TECHNICAL SCIENCES
Abbrev.: Techn. Sc., No 7, Y. 2004

STABILIZATION OF OAT GROATS BY INFRARED TREATMENT

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Key words: oat groats, micronization, infrared heating, enzyme inactivation, peroxidase.

Abstract

Micronization (infrared heating) with a lab-scale micronizer was studied as an alternative method of heat treatment for oat groats. The objective of the study was to determine the optimum infrared heat processing conditions that would inactivate lipolytic enzymes without burning the oat groats. Prior to micronization, the oat groats were tempered to 28% moisture content. Two micronization protocols were examined: (*i*) where the surface temperature of the groats was controlled by spraying with water (spraying tests) and (*ii*) where the temperature of the oat groats was controlled by restricting the infrared intensity (voltage control tests). Processing conditions were evaluated based on negative peroxidase results for both protocols. Either protocol could be used to inactivate peroxidase, but the temperatures at the end of processing were higher for the spraying test (157–161°C) than the voltage control test (137–155°C). The final moisture contents for both protocols ranged from 1.1 to 18%.

STABILIZACJA KASZY OWSIANEJ ZA POMOCĄ PROMIENIOWANIA PODCZERWONEGO

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S ł o w a k l u c z o w e: kasza owsiana, mikronizacja, promieniowanie podczerwone, dezaktywacja enzymu, peroksydaza.

S t r e s z c z e n i e

Prowadzono badanie intensywnego ogrzewania za pomocą podczerwieni (mikronizacja) przy użyciu skali laboratoryjnej mikronazera jako alternatywną metodę obrobki cieplnej stosowanej przy produkcji kaszy owsianej. Celem badań było określenie optymalnych warunków ogrzewania za pomocą podczerwieni, które to warunki prowadziłyby do dezaktywacji tłuszczowych enzymów bez zmiany zewnętrznego koloru kaszy owsianej. Kasza owsiana przed poddaniem jej mikronizacji została nawilgocona do 28% wilgotności.

Rozważano dwa różne schematy technologiczne: (*i*) – gdzie temperatura powierzchni kaszy owsianej była kontrolowana przez spryskiwanie mgłą wodną (testy spryskiwania woda), oraz (*ii*) – gdzie temperatura kaszy owsianej była kontrolowana przez ograniczanie intensywności promieniowania podczerwonego (kontrolowane napięcie w lampach podczerwonych). Warunki procesu technologicznego w obydwu testach oceniano, opierając się na rezultatach negatywnego testu peroksydazy. Obydwa schematy technologiczne mogą być użyte do dezaktywacji peroksydazy, aczkolwiek temperatura przy końcu grzania podczerwonego ze spryskiwaniem powierzchni kaszy wodą była wyższa (157–161°C) niż przy testach, gdy temperatura powierzchni kaszy była kontrolowana przez zmianę intensywności promieniowania podczerwonego i kontrolę napiecia lamp podczerownych (137–155°C). Końcowa wilgotność w obydwu schematach technologicznych wynosiła od 1.1 do 18%.

Introduction

Most of the oats grown in North America are used for feeding poultry and other animals. The popularity of oats for human consumption, however, increased in the 1990s. In 2000, in Manitoba, 384,500 hectares of oats were seeded with 348.000 hectares harvested for grain (*Manitoba Agriculture and Food*, 2000). This represented 2.4 M m^3 of harvested oats. Most oat cultivars are harvested with their hulls on and after the hulls are removed they are referred to as groats (HOSENEY 1986). After cleaning, oats destined for human consumption are heat-treated or dried to inactivate the lipolytic enzymes. Heat treatment also results in the development of a slightly roasted flavour.

It is important to inactivate the lipolitic enzymes as they can produce an intense rancid flavour, which reduces quality and shortens the shelf life of the oats.

Oat groats have the highest lipid concentration of all the cereal crops. The concentration of lipids is highest in the scutellum and embryonic axis (both parts of the embryo) and lowest in the hull (KULP and PONTE 2000). Lipase, lipoxygeanse and lipoperoxidase are some of the oat enzymes, which promote hydrolytic and oxidative reactions leading to the formation of the hydroxyl acids responsible for rancidity.

Oat processing includes cleaning, dehulling, steaming and flaking. Oats are cleaned and graded for size prior to dehulling. Dehulled oats are conditioned (or pretreated) by increasing the moisture content before passing them

through the kiln. During the kilning process, the temperature of the oats is increased to a minimum of 102°C using dry heat radiation. Alternately, steam heat can be used to increase the temperature to 100°C for 60 min. Both approaches result in denaturation of lipolytic enzymes, stabilization of free fatty acids and enhancement of oat flavour.

The use of heat and steam to inactivate lipolytic enzymes is practical in an industrial setting, but is impractical for small-scale operators who want to process their own oats. Micronization (infrared heat processing) may be an economical alternative for small-scale processing because of the lower capital investment and relatively low maintenance cost (FASINA et al. 1999). Micronization involves the exposure of a material to intensive heat radiation in the wavelength range of 1.8 to 3.4 μm. Other advantages of infrared heat processing include simplicity of construction and operation of the micronization equipment, significant energy savings compared to traditional thermal processing, and easy accommodation with convective, conductive and microwave heating. Food industry applications of micronization include inactivation of toxic agents and microorganisms, enhancement of dehulling of legume grains and adding value to cereal grains, legumes and oilseeds (MCCURDY 1992). Infrared heating has the potential to improve the value of these crops as well as their digestibility for animal feed (MCCURDY 1992).

A pretreatment step that increases the moisture content of the grains is required prior to micronization. Pretreatment can be either controlled, as in tempering to a uniform moisture content, or uncontrolled, where grains are soaked in excess moisture for a specified period of time (SCANLON et al. 1998). ROOS et al. (2000) experimented with both tempering methods but anticipated difficulties with the removal of excess water for the uncontrolled pretreatments in a production situation.

The objective of this study was to determine the infrared heat processing condition (heat intensity, duration of exposure to heat, tempering time, moisture-surface conditioning protocol) that would allow for inactivation of the lipolytic enzymes without burning the oat groats.

Materials and Methods

Samples of dehulled oats were stored at –5°C until the pretreatment or tempering stage. The unprocessed oats had an initial moisture content of approximately 11.0%. The moisture content of the oats was measured using the ASAE (2000) standard procedure drying 10 g of sample in a forced air oven at 130°C for 22 h. Using a controlled tempering method, 30 g of oats were placed in a bag and a calculated amount of water was added to raise the moisture content of the oats to 30%. The bags were sealed and tempered for 4 h, shaking periodically to evenly distribute the water throughout the groats.

A lab-scale micronizer (Model 4553 High Density Infrared Pyropanel Strip Heater from Research Inc., Eden Prairie, MN) was used for the experiments (Fig. 1). The micronizer head consisted of four tungsten-filament lamps rated at 500 W each with a low resistance at room temperature. The lamps were connected to a Model 5620 Power Controller (Research Inc., Eden Prairie, MN) to eliminate high inrush currents when turned on. The heater was a perforated ceramic reflector bonded to a metal plate with covered electrical connections. The samples to be micronized were placed in a dish on a vibrating bed 170 mm below the infrared (IR) lamps (Fig. 2). Exact control of input energy allowed for variable capacities and turn down ratios as high as 10:1. A voltage level of 9 indicates a turn down ratio of 9:1.

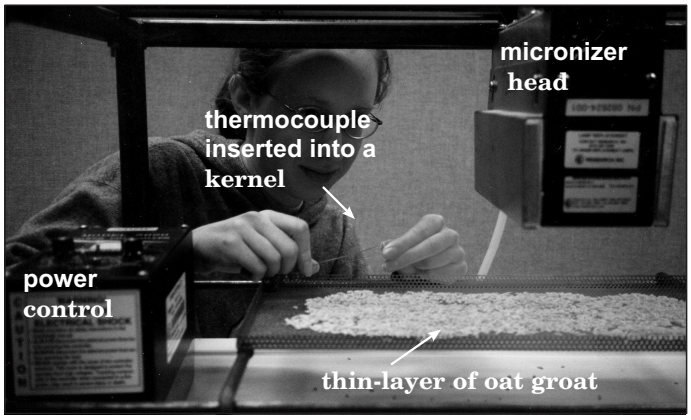

Fig. 1. The experimental apparatus for infrared processing of oat groats

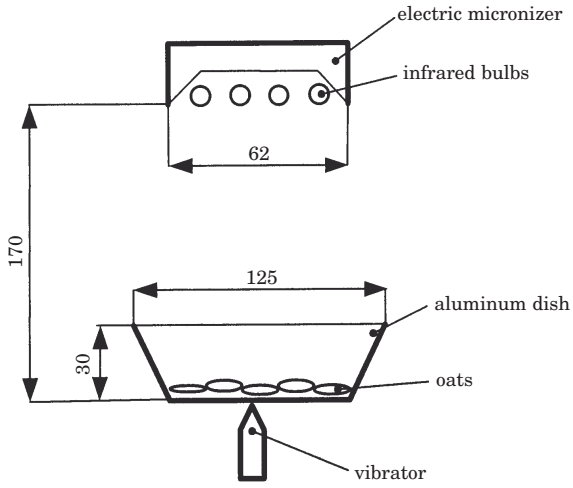

Fig. 2. Positioning an aluminum dish with oat groats under the micronizer head. Dimensions are in mm

Temperature of ambient air, air above the dish, and of individual oat groats were monitored every second using copper-constantan thermocouples and a data acquisition system (Hewlett Packard 3421 Data Acquisition/Control Unit). A soldered 1 mm tip of a thermocouple was inserted in the geometric center of individual groats to monitor their interior temperature (Fig. 1). The groats containing the thermocouples were also positioned 170 mm from the infrared lamp and were turned around continuously along their longitudinal axis during the heating process to ensure uniform heating. This set of experiments was repeated three times.

Infrared processing with water spraying (*spraying test*): Tempered oat samples of 10 to 12 grams were place in a circular aluminum dish (75 mm diameter and 30 mm high). Based on preliminary studies, the voltage input was set to level 10, and samples were micronized for selected times between 2.5 and 3.5 min. This selection was based on the fact that longer times caused visible discolouration of the oat surface and shorter times did not inactivate the enzymes. To increase the residence time under the lamp and to limit the temperature increase, water was sprayed on the surface of the oats. Two different initial spraying times (1.5 and 2.0 min) were examined at two spraying frequencies (0.5 and 1.0 min) – Table 1. At the selected times, the dish was removed from under the lamps, lightly sprayed with a water bottle with an attached nozzle, and returned to the vibrating bed. Each spray deposited approximately 1 g of water on the surface of the oats.

Infrared processing by controlling infrared intensity (*voltage control test*): By decreasing the voltage input to the four IR lamps, water spraying can be eliminated and energy use decreased. This method of processing controlled the temperature by manually lowering the voltage input from the power controller. As with the spraying method, 10–12 g samples of groats were placed in aluminum dishes on the vibrating belt while exposed to the heat. By monitoring groat temperature with the data acquisition system, various combinations of initial and final voltage levels (1 to 10) and times (up to 7 min) were tested. During initial runs, efforts were made to maintain the temperature of the groats at 90 and 100°C; the average temperature had to be increased to promote enzyme inacativation. Conditions used are given in Table 2.

Qualitative peroxidase analysis: Oat products destined for human consumption should be peroxidase free. Even though lipase is the main target when using heat to stabilize oat groats, peroxidase activity is often used as an indicator of enzyme activity due to the ease of the assay involved. The AACC (2000) method (22–80) for the qualitative analysis of peroxidase was followed. A Proctor-Silex coffee grinder was used to grind approximately 10 g of micronized groats for 30 s. The ground groats were sifted through a No 20 sieve and the material that did not pass though the sieve was ground and sifted again. If the residual material that did not pass through the sieve was not less than 1 g (or not less than 10% of the original sample mass) it

Table 1

Conditions used in micronization in which temperature of oats was controlled by spraying their surface with water and no browning of their surface was noticeable. Colour values were measured after processing and compared to unprocessed samples serving as control

Test No	Total processing time, min	Time of spraying, min	Hunter colour values[1]				Peroxidase Test
			L	*a*	*b*	ΔE	
1	2.5	2.0	57.3 (±0.5)[2]	4.6 (±0.1)	29.6 (±0.2)	64.7	LP
2	2.5	1.5, 2.0	56.3 (±0.8)	4.7 (±0.1)	29.5 (±0.1)	63.7	LP
3	2.75	2.0, 2.5	54.4 (±0.6)	4.6 (±0.1)	28.9 (±0.4)	61.8	LP
4	3.0	2.0, 2.5	55.2 (±0.8)	4.7 (±0.1)	28.8 (±0.6)	62.4	LP
5	3.5	2.0, 3.0	55.9 (±0.8)	4.7 (±0.2)	29.8 (±0.4)	63.6	N
6	2.75	1.5, 2.0, 2.5	54.9 (±1.2)	4.6 (±0.1)	29.0 (±0.6)	62.1	LP
7	3.0	1.5, 2.0, 2.5	56.2 (±1.5)	4.9 (±0.2)	28.8 (±0.4)	63.3	LP
8	3.5	2.0, 2.5, 3.0	53.2 (±0.9)	4.7 (±0.3)	29.5 (±0.7)	60.8	N
9	3.5	1.5, 2.0, 2.5, 3.0	52.0 (±2.1)	5.3 (±0.6)	29.5 (±0.8)	60.0	N
Control		unprocessed	56.4 (±0.3)	4.9 (±0.1)	28.4 (±0.2)	63.3	

LP = light positive, N=negative.
[1] *L* = 100 (white) to 0 (black); *a* = + (red), – (green); *b* = + (yellow), – (blue).
[2] Mean ±standard deviation, *n*=3.

Table 2

Conditions used in three micronization tests in which temperature of the oats was controlled by adjusting the voltage of infrared lamps. Colour values were determined after micronization and compared to unprocessed (control) samples

Test No	Micronization time, min	Voltage rate	Hunter colour values[1]				Peroxidase Test
			L	*a*	*b*	ΔE	
10	0 – 4.0	10 2	43.1 (±1.3)[2]	11.6 (±0.6)	27.2 (±0.5)	52.5	N
11	0 – 2.5 2.5 – 7.0	10 2	57.2 (±0.6)	4.7 (±0.1)	29.5 (±0.2)	64.5	N
12	0 – 1.0 1.0 – 2.0 2.0 – 5.0	9 1.5 1	56.7 (±1.5)	4.8 (±0.1)	28.9 (±0.2)	63.8	LP
Control	unprocessed		56.4 (±0.3)	4.9 (±0.1)	28.4 (±0.2)	63.3	

LP = light positive, N=negative.
[1] *L* = 100 (white) to 0 (black); *a* = + (red), – (green); *b* = + (yellow), – (blue).
[2] Mean ±standard deviation, *n*=3.

was ground for a third time. All the sifted samples were then mixed and 1 g sample from the average sift recovery was taken and put into an Erlenmeyer flask for enzyme testing.

Fifty milliliters of water at room temperature were added to the flask and swirled. Two milliliters of ascorbic acid solution (0.5 g in 500 mL of water), 3 mL of sodium 2,6-dichloro-indophenol solution (0.1 g in 500 mL of water) and 0.1 mL of hydrogen peroxide (4 mL of 30% H_2O plus 96 mL of water) were added and thoroughly mixed. The flask was then placed in a warm water (38°C) bath for 5 min, swirled and placed in the water bath for a further 5 min. If there was no colour change after the 10 min in the water bath, the test was recorded as negative. The presence of a definite blue colour indicated the peroxidase enzymes were active and the test was recorded as peroxidase positive.

Moisture content change during processing: The moisture content of the oat groats was determined at various intervals throughout the micronization trials. Partially micronized groats were removed from the IR heat and place into tarred aluminum drying dishes, weighed, dried in a forced air oven at 130°C for 22 h and reweighed to determine the moisture content (ASAE 2000).

Hunter colour values: Changes in colour, as a result of IR heat treatment, were measured on whole peas using a spectrophotometer (Model CM--525i, Minolta, Osaka, Japan) as L, a and b values after standardization with a white color standard. Total color difference (ΔE) was calculated from means using the following equation:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (1)$$

where: Δ is the difference between the standard and the sample readings.

Results and Discussion

Infrared processing with water spraying: The rationale for using water spraying was to maintain the average temperature of the groats between 115 and 120°C. Spraying at a frequency of 0.5 or 1.0 min was necessary to keep the average temperatures in the desired range. Of the nine test conditions examined only three produced negative peroxidase values (Table 1). All three were processed for a total of 3.5 min, only the spraying regimes varied. By limiting the micronization time to 3.5 min, there was no sign of browning on any of these samples.

The Δ values calculated from the three colour scales are shown in Table 1 reflecting the total colour of each sample with lower values meaning reduced lightness in colour. The control (unprocessed) sample gave a ΔE

value of 63.3 and the nine selected experiments resulted in a ΔE between 60.0 and 64.7. This change in the total colour was not noticeable to the unaided eye.

The temperature heating profiles for two of these effective treatments (5–3.5 min spraying twice and 9–3.5 min spraying four times) are shown in Fig. 3. The test with two sprays had a peak temperature of approximately 183°C, an average temperature of 120°C, and a temperature at the completion of micronization of 161°C. When four sprays were used, the peak temperature was reduced to 157°C, the average temperature to 114°C and the final temperature was only 157°C. Despite the addition of more water to the surface by spraying four times, the final temperatures of the micronized groats were similar.

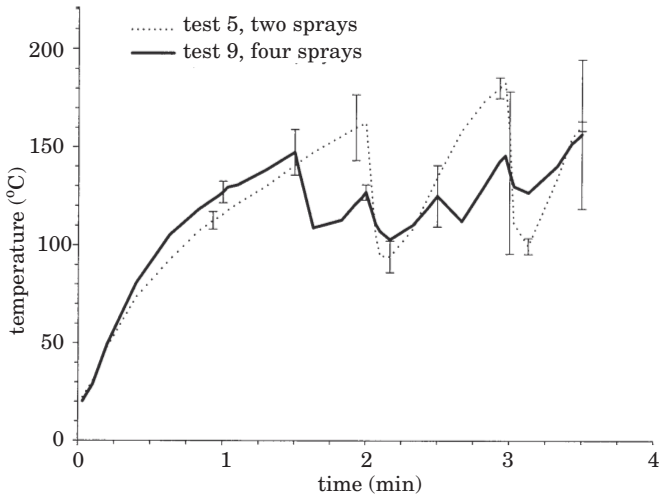

Fig. 3. Temperature change of oat groats during micronization when their temperature was controlled by water spraying. The vertical bars indicate the standard deviations (n=3)

The changes in moisture content of these oat groats during micronization are shown in Fig. 4. Moisture analysis was performed at the beginning and end of processing as well at designated spraying times, just prior to spraying the samples. Both samples began at an initial moisture content of 28% and the moisture content decreased until the time of the initial spraying. The test with the two water sprays had a moisture content of 13.2% at the time of the initial spraying (2.0 min) and a moisture content of 12.7% at the completion of micronization. The sample, which received four water sprays, had a moisture content of 18.6% at the time of the first spray (1.5 min) and a final moisture content of 18.9%. Once spraying was initiated, the moisture content of the groats remained fairly constant, changing by only 0.3–0.5%. The final moisture content of the oat groats was more a function of the time of the initial spraying than the frequency of the water sprays. The lower moisture content of 13.2% is preferred, as there may be concerns about microbial growth at a moisture content of 18.9%.

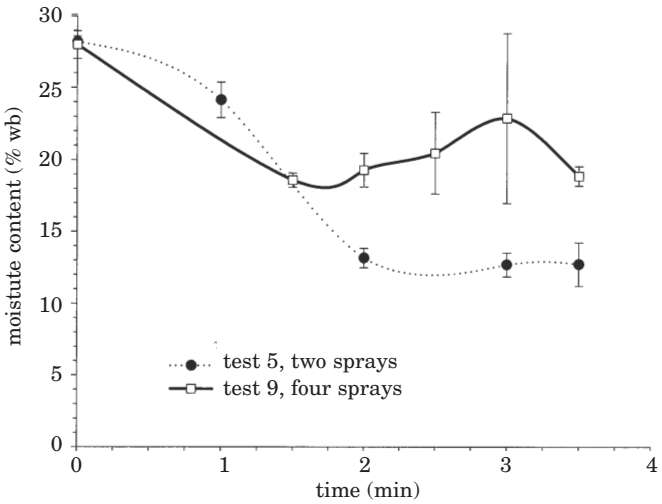

Fig. 4. Moisture content changes during micronization of oat groats when their temperature was controlled by water spraying. The vertical bars indicate the standard deviations (n=3)

Processing by controlling infrared intensity: While many trials in this experiment attempted to keep the temperature of the groats around 100°C, analysis of peroxidase activity indicated this temperature was not high enough and temperatures over 100°C were required as was seen in the spraying experiment. Results from three of these tests are presented in Table 2. Two of these tests gave negative peroxidase results (one with browning having total colour ΔE = 52.5 units and the other without browning with a ΔE of 64.5 units) and the third test gave a light positive peroxidase test, but showed no signs of browning (ΔE = 63.8 units). The substantially reduced lightness in ΔE, from 63.3 units for control to 52.5 units in experiment No 10, was visible even to the unaided eye as browning. That sample would not be acceptable by industrial standards.

The heating profiles during micronization for these samples are shown in Fig. 5. The sample, which gave a negative peroxidase test with browning, was characterized by a peak temperature of 218°C, and average temperature of 160°C and a final temperature of 155°C. For the sample, which gave a negative peroxidase result, but no browning, the peak temperature was only 200°C, with an average temperature of 141°C and a final temperature of 136°C. For the sample with the light positive peroxidase result and no browning the peak temperature was even lower at 151°C, with an average temperature of 105°C and a final temperature of 94°C. For the latter two samples (both with no browning), the temperature went to a constant value following reduction of the voltage at 2.5 and 1.0 min for the negative peroxidase and slight positive peroxidase samples, respectively.

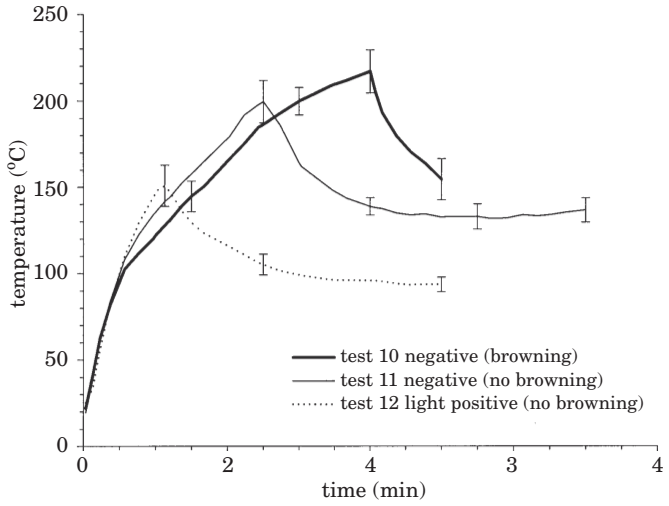

Fig. 5. Temperature change of oat groats during micronization when their temperature was controlled by adjusting the intensity of the infrared heat. The vertical bars indicate the standard deviations (n=3)

All three samples began with an initial moisture level of 28% (Fig. 6). For the light positive peroxidase result with no browning the final moisture content was 17.6%. This value is between the two final moistures seen in the spraying experiment. It may still be too high for prevention of microbial growth. The two samples that gave negative enzyme tests ended the micronization process with almost no moisture remaining in the groat. The sample with the lower moisture level was the one that browned during the process. Such low moisture contents in the micronized product may not be desirable as low moisture micronized products have been shown to exhibit poor rehydration and cooking properties (ARNTFIELD 1998).

It was determined that the high lamp voltage (10) should be maintained for at least 2 min to inactivate the peroxidase but no longer than 3.5 min as browning of the groats was observed at longer times. After 2 min at a voltage of 10 a temperature of 193°C was achieved for the micronized groats.

As it is necessary to cool the groats before further processing, it would be beneficial for the final temperature to be as low as possible. The lowest final temperature for micronized groats exhibiting a negative peroxidase reaction and no browning, was 136°C, obtained for the sample heated for 2.5 minutes at a voltage of 10 and further heating at a voltage of 2 for a total processing time of 7.0 min. Overall the tests in which water was sprayed on the surface of the samples produced higher final temperatures that did the samples from the experiment which controlled the intensity of the IR by adjusting the voltage of the lamps. This was a result of the high voltage (10) use for the entire spraying test.

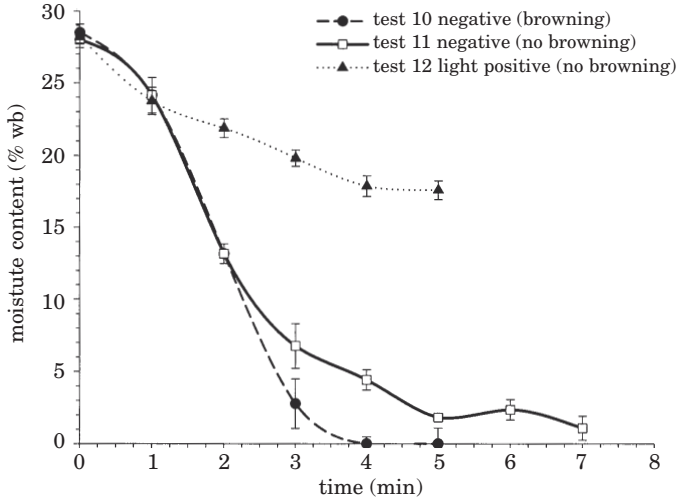

Fig. 6. Moisture content changes of oat groats during micronization when their temperature was controlled by adjusting the intensity of the infrared heat. The vertical bars indicate the standard deviations (n=3)

In traditional heating operations, the moisture content of the groats is reduced to 7–10% (KULP, PONTE 2000). This is low enough to control microbial growth while ensuring adequate rehydration. With the micronized samples where moisture was monitored, the sample heated for 3.5 min with 2 sprayings (final moisture 12.7%) gave the moisture content closest to this ideal value.

Conclusions

The peroxidase enzymes in oat groats were successfully inactivated by micronization. Temperature control to avoid browning during this operation was obtained by either spraying water on the surface of the groats during micronization or by adjusting the voltage on the IR lamps. When using voltage adjustment only, a peak temperature of approximately 200°C destroyed the peroxidase enzyme. This was achieved after 2.5 min at a voltage of 10. Browning of the groats was noted as the micronization proceeded past 3.5 min at a voltage 10, even when spraying with water was incorporated into the protocol. Between 2 and 3.5 min, spraying with water or reduction of the voltage should control the temperature. The ranges of final temperatures (136 to 161°C) and moistures contents (0–18.9%) were relatively large, allowing one to design a process to meet specific requirements. Groats with a moisture content closest to that currently available were obtained by heat at a voltage of 10 for 3.5 min with two water sprays, but the temperature at the

end of the process was 161°C, so that a cooling step would be required. The exact processing conditions, which would depend on the requirements in the end product, could be programmed as part of the overall operation.

Acknowledgments

The authors would like to thank Can-Oat Milling Products, Inc., of Portage la Prairie, MB for supplying the samples of oat groats.

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Accepted for print 2004.05.20