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Study of the storage of wholemeal and partially defatted baru flour in bioriented polypropylene packing

Estudo do armazenamento de farinha integral e parcialmente desengordurada de baru em embalagens polipropileno biorientado

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Abstract: Wheat is a cereal whose flour is an important ingredient in many foods. However, limitations such as the deficit in the Brazilian trade balance of this grain and celiac disease make the use of national substitutes for wheat grow. Baru emerges as a solution to these limiting factors. Thus, the objective of this study was to evaluate wholemeal (WF) and partially defatted baru flour (PDF), as well as to determine their physicochemical characteristics during storage at room temperature in Biorentrated Polypropylene (BOPP) packages over 90 days. Flours were produced by grinding in a domestic blender. The partially defatted flour was obtained by partial oil extraction in Sohxlet. The storage was conducted in DIC under 3x2 factorial (0, 45 and 90 days; WF and PDF). To verify the influence of the treatments, the ash content, wettability rate, pH, flow time, angle of repose, humidity and microbiological activity were analyzed at 5% of significance. The results show that the packaging provided changes in all properties evaluated during the study period, in both flours, despite maintaining the water content and microbiological activity within legal limits.

Keys words: *Dipteryx alata* Vogel, grain processing, lipid content, physico-chemical properties.

Resumo: O trigo é um cereal cuja farinha é um importante ingrediente em diversos alimentos. Contudo, limitações como o déficit na balança comercial brasileira deste grão e a doença celíaca fazem com que cresça a utilização de produtos nacionais que substituam o trigo. O baru, surge como uma solução a esses fatores limitantes. Assim, objetivou-se avaliar as farinhas de baru integral (FI) e parcialmente desengordurada (FPD), bem como determinar suas características físico-químicas durante o armazenamento, a temperatura ambiente, em embalagens de Polipropileno Biorentado (BOPP), ao longo de 90 dias. As farinhas foram produzidas através da trituração em liquidificador doméstico. A FPD foi obtida pela extração parcial do óleo em Sohxlet. O armazenamento foi conduzido em DIC, sob fatorial 3x2 (0, 45 e 90 dias; FI e FPD). Para verificação da influência dos tratamentos procedeu-se as análises de teor de cinzas, taxa de molhabilidade, pH, tempo de escoamento, ângulo de repouso, umidade e atividade microbiológica, à 5% de significância. Os resultados, demonstram que a embalagem proporcionou alterações em todas as propriedades avaliadas no período estudado, em ambas farinhas, apesar de manter o teor de água e atividade microbiológica dentro dos limites legais.

Palavras-chaves: *Dipteryx alata* Vogel, processamento de grãos, propriedades físico-químicas, teor de lipídios.

Introduction

The Cerrado biome covers 25% of the Brazilian territorial extension and presents a vegetal biodiversity of 5,000 to 7,000 species. Among these, some fruit trees stand out because they offer edible fruits of great popular acceptance, as in the case of pequi, cagaita, mangaba and baru (Durigan et al., 2011).

Among the native fruits of the Cerrado, baru (*Dipteryx alata* Vog.) has gained space in Brazilian food. The fruit produces a single seed, with a tegument of reddish-brown to black. The consumption of the almond has been diffused by virtue of its high nutritional value and medicinal properties. Various food products are produced from the nuts (paçoca, rapadura, bar of cereals, cakes), of which flour is often its basic ingredient

(Zuchi et al., 2016). Almond oil is also commercially appreciated and as a by-product of the extraction is the partially defatted flour, which can make up recipes, presenting a higher protein concentration (Guimaraes et al., 2012).

Although wheat is the raw material of many everyday foods (breads, cookies, cakes and pasta), its production volume does not meet the domestic demand in Brazil. It is estimated that in the last harvest, 625.2 thousand tons of wheat were imported (CONAB, 2019). Another limiting factor to the use of wheat is the occurrence of Celiac Disease, a form of intolerance to wheat protein, gluten. About 1% of the world's population has such intolerance and is unaware (Hell & West, 2006).

One option, due to the imbalance in the productive balance of wheat and the celiac population, would be to encourage the use of other types of flour produced from national products, such as baru. Cakes from both whole flour and residual oil extraction cake can be gluten free (Pinelli et al., 2015).

Although the consumption of flour is spreading, the agro-extractivist producers of the fruit find it difficult to establish the costs of baru and its products, especially to processing and storage processes. Thus, studies that demonstrate storage behavior and handling are important.

In view of the above, it is aimed to evaluate wholmeal and partially defatted baru flour; as well as to determine its physicochemical characteristics during the storage in BOPP (Bioriented Polypropylene), for the 90 days.

Materials e methods

The experiment was conducted in laboratories of the Federal University of Mato Grosso, Campus of Rondonópolis. The almonds were obtained from a fragment of vegetation native to the Cerrado, in the city of Montes Claros-MG and dried according to Oliveira et al. (2016).

Flour Processing

To obtain the WF, the almonds were heated for about 4 minutes, in a domestic oven, in order to facilitate the removal of the integument (depellulation). Subsequently, grinding was performed in a blender, where portions of approximately 100 g were exposed for 56 seconds (on average) to grinding at minimum speed. The ground flour was homogenized with the aid of a domestic sieve.

Oil Extraction

The partial extraction of the oil was done chemically, by means of an Oil and Grease Extractor by Immersion. The goal was to achieve an oil content PDF of about 30%. 50 g portions of WF were placed in the cartridges, which were subjected to 1 h and 30 min immersion in Hexane solvent at 100 °C.

For the determination of the oil content in each flour studied, a test was performed to determine the lipid content of WF and PDF, in duplicate, according to a methodology established by Adolfo Lutz Institute (2008), in order to determine if the desired reduction in the lipid content was achieved.

Storage

The flours were stored in bioriented polypropylene (BOPP), with dimensions of 10 x 15 cm, which conditioned 100 g. The storage was carried out at room temperature (about 25 °C), in order to provide shelf-life conditions, for a period of 90 days.

The physico-chemical properties evaluated in this period were moisture, ash, hydrogenation potential (pH), flow time, repose angle, wettability and microbiological pattern. The determinations were performed according to the following methodologies:

Moisture: The Direct Drying method at 105 ± 3 °C (IAL, 2008) was used, in which glass crucibles containing 10 g of flour were placed in the oven for 3 h. The operation was repeated until there was constant mass between three measurements.

Ash content: For the test, 10 g samples for each replicate were weighed in porcelain crucibles and placed in muffle at 550 ° C for 24 h (IAL, 2008).

pH: determined by the potentiometric method using a portable digital pH meter, where 10 g of flour was diluted in 100 mL of distilled water, uniform for 30 minutes on a magnetic stirrer. After 10 minutes of rest, the pH value was measured.

Flow Time: evaluated using a polyethylene funnel and iron tripod structure. 100 g portions were placed in the funnel, the outlet of which is sealed, and when unobstructed, the time required for the whole mass to flow, following the methodology established by Gomes et al. (2002).

Repose angle (α): was calculated by the method of Gomes et al. (2002), from a sample stabilized based on millimeter paper, in which the height (h) and the diameter (D) of the formed pile of flour were measured by means of a ruler, which were applied in Equation 1.

$$\alpha = tg^{-1}\left(\frac{2 \cdot h}{D}\right) \quad (1)$$

Wettability rate: was established by the Static Wetting Method, by Schubert, adapted Gomes et al. (2002). About 1 g is poured into a 250 mL beaker containing 100 mL of distilled water. The time for complete submersion of all particles is timed. The wettability is calculated by the ratio of the flour mass to its wetting time.

Microbiological Activity: The Most Likely Number (MPN), for Total and Fecal Coliforms, was determined following the methodology of the American Public Health Association (1992), in triplicate. The analyzes were carried out for WF at 17 and 84 days of storage; and PDF at 22 and 90 days of storage.

The experiment was conducted in a completely randomized design (CRD), arranged in a 3x2 factorial scheme, with four replications. The treatments were established from two factors: storage time (0, 45 and 90 days) and the type of flour (whole and partially defatted).

In order to evaluate the interaction between the factors, and their isolated effects, under the properties the Analysis of Variance was carried out using the software Assitat 7.7 (Silva and Azevedo, 2016). When the interaction between them was significant, the property was subjected to the Tuckey test at 5% probability. For the variables that demonstrated significance in the storage time factor, the Regression Analysis was performed through SigmaPlot 14.0 software. The regression was tested for linear and quadratic equations, among which the most appropriate was selected considering the coefficient of determination (R^2) and the estimated mean error (SE) (Equation 2).

$$SE=\sqrt{\frac{\sum_{i=1}^{n}(Y-\hat{Y})^2}{GLR}} \quad (2)$$

Where: SE – estimated mean error;
Y – experimental value of the studied characteristic;
$\hat{Y}$ – value estimated by the equation for the studied characteristic;
GLR – degrees of freedom of the model.

RESULTS AND DISCUSSION

The lipid content of wholemeal and partially defatted flours was 45.6% and 30.2%, respectively. About 15% of WF was reduced, compared to PDF.

The properties of ash content, color, wettability, pH and repose angle were not significant for the interaction between the type of flour and storage time, so they act independently on the stored product. Table 1 shows the adjustment parameters and statistical criteria of the regression analysis for these attributes. The equations that presented the best representativeness for the characteristics, obtained values of R^2 highly satisfactory, above 99.9%. According to Draper and Smith (1998), the ability of a model to accurately predict a physical process is inversely proportional to the estimated mean error (SE), therefore smaller values for this statistical parameter indicate good adjustments. Thus, the second-degree polynomial equation adjustment is adequate to describe the ash content, pH and resting angle behavior for WF and PDF during the 90 days of storage in BOPP packages. The first-degree equation, in turn, best describes the behavior of the wettability rate of the flours, under the same storage conditions.

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Table 1. Adjustment parameters, determination coefficients (R^2), estimated mean error (SE) for the best adjustments of ash, wettability, pH and rest angle properties for WF and PDF, over 90 days stored in BOPP packaging.

		WF				
Property	**Equation**	**Parameters**			**R^2 (%)**	**SE**
		A	**B**	**C**		
Ash content	$C=At^2+Bt+C$	0,00003	-0,0063	3,04	99,99	0,003
Wettability rate	$M=At+B$	0,0032	3,663	-	99,73	0,0106
pH	$pH=At^2+Bt+C$	0,000017	-0,0030	6,53	99,98	0,0021
Repose angle	$AR=At^2+Bt+C$	0,0006	-0,016	28,00	99,99	0,0002
		PDF				
Property	**Equation**	**Parameters**			**R^2 (%)**	**SE**
		A	**B**	**C**		
Ash content	$C=At^2+Bt+C$	0,00003	-0,0080	3,96	99,99	0,004
Wettability rate	$M=At+B$	0,0047	0,0167	-	99,87	0,0106
pH	$pH=At^2+Bt+C$	0,00004	-0,016	6,4	99,96	0,0007
Repose angle	$AR=At^2+Bt+C$	-0,0006	0,104	27,87	99,89	0,0004

Considering the selected models, the curves of ash content, wettability, pH and rest angle are represented in figure 1.

It can be seen from the regression graph for the ash content that the mineral waste was higher for PDF than for WF. This fact can be justified by the higher content of organic matter in the WF, due to the higher lipid content that is removed by the incineration process. Therefore, proportionally the PDF has a greater mineral residual than the WF, because it contains less oil. Similar results were obtained by Guimarães et al. (2012) when comparing the ash content of the defatted flour of baru with that of the whole flour. The defatted flour had an ash content of 4.91%, while the whole of 3.8%. During the storage, the ash content presented a reduction in the two flours, a fact justified by the increase of humidity during the period.

As for the wettability rate, it was noted that this property was higher for WF. Since PDF has a larger amount of water molecule adsorption sites, the same PDF mass has more spaces for hydrophilic interactions than WF. Thus, the complete surface wetting of PDF requires more time than the same whole flour mass. Since wettability is the ratio of mass to wetting time, this causes a lower rate for PDF and higher for WF. However, baru flour had higher wettability rates than mandacuru pulp (Oliveira et al., 2015) and cumbeba powder (Diogenes, 2018). Oliveira et al. (2015) also observed that as the storage time of mandacaru pulp increased, the wettability rate increased, which also occurred in the present study for WF and PDF.

By regression of the pH data, it is verified that WF contains a higher pH than partially defatted flour, although both are close to neutrality and can be characterized as low acidic foods. Correa et al. (2018) also classified the carrot flour in advanced stage as little acidic. The WF has a higher pH due to the interaction with the H^+ ions provided by the phenomenon of the resonance of the carboxyl radical (-COOH) present in the fatty acid molecules, which are in higher concentration in the wholemeal. The storage provided a reduction in pH values for WF, while in PDF this reduction occurred between the periods of 0 and 45 days, with a slight increase at 90 days. Santos et al. (2010) did not observe pH variation in storage for 90 days of green banana meal in polyethylene tereftelato (PET) packages.

The resting angle was increasing for both WF and PDF in the storage periods studied. For the first two-time intervals of WF, as well as day 0 for PDF, the flow was very free, remaining below 30 ° (Tannous et al., 2013). At 45 and 90 days of storage of PDF, and at 90 days of WF, the flow was considered as free, considering the same classification. The angle of repose, at the end of the storage of baru flour, was similar to that of cumbeba powder, dried at 50 ° C (Diogenes, 2018).

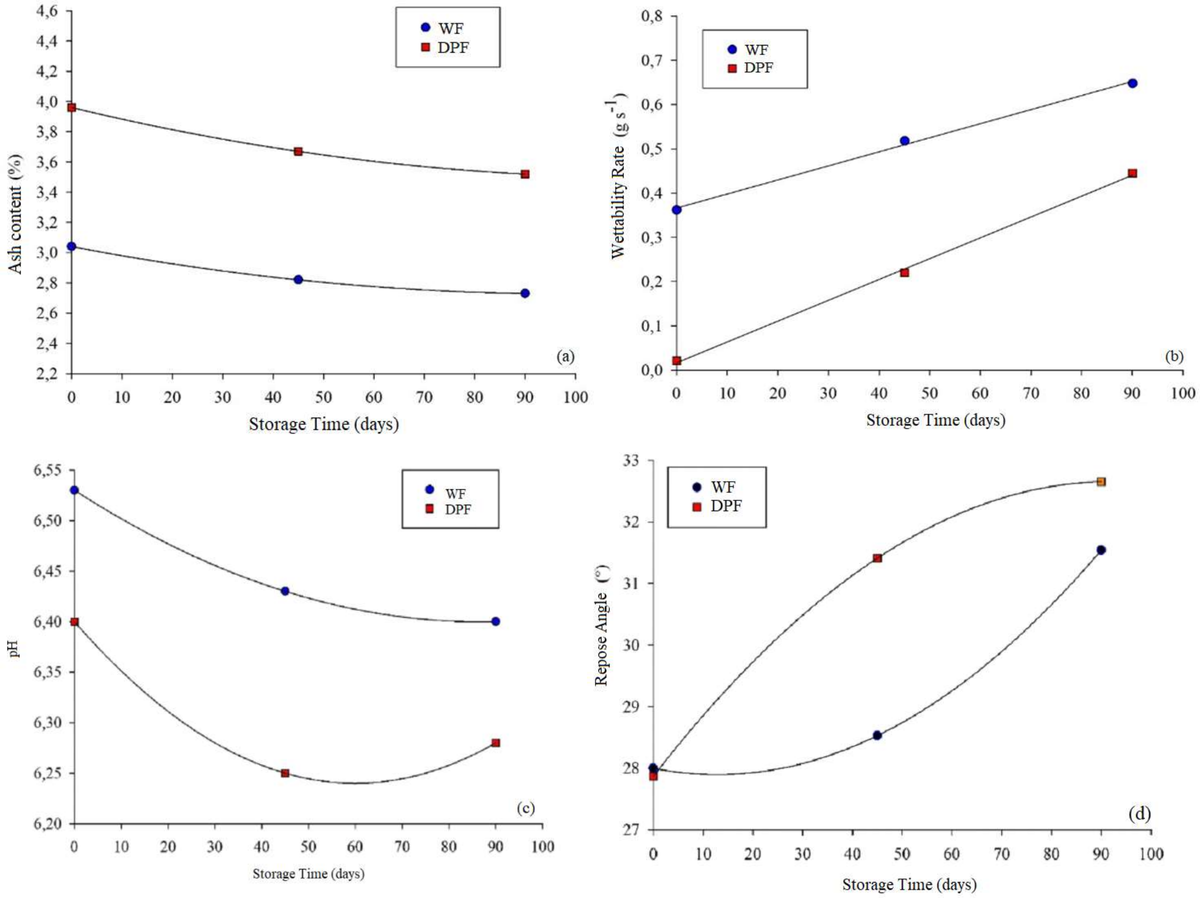

Figure 1. Mathematical adjustments curves of ash properties (a), wettability (b), pH (c) and rest angle (d) for the WF and PDF, stored in BOPP packages.

Although WF presented this aspect of flow, in agreement with the values of repose angle, it did not present enough fluidity to carry out the run-time test. This fact is justified by the high oil content thereof, since the amount of liquid between the solid particles allows a greater cohesive force, which is increased by the viscosity of the oil. In relation to PDF, in turn, it was observed that the flow time was 6.69 ± 2.08 seconds, which allows classification as optimal flow, according to Villanova et al. (2012). However, the storage time did not influence the run time by the analysis of variance, so the regression analysis was not performed Knowledge of the flowability of agricultural products is important in routine industrial operations such as silo unloading. Therefore, the storage of the PDF, in BOPP packages for 90 days, does not influence this property. Silva et al. (2017) determined a flow time of 2 seconds for flour of the carolina seed residue.

Moisture was the only one of the studied properties that presented positive interaction between the type of flour and storage time. The interaction between the means and the comparison between them can be observed in Table 2.

Table 2. Averages moisture (%) for interaction between WF and PDF and storage time (0, 45 and 90 days)

Flour	Storage Time (days)		
	0	**45**	**90**
WF	4,09 aB	5,87 aA	6,39 aA
PDF	3,19 bC	4,48 bB	6,42 aA
LSD lines		0,55	
LSD columns		0,45	

Means followed by the same lowercase letter in the columns and by the same capital letter in the lines do not differ from each other by the Tuckey test at 5% probability. LSD: least significance difference.

The water contents were statistically different for the first two periods (0 and 45 days),

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for the flour type, equaling the end of the storage period (90 days). The highest moisture content was found for both flours at the end of storage. In the case of WF, moisture was statistically the same between the periods of 45 and 90 days, which differed from the beginning of storage (day 0). For PDF, there was a progressive increase of humidity, where in the three periods analyzed, the humidity values showed a difference between them.

In general, the storage promoted an increase in humidity, because the containers were not hermetic, in which the relative humidity of the medium occurred influence. Another factor that may have contributed to this increase in water content was observed coliform growth, which may also indicate a development of other microorganisms not visible to the naked eye, as in the case of fungi. These beings have a respiration rate, which in the process oxidizes glucose, promoting the release of energy (677 kcal), carbon dioxide and water (Santos et al., 2012).

Although the water content increased, it was still within the limit established by current legislation for flours, from 15% (Brasil, 2005). The green banana flour presented final moisture (6.47%) close to the values of the present study, stored in PET packaging for 90 days, at room temperature of ±26 ° C, in the study conducted by Santos et al. (2010). Reis et al. (2017) determined high humidity values between 18.78% and 25.48% for acerola meal (differentiated by the presence or absence of the seed in its composition) stored for 75 days in PET packages.

The Table 3 contains the Most Likely Number data for total coliforms of WF and PDF.

Table 3. Mean values of the microbiological analysis of total coliforms in baru flour stored in BOPP packages for 90 days.

WF	
Storage Time (days)	**Total Coliforms (NMP g^{-1})**
17	2,47
84	13,00
PDF	
Storage Time (days)	**Total Coliforms (NMP g^{-1})**
22	1,20
90	11,6

The presence of total coliforms (hygienic sanitary parameter) at the beginning indicates contamination during the processing of the flours. Throughout the storage there was an increase in the presence of total coliforms in both flours. This happens because the pH of the environment is in the range of the ideal for microorganisms, potentiated by the increase of the humidity of the product during the period. The lower presence of total coliforms in the PDF can be justified by the thermal treatments that were submitted to the oil extraction process, carried out at high temperatures, which provided this reduction in the initial population.

The applied tests did not indicate the presence of fecal coliforms in the flours, in all the periods studied in the storage. Therefore, the microbiological standards were met, with MPN values below the limit established by ANVISA RDC No. 12/01 for flour (Brazil, 2001). A similar result was found by Jesus et al. (2018) in the microbiological quality study of cassava flour marketed in the state of Acre.

CONCLUSIONS

Throughout storage, the BOPP packaging changed all studied characteristics, both in WF and PDF, except for the flow time for PDF. However, the packaging preserved the moisture values and microbiological standards within the limits established by the flour legislation, allowing the use for the storage of baru flour within 90 days.

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