Original

Effect of drying temperature on quality of β-glucan in white oat grains

Avaliação da temperatura de secagem na qualidade de β-glicanas em grãos de aveia branca

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Abstract

Oats have received attention because of their nutritional characteristics, especially their high-quality content of β-glucan. The drying process reduces water content; therefore they can be preserved for long periods. However, high-temperature drying process may affect the physical, chemical, and functional properties of the grains. The objective of this study was to evaluate the effect of different drying temperatures on β-glucan quality in oat grains. Grains of oats (*Avena sativa,* L.), cultivar Albasul, harvested at harvest moisture content of 23% were submitted to stationary drying at air temperatures of 25, 50, 75, and 100 °C until they reached 13% moisture content. The β-glucan content was determined in samples of oat grains and extraction was performed using water as solvent at 90 °C. The β-glucan extract was evaluated for water holding capacity, water retention capacity, capacity of displacement, and gelation properties. Stationary of oat grains at air temperatures above 25 °C decreased the water holding capacity, whereas the content of β-glucan and the water retention capacity of β-glucan extract was affected at temperatures above 50 °C. Physical changes such as increased gelation capacity of the β-glucan extract occurred following drying at air temperature over 75 °C.
Keywords: *Avena sativa; water absorption; water retention; gelatinization.*

Resumo

A aveia tem recebido atenção devido às características nutricionais, principalmente pelo alto teor e qualidade de β-glicanas. Com a secagem da aveia, ocorre redução do conteúdo de água a valores que permitam a sua conservação por longos períodos. A alta temperatura do ar de secagem pode afetar características físicas, químicas e funcionais dos grãos de aveia. Objetivou-se, com o trabalho, avaliar o efeito de diferentes temperaturas de secagem na qualidade de β-glicanas em grãos de aveia branca. Grãos de aveia (*Avena sativa,* L.), cultivar Albasul, colhidos com umidade de 23% foram submetidos à secagem estacionária em temperaturas do ar de 25, 50, 75 e 100 °C até a umidade de 13%. Nas amostras de grãos de aveia, foi determinado o teor de β-glicanas e realizada sua extração utilizando água como solvente na temperatura de 90 °C. O extrato de β-glicanas foi avaliado quanto à capacidade de absorção de água, capacidade de retenção de água, capacidade de escoamento e propriedades de gelificação. A secagem dos grãos de aveia em sistema estacionário em temperaturas do ar acima de 25 °C reduziu a capacidade de absorção de água, sendo que o teor de β-glicanas e a capacidade de retenção de água do extrato de β-glicanas foram afetados em temperaturas acima 50 °C. A capacidade de gelificação do extrato de β-glicanas se alterou, ocorrendo aumento na secagem realizada com temperatura do ar acima de 75 °C.
Palavras-chave: *Avena sativa; absorção de água; retenção de água; gelatinização.*

1 Introduction

Oats are distinguished among cereals by their excellent functional and nutritional properties and have been subject of increasing interest to consumers and researchers (KLOSE; SCHEHL; ARENDT, 2009). This cereal is known for its profile of balanced amino acids and high digestibility of its protein content, essential fatty acids, vitamins, minerals, sterols, antioxidants, and high soluble fiber content, especially β-glucan. Fiber consumption can reduce the risk of cardiovascular disease, diabetes, hypertension, and obesity and improves bowel functioning (WOOD, 2007; BUTT et al., 2008; KHOURY, 2011).

β-glucans are linear unbranched polysaccharides composed of glucose units (β-D-Glicopiranosil) joined by glycosidic bonds β-1,3 and β-1,4 (WOOD, 2004). The growing interest in the presence of β-glucan in foods is not only related to their nutritional benefits, but also because of their viscosity in water, which allows its use as a thickener. Another application of interest is as fat replacer in light and diet foods formulation due to their pleasant flavor and smooth texture (BRENNAN; CLEARY, 2005; GUTKOSKI et al., 2007). The content of β-glucan in oats varies, and it is influenced by genetic and environmental factors. The oat caryopsis contains 3.51 to 6.50% of β-glucan, and the bran contains 4.67 to 9.51% (SÁ et al., 2000).

The processing of oats can affect the molecular (chemical structure and degree of polymerization), structural (molecular

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interactions), and functional (viscosity, water-binding ability, and solubility) properties of β-glucan. β-glucan viscosity is the factor responsible for lowering cholesterol and the glycemic index. Therefore, knowing how the solubility and extraction of β-glucan are affected by the processing is very important (WOOD, 2007). Mechanical processing can affect the molecular (chemical structure and degree of polymerization), structural (molecular interactions), and functional (viscosity, ability to retain water, and solubility) properties of β-glucan (WOOD, 2007). High temperatures can degrade the β-glucan into low molecular weight fragments or even depolymerize the linear structures of this component, thereby altering its amount, probably compromising its behavior (BUTT et al., 2008). Furthermore, relatively low-temperature conditions of extraction (50 to 60 °C) may not be sufficient to inactivate endogenous β-glucanases, increasing depolymerization (FASTNAUGHT, 2001).

The drying of oat grains is a critical procedure in the post-harvest operations that, when not done properly, may cause significant changes in the grain technological quality. Drying can be done by various natural and artificial methods (ELIAS et al., 2007). Due to drying, the grain moisture content is reduced to values that permit the preservation of its taste and nutritional quality for long periods (BERTOL; CARNEIRO, 2002).

Drying at high temperatures may compromise the physical and chemical characteristics of grains, but there is no consensus on the resulting changes in the nutritional value (ELIAS et al., 2007). In oats, drying requires special attention because the grain has a strong tendency to rancidification caused by the action of lipases resulting in free fatty acids; however, the lipase is sensitive to high temperatures and more sensitive to humid heat (MARINI; GUTKOSKI; ELIAS, 2005).

Little information was found about the impacts of processing on the functional properties of oats. This study aimed to evaluate the effects of different drying temperatures on the β-glucan quality of white oat grains, Albasul cultivar.

2 Material and methods

2.1 Material

White oat grains (*Avena sativa,* L.), Albasul cultivar, produced in Palma Experimental field, Federal University of Pelotas, in the city of Capão of Leão, RS, Brazil (agricultural harvest of 2005), were used in the present study. The physical and chemical analyses were performed at the Laboratory of Postharvest, Industrialization and Quality Control of Grain (DCTA-FAEM-UFPel) and at the Laboratory of the Research Center in Food of the University of Passo Fundo (UPF).

2.2 Experimental design

The experiment was conducted as a completely randomized design with four treatments (25, 50, 75, and 100 °C), and the assays were performed in triplicate. For each response variable, the tests were analyzed at least twice.

2.3 Drying

The oats were harvested at harvest moisture of 23%, and pre-cleaning was performed using a machine pilot air screen until the concentration of impurities and foreign matter fell below 1%. The samples were dried in a stationary dryer at two different stages. In the first stage, the samples with initial moisture of 23% were kept in the drying camera and received air at 25 °C until reach intermediate moisture of 15 to 16% to reduce thermal damage to the grains. In the second stage, the samples were submitted to four different air temperatures until they reach final moisture of 13%. In the first drying treatment, which was used as the control, the air temperature was kept at 25 °C, while in the other treatments the air temperatures used were 50, 75, and 100 °C, respectively, until the grains reach the expected moisture.

To monitor the water content of the grains during the drying, a dielectric conductivity system was used, and the values were confirmed by the oven method at 105 ± 3 °C with natural air circulation in accordance with the grain analyses, recommended by the Ministry of Agriculture (BRASIL, 2009). The results were expressed in percentage of moisture.

2.4 β-glucan content

The content of β-glucans was determined in accordance with the methodology proposed by AOAC (ASSOCIATION..., 2000), method nº 995.16. β-glucans were hydrolyzed by lichenase to obtain oligosaccharides and quantitatively cleaved to glucose by β-glucosidase. The glucose concentration was determined using glucose oxidase-peroxidase, and the results were expressed in percentage of β-glucan.

2.5 β-glucan extraction

The oat bran was fractionated by grinding in a Perten laboratory mill model 3100, French, using an 841 µm sieve, and cold-defatted with hexane solvent (solid: solvent proportion of 1:4) for 24 hours under agitation. The solvent separation was carried out by filtration, and the residual hexane was removed in an oven with air circulation at a controlled temperature of 80 °C for one hour. The retained material was ground in the mill using a 595 µm sieve and fractionated using a 74 µm sieve. The third grinding of the coarse fraction was performed with a 40 mm sieve and split into a 74 µm sieve to obtain the β-glucan concentrate, which was then was used to produce the β-glucan extract in accordance with the methodology proposed by Knuckles, Chiu and Betschart (1992).

The β-glucan concentrate was subjected to water reflux treatment at 90 °C for 1 hour and centrifuged at 6000 g for 15 minutes. The residue from centrifugation was discarded, and the supernatant was added to ethanol (solvent: solid proportion of 1:2) for the precipitation of β-glucan. The solution was centrifuged after resting for 24 hours at 4 °C. The β-glucan extract was dried in a vacuum oven Servilab, (model SEO21, Brazil) for 2 hours at 50 °C prior to the analysis.

2.6 Water holding capacity (WHC)

The water holding capacity was determined according to the method described by Gloria and Regitano-D'arce (2000) by homogenization of 0.5 g of sample and 5 mL of distilled water in a graduated tube centrifuge for 1 minute. The solution was centrifuged for 30 minutes at 2500 g after standing for 30 minutes at room temperature. The water retained after centrifugation was considered as the absorbed water. The sediment in the centrifuge tube after separation of the supernatant was weighed, and WHC was determined by the relationship between the sediment mass and the mass of the whole sample on a dry basis. The result was expressed as a percentage.

2.7 Water retention capacity (WRC)

The water retention capacity was determined in accordance with the method proposed by Chaud and Sgarbieri (2006), adjusted for homogenization of 2.5 g of sample in 30 mL of water. The solution was stirred constantly for 30 minutes and centrifuged at 2300 g for 15 minutes at 20 °C. The sediment and the supernatant were weighed to determine the amount of dry residue (solid soluble) after evaporation. The WRC was determined by the ratio of the mass of the residue obtained by centrifugation and the difference between the mass of the sample on a dry basis and the evaporation residue mass.

2.8 Gelation properties

The determination of the minimum sample concentration at which gelation occurs was performed in accordance with the methodology proposed by Chaud and Sgarbieri (2006) through the preparation of dispersions at concentrations of 2, 3, 4, 5, and 6 g.100 g^{-1} in 10 mL phosphate buffer 20 mM, pH 7.0. The suspensions were placed in test tubes, heated for 1 hour at 90 °C, cooled rapidly, and maintained at 4 °C for 2 hours.

The lowest concentration capable of promoting gelation was one at which the samples did not fall or slide down the wall of the tube when the tubes were inverted. The gelation temperature was determined visually by the physical change of beads in the sample solution during heating.

2.9 Capacity of displacement

The capacity of displacement was determined using a Marconi consistometer, model MA 441, Brazil raised to an angle of 45°, at a sample temperature of 20 °C for 10 minutes. The results represent the average of five replicates expressed in cm.min^{-1}.

2.10 Statistical analysis

The results of the physical and chemical determinations were evaluated using analysis of variance (ANOVA), and Tukey tests were performed to compare the means in significant models at 95% confidence interval using the Statistica software version 5.0.

3 Results and discussion

Figure 1 represents the content of β-glucan in oat grains, Albasul cultivar, submitted to different temperatures during air drying. Increased air temperature during the drying of oat grains promoted reduction of the β-glucan content in the oats.

The results of drying at air temperatures of 25 and 50 °C did not differ significantly, with β-glucan content values of 3.51 and 3.48%, respectively. However, with the use of higher temperatures, a significant reduction of these values was verified; the lowest value was obtained at the temperature of 100 °C. The high temperatures used in drying may have caused the degradation β-glucan into fragments of low molecular weight, or it may even have depolymerized the linear structure thus changing the concentration of β-glucan and probably impairing their behavior (BUTT et al., 2008).

Andersson et al. (2004) assessed the effect of baking on β-glucan in barley bread and did not observe differences in molecular weights between samples of the dough and baked bread thus demonstrating that the temperature used for baking did not reduce the molecular weight of β-glucans. To ensure that possible changes in the structure of β-glucan do not compromise the nutritional quality and functional products that are added, it is necessary to understand and manipulate the manufacturing process.

Even with the β-glucan reduction with increasing temperature of the drying air, the levels of β-glucan found are in agreement with those of several studies in the literature. Gutkoski and Trombetta (1999), studying Brazilian oat genotypes, found concentrations of β-glucans ranging from 3.01 to 4.13%, while Sá et al. (2000), also working with Brazilian genotypes, observed values between 3.51 and 6.50%. Dallepiane (1997), investigating the level of β-glucan in Brazilian, Argentinian, and American oat cultivars, concluded that the source of greatest variation was genetic factors. The average β-glucan content of Brazilian cultivars was 4.50%, and the highest value was found for CTC 3, similar to that of the American cultivar Milton.

Water holding capacity (WHC) is a relevant property for application in breads and cakes since high levels of WHC contribute to the maintenance of appropriate moisture levels. The water absorption of a food ingredient determines not only the acceptability of the final product in terms of texture and juiciness, but also its profit margin (HALL, 1996).

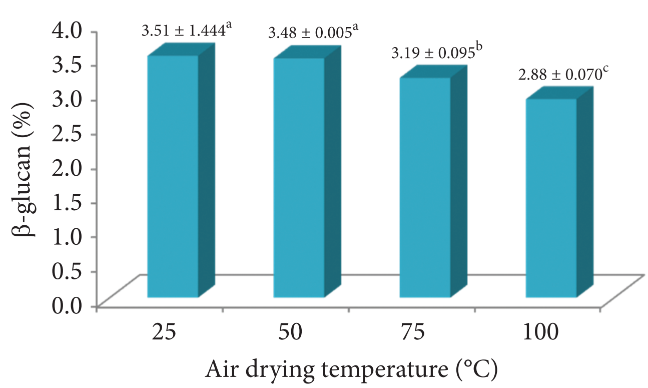

Figure 1. β-glucan content in white oat grains, Albasul cultivar, subjected to air drying at different temperatures.

The oats dried at temperatures of 50, 75, and 100 °C exhibited significant differences in terms of the WHC of their β-glucan extracts (Figure 2). Samples of oat grains dried at 25 °C showed higher value of WHC, differing significantly from the others treatments.

The WHC values observed in the present study revealed the existence of high-attraction hydrophilic fiber. The analysis showed that the β-glucan fraction absorbed water rapidly and then stabilized. The structure has a great capacity for water absorption and gel formation. Chaud and Sgarbieri (2006), in a study aiming to fractionate, characterize, and evaluate the functional properties of the cell walls of yeasts, found water holding capacity of 1.53 mL water.g sample^{-1}for the soluble β-glucan.

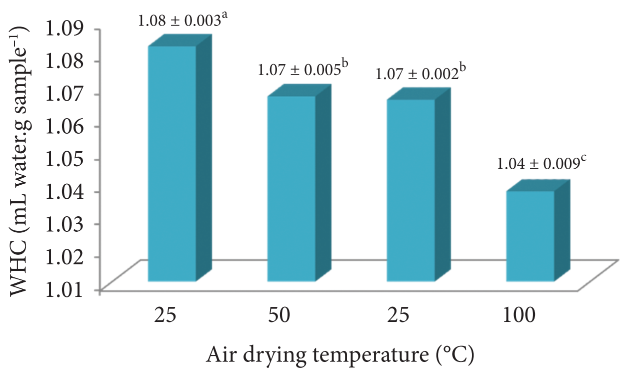

Figure 2. Water holding capacity (WHC) of β-glucan extracts of oat grains subjected to different air drying temperatures.

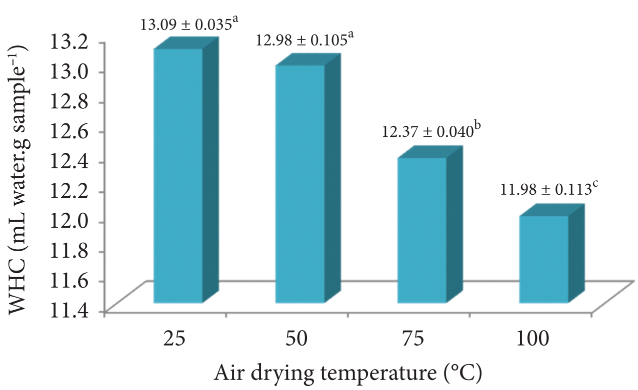

Figure 3. Water retention capacity (WRC) of β-glucan extracts of oat grains subjected to different air drying temperatures.

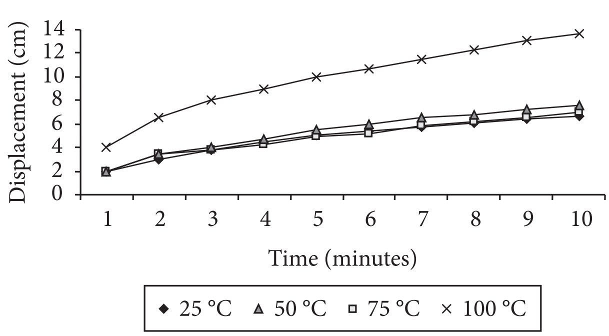

Figure 4. Effect of drying temperature of oat grains on capacity of displacement of β-glucan extracts.

Figure 3 shows the effect of drying oat grains at different air temperatures on the water retention capacity (WRC) of the resulting β-glucan extract. Drying at 25 and 50 °C did not significantly change WRC, but the treatments at 75 and 100 °C exhibited a significant reduction. The high values found for WRC showed the presence of a strong water-gelling agent interaction (ANDERSSON et al., 2004). The behavior verified for WRC was similar to that verified for β-glucan content. The WRC reduction can be explained by physical damage to the linear structure of the fiber at higher temperatures, thus changing the ability of a gel to form. WRC is very useful in the preparation of frozen bakery products because it prevents water loss during thawing (CHAUD; SGARBIERI, 2006).

The oat grain drying temperature did not significantly influence the β-glucan extract gelation temperature, which occurred at 55 °C in all treatments. The minimum amount of sample necessary for gel formation varies with the nature of the gelling agent since it is necessary for the present solubility agent to interact with the solvent and water-holding capacity in the three-dimensional matrix of macromolecules (ARMSTRONG et al., 1994). The concentration of β-glucan extract (6%) required for the occurrence of gelation for oats subjected to a drying temperature of 100 °C was significantly higher than that of the others (5%).

The capacity of displacement of the β-glucan extracts in oats grains exposed to different drying temperatures was higher at a drying temperature of 100 °C (Figure 4). The results of the capacity of displacement, WHC, and WRC analyses indicated that there were changes in the quality of the β-glucan extracts when the oat grains were dried at air temperatures of 50, 75, and 100 °C. The higher temperatures may have broken down the linear structure of β-glucan, changing their properties. The depolymerization of the linear structure reduces the molecular weight of the β-glucan making the sample more fluid (WOOD, 2007).

4 Conclusions

Drying oat grains in a stationary dryer at air temperatures above 25 °C reduced water holding capacity (WHC), whereas the content of β-glucan and the water retention capacity (WRC) of β-glucan extract were affected at temperatures above 50 °C. Physical changes such as increased capacity of displacement of the β-glucan extract occurred following drying at air temperature above 75 °C.

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