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Malting of preharvest sprouted wheat[1]

Maltagem de trigo com germinação pré-colheita

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ABSTRACT - Pre-harvest sprouting is one of the most important problems of the wheat crop and it is necessary to find alternative uses for the grain because millers reject the damaged wheat. In the field these grains were stimulated to germinate, due to weather conditions and their metabolic activity was enhanced, the hydrolytic enzymes promoted changes in the proteins and reserve carbohydrates, which reflect on the flour quality. Similar to malting germination has started, but with different intensity and under different conditions. There are some studies about malting of sprouted barley and the malting of rain-damaged wheat could be a possibility worth investigation. The objective of this work was to evaluate the malting of pre-harvest sprouted wheat samples. Four wheat samples were characterized by falling number and germination power; and three of them that were considered sprouted. A randomized standard experimental design was applied and the malting conditions were: moisture content 43%, germination time 78 hours, and germination temperature 12.5 ºC. Malt quality parameters determined were: malting losses, extract, limit attenuation, viscosity, total protein, soluble protein, Kolbach index, alfa and beta-amylase. The malting process resulted in increased soluble protein, FAN, Kolbach index and α-amylase activity, but decreased β-amylase activity for all rain damaged samples. There was no difference among the rain damaged samples for FAN, Kolbach index, α and β-amylase activity, extract, apparent attenuation limit and viscosity. A sound sample malted had higher α and β-amylase activity, extract, and the lowest soluble protein content.

Key words: *Triticum aestivum*. Malt quality. Hydrolytic enzymes.

RESUMO - Germinação pré-colheita é um importante problema da cultura do trigo, sendo necessário encontrar alternativas para uso desses grãos porque eles são rejeitados pelos moinhos. No campo, sob determinadas condições climáticas, os grãos são estimulados a germinar, a atividade metabólica aumenta e as enzimas hidrolíticas alteram proteínas e carboidratos de reserva, refletindo na qualidade da farinha. Tais alterações são similares às que ocorrem na maltagem, diferindo quanto às condições e intensidade. O objetivo deste trabalho foi avaliar a maltagem de amostras de trigo com germinação pré-colheita. Quatro amostras de trigo foram caracterizadas quanto a número de queda e poder germinativo, e três delas apresentavam germinação pré-colheita. O estudo obedeceu a um delineamento inteiramente casualizado e as amostras foram malteadas nas seguintes condições: 43% de umidade inicial do grão, 78 horas de germinação, sob temperatura de 12,5 ºC. Os parâmetros de qualidade do malte avaliados foram: perdas, extrato, atenuação limite, viscosidade, proteína total, proteína solúvel, amino nitrogênio livre, índice de Kolbach, atividade de α e β-amilases. O processo de maltagem resultou em aumento dos teores de proteínas solúveis, amino nitrogênio livres, índice de Kolbach e atividade de α-amilase, mas reduziu a atividade de β-amilases para todas as amostras de trigo com germinação pré-colheita. Não houve diferença entre amostras com germinação pré-colheita para amino nitrogênio livres, indíce de Kolbach, α e β-amilases, extrato, atenuação limite e viscosidade. A amostra intacta apresentou as maiores atividades de α e β-amilases, extrato e o menor teor de proteína solúvel.

Palavras-chave: *Triticum aestivum.* Qualidade de malte. Enzimas hidrolíticas.

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INTRODUCTION

Pre-harvest sprouting (PHS) is an important problem in wheat crop around the world. The grain is stimulated to germinate and even if there are no visible germination signs, a complex metabolic process is in course. Different enzymes are activated and amylases, glucanases and proteinases hydrolyze various grain components. Flour from this wheat is not suitable for bakery resulting in low commercial value and due to the observed changes in chemical composition, hardness and germination power, it is mostly used as feed grain. Genetic, anatomic and climatic factors are involved with PHS but the phenomenon is not completely elucidated (BARNARD; SMITH, 2009). For its detection, falling number (FN) is the most common test to quantify the relative amount of α-amylase activity (MARES; MRVA, 2008), determining the viscosity of a heated suspension formed by the milled cereal and water. Wheat samples with FN bellow 200 s are characteristic of pre-harvest sprouted grains.

Different studies tried to find other uses for this damaged grain, but there are limitations. Malting might be a possibility as wheat is used to prepare *weiss* beers in various countries. Industrially produced wheat malt for beer production in China demonstrated that Chinese wheat varieties could produce good quality malt, although wheat protein content interfered in some parameters (JIN; ZHANG; DU, 2008). Some authors studied the malting of wheat with focus on protein content, since wheat usually has higher protein content than barley, which affects beer characteristics (JIN *et al.*, 2012). Compared to barley malt there are less reports and information on malts of other cereals. The diversification of beer production and the number of microbreweries that have had success in the last decade also contribute to the study of alternative malting grains for beer production. In the United States, artisanal beers represented 8% of the consumer market and 14.3% of the value, since they are commercialized with higher price than common beer industrialized in large breweries.

Malting is a controlled process to obtain a product with high enzymatic activity and ability to release a high soluble solids concentration to the wort. Pre-harvest sprouting is uncontrolled, so grain modification is variable but it is a similar process. Some authors studied pre-harvest sprouted grains in malting. Field rain damaged and artificially pre germinated barley were studied for their potential longevity during storage and to identify which test would best predict the behavior of the stored grain for malting; falling number had a positive linear relationship with the potential longevity of the stored barleys and lots with FN bellow 100 s had lower viability and a diminishing potential for germination during storage (GUALANO; DEL FUEYO; BENCH-ARNOLD, 2014). Good quality malts were produced with barley with up to 5% of PHS grains (SOLE, 1994).

Our intention and objective was to evaluate the possibility of using rain damaged wheat for the malting process.

MATERIAL AND METHODS

Wheat samples

Three samples of rain damaged wheat grain with falling numbers bellow 200 s, harvested in 2012, Parana, Brazil, of three different cultivars, Pardela, Tangará and Cristalino, were used in the malting experiments. The fourth sample (Tangará-Pitanga), was the same variety, but harvested in Pitanga (Parana) and it was not rain damaged after maturing and sound by the falling number test. The samples were cleaned and stored for six months under environmental conditions until the beginning of the malting.

As soon as received from the field the samples were characterized by their falling number (method n. 56-81B of the AMERICAN ASSOCIATION OF CEREAL CHEMISTS (AACC) (AMERICAN ASSOCIATION OF CEREAL CHEMISTS, 2000) and germination percentage (BRASIL, 2009) and again after the first six months of storage. Samples with falling number lower than 200 s were analyzed for total protein, (method 46-12, N x 5.7-AACC) (AMERICAN ASSOCIATION OF CEREAL CHEMISTS, 2000), soluble protein (method 4.9.1- of the EUROPEAN BREWERY CONVENTION (EBC), free amino acids nitrogen (FAN) (method 4.10-EBC) (EUROPEAN BREWERY CONVENTION, 2005), α-amylase (method Ceralpha, Megazyme International, Ireland), and β-amylase activities (method Betamyl, Megazyme International, Ireland). For α and β-amylase activities the results were expressed in Ceralpha units and Betamyl units respectively.

Malting

Before malting, wheat samples (300 g) were stored in a controlled camera (Tecnal-Te-381, Brazil) at 4 ^{o}C. Previously determined conditions were steeping and germination at 12.5 ^{o}C, germination time of 78 hours and degree of steeping of 43%. Grains were steeped in distilled water at 12.5 ^{o}C with a cycle of 6 hours wet and 6 hours dry until reaching the desired moisture. When 43% moisture was reached a gibberellic acid (In lab, São Paulo, Brazil) solution of 0.65 mg/kg grain was applied with a manual spray apparatus and repeated 24 hours later. Gibberellic acid is one of the plant hormones that diffuses into the aleurone layer of the grain and triggers

the production of enzymes that will modify the endosperm during germination (O'BRIEN; FOWKES; BASSOM, 2010).

Moisture loss was replenished every 24 hours with chlorinated distilled water (100 ppm) with the manual spray and at every 12 hours the material was revolved. When pre-defined germination time was reached, the material was dried in a thin layer in an oven with air circulation for 12 hours at 55 ºC and for 18 hours at 65 ºC. At the end of the drying period roots and epicotyls were removed and the malted grain stored for 20 days at environmental conditions and then in refrigerated storage at 4 ºC until final analysis.

Analytical determinations

The malt characteristics were analyzed by the methods described by AACC-American Analytical Cereal Chemistry (AMERICAN ASSOCIATION OF CEREAL CHEMISTS, 2000) and EBC-European Brewery Commission (EUROPEAN BREWERY CONVENTION, 2005). All concentrations are base in dry weight.

Malting loss. After removing roots and epicotyls, the material was weighted and losses calculated using the formula:

%yield = [mass of malt (g d.b.)/initial mass of wheat (g d.b.)] x 100 (1)

Total nitrogen: Micro Kjeldahl, 46-12 da AACC (N x 5.7) with three repetitions.

Soluble nitrogen: The amount of malt protein nitrogen that is solubilized at the end of the mashing process, measured by method 4.9.1 of EBC, triplicate of each extract.

Kolbach index: The ratio of total to soluble nitrogen, an important indicator of brewing performance was calculated as described by EBC, using the formula:

KI = soluble protein (%)/total protein (%) (2)

Free amino nitrogen (FAN): Quantification of small peptides and amino acids in the wort an important determination for the nutritional value of wort to the yeast. The amount of FAN was measuring by method 4.10 of EBC, triplicate of each extract.

Extract: Measure of soluble solids recovered from the malt after mashing as specific gravity using pycnometer (PHOX 50 mL) (method 4.5.1 of EBC), duplicate of each malt sample.

Viscosity: Wort viscosity was measured using a capillary viscometer (Vidrolabor n.50), method 4.8 of EBC, triplicate of each extract.

Apparent attenuation limit: The amount of fermentable sugar remaining in the extract after the test fermentation determined using method 4.11.1 EBC, with lyophilized yeast for wheat beer (Fermentis/S.I. Lesaffre). Duplicate fermentations.

Activity of α-amylase: it was used Ceralpha assay kit (Megazyme, Ireland), triplicate of wheat and malt samples. One Ceralpha Unit of activity (CU) is defined as the amount of enzyme needed to release one µmol of ρ-nitrophenyl from the substrate ρ-nitrophenylalpha-D-maltoheptaoside (BPNPG7) in one minute in the defined conditions.

Activity of β-amylase: it was used Betamyl assay kit (Megazime, Ireland), triplicate of the wheat and malt samples. One unit Betamyl (BU) is the amount of enzyme that releases one µmol of ρ-nitrophenol from ρ-nitrophenyl α-D maltopentaoside per minute.

Statistical analysis

The analysis was based on completely random experimental design, the samples being the independent variables. Statistica 5.0 was used for the analysis of variance of the analytical results and results with different means were compared with Tukey test at 1% level.

RESULTS AND DISCUSSION

Wheat analysis

Falling number of three samples were below 200 s (PHS samples), and Tangará-Pitanga (FN 352 s) was used for comparison in the malting process (Table 1). Germination of the samples with FN lower than 200 s was low, and decreased, not uniformly, after the storage, with the highest reduction for Pardela -Mariópolis (FN = 180 s), a reduction from 82 to 60%. Tangará-Pitanga, the sound sample that had 93% germination initially increased to 98% after the storage period. A minimum of 95% germination is required for barley to be malted, but there is no minimum for wheat (malting uncommon in Brazil, but it is imported). Stored cereals may alter the germination depending on storage conditions: different barley varieties stored for different periods and temperatures had reduction of germination energy (at 96 h) at temperatures above 25 ºC but at 20 ºC there was no loss of germination energy and even an increase after 9 months of storage (REUSS; CASSELLS; GREEN, 2003). Barleys with FN lower than 200 s (182 to 52 s) had viability of 100% (FN 118 s) to 53 % (FN 52 s) but in accelerated storage condition at 40 ºC, germination decreased faster the higher the pre-germination damage as measured by the FN (GUALANO; DEL FUEYO; BENCH-ARNOLD,

Table 1 - Falling number, initial germination percentage (GP), germination percentage after six months storage (GP6), total protein, soluble nitrogen, free amino nitrogen (FAN), α-amylase and β-amylase activity of wheat

Sample	FN (s)	GP (%)	GP6 (%)	Total protein	Soluble N	FAN	α-amylase	β-amylase
				(%d.b.)	(mg/g d.b.)	(mg/g d.b.)	(UC/g)	(UB/g)
Pardela-H.Serpa	71 ± 3 d	70 ± 1 c	63 ± 1 c	17.1 ± 0.8 a	7.1 ± 0.5 a	0.6 ± 0.03 a	121.6 ± 4.8 a	86.2 ± 4.3 c
Cristalino-Mariópolis	129 ± 3 c	84 ± 1 b	75 ± 1 b	16.9 ± 0.8 a	6.5 ± 0.3 a	0.56 ± 0.03 a	45.9 ± 2.7 b	123.2 ± 3.1 b
Pardela-Mariópolis	180 ± 2 b	82 ± 1 b	60 ± 1 c	15.4 ± 0.4 a	7.3 ± 0.5 a	0.61 ± 0.01 a	25.3 ± 1.8 c	172.8 ± 3.4 a
Tangará-Pitanga	352 ± 6 a	93 ± 1 a	98 ± 1 a	-	-	-	-	-

Values followed by the same letter in columns are not significantly different at P<0.01 (Tukey test)

Table 2 - Total protein, free amino nitrogen (FAN), soluble nitrogen, Kolbach index, α-amylase and β-amylase activity of wheat malt

Sample	Total protein	FAN	Soluble N	Kolbach (%)	α-amylase	β-amylase
	(%)	(mg/g d.b.)	(mg/g d.b.)		(UC/g)	(UB/g)
Pardela-H.Serpa	17.7 ± 0.8 a	4.3 ± 0.2 a	18.4 ± 0.0 a	59 ± 2.8 a	191.2 ± 17 b	55.5 ± 4 ab
Cristalino-Mariópolis	17.3 ± 0.2 a	4.5 ± 0.3 a	18.3 ± 0.5 a	60.5 ± 2.1 a	227.1 ± 19 b	57.1 ± 1 ab
Pardela-Mariópolis	15.1 ± 0.5 b	3.7 ± 0.4 ab	15.3 ± 0.2 b	57.5 ± 0.7 a	200.9 ± 19 b	45.9 ± 3 b
Tangará-Pitanga	10.2±0.2 c	3.2 ± 0.1 c	10.3 ± 0.0 c	61.5 ± 2.1 a	315.1 ± 27 a	60.9 ± 2 a

Values followed by the same letter in columns are not significantly different at P<0.01 (Tukey test)

2014). Alterations in germination properties are not observed in short periods but they happen during storage due to genetic alterations in the mitochondria and damage to cellular membranes as well as to the loss of repairing capacity of enzymes (McDONALD, 1999).

Protein content of the samples with low FN values was equal, as well as soluble nitrogen and FAN, despite the differences in FN (Table 1). Content of soluble nitrogen varied from 22.4% of the total nitrogen for Cristalino (with 2% of FAN) to 27% for Pardela (with 2.2% of FAN), for the samples before malting. Eleven sound wheat varieties selected for malting experiment had protein content that varied from 8.7 to 14.4 g/100 g and soluble protein between 2.07 and 3.9 g/100 g, or soluble nitrogen between 23.8 and 27.1% of the total protein nitrogen (DEPRAETERE *et al*., 2004), comparable to our results, and although the proportion is similar our samples had higher protein content.

The α-amylase activity varied between 25.3 CU/g and 121.6 CU/g and increased according to the reduction of the FN value (Table 1). The β-amylase activity, on the contrary, increased from 86.2 BU/g to 172.8 BU/g as the falling number varied from 71 to 180 s (Table 1). Another study used the same enzymatic assay to detect β-amylase activity in barley but found much higher results, variation from 602.1 to 1407.5 BU/g for the year 2009 and from 780 to 1323.2 BU/g for the year 2012 (ZHANG *et al*., 2014). There was no comparison for wheat samples using the same method, and the higher results for barley may be inherent to the cereal that is the especial grain with all the ideal requirements for malting and brewing, and the barley samples were not PHS.

Malt analysis

Malt had the same apparent total protein for the rain damaged grains with Pardela H.Serpa maintaining a lower value among them but the control malt (Tangará-Pitanga) had the lowest protein content (Table 2). During malting, dry matter losses and protein synthesis may result in nutrients concentration, which could explain the protein contents of the malt samples (TIAN *et al*., 2010). Soluble nitrogen and FAN, on the contrary, increased in concentration as a proportion of total nitrogen for all the samples (Table 2). Soluble nitrogen increased to about 60% of the total nitrogen for the rain damaged samples and the sound sample, as result of the activity of proteases during malting for 78 h. The malted sample of the sound grain differed from the others since it had the lowest concentration of protein, amount of soluble nitrogen and FAN, but still a high proportion of soluble nitrogen as well as of FAN.

The rain damaged samples had higher content of soluble nitrogen and FAN in comparison to another study that evaluated the malting for six days of six different wheat varieties with a range of protein from 14.7 to 18.6 g/100 g that concluded that higher protein content did not result in higher content of soluble nitrogen, which varied from 4 to 4.9 g/100 g/100 g or 7 to 8.6 mg/g of

grain. The results had no relationship with the amount of FAN that varied from 81.3 to 101.6 mg/100 g, but there was a miscalculation for these results, since the authors used a factor of 6.25 to calculate protein from nitrogen, an approximate increase of 9% for each result, even for soluble protein. (JIN; ZHANG; DU, 2008).

In a study using spelt wheat for malting (MUÑOZ-INSA *et al.*, 2013), with germination time of 5 to 7 days, values for soluble nitrogen were on the average half the values for our sprouted samples (FN < 200 s) and FAN values were on the average lower than for our samples even for the sound sample. Gibberellic acid added in the malting increases enzymatic activity which may result in high soluble nitrogen and FAN amounts (BRYCE *et al.*, 2010). FAN refers to ammonia and short peptides detected when using the ninhydrin method (ABERNATHY; SPEDDING; STARCHER, 2009).

The Kolbach index for our samples was high and equal, meaning that there was too much modification of the endosperm (Table 2). The high Kolbach index may be related to a high rate of imbibition that occurs in grains altered by rain and a faster and earlier modification of the endosperm (McCAIG; LI, 2011). Kolbach index for wheat malt between 22.8 and 30.5%, were considered low (JIN; ZHANG; DU, 2008), but the spelt wheat (MUÑOZ-INSA *et al.*, 2013) had values from 28.7 to 41.8% with some samples achieving the desirable index between 37 and 40%. Some authors considered the best Kolbach index 39.5% (JIN *et al.*, 2012) while others found an inverse correlation between Kolbach index and protein content (JIN; ZHANG; DU, 2008). Our samples having 50 and 70% higher protein content for the sprouted samples compared to the sound sample, had no effect on the Kolbach results being all higher than 57% (Table 2). The gibberellic acid application promotes proteolytic activity, in triticale (X Triticosecale Wittmack) malt samples that received gibberellic acid application (concentration not informed) had higher Kolbach index and higher soluble nitrogen concentration (GRUJIC; PEJIN; DENCIC, 2009). Another study reported Kolbach indexes from 31.4 to 45.5% for eight wheat varieties malted for 5 to 7 days at 16 ºC with total nitrogen from 2.3 to 2.5% (protein from 13.1 to 14.3%) and soluble nitrogen from 720 to 1070 mg/100 g, that increased with the germination time (JIN *et al.*, 2012).

Concentration of α-amylase in the malts was higher than for the initial wheat, but the highest activity was for the sound wheat (Table 2). The highest increase of activity for the sprouted samples was for Pardela with FN of 180 s, an increase of 8 times. Grain protein had a relationship to α-amylase activity for wheat malts, the higher the protein content the higher the activity (JIN; ZHANG; DU, 2008), as well as for starch content with a correlation of 0.825 between starch and α-amylase (JIN *et al.*, 2011). Our samples had a relationship between protein and α-amylase for the initial samples but after malting there was an inverted relationship with samples with higher protein content having lower α-amylase activity. The higher the rain damage or the lower the FN the least increment there was for α-amylase activity. Pre-harvest germination promotes enzymatic activity, including protease activity that causes the hydrolysis of nitrogenous compounds. Some soluble fraction of the enzyme may be lost during steeping, as well as other nitrogenous compounds, and then the higher activity associated with the sound sample that had the least amount of total and soluble proteins.

The β-amylase, behaved differently (Table 2), before malting all the rain damaged samples had different activities and the higher the rain damage as shown by the FN, the lower the activity. After malting there was a reduction in activity for all the samples and all had equal activity for the sprouted grains and the highest activity was associated with the sound sample. Due to the use of various methods for determining starch hydrolyzing enzymes activity it is difficult to compare data with other authors, but, using a colorimetric method (3,5 - dinitrosalicylic acid) there was an increase in β-amylase activity from 50 U to 60 U after malting for wheat samples (JIN *et al.*, 2011). Rye malt had α- amylase with similar values, from 76 to 210 CU/g malt, influenced mainly by the germination time of 48 to 144 h, but much higher activity for β-amylase, from 336 to 522 BU/g influenced mostly by the germination temperature, from 10 to 20 ºC during malting (HUBNER *et al.*, 2010). The reduction in the enzymatic activity observed may be due to the proteolytic activity that hydrolyzed β-amylase (SCHMITT; MARINAC, 2008).

Malt characteristics from the sound and sprouted samples had different results for extract, attenuation and viscosity (Table 3). The extract yields were higher for the sound sample probably as result of the lower protein content and higher α and β-activities, indicating a higher concentration of starch hydrolysis products in the extract. Extract values for all samples were close to 83%, the recommended value (FALTERMAIER *et al.*, 2013). The malted six varieties of wheat had extracts that varied from 77.5 to 82% and the higher the protein content the lower the extraction (JIN; ZHANG; DU, 2008), as observed in Tangará-Pitanga. Rain damage malted samples had lower extract yields, probably because there were losses of soluble compounds during steeping.

All samples had attenuation lower than 81-83%, the reference values (Table 3). Attenuation quantifies the extract percentage which is converted to alcohol and depends on both the concentration of fermentable sugars

Table 3 - Extract, apparent attenuation limit (AAL), viscosity and malt losses of pre-harvest sprouted wheat malts

Sample	Extract (%)	AAL (%)	Viscosity (mPa/s)	Malt losses (%)
Pardela-H.Serpa	79.8 ± 0.4 b	63.2 ± 2.6 b	1.13 ± 0.00 ab	12.6 ± 0.2 a
Cristalino-Mariópolis	80.4 ± 0.4 b	67.7 ± 3.8 ab	1.16 ± 0.07 a	12.4 ± 1.0 a
Pardela-Mariópolis	82.0 ± 1.7 b	70.2 ± 4.0 ab	1.29 ± 0.04 a	9.2 ± 0.0 b
Tangará-Pitanga	87.4 ± 0.1 a	79.2 ± 2.9 a	1.03 ± 0.01 b	10 ± 1.2 ab

Values followed by the same letter in columns are not significantly different at P<0.01(Tukey test)

and on an adequate supply of amino acids for the yeast (BRIGGS, 2002). FAN was not limiting for our malts. The reduced activity of β-amylase compared to the non-malted wheat, contributed to an inadequate extract composition that resulted in low alcohol production.

Malt losses were higher for the sprouted samples with lower FN, 71 and 129 s, while the sample with 180 s of FN had the lowest loss, the sound sample did not differ from the others. During steeping, pre-harvest sprouted samples may have soluble losses, especially of sugars already formed during the field damage, and might explain the difference among rain damage samples. The sound sample had higher germination percentage, so greater losses by roots development. Another study about wheat malt had losses from 8.4 to 18.9% that increased with the increasing Kolbach index, for eight samples with different steeping moistures and germination times (JIN *et al.*, 2012).

Wort viscosity (Table 3) of the pre-harvest sprouted samples was different and higher than for the malt of the sound sample. Wheat malts tend to have higher viscosity than barley malts. Barley malt extracts had viscosities of 1.325 and 1.993 mPa/s, and adding 40% wheat malt increased viscosities to 1.398 and 2.089 mPa/s (LU; LI, 2006). In a survey of wheat malts used in breweries viscosities lower than 1.800 mPa/s are recommended (FALTERMAIER *et al.*, 2013), within the values for all our samples. Wort viscosity is a result of the hydrolysis and solubility of different compounds as well as of their concentrations and without a clear explanation of the role of each. Arabinoxylans and glucans are the major constituents of cell wall of the starchy endosperm and if they are not degraded sufficiently, a high wort viscosity is observed. In our study, the malting conditions contributed to reduce the viscosity since arabinoxylanases and β-glucanases are amongst the first activated enzymes in the early stages of germination, as observed in barley (KUNTZ; BAMFORTH, 2007) and probably they were activated during pre-harvest sprouting. In the sound sample, the higher α-amylase activity promoted the hydrolysis of α 1-4 linkage, resulting in oligosaccharides and in a first moment, low molecular carbohydrates can reduce the viscosity.

CONCLUSION

The results indicated that the PHS samples produced malts that met most quality parameters, but are not realy suitable. The intensity of PHS was not relevant as all samples behaved in a similar way. Assessment of the food safety of this raw material as well as its use in the production of low-alcohol beers may be possible.

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