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Influence of wheat conditioning duration on the technological qualities of flour

Influência do tempo de condicionamento dos trigos sobre a qualidade tecnológica das farinhas

Influencia del tiempo de acondicionamiento del trigo en la calidad tecnológica de las harinas

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Abstract
Wheat is amongst the most consumed cereals in the world. Triticum aestivum is the most produced and consumed species of wheat in the form of refined flours, a result of grinding and sifting the grain. To obtain a lighter form of flour with fewer bran flakes, water is added to the wheat grains. The added water conditions the wheat grains by adjusting humidity, thus making the endosperm more friable and the bran more malleable. This study aimed to analyze the influence of the duration of wheat conditioning on the resulting flour's technological characteristics, using time periods of 13, 15, 17, 19, and 21 hours. The extraction rates, color, ash, humidity, gluten, falling number, and alveography of each flour sample were analyzed. The acquired results exhibit an insignificant difference ($p \leq 0.05$) in flours with different conditioning times for gluten, falling number, color (L*), ash content, and humidity. However, there was a significant difference ($p \leq 0.05$) in extraction rate, gluten strength (W), as well as in tenacity and the extensibility ratio (P/L). Thus, 17 hours was discovered as the best conditioning durations, although a 13-hour conditioning could be used by companies who believe that the benefits outweigh the costs.
Keywords: Milling; Falling number; Rheology; *Triticum aestivum*.

Resumo
O trigo está entre os cereais mais consumidos do mundo, sendo Triticum aestivum a mais produzida e consumida em forma de farinhas refinadas, que é o resultado da moagem e peneiramento dos grãos. Para se obter farinhas mais claras e com menos fragmentos de casca é preciso adicionar água na massa de trigo e condicionado por um período, para ajustar a umidade e tornar o endosperma mais friável e a casca mais maleável. O objetivo do trabalho foi analisar a influência do tempo de condicionamento do trigo nas características tecnológicas da farinha para os tempos de 13, 15, 17, 19 e 21 horas. Foram analisadas as taxas de extração, cor, cinzas, umidade, glúten, falling number e alveografia de cada amostra de farinha. Os resultados obtidos mostram que não houve diferença significativa ($p \leq 0,05$) nas farinhas com diferentes tempos de condicionamento para glúten, falling number, cor (L*), cinzas e umidade, mas houve diferença significativa ($p \leq 0,05$) para os parâmetros de taxa de extração, força do glúten (W) e relação tenacidade e Extensibilidade (P/L). Desta forma, o melhor tempo de condicionamento foi o de 17 horas, mas tempos como 13 horas podem ser utilizados pela indústria se esta entender que o custo benefício é positivo.
Palavras-chave: Moagem; Número de queda; Reologia; *Triticum aestivum*.

Resumen
El trigo se encuentra entre los cereales más consumidos en el mundo, siendo Triticum aestivum el más producido y consumido en forma de harinas refinadas, que es el resultado de moler y tamizar los granos. Para obtener harinas más ligeras con menos fragmentos de cáscara, se debe agregar agua a la masa de trigo y acondicionar por un tiempo, para ajustar la humedad y hacer que el endospermo sea más friable y la corteza más maleable. El objetivo de este trabajo fue analizar la influencia del tiempo de acondicionamiento del trigo sobre las características tecnológicas de la harina para los tiempos de 13, 15, 17, 19 y 21 horas. Se analizaron las tasas de extracción, color, ceniza, humedad, gluten, número de caída y alveografía de cada muestra de harina. Los resultados obtenidos muestran que no hubo diferencia significativa

($p \leq 0.05$) en harinas con diferentes tiempos de acondicionamiento para gluten, número de caída, color (L *), cenizas y humedad, pero sí una diferencia significativa ($p \leq 0.05$) para los parámetros de tasa de extracción, fuerza del gluten (W) y relación de tenacidad y extensibilidad (P / L). Por lo tanto, el mejor tiempo de acondicionamiento fue de 17 horas, pero la industria puede utilizar tiempos como 13 horas si cree que el costo beneficio es positivo.
Palabras clave: Molienda; Número de caída; Reología; *Triticum aestivum*.

1. Introduction

Cereals are important crops for human consumption. Among these cereals, wheat, a grass of the *Triticum* genus, is one of the most cultivated plants globally, with over 30 cultivars according to the USDA. Wheat is cultivated in all climates and is the second most-produced grain crop worldwide. Brazil ranks 19th in world wheat production while being the 11th largest consumer, with production of an average of 10.6 million tons per year (Abitrigo, 2020; Conab, 2020).

The quality of grains is identified by physical parameters, such as hectoliter weight, the weight of a thousand seeds, grain hardness, color, and physical-chemical criteria (including moisture, ash, and protein content, as well as falling number). As for wheat flour, its quality is identified by the physicochemical and rheological parameters of moisture, ash content, proteins, falling number, gluten content and strength, water absorption, mixing properties, elastic, extensibility, bread volume and gas holding capacities of the resulting bread dough (Upadhyay, Ghosal & Mehra, 2012; Nuttall, et al., 2017).

Wheat grain processing is carried out in five stages: the reception and storage of wheat, cleaning, conditioning, grinding, and the storage and packaging of the flour. The grinding process to obtain white wheat flour is defined as the reduction of the endosperm to flour, which is preceded by the separation of the bran and germ for the production of products with a higher quality (Scheuer, et al., 2011). Conditioning involves adjusting the moisture content to increase the malleability of the bran during milling and endosperm friability, thus improving the efficiency of flour extraction (Warechowska, et al., 2016).

Acoording to Warechowska et al. (2016), conditioning has five purposes: (1) to stiffen the bran, thereby reducing the formation of bran dust; (2) soften the endosperm to enhance its machinability and reduce the ener6gy consumption of the reduction rollers; (3) facilitate the separation of bran from the endosperm to reduce the power consumption of the rupture rollers consequently reducing water loss through evaporation; (4) ensure easy sieving; and (5) to ensure sufficient moisture content, which is approximately 14–15% for the endosperm in the final product. Although there is a large volume of wheat flour produced in Brazil, few studies provide quantitative data showing the effects of the varying durations of wheat conditioning on the technological characteristics of flour. This step, which occurs at the beginning of the grinding process, is extremely crucial, as the water absorption occurs quickly in the early stages of soaking but slows down as time passes (Vengaiah, et al., 2012), and as such the duration must be sufficient for the grain to reach the equilibrium humidity.

This study aims to evaluate the conditions of wheat preparation, before milling, in terms of its conditioning and influence on the technological quality of the flour. This will be conducted by analyzing the physicochemical and rheological parameters, using the flours obtained from wheat extraction, and submitting to the conditioning times of 13, 15, 17, 19, and 21 hours.

2. Metodology

2.1 Material

The material was a batch of wheat (Triticum aestivum) from the regions of Arapoti and São Sebastião da Amoreira, Paraná, Brazil, and were harvested between September and November of 2018. These wheat samples were supplied to us by a milling company in the city of Londrina, Paraná, and had been processed, homogenized, freed from impurities and dirt, packed in a raffia bag, and stored in a dry, ventilated place.

2.2 Methods

The wheat grains were characterized and analyzed after conditioning, while the wheat flour samples were characterized after the grain milling. The analyses were carried out in triplicate, between September and November 2018, in the quality-controlled laboratory of the milling company. The following variables were quantified: Humidity content, ash contents, hectolitre weight, grain hardness, grain size, thousand grain weight, falling number, conditioning and humidification duration, experimental milling process, humid gluten contents, flour color and alveographic analysis.

2.3 Physicochemical characteristics

The following physicochemical parameters were measured:

2.3.1 Humidity content

The humidity contents of the wheat grain and flour were determined in triplicate, according to standard method no. 110 / 1.ICC.

2.3.2 Ash content

The detection of ash or fixed mineral residue from the wheat grains and flour samples were carried out in triplicate, according to AACC method no. 08-12 (2000).

2.3.3 Hectolitre Weight (HW)

To determine the hectoliter weight (HW) of the wheat grains, method 55-10 of the AACC (2000) was used, and the results were expressed in kg . hL^{-1}.

2.3.4 Grain hardness

The grain hardness was determined by adapting the AACC method 55-30 (2000). A sample of 100 g of wheat grain was weighed and crushed in an experimental mill and sieved in a 425 mesh sieve, on an automatic shaker for 1 minute and 30 seconds, and then weighed.

2.3.5 Grain size

The grain size was determined in triplicate by weighing 100 g of wheat and sifting the sample through 2,800, 2,000, and 1,700 mesh sieves, using an automatic shaker for 1 min. Thereafter, the retained and disseminating wheat was weighed (Brasil, 2009).

2.3.6 Thousand grain weight

The thousand grains weight (TGW) (Brasil, 2009) was obtained by manually counting and weighing a hundred grains of wheat (W100), and performing the following equation:

(W100 * 10) / (100% / (100% - HC)),

where HC is the wheat humidity content (%).

2.3.7 Falling Number

The falling number analysis was performed on the Perten model 1700, in triplicate, based on the AACC method 56-81B (2000).

2.4 Humidification and conditioning duration

The wheat sample was homogenized and separated into five batches for the production of wheat flour. Based on the AACC method 26-10.02 (2000), in order to adjust the final moisture to 15%, the moisture of the wheat sample was determined to calculate the amount of distilled water to be added. The following equation was used:

Aw = (((100-Hi / 100-Uf) -1) * SW,

where Aw = added water (mL), Hi = initial humidity (%), Hf = final humidity (%), SW = sample weight (g).

The samples were then humidified in 10 L plastic drums and immediately taken to a Chopin MR10 homogenizer for 30 minutes. Thereafter, the wheat was conditioned for durations of 13, 15, 17, 19, and 21 hours.

2.5 Milling

Grinding was carried out in a Chopin model CD1 pilot mill, according to the equipment's technical manual, with one pass through the brake system and three passes through the reduction system, based on method 26-70.01 of the AACC (2000). The extraction percentage of each batch was determined in triplicate through the relationship between the final product of the grinding after the reductions and the initial quantity of milled wheat. To assess the significance, ANOVA was used at a 5% level ($p \leq 0.05$). The analyses were performed using STATISTICA version 10 software.

2.6 Wet gluten content

The wet gluten content was determined in a Glutomatic Perten 2200, based on the AACC method 38-12 (2000). The wet gluten percentage was determined at 14% moisture, calculating the ratio between total wet gluten weight per gram and 100% moisture in the sample.

2.7 Color

The color of each wheat flour sample was determined using a Minolta Chroma Meter CR 400 colorimeter, according to the AACC (2000) method 14-30, standardized with a D65 light source (daylight-including UV radiation). The measurement area of the device was 50 mm in diameter, and the measurement angle was 0°. The CIELAB color space was used, where the three values L*, a*, and b* express, respectively, the lightness from black (0) to white (100), chromaticity in the green/red spectrum, and chromaticity in the blue/yellow spectrum. The alveography experiment was carried out on an alveograph (model NG Consistograph, Chopin), based on method No. 54-30 of the AACC (2000).

2.8 Alveography

Alveography is a rheological test utilized in various countries to determine qualitative characteristics of wheat. The parameters analyzed are gluten strength ($Wx10^{-4}J$), elasticity (P), extensibility or tenacity (L), and elasticity index (EI) (Gutkoski, et al., 2008). The term gluten strength is utilized to characterize a flour’s capabilities of undergoing mechanical treatment when mixed with water, as well as capacity of absorbing and holding water through it’s gluten content, which combined with it’s carbon dioxide retention capability can characterize how well a bread will hold its volume, texture and open granulometry (Dobraszczyk & Morgenstern, 2003; Mittelmann, et al., 2000). This test is done in triplicate in a Chopin alveograph, which simulates the dough’s behaviour during the fermentation stage of bread making. From the data graph are extracted the W index, represented by the curve’s surface quantifying gluten strength; the P index, represented by the maximum in the ordinate axis and quantifying dough tenacity; and the L index, the maximum in the abscissa axis and quantifying dough extensibility. The P/L ratio expresses the equilibrium point of the dough.

2.9 Statistical analysis

To analyze significance of treatments, ANOVA models were utilized at $p \leq 0,05$. Data was processed in the STATISTICA v.10 software.

3. Results and Discussion

The resulting composition and physicochemical characteristics of the wheat samples are shown in Table 1. The average moisture content of 12.70% (Table 1) is in accordance with the standards specified by Brazilian legislation, Normative Instruction (IN) nº 07 of the Ministry of Agriculture, and Livestock and Supply (MAPA), which establishes the maximum content of 13% moisture for wheat to ensure grain conservation (BRASIL, 2001). The ash content obtained was 1.53% (Table 1), which is considered ideal for flour production since lower ash contents (<1.80%) increase yield in the grinding process. A high ash content results in a high extraction of bran with flour, resulting in inferior cooking ability, undesirable changes in color, and interference in the continuity of gluten networks. The results for hectoliter weight (PH), humidity, foreign matter, impurities, and damaged grains were within the standards of identity and quality established by the Normative Instruction No. 07 from August 15, 2001 (BRASIL, 2001), framing wheat in type 1. PH is considered an important quality factor in the milling industry. Its value can be influenced by uniformity, shape, density, and grain size, in addition to the content of foreign matter and broken grains in the sample.

Table 1. Composition and physicochemical characteristics of wheat.

Parameters		**Values***
Moisture content (%)		12.70±0.07
Ash content (%)		1.53±0.01
Hectoliter weight – PH (kg hl^{-1})		81.25±0.36
The thousand-grain weight (g)		32.42±0.18
Hardness (ID)		88.55±0.15
Falling Number – FN (s)		351.00±11.4
Damaged grains (%)		0.81±0.02
Impurities and foreign matter (%)		0.18±0.01
Size of wheat grains (%)	2,800 µm	81.39±0.12
	2,000 µm	18.57±0.17
	1,700 µm	0.04±0.01
	<1,700 µm	0±0.00

* Average valuesof 3 repetitions followed by standard deviation.
Source: Authors.

Wheat in this study had an SML of 32.42 g, which can be classified as small. The size of wheat grains can be classified in the following manner: very small (15–25 g), small (26–35 g), medium (36–45 g), large (46–54 g), and very large (≥ 45 g). The thousand-grain weight (SML) and grain diameter are important parameters for predicting the milling process (RAD et al., 2010). Oversize grains are not desirable, as they adjust the cleaning and grinding equipment, possibly generating losses in production (Warechowska, et al., 2016). Small grains, on the other hand, can pass through the cleaning sieves and be discarded. As for hardness, the wheat showed an index of 88.55 (ID), thereby being classified as very hard, according to the range established by AACC, which is 81-90 (ID).

The result of the 351s Falling Number (FN) analysis was slightly above desirable values for production of leavened biscuits and breads (250 to 350s), but is a common value found in wheat samples in general. In a study reviewing 23 wheat cultivars in Latin America, it was found that for those the falling number varies between 337 and 428s (Vásquez, et al., 2012). Lower or higher enzymatic activity is not a difficult problem to solve, since two flours can be mixed to obtain a certain FN and establish the enzyme doses to be added to the flour if necessary.

Table 2 shows the physicochemical and rheological characteristics of the flours obtained from wheat and subjected to the five conditioning durations.

Table 2. Physicochemical and rheological characteristics of flours obtained from wheat samples submitted to different conditioning times at 15% humidity.

Análise*	13 Hours	15 Hours	17 Hours	19 Hours	21 Hours
Extration rate (%)	71.15 ± 0.82 [bc]	69.32 ± 1.68 [bcd]	73.11 ± 0.18 [a]	71.53 ± 0.62 [b]	68.81 ± 1.01 [cd]
humidity (%)	15.1 ± 0.23 [a]	15.27 ± 0.15 [a]	15.13 ± 0.21 [a]	15.13 ± 0.06 [a]	15.28 ± 0.06 [a]
Ash content (%)	0.43 ± 0.03 [d]	0.55 ± 0.02 [a]	0.54 ± 0.01 [ab]	0.53 ± 0.01 [ac]	0.51 ± 0.01 [ad]
Gluten (%)	24.36 ± 0.30 [a]	24.27 ± 1.06 [a]	23.17 ± 0.56 [a]	24.00 ± 0.73 [a]	23.35 ± 0.73 [a]
Color					
L*	93.27 ± 0.20 [a]	93.33 ± 0.04 [a]	93.00 ± 0.34 [a]	93,27 ± 0.13 [a]	93.30 ± 0.02 [a]
a*	-0.24 ± 0.01 [abc]	-0.27 ± 0.03 [abcd]	-0.23 ± 0.00 [a]	-0.24 ± 0.01 [ab]	-0.30 ± 0.02 [bd]
b*	8.14 ± 0.13 [bcd]	8.18 ± 0.24 [ab]	8.09 ± 0.01 [bcd]	8.16 ± 0.32 [abc]	8.36 ± 0.11 [a]
Falling Number FN (s)	319 ± 10.50	315 ± 4.73	325 ± 17.9	310 ± 4.73	312 ± 2.56
Alveography					
Tenacity P (mm)	101 ± 5.00 [abcd]	112.3 ± 7.51 [ab]	106 ± 3.61 [bcd]	114.67 ± 1.53 [a]	111.67 ± 2.52 [bc]
Extensibility L (mm)	64.67 ± 2.52 [a]	47.33 ± 2.52 [cd]	56.67 ± 0.58 [b]	53 ± 1.73 [bc]	46 ± 1.00 [d]
Ratio P / L	1.35 ± 0.20 [d]	2.28 ± 0.12 [b]	1.84 ± 0.05 [d]	2.20 ± 0.03 [bc]	2.40 ± 0.03 [a]
Gluten strength W (10^{-4}J)	213 ± 1.00 [d]	217 ± 1.00 [d]	255.67 ± 8,51 [a]	249.67 ± 4.51 [ab]	229 ± 4.00 [c]

* Average valuesof 3 repetitions followed by standard deviation. Same letters on the same line do not differ significantly (p ≤ 0,05).
Means followed by equal letters (horizontal) do not differ statistically from each other by the Tukey test at 5%.
Source: Authors.

The extraction rate in this study ranged from 68.81–73.11% (Table 2) and represents the percentage of flour obtained in relation to the amount of ground wheat. Studies carried out by Kweon, Martin, and Souza (2009) on the effect of conditioning on the performance and functionality of flour, obtained extractions of 69.47% and 70.47% for 3 and 24 hours of wheat conditioning, respectively (p ≤0.05). In this study, the best extraction rate was observed after 17 hours of conditioning, with shorter and longer conditioning times showing a significant extraction loss (p ≤0.05). Many factors influence extraction rates, such as the grain's physical-chemical characteristics, grinding technique, and the standard the flour must meet. Factors in wheat conditioning such as moisture rate, water temperature, and application technique all require that the mills adapt their methods to obtain the highest extraction rate possible.

When studying conditioning of wheat samples, Chen et al. (2020) applied vapor for different durations until it reached 16% grain humidity. Extraction rates were found to be between 63.88% and 66.19%. The variations in the extraction rate, however small, can be significant for the industry due to the sheer volume of milling. Although a sample might present the same final humidity rate, the distribution of moisture throughout the grain might be irregular (CHEN et al., 2020). Difference in humidity in different parts of the grain interfere in the milling process and might consequently reduce extraction rates, as different amounts of energy are required for grinding each grain, resulting in irregular particle size (Warechowska, et al., 2016). This, in turn, may be the reason for lower extraction rates in shorter conditioning durations.

As shown in Table 2, the humidity values for different conditioning durations did not show significant difference (p>0.05). When analyzing two cultivars of 7aintain wheat in two different milling systems, El-Porai et al., (2013) found variations in humidity content in function of conditioning durations for both milling systems, with the shorter (12 h) conditioning time presenting much lower humidity rates than the longer conditionings (24 h and 36 h). To a certain point, conditioning time is one of many variables that changes humidity in a flour, as the longer the grain is immersed in water, the more diffused throughout the grain moisture is. In this study, however, average humidity values were not differing even with durations varying between 13 and 21 hours.

The ash contents were between 0.43–0.55%, with the 13 h conditioning showing significant differences ($p \leq 0.05$) as compared to the other durations. Shorter conditioning times lead to an increase in ash content, caused by the low moisture absorption through the wheat husk and leading to greater fragmentation during milling, as it is more brittle and particle sizes are smaller (Warechowska et al., 2016), making the separation of bran harder. However, after 15 hours of conditioning, the ash content was the highest amongst the studied times. The ash content is one of the identifying parameters of the type of flour produced commercially in Brazil (BRASIL, 2005). According to IN nº 08 of MAPA, the flours obtained in this study were type 1.

Wet gluten results were between 23.17-24.27%, showing no significant difference while maintaining similar performances for each batch of different conditioning durations. Samples of four wheat varieties were observed to have lower dry gluten content at 18% but no significant difference between 12% and 16% humidity (Warechowska et al., 2016). Wheat cultivar may interfere in that parameter. El-Porai et al. (2013) found that two different cultivars that underwent different conditioning durations (12 h, 24 h and 36 h) and ground in two different systems had differing wet gluten characteristics – while for one the conditioning duration did not interfere in wet gluten content, the other showed reduction of wet gluten for longer durations.

The average FN results were between 310–325 seconds (Table 2), thus demonstrating enzyme activity that could be considered low for flour for the samples, with increases in conditioning time not increasing enzyme activities. The submersion of wheat grains in water during conditioning stimulates germination processes and activates enzymes. Among them is alpha-amylase, measured by the falling number test. The conditioning durations in this study, however, do not seem to have influenced that process sufficiently for significant results. In a study analyzing four different wheat cultivars, Ahmed et al. (2014) found that high water contents and conditioning temperature were linked to lower falling number values.

Flour color directly relates to its quality – the whiter the flour ($L^* \geq 93.00$), the higher the quality (Silva, et al., 2015). The results of the color analysis were not statistically significant ($p > 0.05$) for the L* luminance parameters, but showed significant differences ($p \leq 0.05$) for chromaticity coordinates b* (blue/yellow axis) and a* (green/red axis) between treatments (Table 2). The color of flour is rated by measurements of brightness and yellow intensity. The luminosity of flour is affected by bran and foreign contents, which is linked to ash content. As results demonstrated that, aside from the 13h conditioning sample, there was no significant ($p \leq 0.05$) difference of ash contents (Table 2), the luminosity results were within expectations. While the intensity of coordinated yellow chromaticity b* relates to the amount of this color's carotenoid pigments present in the wheat. Both the L* and b* values were within the ones found by Vázquez et al. (2012).

The analysis of the average alveographic parameters of tenacity (P), extensibility (L), their ratio (P/L), and gluten strength (W), differed significantly ($p \leq 0.05$) between batches, with improvements on tenacity not being as drastically observed as the others. The protein contents are strongly linked to gluten strength (Abedi & Pourmohhamadi, 2020). Gluten strength in this study was observed ranging from 213 to 255.67 x 10-4J, having peaked at 17 hours. Similar results were found by El-Porai et al. (2013) for alveography parameters when studying conditioning of 16% for 12, 24 and 36 h.

In terms of strength, wheat flour can be classified by it's W value as follows: medium when W is lower than 200 x 10-4 J; medium strong when W is between 201 and 300 x 10-4J; and strong if W is above 300 x 10-4 J. Cazetta et al. (2008) describes that, for bread products, gluten strength (W) ideally should be between 150 and 280 x 10-4 J and P/L between 0.5-1.7. Conditioning duration did not alter the wheat's classification, as it maintained W and P/L values adequate for bread production.

4. Conclusion

We conclude that for the wheat samples obtained in this study, conditioning for 17 hours resulted in a higher rate of extraction, in addition to better rheological properties of the wheat flour for baking. The conditioning duration did not have a discriminatory effect on the color parameters (L *), humidity, FN, and gluten of the wheat samples. However, shorter conditioning times of 13 hours can attain specifications similar to 17-hour conditioning. This presents the possibility for the milling industry to utilize the lower extraction rate of 13-hour conditioning in exchange for faster delivery time to customers, should a pressing demand arise. Therefore, with the data obtained in this study, it is possible to aid mills in determining the costs and benefits of such a situation.

Thus, this study reinforces the current understanding of milling industries regarding longer conditioning times that favor better production results. However, we believe that in a saturated production industry market, shorter conditioning is an interesting proposition, in that a faster production cycle and delivery time (with lower yields) continues to retain the quality and properties of the final product, as mentioned above.

Narrowing analysis to the 13h and 17h conditionings, with more in-depth measurements in quality parameters for these durations, are possible improvements for future studies.

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