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Influence of Thermal Processing of Wheat and Barley on *in Vitro* Cellulose Digestibility

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Abstract

The study was conducted to evaluate the effect of thermal processing on cellulose digestibility of wheat and barley submitted to *in vitro* simulated digestion. The samples were heated in a forced air oven, or by exposing to microwave radiations. The in vitro digestion consisted of a two step enzymatic procedure: an initial simulation of the gastric digestion by pepsin, followed by a pancreatin digestion which simulated small intestine digestion. The wheat cellulose digestibility improves with the heating time; when heating 15 minutes at 150ºC, digestibility is 8.39% higher than the digestibility of raw wheat. The microwave treatment of wheat has a negative effect, the cellulose digestibility being reduced with 67.83% at 90 seconds treatment. When heating barley at 150ºC, the cellulose digestibility is higher than that of the unprocessed sample, and decreases with the heating time, suggesting formation of non soluble polysaccharide aggregates. The microwave treatment improves the cellulose digestibility in barley with up to 38.30% at 30 seconds treatment; microwave treatment for 90 seconds has a negative effect, the digestibility being reduced with 4.65%.

Keywords: cellulose digestibility, *in vitro* digestion, barley, wheat

1. Introduction

The polysaccharides of plant cell walls are resistant to digestion by human enzymes in the small intestine and are considered to be delivered to the colon in a chemically unaltered state [1]. Dietary cellulose is thought not to be digested in the stomach and small intestine. There are some reports [2,3] on the amount of dietary fiber reaching the terminal ileum in humans. Englyst and Cummings [4,5] found more that 90% of the non-starch polysaccharides of some cereals were found in the ileostomy fluid.

Cellulose consists of long unbranched chains of glucose, (1-4) β linked D-glucopyranose. Cellulose is found in abundance in nature in virtually all plant tissues and is therefore a common component of our diet. Cellulose seems to play a role in bile acid-binding when it stabilizes the cell wall architecture after the digestion process [6]. The digestive breakdown of cellulose is dependent on its degree of crystallinity, and the action of cellulase enzymes [7-11].

Humans are unable to digest cellulose because the cellulase enzymes to breakdown the beta acetal linkages are lacking. In the large intestine however, cellulose is fermented [10,12] by the microflora with the ultimate production of short chain fatty acids, hydrogen, carbon dioxide and methane [13,14]. The relative chemical inertness of cellulose, as well as its occurrence in many different forms, results in difficulties in its quantitative measurement [15]. Several studies have been performed to assess the digestion of dietary cellulose within the human gastrointestinal tract, and the results reported have been very variable [9,10,16], perhaps reflecting inadequacies of older methodology.

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Thermal processing of plant tissues alters the physical and chemical properties of plant cell wall and modifies fiber solubilization. Processing methods can alter molecular structure and viscosity of β-glucan without affecting β-glucan content [17-21]. Heat processing of cereals at temperatures above 90°C is a common practice to improve nutrient digestibility and productive performance in piglets [22,23]. Methods for studying carbohydrate digestion in vivo are generally time consuming, costly, and related to important ethical constraints. An alternative is the application of in vitro models that simulate the human gastrointestinal tract.

The study was conducted to evaluate the effect of thermal processing on cellulose digestibility of wheat and barley submitted to in vitro simulated digestion.

2. Materials and methods

Wheat and barley samples were milled by a laboratory grinder to 500 µm granulation and heated in a forced air oven, or by exposing to microwave radiations. Samples were heated for 5, 10 and 15 minutes at 150ºC and 180ºC in a Froilabo AC60 forced air oven. The microwave treatment was made in a Vortex WD800D-823 oven (800 W and 2450 Hz), for 30, 60, 90 and 120 seconds

All samples were submitted to an *in vitro* digestion that consisted of a two step enzymatic procedure: an initial simulation of the gastric (G) digestion by pepsin, followed by a pancreatin digestion which simulated small intestine (SI) digestion.

The *in vitro* digestion in the stomach was an enzymatic hydrolysis with a pepsin solution at pH 2.0 and 37°C for 75 min, in the presence of chloramphenicol. The *in vitro* intestinal digestion was simulated by hydrolysis with the multi-enzyme pancreatin (mixture of protease, amylase and lipase, from porcine pancreas), at pH 6.8 and 37°C for 4 h.

Cellulose content was determined by Scharrer method, using a VELP Scientifica FIWE 6 raw fiber extractor.

3. Results and Discussion

The obtained experimental results are presented in Table 1. The cellulose content of *in vitro* digested raw wheat was 2.86% and of raw barley 3.89%.

The lowest cellulose content of processed wheat submitted to *in vitro* pepsin-pancreatin digestion was registered when heating 15 minutes at 150ºC (2.62%) and the highest value was obtained when processing in microwave oven for 90 seconds (4.80%).

The cellulose content of processed barley submitted to *in vitro* pepsin-pancreatin digestion ranged between 2.40% when processing in microwave oven for 30 seconds, and 4.08% when processing in microwave oven for 90 seconds.

When heating in a forced air oven at 150ºC, the cellulose content decreases with the processing time in wheat. Thermal processing increased the soluble dietary fraction. In general, the changes in the dietary fiber composition during thermal processing may be partly attributed to the redistribution of the insoluble and soluble components of dietary fiber, and partly to the formation of resistant starch. An increased temperature breaks week bonds between polysaccharide chains and split glycosidic linkages in the polysaccharides [24]. As consequence, the architecture of the fiber matrix may be modified and insoluble fiber solubilized [25].

In barley, the cellulose values of thermal processed samples after *in vitro* digestion increase with the processing time. The experimental data reveal that although the β-glucan aggregates were disrupted by the gastric conditions (compared with when they were dispersed in water), the subsequent small intestinal digestion resulted in the re-formation of aggregates.

The cellulose content increases in time during the microwave radiations treatment both in wheat and barley.

Table 1. Cellulose content (%) of *in vitro* digested wheat and barley

Treatment	Processing conditions	Processing time	Wheat	Barley
forced air oven	150 ºC	5’	3.69	3.01
		10’	3.04	3.06
		15’	2.62	3.56
microwave radiations	800 W and 2450 Hz	30’’	2.80	2.40
		60’’	3.14	3.52
		90’’	4.80	4.08

In vitro cellulose digestibility of processed wheat and barley as percentage of *in vitro* cellulose digestibility of raw wheat and barley are presented in Figures 1 and 2.

When heating 5 and 10 minutes in a forced air oven at 150ºC, the cellulose *in vitro* digestibility of wheat is lower than that of the unprocessed sample. The digestibility improves with the heating time, so that when heating 15 minutes at 150ºC the cellulose digestibility is 8.39% higher than the digestibility of raw wheat. The microwave treatment of wheat has a negative effect, the cellulose digestibility being reduced with 67.83% at 90 seconds treatment.

When heating barley at 150ºC, the cellulose *in vitro* digestibility is higher than that of the unprocessed sample. The digestibility decreases with the heating time, suggesting formation of non soluble polysaccharide aggregates.

The microwave treatment improves the cellulose digestibility in barley with up to 38.30% at 30 seconds treatment. The microwave treatment of barley for 90 seconds has a negative effect, the cellulose digestibility being reduced with 4.65%.

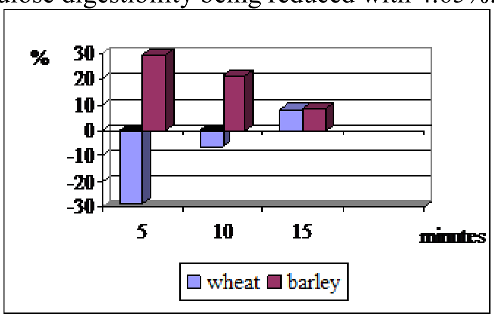

Figure 1. *In vitro* cellulose digestibility of thermal processed wheat and barley as percentage of *in vitro* cellulose digestibility of raw wheat and barley

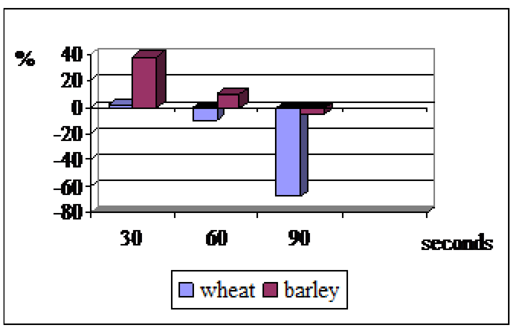

Figure 2. *In vitro* cellulose digestibility of microwave processed wheat and barley as percentage of *in vitro* cellulose digestibility of raw wheat and barley

4. Conclusions

When heating in a forced air oven at 150ºC, the cellulose content decreases with the processing time in wheat and increase in barley.

The cellulose content increases in time during microwave processing both in wheat and barley. When heating 5 and 10 minutes in a forced air oven at 150ºC, the cellulose *in vitro* digestibility of wheat is lower than that of the unprocessed sample. The digestibility improves with the heating time.

The microwave treatment of wheat has a negative effect, the cellulose digestibility being reduced with 67.83% at 90 seconds treatment.When heating barley at 150ºC in a forced air oven, the cellulose *in vitro* digestibility is higher than that of the unprocessed sample. The digestibility decreases with the heating time, suggesting formation of non soluble polysaccharide aggregates.

The microwave treatment improves the cellulose digestibility in barley at 30 seconds treatment. The microwave treatment for 90 seconds has a negative effect, the cellulose digestibility being reduced. Short thermal processing of barley modifies the physical and chemical structure of the cereal, improving accessibility of enzymes to dietary components and facilitating its utilization.

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