Correction Equation Development for Falling Number Values from Ground Wheat Meals

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ABSTRACT

The effect of altitude on falling number (FN) values was studied with 18 ground hard wheat meals (protein = 14.4–19.9%) varying in sea level FN values. Experiments were conducted at sea level, 2,000, 4,000, 6,000, 8,000, and 10,000 ft of elevation. As elevation increased, FN values increased because of the lower boiling point of water at reduced atmospheric pressures. An equation was developed that permits calculation of sea level FN value from any FN value obtained at a different altitude. Results of a collaborative ringtest study with 10 laboratories in various countries indicated that the correction equation produces reliable sea level FN values when used at elevations above 2,000 ft.

The falling number (FN) method is based on α-amylase activity on starch in grains and flours. The FN is measured as time in seconds for a stirrer to fall a measured distance through a hot starch suspension. The FN is an approved method of the AACC (1983). Methodology was approved in 1972 by AACC, and revised in 1982 to incorporate a correction formula developed by Lorenz and Wolt (1981) for use with flours. The latest revision, approved by AACC in 1992, incorporates a correction formula for use with wheat meals.

The FN determination is used widely in the baking and milling industries to determine quality of wheats and flours. It is applicable to wheat, rye, barley, other grains, and malted cereals (AACC 1983). The International Association for Cereal Science and Technology has adopted the FN method as a test for determining sprout damage (Method 107). It is used in European countries for this purpose, as well as a general index of grain quality (Perten 1967).

This study was conducted to determine the effects of altitude or reduced atmospheric pressure on FN values for ground wheat meals. It was used as the basis for the latest revision of AACC method 56-81B.

MATERIALS AND METHODS

Sample Preparation

A total of 18 ground hard wheat meals, varying in sea level FN values, were obtained from commercial mills. Six 10-kg samples each of spring wheat, winter wheat, and durum wheat were passed through a mechanical divider. One-third of each was collected for further preparation. The remaining two-thirds was retained by Perten Instruments North America, Inc. (Reno, NV) for reference purposes. Approximately 3 kg of each sample were ground in a Falling Number Laboratory mill 3100 equipped with an 0.8-mm screen (Perten Instruments North America, Inc.). Each ground sample was thoroughly mixed. Sample aliquots were placed in 4-oz seamless tins for distribution to test sites. Remaining ground samples were retained in 1-gal sealed containers.

Proximate Composition

Standard AACC methods (AACC 1983) were used to determine moisture (44-15A), nitrogen (46-11A), fat (30-10), and ash (08-01) to characterize the ground wheat meals used in the study. Values were converted to a dry weight basis.

Equation Development

FN values were determined in duplicate per analysis with a type 1600 Falling Number apparatus using AACC method 56-81B. Deionized water was used in the water bath. The temperature of the water bath was not adjusted for FN measurements at the various altitudes.

Experiments were conducted in a special high-altitude laboratory that permits adjustments of atmospheric pressure to simulate any altitude between sea level and 10,000 ft of elevation. Ambient temperature and relative humidity were used for data collection. Determinations were made at atmospheric pressures equivalent to sea level and to 2,000, 4,000, 6,000, 8,000, and 10,000 ft of elevation.

Data were replicated five times on duplicate samples for determination of the correction formula. Data were evaluated statistically using analysis of variance procedure and multiple regression through the origin (SAS 1985). Regression equations were developed to permit calculation of sea level log FN values from FN values obtained at any elevation.

Ringtest for Equation Validation

Ten additional ground wheat meal samples also were sent for analysis to 10 laboratories worldwide, located at different altitudes and representing academia, government, and industry. Uncorrected FN values reported by these laboratories were converted to sea level FN values using the equation to test its reliability. Four replications on duplicate samples were used in the worldwide ringtest.

RESULTS AND DISCUSSION

Proximate composition of ground wheat meals used in developing the FN correction formula is presented in Table I. Protein content of the 18 ground hard wheat meals ranged from 14.4 to 19.9%. Samples were 1.2–1.8% fat and 2.1–3.2% ash.

FN mean values of ground spring, winter, and durum wheat meals determined at six different elevations under simulated conditions in the high-altitude laboratory at Colorado State University are given in Table II. All FN values increased as simulated elevation increased, as noted in earlier work on hard wheat flours by Lorenz and Wolt (1981) and Perten (1967). This was expected, because the boiling point of water is a function of the atmospheric pressure and, therefore, is dependent upon the altitude at which the measurement is made. This affects temperatures that can be reached during the test by the FN water bath and the suspension. Consequently, the temperature of gelatinization of starch and α- amylase activity is also affected, because temperature of the wheat meal suspension depends on the temperature

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of the water bath. Wheat meal suspension temperature will always be lower than that of the water bath, because there is inadequate time for the wheat meal time to reach the temperature of the water bath (Perten 1964). However, the wheat meal suspension reaches the critical temperature range for α-amylase activity. Reed and Thorn (1971) reported optimum wheat α-amylase activity occurs at 60–66° C. The higher the temperature of the water bath and that of the wheat meal suspension, the sooner the optimal temperature for α-amylase activity during stirring is reached.

Standard errors of FN values partitioned by altitude are reported in Table III. Standard errors were greatest at the highest altitude.

Between sea level and 2,000 ft of elevation, increases in FN values were small with a mean increase for all wheat meals of 8.8% (Table II). Increases between FN values at sea level and 4,000 ft. averaged 19.8%. Additional analyses from data obtained from laboratories located at different altitudes were conducted to determine the elevation at which a correction equation should be applied.

Equation Development

An equation was developed through regression analysis to calculate a sea level FN value for wheat meal from any FN value obtained at a different elevation about 2,000 ft. The correction equation to determine the log of the sea level Falling Number (FN_{Sl}) is:

$$\begin{aligned}\log_{10} FN_{Sl} &= 1.0 \text{ x } \log_{10} (FN_{alt}) \\ &- (1.63093 \times 10^{-4} \times \text{elevation}) \\ &+ (2.63576 \times 10^{-8} \times \text{elevation}^2) \\ &+ [5.75030 \times 10^{-5} \times \log_{10} (FN_{alt}) \times \text{elevation}] \\ &- [1.06922 \times 10^{-8} \times \log_{10} (FN_{alt}) \times \text{elevation}^2]\end{aligned}$$

TABLE I
Proximate Composition[a] of Ground Wheat Meal Samples Used to Establish Correction Equation

Meal Sample	% Protein	% Fat	% Ash
Hard Red Spring Wheat			
1	17.0	1.6	2.6
2	19.9	1.5	2.6
3	16.7	1.3	2.6
4	18.3	1.3	2.7
5	16.9	1.6	2.6
6	16.7	1.6	2.8
Winter hard wheat			
7	14.7	1.5	3.1
8	14.4	1.4	3.0
9	14.7	1.3	2.8
10	14.8	1.4	2.8
11	14.6	1.2	2.9
12	14.5	1.2	2.9
Durum wheat			
13	15.8	1.7	2.2
14	16.4	1.7	3.2
15	16.2	1.4	2.1
16	16.3	1.7	2.6
17	16.6	1.8	2.5
18	16.1	1.6	2.2

[a]Dry weight basis.

TABLE II
Falling Number (FN) Mean Values[a] of Ground Wheat Meals at Different Elevations

	FN Mean Values at					
Meal	[b]0 [c]758.5 [d]100.0	2,000 706.6 98.0	4,000 656.2 96.1	6,000 611.7 93.9	8,000 565.8 92.0	10,000 526.4 89.9
1	273	295	326	352	413	482
2	146	164	185	215	242	270
3	348	370	396	446	573	912
4	208	222	246	282	313	337
5	299	337	359	388	492	654
6	344	353	394	444	611	942
7	259	283	314	350	407	467
8	375	401	435	528	757	1,502
9	215	236	258	300	340	366
10	146	163	184	199	232	246
11	191	210	234	266	301	337
12	318	356	388	432	572	838
13	343	375	404	464	650	1,345
14	211	227	262	285	321	342
15	372	412	439	525	745	1,533
16	247	269	301	327	378	418
17	173	185	212	248	271	291
18	306	322	349	396	508	853

[a]Each FN value is a mean of duplicate determinations and five replicates.
[b]Elevation, ft.
[c]Barometric pressure, mm Hg.
[d]Boiling point of water, °C.

TABLE III
Standard Errors for 18 Whole Meal Samples Partitioned by Altitude

Altitude	Mean Value[a]	Mean Residual	Standard Error of Estimate
0	254	0.09	7.48
2,000	276	−3.55	11.38
4,000	304	−3.71	12.05
6,000	344	−0.91	14.25
8,000	422	8.09	18.08
10,000	562	−4.39	31.96

[a]Each value is a mean of 90 determinations.

TABLE IV
Identification and Proximate Composition[a] of Ground Wheat Meals Used by 10 Laboratories in Ringtest

Sample	Wheat Type	% Protein	% Ash
1	Dark northern spring	17.0	2.3
2	Hard red spring	16.8	2.1
3	Hard red winter	14.8	2.0
4	Hard red spring	15.9	2.0
5	Biscuit white	13.4	2.1
6	White	11.4	1.6
7	Hard red winter	14.6	1.7
8	Bread white	13.9	1.9
9	Bread white	14.0	2.0
10	Hard red spring	17.6	1.9

[a]Dry weight basis.

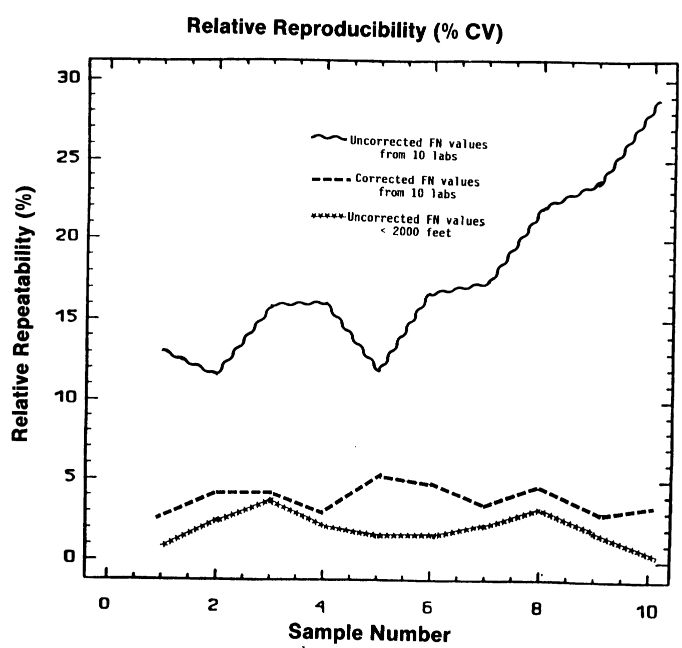

Fig. 1. Relative reproducibility of Falling Number mean values with and without use of correction formula.

TABLE V
Effect of Altitude on Falling Number (FN) Values[a] Corrected at International Laboratories Above 2,000 ft

	FN Corrected Values at									
	[b] 106	360	787	970	975	2,198	3,139	3,312	4,412	8,136
	[c] 749	751	766	735	734	707	670	666	647	566
Meal	[d] 100.2	99.0	100.0	99.4	100.0	97.5	96.5	97.3	95.6	92.0
1	210	212	217	213	217	203	208	210	208	208
2	220	224	221	226	235	206	216	217	210	209
3	237	240	245	252	260	226	241	248	250	245
4	254	262	266	263	271	254	263	273	270	259
5	305	308	302	311	315	281	298	296	279	270
6	344	341	342	356	350	315	323	322	315	326
7	383	374	381	380	396	362	368	374	365	357
8	425	412	399	435	420	388	397	394	400	413
9	473	462	453	457	474	450	452	449	443	461
10	491	482	474	483	493	475	472	487	487	518
Mean	334	332	330	338	343	316	324	327	323	326

[a]Each FN value is a mean of duplicate determinations and four replicates.
[b]Elevation of laboratory, ft.
[c]Barometric pressure, mm Hg.
[d]Boiling point of water, °C.

TABLE VI
Summary Comparisons of Falling Number (FN) Values Using the Correction Formula Above 2,000 ft Versus Uncorrected Values

	Uncorrected FN Values		Corrected FN Values	
Meal	Range	Variance, %	Range	Variance, %
1	210–317	20	203–217	3.3
2	220–319	18	206–235	6.6
3	237–392	25	226–260	7.0
4	254–421	25	254–273	3.2
5	302–446	19	270–315	7.7
6	341–571	16	315–356	6.1
7	374–644	27	357–396	5.2
8	399–780	32	388–435	5.7
9	453–900	33	443–474	3.4
10	474–1,051	38	474–518	4.4
Mean Variation		25		5.3

In this equation FN_{alt} is the original FN value as measured at a specific altitude, and elevation is the laboratory altitude in feet. The FN at sea level is calculated as:

$$FN_{Sl} = 10^{\log_{10}(FN_{Sl})}$$

Typically, FN is reported on 14% moisture basis. This is accomplished by adjusting the sample weight used in the procedure to a 14% moisture basis before beginning the FN determination. The FN also can be determined without prior adjustment and reported on a 14% moisture basis using the following formula:

$$FN\ (14\%\ mb) = FN_{as\ is} \times (100 - 14)/(100 - \%\ moisture\ of\ sample)$$

Equation Validation

Application of the regression equation deemed the correction formula statistically appropriate for adjustment at any altitude, including those laboratories at 500 ft of elevation. The correction equations were tested at laboratories in several countries at various altitudes. Wheats were obtained from different countries in Europe and North America. Protein content of ground wheat meals used was 11.4–17.6% (Table IV). Figure 1 can be used to show that laboratories at altitudes below 2,000 ft do not need to use the correction formula. Therefore, any statistical deviation is not relevant between the corrected and uncorrected FN values below 2,000 ft of elevation.

Sea level FN values were calculated from FN values corrected for altitude for laboratories above 2,000 ft. Data were obtained from 10 laboratories in an international ringtest (Table V). A comparison was made in Figure 1 between uncorrected FN values and data corrected above 2,000 ft. Relative repeatability as determined by covariance is much better when FN values from laboratories above 2,000 ft are corrected using the equation (Table VI). Mean variance was 25% in uncorrected FN values, but this was reduced to 5% by application of the correction formula.

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