Effect of Kiln Drying on Falling Number of Oats

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ABSTRACT

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The suitability of the falling number method for oats was studied using samples of oat groats, oat bran, oat endosperm flour, and rolled oats. Sample sizes of 4.5–8 g were tested. The results showed that a standard 7-g sample falling number determination would be suitable for oats, the falling number of samples varying from 328 to 721 sec. Due to high gelatinization temperature of oat starch, falling number values <300 sec showed greater variation than those >300 sec. Oat groat samples from two separate kiln drying processes showed that kiln drying increased the falling number values by 30–89%. The falling number determination is a potential tool for estimating the adequacy of kiln drying of oats. However, further modifications of the method should be developed to better consider the pasting properties of oat starch.

Gelatinization properties, measured either as consistency in a rotating or oscillating system or by differential scanning calorimetry, are often reported when properties of oats or oat starch are discussed (Oomah 1987, Mahnke et al 1989, Wikström et al 1991, Raheem 1995, Doehlert et al 1997, Zhou et al 1998). Some oat mills consider high viscograph peak consistency of kiln-dried oats to guarantee sufficient inactivation of enzymes, thus ensuring good keeping properties in the final product.

Although widely used for the quality control of wheat and rye, the falling number determination of oats has only been reported by Raheem (1995), who found the method not suitable for consistency measurements of oat bran due to wide variation of results. In that study, Raheem (1995) used small sample weights (5.0–6.5 g), because unusually high falling number values were obtained at the 7-g sample level.

The falling number method measures the liquefaction of gelatinized starch in a boiling water bath. During the 60-sec incubation and stirring, the temperature in the test tube rises to 80°C, which is enough to inactivate α-amylase and completely gelatinize wheat flour starch (Perten 1990). However, oat starch has started gelatinizing, measured as an increase in consistency, only at temperatures >80°C (Wang and White 1994, Mua and Jackson 1995). Consistency peaks of oat samples at >90°C have been reported by Wang and White (1994) and Doehlert et al (1997).

The purpose of this study was to examine the suitability of the falling number determination for oats. The effect of kiln drying on falling number of oats was studied with special reference to falling number as a potential indicator of the sufficiency of the heat treatment.

MATERIALS AND METHODS

Samples from commercial oat mills were kindly provided by Melia Ltd. (Raisio, Finland). Samples of untreated oat groats, kiln-dried oat groats, oat bran, oat endosperm flour, and instant rolled oats were obtained from the Raisio plant. Samples of untreated oat groats, kiln-dried oat groats, and rolled oats were obtained from the Nokia plant. All samples, except for the untreated oat groats, had been kiln-dried in the mill. Four additional oat groat samples, before and after kiln drying, were obtained from the plants to study the effect of two separate kiln drying processes.

Oat samples were ground with a falling number mill to pass through a 0.8-mm sieve, except for oat endosperm flour, which was used as is. Ash, fat, and moisture content of the samples were determined according to Approved Methods 08-02, 30-10, and 44-15A, respectively (AACC 1995). Protein content was determined as N × 6.25 using the standard Kjeldahl method. The composition of the samples is presented in Table I.

Falling number was determined according to the ICC Standard 107/1 (1995) using a Falling Number 1600 apparatus. The effect of sample size was studied by weighing samples from 8.0 g (14% moisture basis) downward, with 0.1-g intervals until a falling number of 62 sec was obtained. To get information about the applicability of the method at different sample weight levels, the measurement was not repeated, although the duplicate results differed by >5% of the mean value, which is the accepted tolerance determined in the standard.

The temperature of the slurry inside the falling number test tube was measured by replacing the arm of the plunger with a metal tube (4 mm, o.d.) and inserting a thermocouple into the tip of the tube. Temperature was recorded at 10-sec intervals during the falling number measurement. The temperature of a reference sample containing 7 + 25 g of water was recorded correspondingly.

Viscograph pasting properties were determined using a Brabender Viskograph-E according to the ICC-Standard 126/1 (1992), except that a 40-g sample (14% moisture basis) was used.

All determinations were done in duplicate and results are presented as mean values.

RESULTS AND DISCUSSION

The falling numbers of oat milling fractions from Raisio and Nokia plants as a function of sample weight are presented in Fig. 1. In 49 of the 243 duplicate measurements, results differed by >5% of the mean value. In most of the cases (34 of 49), falling number was <300 sec. This indicates that starch gelatinization is incomplete and inconsistent during the first 5 min of the measurement. If the starch content of the slurry is not high enough to produce thick consistency at this stage, the plunger falls unevenly and the variation of the results increases.

TABLE I
Composition of Oat Samples, % db

	Protein	Ash	Fat
Raisio			
Oat groats	15.8	2.2	7.9
Kiln-dried oat groats	15.8	2.2	7.8
Oat bran	17.8	2.9	8.2
Oat endosperm flour	11.1	1.1	6.8
Instant rolled oats	16.0	2.1	8.0
Nokia			
Oat groats	17.8	2.2	8.3
Kiln-dried oat groats	17.7	2.1	8.3
Rolled oats	17.2	2.1	8.5

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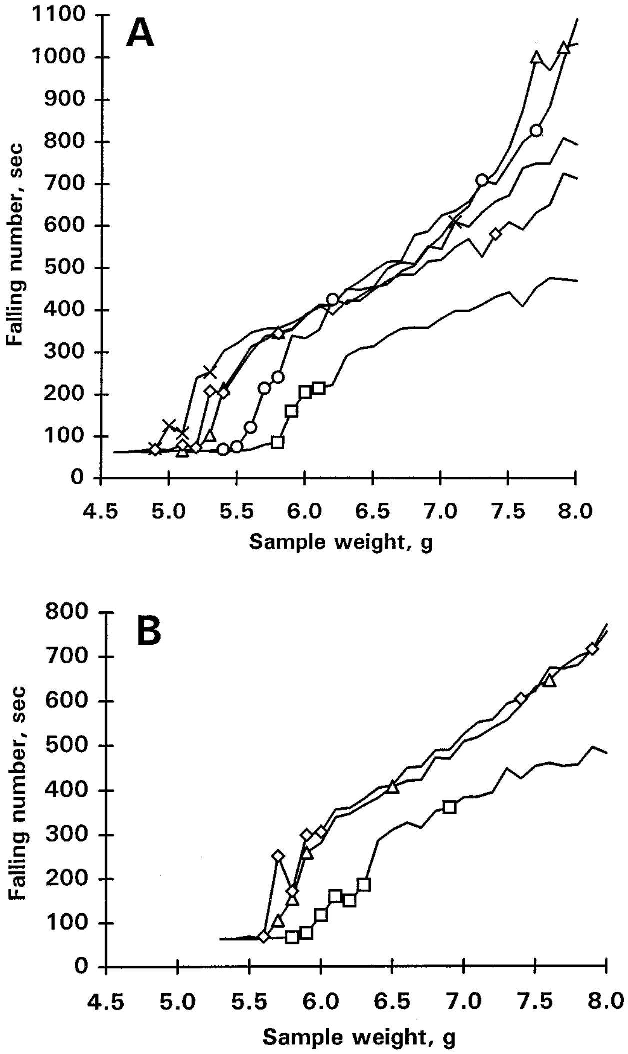

Fig. 1. Falling number of oats and oat products as function of sample weight. **A,** Raisio plant; **B,** Nokia plant. □ = Untreated oat groats, Δ = kiln-dried oat groats, ◇ = rolled oats, ○ = oat bran, and × = oat endosperm flour. Markers show points where duplicate determinations differed by >5% from mean value.

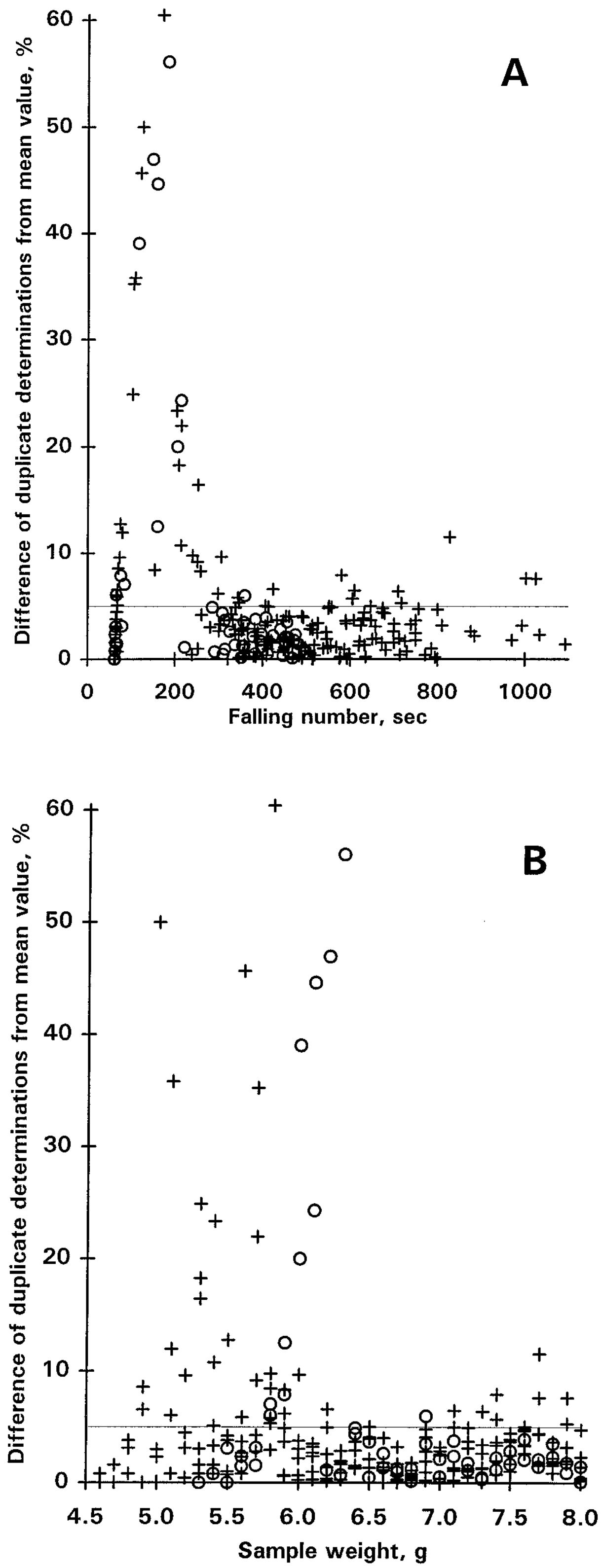

Fig. 2. Difference of duplicate falling number determinations of oat groats as function of falling number **(A)** and sample weight **(B)**. ○ = Untreated oat groats, + = kiln-dried oat samples.

The inconsistency of falling number values <300 sec can be seen in Fig. 2A, where difference of duplicate determinations from the mean value as a function of falling number is presented. The samples showed marked variation during the first 5 min (FN <300 sec) of the determination. Between falling numbers 300 and 600 sec, the variation was small, and only seven determinations of 125 exceeded the 5% tolerance. Unlike the wheat application, where falling number >400 sec is considered meaningless due to low enzyme activity, the falling number of oats appears most meaningful at values considerably higher than those for wheat and rye.

At >600 sec, the variation increased again, with eight samples out of 48 exceeding the 5% tolerance. Differences between duplicate determinations from the mean value are presented as a function of sample size in Fig. 2B. The variation was smallest at sample sizes ≥6.4 g, with only 11 determinations of 136 exceeding the accepted tolerance, as compared with 38 of 107 determinations at sample size <6.4 g. The greater variation at sample sizes <6.4 g is the result of insufficient consistency due to low concentration of gel forming compounds, mainly starch, and too low temperature for complete gelatinization of starch. Similar results were also reported by Raheem (1995).

Figure 3 shows the temperature inside the tube during falling number determination of oats as compared with temperature of a corresponding amount of water. During the first 60 sec (5 sec of heating + 55 sec of stirring), the temperature of the oat-water slurry rose to 72°C. However, the viscograph curves (Fig. 4) and pasting properties (Table II) show that the consistency of all oat samples still increased above that temperature, and the maximum

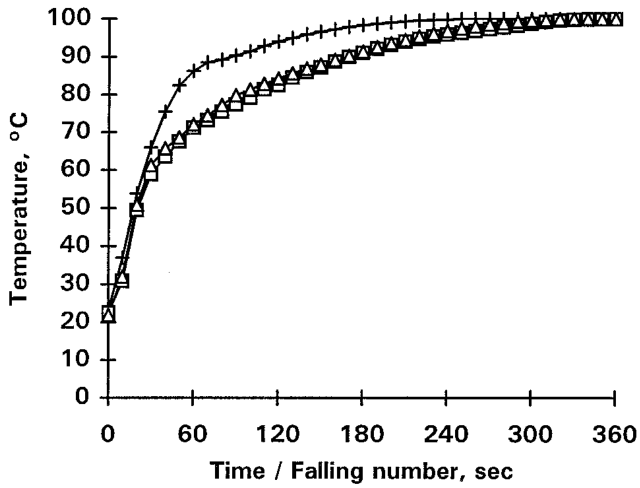

Fig. 3. Temperature inside the falling number tube containing water (+) and oat-water suspension (□ = untreated oat groats, Δ = kiln-dried oat groats).

TABLE II
Pasting Properties of Oat Samples

	Pasting Temperature[a] (°C)	Peak Consistency (BU)	Peak Temperature (°C)
Raisio			
Oat groats	87	326	95
Kiln-dried oat groats	58	580	91
Oat bran	55	586	92
Oat endosperm flour	81	419	92
Instant rolled oats	46	586	90
Nokia			
Oat groats	88	265	95
Kiln-dried oat groats	75	411	92
Rolled oats	53	485	93

[a] Temperature at baseline + 10 BU (Brabender units).

TABLE III
Falling Number (sec) of Oat Samples from Raisio and Nokia Plants

	Untreated	Kiln-Dried	Increase (%)
Groats			
Raisio 1	379	625	65
Raisio 2	332	628	89
Raisio 3	328	500	52
Nokia 1	383	509	30
Nokia 2	399	721	81
Nokia 3	372	586	58
Other samples			
Raisio			
Rolled oats		519	
Oat bran		576	
Oat endosperm flour		545	
Nokia			
Rolled oats		525	

consistency was reached only after reaching 90°C. Corresponding results by Wang and White (1994) and Doehlert et al (1997) imply that the incubation and stirring time of the falling number measurement should be increased in oat applications.

The temperature in the tube containing oat-water slurry rose more slowly than in the tube containing water (Fig. 3). This was due to better heat transfer in pure water than in a dispersion that also contained air bubbles after vigorous stirring. Part of the heat energy is also needed for gelatinization of starch, but this could not be seen in the curve. The temperature of untreated and kiln-dried oats slurries rose similarly, even though the pasting curves

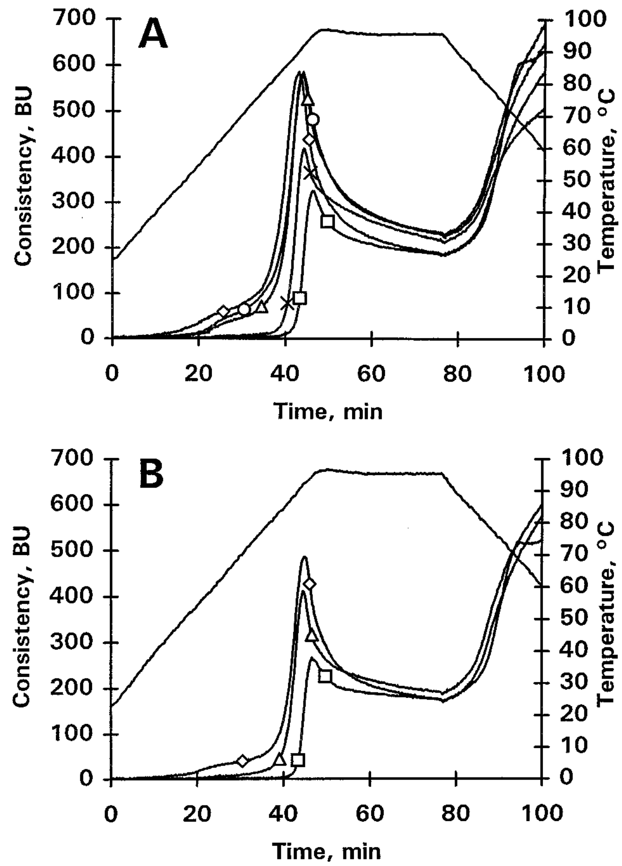

Fig. 4. Viscograms of oats and oat products. **A,** Raisio plant, **B,** Nokia plant. □ = Untreated oat groats, Δ = kiln-dried oat groats, ◇ = rolled oats, ○ = oat bran, and × = oat endosperm flour.

presented in Fig. 4 indicated different stages of gelatinization, measured as consistency, at 60–95°C.

In Table III, falling numbers (7 g) of the samples as well as four additional oat groat samples, before and after industrial kiln drying, are presented. Kiln drying increased falling number values markedly, however the increase varied considerably (30–89%). A corresponding increase in consistency was also recorded in viscograph peak consistency values ($r = 0.86$). The results support those reported by Hoover and Vasanthan (1994), who showed that hydrothermal treatment of starch (30% moisture, 100°C, 16 hr) markedly increased apparent viscosity of gelatinized oat starch paste.

Kiln drying inactivates lipid-degrading enzymes and other enzymes including amylases, and thus increases consistency by reducing enzymatic degradation of starch in the gelatinizing flour paste during falling number and viscograph determinations. Inactivation of endo-β-glucanases during kiln drying may also play an important role in the consistency of gelatinizing oat pastes because steaming of oat grain increased intrinsic viscosity of flour slurries (Doehlert et al 1997). Zhang et al (1998) further suggested that heat treatment of oat grain affects physical properties of the β-glucan polymer such as molecular conformation and thus increases the intrinsic viscosity of oat β-glucans after steaming.

CONCLUSIONS

The standard determinations of falling number according to ICC or AACC methods can be used for oats. However, higher falling number values are obtained for oats than for wheat and rye due to high gelatinization temperature and consistency of oat starch. Modification of the method by increasing the incubation and stirring time until the oat starch is properly gelatinized could be justified because of high gelatinization temperature of oat starch.

Furthermore, increased stirring time results in faster falling of the plunger and lower falling number values (results not shown).

In this study, falling number values between 300 and 600 sec gave most reliable results. The 7-g sample falling number of untreated oat groats varied between 328 and 399 sec, and that of kiln-dried samples from 500 to 721 sec, which can be considered high when compared with wheat and rye.

Sufficiency of kiln drying can be estimated by determining falling number before and after the heat treatment. Inactivation of lipid-degrading enzymes and good keeping quality of milled oat products was obtained when the increase of falling number was >30%.

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