A Note on the Effect of Varying Atmospheric Pressure on the Amylograph Viscosity of Flours[1]

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ABSTRACT

The amylograph viscosity of flours is affected by atmospheric pressure. Peak viscosity Brabender Unit (B.U.) values of flours increase approximately 3.5 and 9.5% at elevations of 2,500 and 5,000 ft., respectively, over those obtained at sea level conditions. The changes in B.U. value were found to be significant statistically. Many commercial bakeries and flour mills are located at elevations of up to 5,000 ft.; this should be taken into consideration when examining or reporting flour analyses. The operation of the amylograph at elevations above 5,000 ft. can lead to very unrealistic results because of rapid moisture loss from the boiling flour slurry at peak viscosity.

The amylograph records viscosity changes as the temperature of a flour-water suspension is increased at a uniform rate. The increase in viscosity occurring when the starch gelatinizes is opposed by the liquefying action of amylases. Curve height at maximum viscosity is considered an index of amylase activity (1,2).

The function, construction, and operation of the amylograph and the literature on the subject have been published (1).

Amylograph curve characteristics are affected by bowl speed (3), starting temperature and temperature rise (4), flour type (5), enzymes (6), and several ingredients used in bread-and cake-baking (7).

A standard procedure, therefore, has been adopted to eliminate such variables (8) and permit comparison and evaluation of flour data obtained in cereal laboratories everywhere. Variations in Brabender Units (B.U.) recorded by different laboratories for the same flour are often blamed on inconsistencies in performance of the amylograph.

The present procedure, however, does not compensate for differences in atmospheric pressure under which amylograph data are obtained. Approximately one-third of the U.S. is located at 2,500 ft. or above (9), and many commercial flour mills providing flour analyses including amylograph values are located within this high altitude region.

This study was, therefore, undertaken to investigate the effects of operating the amylograph under varying atmospheric pressures.

MATERIALS AND METHODS

Commercial flour samples varying in composition and treatment were obtained from several mills. The flour analyses and treatments are given in Table I. Amylograph viscosities of the flours were determined using the AACC approved amylograph procedure (8).

The investigation was carried out in a special laboratory consisting of a steel cylinder 7 ft. in diameter and 9 ft. high. This laboratory can be ventilated, and temperature and humidity controlled. The atmospheric pressure can be adjusted

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TABLE I. COMPOSITION AND TREATMENT OF FLOUR SAMPLES

Flour No.	Sample Labeled	Bromate p.p.m.	Ash[a] %	Protein[a] %
1	Spring-winter blend; 40% HRW, 60% DNS	6.0	0.44	12.50
2	100% DNS	9.0	0.48	13.40
3	100% DNS	9.0	0.51	14.60
4	100% HRW	3.0	0.42	11.20
5	100% HRW	None	0.44	11.40

[a]14.0% moisture basis. DNS = dark northern spring; HRW = hard red winter.

and maintained to simulate conditions between sea level and 12,000 ft. of elevation. The experiments were carried out at atmospheric pressures equivalent to sea level, 2,500, 5,000, 7,500, and 10,000 ft. of elevation. The temperature and relative humidity inside the laboratory were maintained between 20.3° ± 0.1°C. and 48 to 50%, respectively. The data given are the averages of three separate determinations.

RESULTS AND DISCUSSION

Maximum B.U. values of flour-water suspensions increased as atmospheric pressure at which the amylograph was operated decreased. The higher the sea level B.U. value, the higher the increase with increasing elevation (Table II). Flours 1 and 5, which had sea level B.U. values of 850 and 900, respectively, showed increases of 30 B.U. between sea level and 2,500 ft.; whereas flour 2, which had a sea level B.U. value of 360, produced only a 10-B.U. increase. The average percent increase in B.U. value for all flours, operating the amylograph at 2,500 ft. elevation instead of sea level, amounted to 3.5% over the sea level B.U. value. The average percent increase in B.U. value between sea level and 5,000 ft. of elevation amounted to 9.5% with values ranging from an 8% increase for flour 4 to a 12.3% increase for flour 5. The average percent changes in B.U. value for each flour are illustrated in Fig. 1. Maximum B.U. values increased gradually for flours having sea level B.U. values of 550 or below (flours 2, 3, 4). The maximum percent changed between sea level and 10,000 ft. B.U. values of these flours was 11.3% on the average. Flours having a sea level B.U. value of 850 and 900, respectively, showed an enormous

TABLE II. MAXIMUM B.U. VALUES OF FLOUR-WATER SUSPENSIONS AT DIFFERENT ATMOSPHERIC PRESSURES

Atm. Pressure mm.	Elevation ft.	Flour No.				
		1	2	3	4	5
765	Sea level	850	360	500	550	900
695	2,500	880	370	520	570	930
635	5,000	930	390	540	600	1,010
580	7,500	1,320	390	540	610	1,470
525	10,000	1,440	400	550	620	1,660

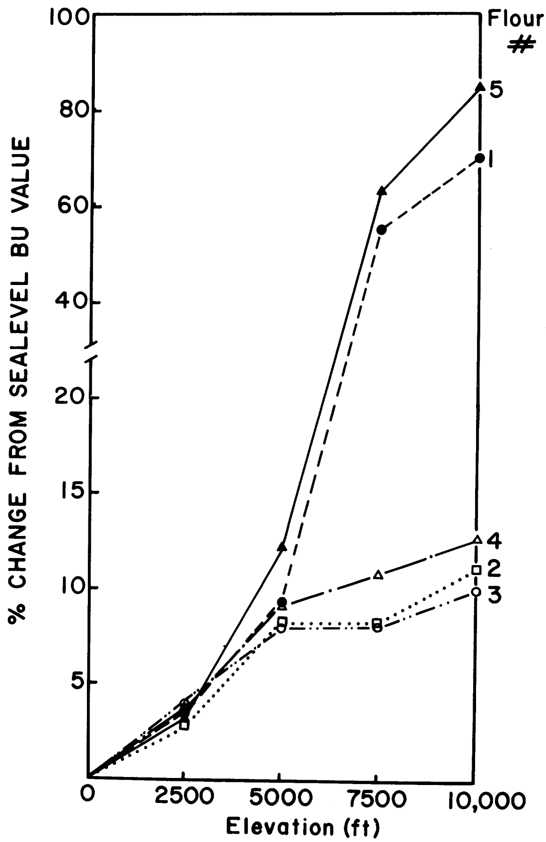

Fig. 1. Percent change in B.U. value with increase in elevation.

increase in peak B.U. value when the amylograph was operated at 7,500 or 10,000 ft. of elevation (Table II and Fig. 1). Adjustment of the initial sea level B.U. value of flour 5 (900 B.U.) to that of flour 3 (500 B.U.), however, resulted in the same increase in B.U. values for both flours with an increase in elevation.

The initial temperature of gelatinization, taken when the curve reached a B.U. value of 20, was essentially the same for each individual flour over the entire range of atmospheric pressure investigated. This initial temperature of gelatinization varied by only 1.5°C. between the different flours (Table III). The temperature at peak viscosity, however, varied considerably between flours. As atmospheric pressure decreased, the temperature at peak viscosity decreased. This change was most pronounced at elevations above 5,000 ft. or below an atmospheric pressure of 635 mm. Hg. At 7,500 and 10,000 ft. of elevation flours 2, 3, and 4 reached their maximum peak at temperatures between 76° and 79.5°C. and well before the flour slurry began to boil. Flours 1 and 4 reached their maximum peak between 82.5°and 84°C. At these temperatures the flour slurries were boiling. (Remember that the boiling point of water decreases by about 1° for every 1,000 ft. of elevation.)

TABLE III. TEMPERATURE AT INITIAL GELATINIZATION (20 B.U.) AND TEMPERATURE AT PEAK VISCOSITY OF FLOUR-WATER SUSPENSIONS AT DIFFERENT ATMOSPHERIC PRESSURES[a]

		Flour No.				
		1	2	3	4	5
Atm. Pressure mm.	Elevation ft.	Initial-peak temp. °C.	Initial-peak temp. °C.	Initial-peak temp. °C.	Initial-peak temp. °C.	Initial-peak temp. °C.
765	Sea level	63.0-87.5	63.0-78.0	63.0-82.5	61.5-78.0	63.0-88.5
695	2,500	61.5-87.5	63.0-78.0	63.0-82.5	61.5-77.0	61.5-88.5
635	5,000	62.0-87.5	63.0-78.0	62.0-81.0	61.5-76.0	63.0-87.0
580	7,500	63.0-84.0	62.0-76.5	62.0-79.5	61.5-76.0	63.0-84.0
525	10,000	63.0-84.0	62.0-76.5	62.0-79.5	61.5-76.0	63.0-82.5

[a]Amylograph starting temperature, 30° C.

TABLE IV. ANALYSIS OF VARIANCE OF VISCOSITY (B.U.) VALUES

Sources	DF	MS	F
Total	44	...	...
Elevations	2	14,948.889	231.9**
Flours	4	550,408.889	8,540.8**
Flours X elevations	8	965.555	14.9**
Error	30	64.444	...

The increase in viscosity of flours 2, 3, and 4 with increase in elevation as indicated by increased B.U. peak values can be attributed to an easier and greater expansion of the starch granules at reduced atmospheric pressures. The solid-to-liquid ratio at peak viscosity of flour-water suspensions of flours 2, 3, and 4 did not change when the amylograph was operated at reduced pressures. This was determined by simply weighing the amylograph bowl plus contents after peak viscosity had been reached. This ratio, however, changed at peak viscosities of flours 1 and 5 at elevations of 7,500 and 10,000 ft. These slurries boiled at peak viscosities, resulting in a rapid moisture loss and, consequently, in an increase in total solids of the flour slurry. The high B.U. peak values of flours 1 and 5 at 7,500 and 10,000 ft. can, therefore, be attributed to an easier and greater expansion of the starch granules at reduced pressures combined with an increase in viscosity due to rapid moisture loss.

An analysis of variance of the viscosity values is presented in Table IV. Only the three viscosity values of each flour obtained at sea level, 2,500 ft., and 5,000 ft. of elevation were included in the analysis. All five flours behave similarly in this range (Fig. 1). Furthermore, very few cereal laboratories are located above 5,000 ft.

The analysis indicated that there is a linear relationship between flour viscosity and elevation. Differences in B.U. value between sea level and 2,500 ft., sea level and 5,000 ft., and 2,500 and 5,000 ft. of elevation were significant at the 1% level.

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