavior of the material during malting.

The procedure adopted for micromalting was the same for both samples. To monitor water absorption, the Moisture of the material was determined before processing and after each dry period (after 20, 36 and 54 hours), as shown in Table 1. The program used reached the percentage of Moisture necessary to start

Moisture of the samples (%)	20 hours	36 hours	54 hours	Expected
CC8	35,98	43,46	47,29	42-46%
CP8	34,74	42,44	45,64	

Table 1 – Moisture absorption during maceration.

Elaborated by the authors.

to germination; however, it must be considered that the CC8 sample exceeded this range (47.29%), reaching a Moisture content that is used for the production of dark malts (45% - 47%), which could cause overmodification of the material (BRISSART, 2000).

Room temperature (25 ± 1 °C) was adopted as the temperature of the first wetting, in order to promote the rapid entry of water at the first moment. Then, the temperature was reduced to 13 ± 1 °C. This value was adopted based on previous studies. Brissart (2000) reported that low temperatures and high levels of Moisture (approximately 46%) stimulated the production of these enzymes, especially at 12 °C, favoring the formation of α-amylase.

It is concluded, then, that the adaptations carried out had the objective of providing better quality to the products obtained, respecting the peculiarities of the genotype and its response to the production environments, as presented in part 1 of this article. malting capacity under standard conditions, which may not be the most suitable for each of the studied Barleys (MEREDITH, 1962). This procedure, however, becomes a starting point for adapting the process and variety used to the growing region, aiming at malt quality in a commercial context.

MALT ANALYSIS

The malt analyzes were carried out with the intention of evaluating the malting capacity, the quality of the malting process and also to characterize the malts produced.

Physical-mechanical evaluation

Physical-mechanical evaluations are carried out through classification and friability analyses, which determine the structural characteristics of the grain (size and "hardness"), and reflect mainly on the homogeneity of the material (MACLEOD; EVANS, 2016).

The Barleys used in this work presented first quality ratings of 81.82% and 95.19% for CC8 and CP8, respectively. After the drying of each of the parcels (after malting), a new classification was carried out, and the results are expressed in Table 2. Observing the results presented, an increase in the value of first quality of the malts can be seen, which is due to precisely to the pre-processing segregation carried out (fragments with thicknesses smaller than 2.2 mm removed). In addition, there is a variation in the assortment between the germination days of the same sample, which was more evident in the Barley cultivated in Cristalina, since it had a higher percentage of grains in the 2.5 mm sieve (56.74%) when compared to Perdizes (20.34%). With increasing germination days, there was an increase in malting losses and the volume reduction was more significant (TAYLOR, 2018). This reduction is also caused by the evolution of grain modification with the days of germination, providing more friability to the grain, making it more brittle.

At the end of the process, the amount of water, which was initially between 10% and 13%, was reduced to values below 8%

Classification (%)	Barley	Malt, 3 days	Malt, 5 days	Malt, 7 days
CC8	81,82	90,8	90,3	89,6
CP8	95,19	96,4	96,4	96,3

Table 2– Grain classification expressed in terms of first quality.

Elaborated by the authorss.

(BRASIL, 2013). The loss of water, added to the losses due to root removal and grain respiration, caused a reduction in the weight of the total mass (12%-15%) and also in its volume (BRIGGS, 1998; EVANS, 2014; TAYLOR, 2018). The material that goes into production therefore has a different classification result from the final product, which explains the reduction in values over the course of germination time due to the modification of the endosperm.

The friability results allowed the construction of column graphs to measure the evolution of friability and the amount of vitreous grains (Figure 1) remaining in the samples after the days of germination.

Taking into account the results of figure 1, the evolution of the modification of the samples can be seen. It is possible to observe a reduction in the vitreous grain content, this being the most evident parameter from the third to the fifth day of germination, in which there was a more significant reduction (from 65.1% to 28.0%, and from 43.6% for 10.0%), reaching values lower than the calculated averages (35% for CP8 and 21% for CC8) in this time interval. On the other hand, the percentage of friability increased over the days of germination, which is consistent with the results obtained by Taylor (2018). On the third day of germination, CC8 showed greater friability (14.9% compared to CP8,

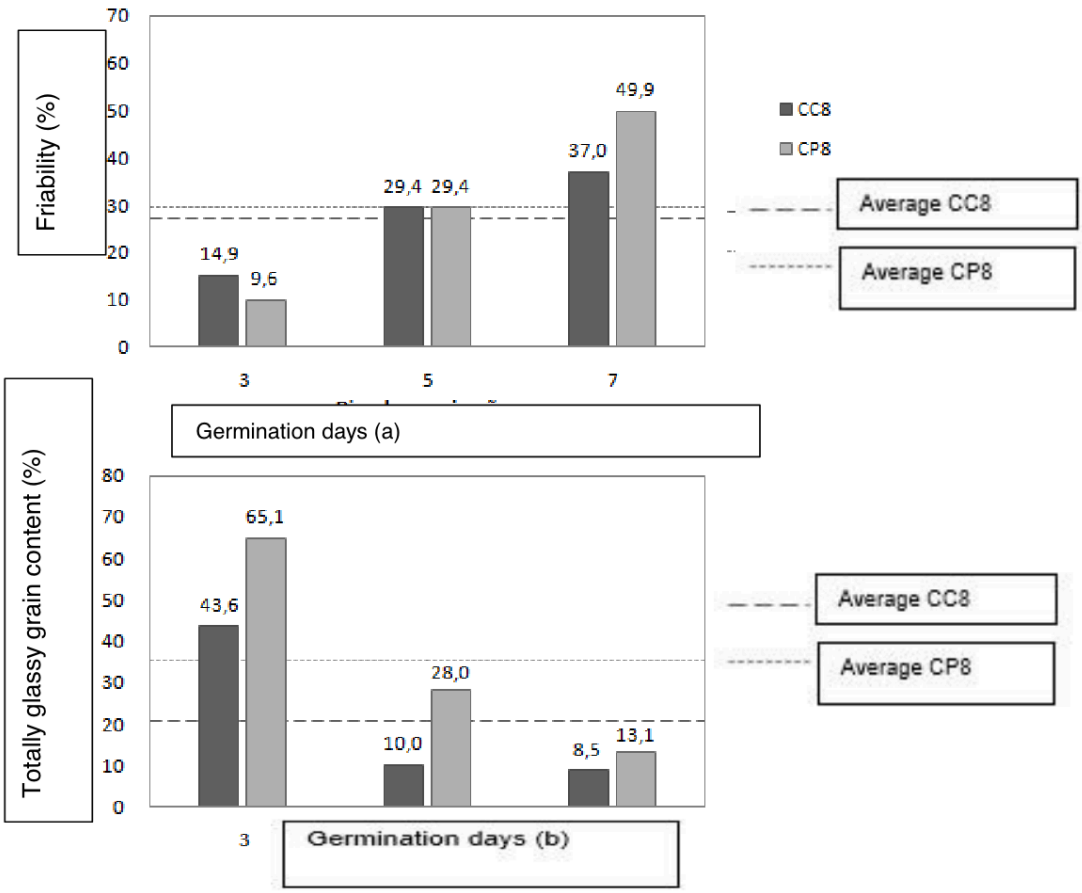

Figure 1 – Result of the analysis carried out with the friability meter for the malts produced with 3, 5 and 7 days of germination for the Barleys cultivated in Cristalina (CC8) and Perdizes (CP8). The friability (%) is represented by (a); and the content of fully vitreous grains (%) is represented by (b).

Source: Elaborated by the author.

with 9.6%), but it did not guarantee a similar result at the end of the seven days of the process, when CP8 presented a value of 49.9 %, against 37.0% for CC8.

Sá and Palmer (2004) state that the rate of modification depends on four factors, namely the distribution of water through the endosperm, the rate of synthesis of hydrolytic enzymes, the extent of release of these enzymes, and the structural characteristics of the endosperm. The characteristics presented refer to Barleys that have a high protein and β-glucan content. The literature brings values between 3% and 7% for β-glucans and up to 12% for proteins (BRASIL, 1996; ZHANG, 2001; WANG; ZHANG, 2009). The Barleys used have a high protein content, but the β-glucan content is in the Expected range. CC8 has 4.11% of β-glucans and 17.47% of proteins, while CP8 has 4.35% and 15.57%, respectively in part 1 of the article.

Under these conditions, the malts produced are considered undermodified, as they did not reach the minimum friability, whose defined value is 80%. In addition, they exceeded the maximum stipulated vitreous grains (3%) (ANGER, 2009), which are crucial for an adequate modification. Due to the high degree of maceration, 47.29% for CC8 and 45.64% for CP8, an overmodification was expected after 7 days of germination. However, friability values were extremely low (37.0% for CC8 and 49.9% for CP8).

It is known that even 5% unmodified grain in a malt can have negative impacts on the brewery. A malmodified malt, when milled, is not ideally disaggregated, causing a delay in starch saccharification during mashing, as access to it is impeded by the amount of protein and remaining β-glucans. These compounds still cause a delay in filtration, as they provide more viscosity to the must, in addition to causing unwanted turbidity and causing low process yield (BRIGGS, 1998; SA; PALMER, 2004). These other parameters will be discussed in more depth below.

Chemical evaluation

Seeking to relate the modification, the malting capacity and the potential of the materials for the production of beer, the protein content of the produced malts, the amount of total nitrogen (NT) and soluble (NS) were determined, as well as the content of soluble proteins (PS), the amount of free amino acids (FAN) and pH. These values are present in Table 3.

Evolution of malting	Cristalina				Perdizes			
	3 days	5 days	7 days	Average	3 days	5 days	7 days	Average
Malt protein (%)	16,78	16,82	16,10	16,57	14,70	14,83	14,91	14,81
Total nitrogen(%)	2,50	2,54	2,45	2,50	2,35	2,37	2,39	2,37
Soluble nitrogen(mg/L)	773	933	1163	956,3	562	764	857	727,7
Soluble nitrogen(mg/100g)	707	841	1041	863,0	515	691	772	659,3
Soluble protein (%)	4,4	5,3	6,5	5,40	3,2	4,3	4,8	4,10
FAN I.A. (mg/L)	142	194	242	192,6	101	138	162	133,7
Ph	5,85	5,83	5,78	5,82	5,93	5,84	5,81	5,86

Table 3– PH values and nitrogenous compounds present in malt and values of their respective solubilization in the wort.

Source: Prepared by the authors.

Comparing the result of the protein content of Barley and malts, the expectation was – due to process losses – that there would be a reduction of up to 0.5% of the value presented for Barley compared to malts (BRIGGS, 1998). The Barleys used showed values of 17.7% and 15.6% (CC8 and CP8, respectively), and the malts produced, an average of 16.57% and 14.81%. In both cases, due to losses, a reduction in values can be seen, such as Expected (root loss). However, it was expected that the loss would be greater with increasing germination time, which was not identified. CP8 showed an increase with the evolution of malting, and CC8 showed an increase for the fifth day (from 16.78% to 16.82%) and a more pronounced reduction for the seventh day, reaching 16.10%. It is then considered that there was a deviation in the results, probably due to errors associated with the analyzes or uncertainties in the measurements.

The soluble protein content in the wort depends on the amount of total protein in the malt (EDNEY, 2012). Many literatures indicate that a good malt has 35% to 40% of soluble proteins (BRIGGS, 1998; O'ROURKE, 2002; CELUS, 2006; EDNEY, 2012). Taking into account only the solubilization percentage, the results obtained would be within the Expected range or below it (from 6.1% to 7% for CC8, and from 5.5% to 6.4% for CP8, considering 17, 7% and 15.6% as malt protein contents, respectively). However, Kunze (2004) stated that about 0.55% to 0.75% of the nitrogen present in malt (dry basis) is soluble, that is, 550-750 mg/100g[1]. The produced malts present results between 707 and 1041 (CC8) and 515 and 772 (CP8) mg/100g of NS, characterizing the increase in solubilization with the increase in germination time. It is noticeable that the Barley with the highest protein content (CC8) presented higher NS values, so that only the malt with 3 days of germination fits into Expected. CP8, on the other hand, has only the malt of 7 days of germination outside the range, as it has a lower protein content.

With increasing germination time, there was greater nitrogen solubilization in congress must; consequently, the soluble protein content also increased, as well as the amount of free amino acids (FAN).

ANA is expected to be between 150-200 mg/L; high values can cause must acidification (BATHGATE, 2016). CP8 malting resulted in 101-162 mg/L malts, so modifications to the malting plan were required to achieve the recommendation; on the other hand, due to the high protein content, CC8 obtained 142-242 mg/L for ANA. It was concluded that yeast nutrition would not be impaired by the lack of amino acids, but there was a reduction in the pH of the solution of 5, 85-5.78 for CC8, and from 5.93 to 5.81 for CP8.

The extent of protein hydrolysis is affected by the nitrogen content of the material and, as a consequence, interferes with the modification of the endosperm (AGU, 2003), which explains the friability results reported in Figure 1(a). The high nitrogen content and the poor modification of the endosperm favor the reduction of starch digestion by amylases, even if the cell wall has been degraded, as the starch granules can remain embedded in the protein matrix (YU, 2017). This way, the production of fermentable sugars is impaired. This way, the extract content – and therefore the process yield – is reduced.

Malt extracts were also disadvantaged due to their correlation with grain friability and protein content. The progression of the extract is shown in figure 2.

Good quality malts have an extract content between 79% and 82% (MEBAK, 2011).

1. Milligrams per 100g of water-free malt.

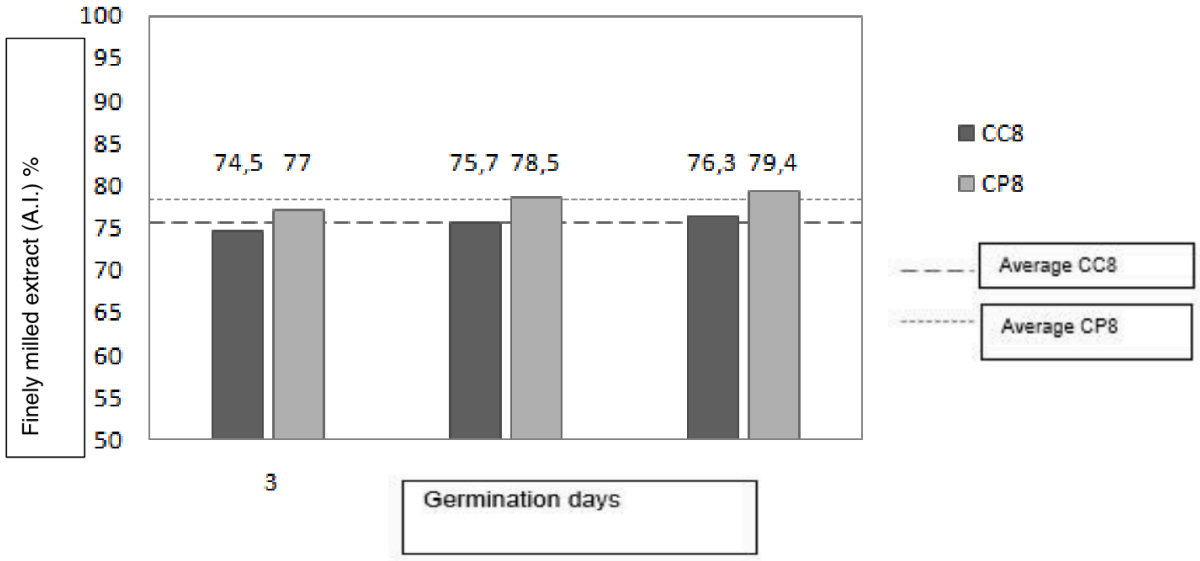

Figure 2 – Fine grinding extract results obtained from the realization of the congress wort for the malts produced with 3, 5 and 7 days of germination, for the Barleys CC8 and CP8.

Source: Elaborated by the author.

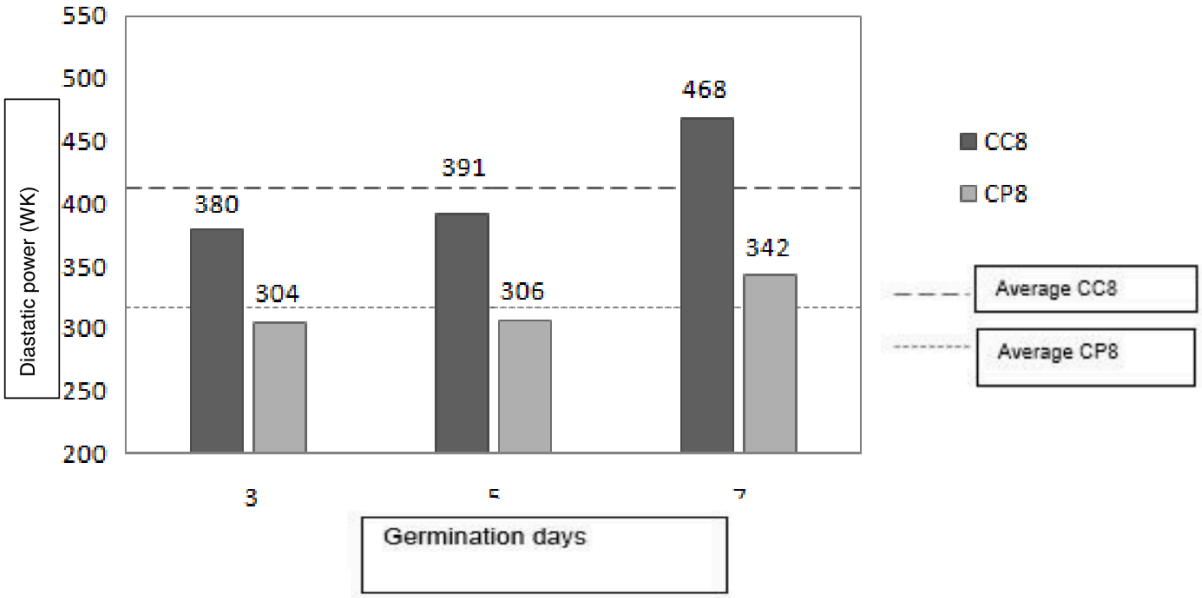

Figure 3 – Diastatic power obtained for malts produced with 3, 5 and 7 days of germination for Barleys CC8 and CP8.

Source: Elaborated by the author.

Due to the solubilization of carbohydrates and proteins, the finely ground extract reaches its maximum value on the fifth day of germination. During this period, the composition of the extract is, for the most part, fermentable carbohydrates. After that day, the levels of soluble nitrogen begin to increase due to the consumption of simple carbohydrates in the respiration of the grains. This way, the levels of extract from Barleys that present normal conditions for malting (high percentage of starch and low protein) begin to decrease (BATHGATE, 2016).

However, these results, overall, did not reach the minimum extract required for a good malt (>79%). For CC8, it was obtained from 74.5% to 76.3%. For CP8, the range was between 77.0% and 79.4%. The most pronounced yield in the Perdizes samples (15.6%) is a consequence of the amount of protein in the sample, which is considerably lower than that of Cristalina (17.7%). This is due to the existing starch/protein ratio in Barley (FANG, 2019).

Extract content is intrinsically related to grain composition, but also depends on the enzymatic capacity generated during malting. The term Diastatic power is used to describe the activity of starch degradation enzymes, namely α-amylase, β-amylase, limit dextrinase and α-glucosidase (FOX, 2008; FANG, 2019). However, Farzaneh (2017) assures that 99% of malt diastasis is given by α and β-amylases. The data acquired for Diastatic power are reported in figure 3.

Barleys that have more protein content usually have high Diastatic power. The results presented by the malts produced confirm this statement, since CC8 presented higher values (380-468 WK) than CP8 (304-342 WK). It is also observed the evolution of the enzymatic capacity with the passing of the days of germination. Similar results were obtained by Farzaneh (2017), who related these increments to the formation of α-amylase enzymes. It is known that Barley, before processing, already has the content of established β-amylases, which are activated and released during malting. In contrast, α-amylase is not present in Barley. Under these conditions, the Diastatic power is low and relatively stable until the third/fourth day of germination. Values below the médays are reported up to the fifth day of germination (CC8 – 413 WK and CP8 – 317 WK). Subsequently, there is a sharp increase, reaching 468 and 342 WK, for CC8 and CP8, respectively.

The Barleys used in this study had levels of 4.11% (CC8) and 4.35% (CP8) of β-glucans, values considered high, but still within the acceptable range (3% to 4.5%) (FOX, 2008). Therefore, it was presumed that the solubilization of these hemicelluloses in the wort would be excessive if there was bad modification of the endosperm during malting. It was proved that the modification of the malt was impaired, since the results, both for β-glucans and viscosity, were higher than recommended, up to 200 mg/L and 1.60 m.Pa.s (KREISZ, 2009), respectively, even after 7 days of germination for both cultivars.

However, it was found that there was degradation of the cell wall, even if only partially, since the levels of these parameters reduced over the days of germination, that is, the presence of cytolytic enzymes was confirmed during malting. Runavot (2011) explain that the low degree of maceration causes poor diffusion of β-glucanases, which in turn negatively impacts the degradation of β-glucans – reduces degradation. However, the degree of maceration reached was high: 47.29% for CC8 and 45.64% for CP8, confirming that hydrolysis was not impaired by absorption, but by poor distribution of water content within the grain, which it also affects the distribution of β-glucanases.

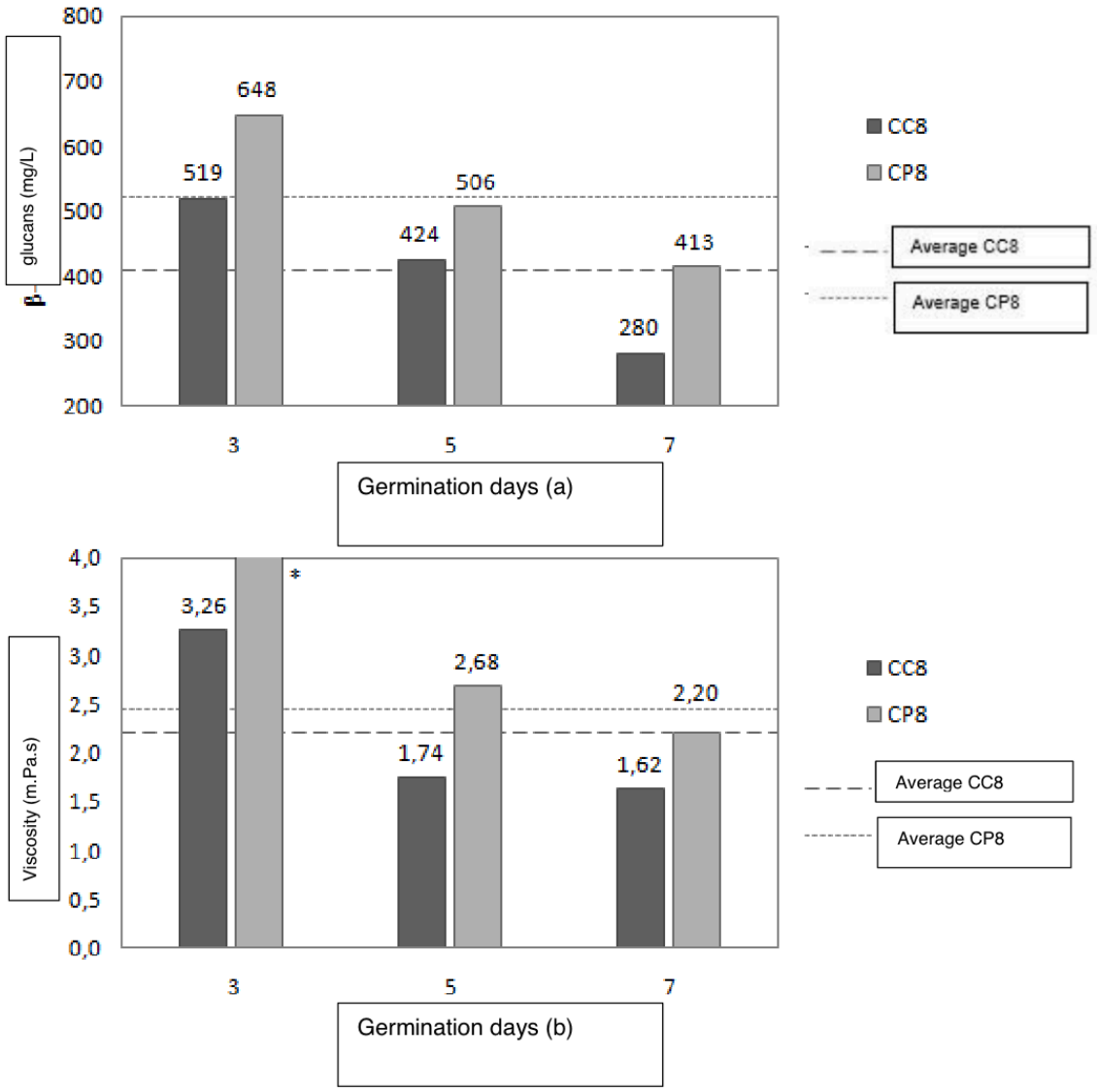

Figure 4 - Analysis of malts produced with 3, 5 and 7 days of germination for Barleys cultivated in Cristalina (CC8) and Perdizes (CP8), in which (a) represents the β-glucans (mg/L), and (b) represents the viscosity (%). The asterisk (*) indicates that the wort filtration time was longer than 60 min, due to the high viscosity (in this case, the viscosity analysis was not performed).

Source: Elaborated by the author.

Moisture (%)	Barley	Malt 3 days	Malt 5 days	Malt 7 days	Average	Expected
CC8	9,30	6,9	5,6	4,9	5,8	< 8%
CP8	10,54	7,0	5,7	5,3	6,0	

Table 5 – Moisture of the Barleys used and the malts produced.

Source: Prepared by the authors.

As for the Moisture content of the malt, it must be determined to predict the behavior of the material and the conditions that must be adopted during storage and commercialization. In the commercialization of the cereal, the water present in the grain contributes to the increase in weight, increasing the cost for the customer (ANGER, 2009). Normative 11/2013 prescribes that the water content of the grain must not exceed 8% and 6%, for pilsner and special malt, respectively (BRASIL, 2013).

The results of malt moisture are discussed in Table 5, which reached the value stipulated by legislation, considering that the malt does not fit the parameters of Pilsen type malt.

It is therefore concluded that the characteristics presented by the barley used and the results obtained from the malts produced make the use of these materials for the production of pilsen malt unfeasible, as they do not fit the current legislation (Ordinance 691/96 and Normative 11/2013) nor the specifications suggested by research organizations (EBC, ASBC, MEBAK or IOB). In the beginning, Pilsen malt was basically used for brewing, due to the cost of the material and its high yield, but this has been changing with the emergence of microbreweries. The high protein content, the main parameter that makes the material unfeasible, can be turned into an advantage for the market, such as creaminess of the foam and differentiated coloration (PINHEIRO, 2016). In addition, the high protein content provides high Diastatic power, that is, greater production of enzymes, which can replace part of the malt used in order to increase extract production. The considerations made here can be used to justify the use of these barleys in the production of special malts, which adds peculiarities to the product, in addition to adding value to it.

Currently, in the Cerrado region, there is already a malt shop, BR Malte, located in Paracatu-MG. 6 types of malts are produced there; among them, Pilsen and Pale Ale, considered base malts [2]. The malting plant has its own barley production, and even though the property is located in the Cerrado, the cultivated genotypes manifest responses within the expected parameters, due to the climate, soil and proper management. The existence of a malting plant in the region confirms its potential for cereal production, even though research is still needed to adapt or design specific varieties, with a view to expanding its cultivation throughout the territory. research by providing reports on its base malts, so that it was possible to compare the results obtained with commercial malts that are already produced in the region (Table 6).

From these data, it is observed that the malts produced do not fit into these classes. Research must continue, however. It is known that most of the inputs used for brewing are imported, including barley malt (VALENTE JR; ALVES, 2016; PINHEIRO, 2016). The continuity of research (and the value attributed to it) aims to reduce the import of these inputs and expand national cultivation, since Brazil is the largest importer of barley in the world (OEC, 2019). Due to the growth of breweries in the country, it is also necessary to take into account that the productive chain of the brewing sector has been demanding more and more raw materials. The results obtained thus serve to alert producers in the region to the potential for growing barley on their properties, as long as proper management is employed and specific cultivars are used. The expansion of barley cultivation can also provide new opportunities trade and favor the Brazilian economy.

2. Malts that have low coloration, high enzymatic efficiency and high extract yield.

Evolution of malting	Cristalina			Perdizes			BR Maltes	
	3 days	5 days	7 days	3 days	5 days	7 days	Pilsen	Pale Ale
Moisture (%)	6,9	5,6	4,9	7,0	5,7	5,3	3,4	3,0
Dry base extract (%)	74,5	75,7	76,3	77,0	78,5	79,4	80,1	79,3
Saccharification time (min)	10	10	10	**	10	10	10	10
Viscosity (m.Pa.s)	3,26	1,74	1,62	**	2,68	2,20	1,45	1,45
Totla nitrogen (%)	2,843	2,870	2,941	2,352	2,373	2,386	1,84	1,9
Soluble nitrogen (mg/100g)	707	841	1041	515	691	772	790	810
soluble protein (%)	4,4	5,3	6,5	3,2	4,3	4,8	4,9	5,1
pH	5,85	5,83	5,78	5,93	5,84	5,81	6,00	5,90

** Analyzes whose completion time was longer than expected

Table 6 – Results of analysis of malt produced from barley grown in the Brazilian Cerrado.

Source: Prepared by the authors.

CONCLUSIONS

Most of the results found are below the target, considering the objective of producing pilsen-type base malt – whose production period varies from four to five days – as provided for in Regulation 11/2013 and the official and standardized analytical methods (EBC, ASBC, MEBAK or IOB). These irregularities are mainly caused by the quality of the barley used, which also did not meet the appropriate specifications – mainly protein content of 17.47% and 15.57%, for CC8 and CP8, respectively.

The high protein content (> 12%) is not recommended for the production of pilsner malt, as it impacts the turbidity and shelf life of the beer, in addition to making it difficult to modify the grain during malting. Recommended use for the production of specialty malts. However, from another perspective, it provides high foam stability and differentiated color, in addition to high Diastatic power (> 200 WK). Another bias is the use in mashing, with perspectives of high drinkability and reduction of beer costs, that is, using adjuncts, since their contribution is relevant only in carbohydrates.

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