

The effects of steaming and roasting treatments on lipase activity and nutritional components of “oat rice” (OR): the peeled naked oat (*Avena nuda*) kernels*

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ABSTRACT

Peeled naked oat kernels, named “oat rice” (OR) by Chinese food scientists and processors, are novel oat products in China. This study examined the effects of steaming and roasting treatments on the enzyme activities, nutritional contents, and flour pasting properties of OR kernels. Results showed that a peeling time of 20 s caused 16.13% β -glucan loss, while a peeling time 25 s caused 34.29% β -glucan loss in the kernels. OR kernels with a 20 s peeling treatment demonstrated significantly higher starch levels and kernel whiteness compared with normal oat kernels ($P < 0.01$). It was also found that normal pressure steaming, autoclaved steaming and infrared roasting treatments could exterminate lipase activities in the OR kernels, and provide the OR kernels with significantly lower final viscosities and setback values than normal kernels ($P < 0.01$).

Keywords: Naked Oat (*Avena Nuda*); Oat Rice; Peeling Treatment; Lipase Activity; Infrared Roasting

1. INTRODUCTION

It is widely known that high lipid enzyme activities in oat kernels can lead to oxidation and spoilage in oat processing and storage [1-3]. Hot-air roasting (HAR), normal pressure steaming (NPS), and autoclaved steaming (AS) are methods traditionally used for oat enzyme

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deactivation in China. But, these commonly used methods are time-consuming, and thus do not fit the industrialization process found in large oat-processing companies in the country. Recently, infrared roasting (IR), a new method, has attracted much attention and research interest for the high efficiency of the method. However, due to its short treatment time (e.g. 18 s), the IR treatment also has a drawback in that the method fails to exterminate the lipase activities in some oat varieties [4]. In order to solve this problem, it is necessary to remove part of the kernel lipase before it receives an IR treatment.

Peeling treatment has been proven to be a useful method for reducing lipase activities in oat kernels before IR treatment [5]. For example, the lipase activities in the VAO-2 oat kernels (a Canadian oat variety) subjected to a 20 s peeling treatment are only 66.5% of those in normal VAO-2 kernels subjected to the same treatment [5].

The peeled oat kernels are designated as “oat rice” (OR) by oat processors and researchers in China. There are two reasons for this designation. The first is that the peeled oat kernels are close to rice kernels in shape and color. The second is that peeled oat kernels can be mixed with rice kernels and cooked together as human food in China [5]. Because OR kernels can be consumed together with rice, the most important staple food in China, the market potential for OR kernels is huge. So it is propitious to determine the effects of peeling and enzyme deactivation treatment on the enzymatic levels, and the nutritional and functional properties of the new oat product in China. Our previous research reported on the relationship between kernel size and shape of, and on lipase activity in, OR kernels and normal kernels [5]. We also reported on the effects of steaming and roasting treatments on the β -glucan, lipid and starch levels in normal oat kernels [4]. In the present study, we aimed to determine the optimal peeling time for the present study,

we aimed to examine the effects of IR, NPS, AS and HAR treatments on the nutritional contents, lipase activity, and flour pasting properties of OR the production of OR kernels.

2. MATERIALS AND METHODS

2.1. Materials

VAO-2 naked oat kernels were harvested in 2005 from a 15 ha field in Ottawa (Ontario, Canada). The oat kernels were cleaned, and purified, and then graded with a dockage tester (5/64 × 3/4 mm). Kernels left in the upper side of the dockage tester were chosen for the lipase deactivation treatments.

OR kernels were produced through peeling treatments using a TM-05C Satake Mill (Satake Corporation, Hiroshima, Japan) as indicated in our previous report [5]. Before peeling treatments, the machine was first warmed for 600 s. Then, for each treatment, 150 g VAO-2 oat kernels were placed in the specimen cup of the machine and peeled for the designated period of time. In order to get OR kernels with different peeling ratios, nine different treatment times were designated from 0 to 45 s at 5 s intervals.

2.2. Methods

Enzyme activities were deactivated by the four different treatments described as follows.

NPS treatments were implemented following Ames and Rhymer's method [6]. Here, OR kernels were placed into the metal basket of a vegetable steamer and treated by boiling water for 20 min. The kernels were steamed in batches of 250 g, which allowed the kernels to form a layer no deeper than 1 cm in the steamer basket. After the NPS treatment, the kernels were kept at room temperature for 24 h for moisture equilibration. They were then put in an air oven at 33°C for 12 h.

AS treatments were implemented according to Zhang *et al.*'s report [7] and modified slightly. Using an autoclave, OR kernels were steamed at 121°C and 15 psi for 10 min. The samples were then exposed at room temperature for 24 h to allow moisture equilibration. They were then kept in an air oven at 33°C for 12 h.

HAR treatments were performed following Zhang *et al.*'s report [7]. Before the roasting treatment, OR kernels were tempered for 3 h to a moisture content of 20%. The tempered OR kernels were then roasted in a hot-air oven at 155°C for 30 min. Finally, the HAR-treated kernels were kept in an air oven at 33°C for 12 h, which caused the moisture content to drop to about 10%.

IR treatments were implemented using a BO-04 infrared instrument (Micronizing Company UK Ltd, Charnwood Mill, Framlingham, UK). Tempered OR

samples with a moisture content of 20% were infrared-roasted at 580°C for 18 s. After the IR treatment, the moisture content of the OR kernels was adjusted to about 10% by keeping the kernels in an air oven at 33°C for 12 h.

The starch content and viscosity properties of OR flour, as well as the β -glucan content, kernel lipid content, and peroxidase activities of the OR samples were tested according to AACC76-13, AACC76-22, AACC31-22, AACC30-10, and AACC22-80, respectively. The whiteness of the OR kernels, moreover, was determined using a Minolta CR310 chromo meter (Minolta Camera Co., Ltd. Japan).

The lipase activities of the kernels were determined according to Kwon and Rhee's reports [8]. Briefly, the OR kernels were powdered and defatted, and the resulting 0.5 g defatted oat powder was mixed with 98 μ L of triolein. The mixture was then added to 330 μ L buffer (0.05 mol·L⁻¹ Tris-HCl, pH 7.5, containing 1% v/v Triton X-100) and stirred to form oat dough. The dough was incubated at 37°C for 1 h, and after which 100 μ L 1 mol/L HCl was added to stop the incubation. HCl was then added immediately as a zero-time control. The dough was soaked and boiled in 5 mL isooctane extractant for 300 s to extract oleic acid, which was the product of triolein hydrolysis. The absorbance of the extract was then measured at 715 nm, and was further compared with the absorbance from an oleic acid standard. The resulting lipase activity was described in units of μ moles of oleic acid per hour per gram.

2.3. Statistical Analysis

The values were provided as means \pm standard deviation (SD). The statistical significance of the differences among the parameters was assessed using analysis of variance (ANOVA) by SAS software, and group means were considered to be significantly different at $P < 0.01$.

3. RESULTS AND DISCUSSION

3.1. Determination of the Optimal Peeling Time for the Production of OR Kernels

We found in our previous study that a 20 s peeling treatment could effectively reduce relative lipase activity to 66.5%, and that 20 s peeling treatments produced OR kernels with the highest lipid content (7.06%) [5]. One of the aims of the present study was to examine whether or not 20 s peeling treatments could avoid great nutritional loss in the levels of β -glucan, starch and protein. The present study paid special attention to the relationship between the peeling time and β -glucan content in OR kernels, because it is widely known that the cholesterol-lowering and anti-atherogenic activities of oat food

are attributed to β -glucan [9-11]. Oat β -glucan is not distributed evenly in the kernel outer layer. The β -glucan level in the aleurone layer is much higher than in the cortex of naked oat kernels [4]. For this reason, during peeling treatment, in order to avoid great β -glucan loss, the β -glucan-rich aleurone layer should not be damaged.

The Results showed that as the peeling time increased from 0 to 20 s, the β -glucan content in 100 gram OR kernels decreased gradually from 3.47 g to 2.91 g ($P < 0.01$); moreover, as the peeling time increased from 20 to 25 s, the β -glucan content decreased greatly from 3.47 g to 2.28 g ($P < 0.01$) (Table 1). Compared with the normal control group, a peeling time of 20 s caused 16.13% β -glucan loss, while a peeling time 25 s caused 34.29% β -glucan loss. The above results, therefore, indicate that peeling times should not exceed 20 s, otherwise the peeling treatments could damage the aleurone layer and result in OR kernels with very low β -glucan levels.

Starch and protein are also nutritionally important for oat food. The OR kernels receiving a 20 s peeling treatment demonstrated significantly higher starch content compared with normal kernels (63.3 g vs 57.0 g, $P < 0.01$) (Table 1). On the other hand, while the protein level in OR kernels exposed to a 20 s peeling treatment tended to be higher than normal control (16.02 g vs. 15.88 g), there was no significant difference ($P > 0.01$) (Table 1). In addition, the 20 s peeling treatment produced OR kernels with significantly higher kernel whiteness than the normal kernels (79.9 vs 77.0, $P < 0.01$). All the above results point to the conclusion that 20 s peeling treatments can efficiently reduce kernel lipase activity, avoid great β -glucan loss, and markedly

increase kernel whiteness, lipid levels and starch levels in OR kernels. In light of these results, we suggest that 20 s is the optimal peeling time for the production of OR kernels.

3.2. Effects of Steaming and Roasting on the Levels of β -Glucan, Lipid, Protein and starch in OR kernels

We previously reported that steaming and roasting treatments did not show significant effects on oat β -glucan and lipid levels in normal oat kernels [4]. In the current study, we tested the effects of the same steaming and roasting treatments on the levels of β -glucan, lipid, protein and starch in OR kernels. We did not find significant differences ($P > 0.01$) in the levels of β -glucan, lipid, protein and starch between any of the deactivation groups and the control group (Table 2).

This indicated that the steaming and roasting treatments did not cause significant nutritional loss in OR kernels.

3.3. Effects of Steaming and Roasting on the Lipase and Peroxidase Activities in OR Kernels

The present study demonstrated that NPS, AS and IR treatments exterminated lipase and peroxidase activities in VAO-2 OR kernels, while HAR treatments failed to exterminate lipase and peroxidase activities, leaving 19.8 $\mu\text{-mol}\cdot\text{g}^{-1}\cdot\text{h}^{-1}$ lipase activity and detectable peroxidase activity in VAO-2 OR kernels (Table 2). The results also indicated that IR, NPS, and AS treatments were effective

Table 1. Starch level, protein level, β -glucan level and whiteness of OR kernels with different peeling time.

No.	Peeling time (s)	β -glucan level (g)	Starch level (g)	Protein level (g)	Whiteness
1	0	3.47 \pm 0.16a	57.0 \pm 1.2b	15.88 \pm 0.26a	77.0 \pm 2.8c
2	5	3.53 \pm 0.13a	60.6 \pm 1.7ab	16.08 \pm 0.19a	78.7 \pm 3.5b
3	10	3.24 \pm 0.08b	61.7 \pm 0.8ab	15.96 \pm 0.35a	79.6 \pm 3.3ab
4	15	2.90 \pm 0.10c	63.7 \pm 2.0a	15.93 \pm 0.14a	79.5 \pm 3.8ab
5	20	2.91 \pm 0.32c	63.3 \pm 1.1a	16.02 \pm 0.26a	79.9 \pm 2.8ab
6	25	2.28 \pm 0.25f	63.2 \pm 1.5a	16.02 \pm 0.18a	79.9 \pm 3.0ab
7	30	2.31 \pm 0.09f	63.6 \pm 0.5a	15.82 \pm 0.41a	80.7 \pm 3.1a
8	35	3.02 \pm 0.33c	62.8 \pm 3.0a	15.86 \pm 0.30a	80.4 \pm 4.1a
9	40	2.57 \pm 0.27e	63.0 \pm 1.3a	15.99 \pm 0.25a	80.8 \pm 2.9a
10	45	2.78 \pm 0.08d	65.1 \pm 0.9a	16.00 \pm 0.18a	80.8 \pm 3.1a

Note: values in a column followed by different letters were significantly different at $P < 0.01$. The results of the levels of β -glucan, starch, and protein were presented as β -glucan, starch, and protein contents in grams per 100 grams OR kernels.

Table 2. Nutritional components and enzyme activities in OR kernels with or without deactivation treatments.

Treatments	β -glucan level (g)	Lipid Level (g)	Starch level (g)	Protein level (g)	Lipase activity ($\mu\text{-mol}\cdot\text{g}^{-1}\cdot\text{h}^{-1}$)
Control	3.52 \pm 0.39a	6.60 \pm 0.07a	68.1 \pm 2.2a	16.15 \pm 0.09a	188.0 \pm 1.8a
NPS	2.72 \pm 0.33a	6.31 \pm 0.11a	62.7 \pm 0.5a	15.94 \pm 0.32a	0
AS	3.33 \pm 0.21a	6.81 \pm 0.10a	60.7 \pm 1.4a	15.92 \pm 0.17a	0
HAR	2.91 \pm 0.32a	7.20 \pm 0.19a	66.8 \pm 1.5a	16.11 \pm 0.13a	19.8 \pm 1.4b
IR	3.16 \pm 0.29a	6.85 \pm 0.09a	66.1 \pm 1.2a	16.38 \pm 0.25a	0

Note: values in a column followed by different letters were significantly different at $P < 0.01$. The results of the levels of β -glucan, lipid, starch, and protein were presented as β -glucan, lipid, starch, and protein contents in grams per 100 grams OR kernels. The results of lipase activity were described in units of μ moles of oleic acid per hour per gram ($\mu\text{-mol}\cdot\text{g}^{-1}\cdot\text{h}^{-1}$).

methods for the enzyme deactivation of VAO-2 OR kernels. What should be mentioned here is that the effects of IR treatments on normal kernels and OR kernels of different oat varieties were variable. We previously found that IR treatments could exterminate the lipase and peroxidase activities in VAO-2 naked oat kernels [4]. We found in the present study that the VAO-2 OR kernels exposed to 20 s peeling treatments also showed zero lipase and peroxidase activities after the same IR treatments. Interestingly, the data in our lab from VAO-3 and VAO-10, another two Canadian naked oat varieties, showed that IR treatments (18 s) exterminated lipase and peroxidase activities in peeled kernels (unpublished data). However, IR treatments (18 s) could not completely deactivate the enzyme activities in VAO-3 and VAO-10 normal kernels, with 4 and 14 $\mu\text{mol}\cdot\text{g}^{-1}\cdot\text{h}^{-1}$ lipase activities remained respectively [4]. The results therefore implied that, for some, though not all, oat varieties, peeling pretreatments are essential to the successful enzyme deactivation of subsequent IR treatments.

3.4. Effects of Steaming and Roasting on the Pasting Properties of OR Flour

We also examined the effects of steaming and roasting treatments on the flour pasting properties of OR kernels, because these properties are important for the processing functionality of OR foods. The results showed that the peak viscosity and final viscosity of the OR kernels tested were 281.2 and 606.2 RVU respectively (**Table 1**), and that the levels were significantly higher ($P < 0.01$) than those of the normal kernels tested (240.9 and 466.7 RVU, respectively). There were two possible reasons for the significant differences between the normal kernels and the OR kernels. The first was higher starch levels could have caused higher peak and final viscosities. The second was that the significant differences ($P < 0.01$) in the β -glucan level between the OR kernels and normal kernels could have resulted in the differences in the pasting behaviors between the two kernels. Some have reported that the level of β -glucan seems to affect the

pasting behaviours of flour and starch in cereals. Symons and Brennan (2004) [12] reported that a substitution of 5% wheat starch with barley β -glucan decreased peak viscosity, final viscosity, and breakdown values in comparison to the control starch ($P < 0.05$). Yoo and Lee (2007) [13] reported that the incorporation of β -glucan into wheat flour and starch significantly decreased peak and final viscosities.

Our previous study showed that steaming and roasting treatments improved the starch gelatinization properties in normal kernels [4]. The current study demonstrated that the same steaming and roasting treatments significantly decreased the final viscosity and setback values in comparison to the control group ($P < 0.01$) (**Table 3**). It is believed that heat moisture treatments can increase the content of resistant starch, and that the final viscosity of cereal flour can be significantly reduced by adding resistant starch to the flour [14,15]. We therefore suggest that the roles of steaming and roasting treatments on the level of resistant starch in both OR and normal kernels should be studied.

3.5. The Effects of Steaming and Roasting on the Whiteness of OR Kernels

In China, OR kernels are mixed with rice kernels and consumed together as food. OR kernels with higher whiteness are closer to the color of rice kernels, and can thus provide the products with a better appearance. In the current research, the whiteness of the OR kernels were significantly higher than that of the normal oat kernels. The steaming and roasting treatments did not demonstrate significant effects on the whiteness of the OR kernels compared with the control group ($P > 0.01$).

4. CONCLUSIONS

20 s was suggested as the optimal treatment time for the production of OR kernels, because it was posited that 20 s peeling treatments could significantly reduce kernel lipase activity, avoid great β -glucan loss, and increase

Table 3. Peak viscosity, trough viscosity, breakdown, final viscosity, setback and whiteness of oat rice kernels with or without deactivation treatment.

Treatments	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Whiteness
Control	281.2 \pm 1.7c	192.5 \pm 1.5c	88.6 \pm 1.6a	606.2 \pm 4.4a	413.6 \pm 3.7a	83.1 \pm 3.5a
NPS	322.8 \pm 3.4a	254.9 \pm 4.3a	67.9 \pm 2.3b	458.8 \pm 4.6d	204.0 \pm 2.5d	83.1 \pm 3.0a
AS	287.4 \pm 1.3bc	225.3 \pm 1.5b	62.1 \pm 3.1b	439.2 \pm 0.9d	213.9 \pm 2.8d	76.6 \pm 3.3a
HAR	277.2 \pm 1.8c	195.1 \pm 1.0c	82.0 \pm 3.6a	491.2 \pm 1.1c	296.1 \pm 2.9c	81.9 \pm 2.7a
IR	304.8 \pm 1.8ab	225.5 \pm 1.2b	79.3 \pm 4.3a	536.2 \pm 4.0b	310.7 \pm 3.7b	82.2 \pm 3.6a

Note: values in a column followed by different letters were significantly different at $P < 0.01$.

kernel whiteness, lipid levels, and starch levels in OR kernels. The steaming and roasting treatments did not cause nutritional loss to OR kernels in terms of the levels of β -glucan, lipid, protein or starch. In addition, it was found that the IR treatments could exterminate the lipase and peroxidase activities and significantly reduced the final viscosity and setback value of OR kernels.

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