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Effect of kilning and milling on the dough-making properties of oat flour

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ABSTRACT

Oats are mostly used for porridges, flakes, and cereal breakfast. The current oat kilning and milling methods are suited for these purposes. Bread-making applications have been explored, but the bread quality results are far from optimal. The goals of this study were to determine whether infrared (IR) and steam kilning may impact dough rheology, and to assess if particle size distribution and bran content could impact dough properties. IR kilning had a negative effect on the dough-making properties of oat grains, resulting in a very stiff and short dough, while steam-kilned dough did not change the dough-making properties. Oat meal also resulted in a stiff and short dough, and re-milling did not change this pattern. In contrast, removing all the bran from the oat meal improved dough-making properties. Dough rheology was negatively impacted by the bran, and this effect was larger for large and medium size bran than for fine bran. This was attributed to their high content of beta-glucans. In conclusion, current kilning and milling methods are not suitable for bread-making purposes and these treatments must be optimized. Whole grain oat meal is not a proper material for bread applications in the absence of fractionation.

1. Introduction

The most common uses of oats are related to porridges, flakes and meal, and the current technology is adapted to fit these uses. There is an increasing demand for gluten-free products and oats are considered an interesting alternative because it contains healthy compounds that can supplement the diet (Andon & Anderson, 2008; Gilissen et al. 2012; Gilissen, Van der Meer, & Smulders, 2014), and it has generally been accepted that celiac disease patients can consume oats without detrimental inflammation of the small intestine (Hardy et al., 2015; Janatuinen, Kemppainen, & Julkunen, 2002; Kaukinen, Collin, Huhtala, & Mäki, 2013; Londono et al. 2013; Pulido et al., 2009).

Kilning and milling are two important steps of oat processing that can influence the quality of the grains, affecting their potential use for new applications, e.g., bread-making. Oats contain high lipid and beta-glucan contents in comparison to other cereals, and these compounds represent a challenge during storage and food processing because they can have adverse effects on the sensory properties of grains and of end products. Oxidation of lipids can cause a rancid taste (Lehtinen & Kaukovirta-Norja, 2011), while beta-glucans affect food texture and mouth feeling due to their high viscosity. Therefore, special attention should be given to storage and processing of oats in comparison to other cereals.

Lipid oxidation occurs through the action of lipase enzymes. Lipase activity in oats is exceptionally high (O'Connor, Perry, & Harwood, 1992), which, in combination with the high lipid content, makes the stability of oat lipid a major challenge for the oat-processing industry. Lipolysis produces a rancid taste, and it generally begins when the grains are milled, although it may also start after the dehulling (Peltonen-Sainio, Kontturi, Rajala, & Kirkkari, 2004). The lipase activity is localized mainly in the bran

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fraction, thus pearling of the outer grain layers is an alternative to preserve the sensory quality of the starchy endosperm flour (Hu, Wei, Ren, & Zhao, 2009), although the endosperm also presents some activity that needs to be neutralized. The inactivation of lipases is known as kilning. In the kilning process the dehulled grains undergo a heat treatment in which the heat must reach the outer bran layers of the grains, where enzymes are most active, as well as the inner endosperm layers (Lehtinen, Kiiliäinen, Lehtomäki, & Laakso, 2003). The heat treatment is also beneficial for the taste of oats (Klensporf & Jeleń, 2008). The heat treatment can be performed dry or with steam (Head, Cenkowski, Arntfield, & Henderson, 2011), the latter being the most popular. The higher water content makes steaming more effective in wiping out enzyme activity (Gates, Sontag-Strohm, Stoddard, Dobraszczyk, & Salovaara, 2008). Recently some millers have adopted the infrared (IR) technology for dry kilning because it enables treating larger amounts of grains in a shorter time. Both methods are applied without taking into account the food application for which the grains are intended.

Milling takes place after kilning of the grains. The purpose of grain milling is to produce flour or meal. The most common oat material used for baking applications is whole grain oat meal, which includes the bran fraction and, consequently, the beta-glucans that are mainly present in the bran. It has been shown that the viscosity of beta-glucans may impact negatively dough rheology when present at high concentrations (ca. 5 g/100 g, Londono, Gilissen, Visser, Smulders, & Hamer, 2015). It is known that the texture of the resulting material (flour or meal) is important for bread applications, but also the composition (Londono et al. 2015).

Wheat is the most used cereal for bread applications. Wheat does not need kilning treatment for enzyme stabilization, only drying to lower the moisture level and allow long-term storage, but milling and fractionation are key processing factors that influence wheat baking quality. In wheat it is known that heating can destroy gluten-forming properties (Schofield, Bottomley, Timms, & Booth, 1983), which may be due to sulfydryl groups being oxidized to disulfide bonds (Weegels, De Groot, Verhoek, & Hamer, 1994). For oats, Gates, Dobraszczyk, Stoddard, Sontag-Strohm, and Salovaara (2008) found that mild steam treatments yielded softer oat groats, but it is unknown whether the current kilning and milling methods may impact negatively the dough making properties of the grains.

Here we studied whether the kilning methods currently used (steam and IR kilning) as well as milling and fractionation can affect the dough extensibility properties of oat grains. The results provide information for future standardization specifically for bread applications.

2. Materials and methods

2.1. Materials

We tested the effect of steam and IR kilning methods and of particle size distribution on dough extensibility properties of oat flour. For the kilning experiments we used oat grains from the husked cultivar Gigant, harvested in 2010 and provided by a commercial miller (De Halm, The Netherlands). The grains had been already dehulled by the miller and were stored at 4 °C before milling.

For the fractionation experiments we used commercial oat meal (De Vlijt, The Netherlands). It was stored at 4 °C until use. Vital gluten (Cargill, The Netherlands) and salt (Merck) were used to prepare the dough according to Londono, Smulders, Visser, Gilissen, and Hamer (2014). The composition (as is) of oat meal was 12.5 g/100 g protein (determined using AACC Method 46–30.01; AACC International. 2000), 5.54 g/100 g beta-glucan (AACC Method 32–23.01), 62 g/100 g starch (AACC Method 76–13.01), and 7 g/100 g moisture.

2.2. Kilning treatment

The oat grains were treated following two procedures that are normally used to inactivate lipase activity: steam kilning and infrared (IR) kilning. Untreated grains were used as control. We did not test the efficiency of these methods to inactivate the enzyme, because both are used routinely and known to be effective to prevent lipid oxidation.

The steam kilning treatment was performed in a 0.5 m^3 steel container as described by Londono et al. (2014). First, a grain layer of three cm (2 kg) was placed in the container and steamed for 3 min at 100 °C. Then, the grains were placed in a drying oven at 80 °C overnight for tempering.

The IR kilning was performed following the protocol used by the miller that provided the grains (De Halm, The Netherlands) in a custom-made IR device. First, the grains were placed in a Vibronet (Nebraska, USA) at 17–19 g/100 g moisture for 1 h. Then, the grains were placed on a belt to be heated by eleven IR high-pressure burners (HOAF, The Netherlands) for about 15 s. Finally, the grains were stored in a tempering bunker for 15–20 min.

2.3. Flours

For the experiment about the effect of kilning on dough rheology, flour was prepared from the grains of cultivar Gigant by milling at 8000 rpm using a laboratory pin mill (Hosokawa Alpine D-86199, Augsburg). The resulting material was fractionated using a series of sieves of 0.50, 0.30, and 0.25 mm mesh size that were placed on a Retch AS200 sieving machine for 10 min. Only the fraction that passed through the 0.250 mm sieve was used for the experiments using the standard method developed by Londono et al. (2014). The moisture content of the IR kilned grains before milling was 9 g/100 g and the moisture contents of steamed and untreated grains were 13 and 12 g/100 g, respectively. The moisture content of all the flours was about 11 g/100 g.

2.4. Particle size distribution

We used two approaches to study the effect of particle size distribution on dough properties of oat flour. In the first approach we re-milled commercial oat whole meal using a laboratory mill (Hosokawa Alpine D-86199, Augsburg) at maximum speed (16,000 rpm), to reduce the particle size of the material. The particle size distribution was characterized by sieving the materials using a series of sieves of 0.50, 0.30, and 0.25 mm placed on a sieving machine (Retch AS200) for 10 min. The particle size distribution of oat meal and re-milled oat meal is shown in Table 1.

In the second approach we fractionated the oat meal into bran and fine flour using a series of sieves (0.50, 0.30, and 0.25 mm). The particle size of the fine flour was <0.25 mm. This was used as the oat flour base for the experiments. Then, the bran fraction (0.50 and

Table 1
Particle size distribution of oat meal and re-milled oat meal.

Sieved fraction	Oat meal[a] (g/100 g)	Re-milled oat meal[b] (g/100 g)
>0.50 mm	45	27
0.25–0.50 mm	15	15
<0.25	32	52
Total recovered	92	93

[a] The particle size as it came from the shop.
[b] Re-milled at 16,000 rpm.