Modification of Wheat Flour Dough Characteristics by Cycloheptaamylose[1]

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ABSTRACT

The effects of the addition of cycloheptaamylose (CHA) to wheat flour doughs on the amylograph viscosity, falling number, farinograph characteristics, and loaf volume have been examined. Cycloheptaamylose increased the amylograph viscosity of a sound wheat flour paste. The maximum viscosity of wheat starch was unaffected by CHA, although the temperature at maximum viscosity was lower. Amylograph peak viscosity of wheat flours containing α-amylase was increased by CHA. Cycloheptaamylose decreased the falling number of wheat starch and wheat flour suspensions in both the presence and absence of α-amylase. Farinograph absorption and development time were increased by CHA, as was the loaf volume of bread prepared by the Grain Research Laboratory Remix method.

Cyclodextrins are produced by the action of *Bacillus macerans* amylase on starch and related compounds (French 1957, Bender and Komiyama 1978). They are composed of six to 10 glucose residues linked by α-1.4 to form a ring-shaped saccharide with no reducing end. They have been used industrially beause of their ability to include various compounds within the glucose ring (Bender and Komiyama 1978).

The seven glucose-membered cyclodextrin, cycloheptaamylose (CHA), has been covalently linked to Sepharose 6B and used in an affinity chromatographic procedure to purify cereal α-amylase (Silvanovich and Hill 1976, Weselake and Hill 1982). Cycloheptaamylose has been shown to bind to a noncatalytic site on α-amylase (Weselake and Hill 1982) and to inhibit the hydrolysis of starch granules by the enzyme (Weselake and Hill 1983).

In addition to its inhibitory effect on α-amylase-catalyzed starch granule hydrolysis, CHA increases the swelling power and solubility of wheat starch granules during gelatinization (Kim and Hill 1984). This appears to occur because of disruption of amylose-lipid complexes by CHA, which forms inclusion complexes with lipid (Schlenk and Sand 1961, Szejtli and Bánky-Elöd 1975).

Starch-enzyme-water (Weselake and Hill 1983) or starch-water systems (Kim and Hill 1984) were used previously. The present work was undertaken to extend previous findings of CHA effects on dough properties. We have, therefore, examined the effects of addition of CHA on the amylograph viscosity, falling number, farinograph, and loaf volume of wheat flour.

MATERIALS AND METHODS

Commercial wheat starch (unmodified) and CHA were obtained from Sigma Chemical Co., St. Louis, MO. Wheat flour obtained

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from the Canadian Western hard red spring variety Neepawa, which contained 12.8% protein (as-is basis), was used for all experiments. Moisture content was calculated from the loss in weight after heating at 130°C for 1 hr. The moisture content of wheat starch, CHA, and wheat flour was 10.3, 11.6, and 13.7%, respectively.

Alpha-amylase was prepared from Neepawa wheat flour according to the method of Weselake and Hill (1983). Alpha-amylase activity was determined by the method of Briggs (1961) and expressed in IDC units. One IDC unit is the amount of enzyme required to lower the absorbance for a standard digest from 0.6 to 0.4 in 100 min.

Inactivation of Amylases in Flour

The method described by Meredith (1970) was used. Flour was wetted by shaking with a mixture of water and 0.1 *N* HCl and was held at room temperature for 20 min with occasional agitation. The mixture was then neutralized by adding 0.1 *N* NaOH with vigorous swirling. After 5 min, the mixture was used for the amylograph procedure. For the falling number method, flour was shaken with 0.1 *N* HCl 20 times. After 20 min of standing at room temperature, 0.1 *N* NaOH was added, and the mixture was shaken 20 times. Residual α-amylase activity in flour was tested by the Phadebas α-amylase method of Barnes and Blakeney (1974). No α-amylase was present in the inactivated flour.

Amylograph Procedure

The Brabender Visco-amylo-graph with 700 cm g sensitivity cartridge was used at the 75-rpm bowl speed. The amylograph bowl used was a small bowl for rapid amylogram. Peak viscosity was obtained by heating aqueous suspension from 30 to 95°C at the rate of 1.5°C/min. Amylograms were obtained from 50 to 95°C, at the rate of 1.5°C/min, holding the paste at 95°C for 30 min, and cooling it from 95 to 50°C at the rate of 1.5°C/min. Mean values of duplicate determinations were used, and maximum difference between two values did not exceed 10 BU.

Falling Number

Falling number was determined according to AACC method 56-81B (AACC 1982).

Farinograph Characteristics

Farinograph characteristics were determined using 50 g of flour, according to AACC method 54-21 (AACC 1982).

Loaf Volume

Bread was made by using the Grain Research Laboratory (GRL) Remix method (Irvine and McMullan 1960, Kilborn and Tipples 1981) at constant baking absorption (60.8%), and loaf volume was determined 30 min after baking. The formula consisted of (in percent, flour basis): flour, 100; yeast, 3; salt, 1; sugar, 2.5; potassium bromate, 0.0015; ammonium phosphate, 0.1; and malt, 0.3.

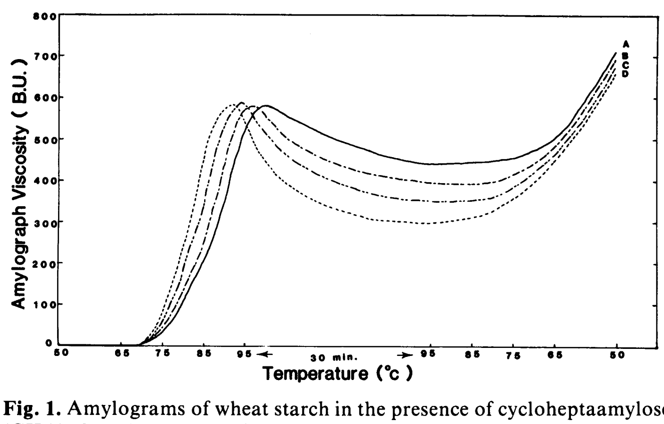

Fig. 1. Amylograms of wheat starch in the presence of cycloheptaamylose (CHA). Starch concentration was 11.7% (w/w). A = 0% CHA, B = 0.5% CHA, C = 1.0% CHA, D = 1.5% CHA.

RESULTS AND DISCUSSION

Amylograph Viscosity

Since CHA increases viscosity of starch pastes (Kim and Hill 1984) and affects the rate at which α-amylase degrades starch granules (Weselake and Hill 1983), its effect on amylograph viscosity of wheat starch was tested in the absence and presence of α-amylase.

In the absence of α-amylase, there was no difference in maximum viscosity upon the addition of various concentrations of CHA (Table I). The temperature at maximum viscosity, however, was shifted to lower temperatures as CHA concentration was increased (Fig. 1). In addition, setback of the starch paste increased as CHA concentration increased. Pasting temperature remained constant at all CHA concentrations.

However, when α-amylase was present in the wheat starch suspension, 1.5% of CHA increased the amylograph viscosity slightly (Table I). The effect of CHA on a wheat flour having a low amylograph viscosity due to α-amylase was greater than that observed with wheat starch with added α-amylase. If α-amylase was inactivated in wheat flour or if a sound wheat flour was used, there was still an increase in amylograph viscosity due to CHA, but not as great as that observed when an active α-amylase was present.

It was shown previously that the viscosity of starch pastes is increased by CHA (Kim and Hill 1984). In the amylograph, CHA did not alter the maximum paste viscosity (Table I, Fig. 1), although the temperature at which this occurred was lower (Fig. 1). Swelling and release of soluble carbohydrate occur at lower temperatures in the presence of CHA (Kim and Hill 1984), which increases the time during which starch was exposed to shear in the amylograph. This shift to a lower temperature also accounts for the temperature shift of amylograph peak viscosity. Increased swelling of the gel would make the matrix more susceptible to shear and could account for increased setback in gels containing CHA.

Melvin (1979) and Eliasson et al (1981) reported similar findings upon the removal of lipid from the wheat starch, which further supports the contention that CHA disrupts amylose-lipid complexes.

Some slight increase in maximum paste viscosity was obtained by adding CHA to starch preparations containing α-amylase. This may have been caused by inhibition of starch granule hydrolysis by α-amylase in the presence of CHA (Weselake and Hill 1983). Cycloheptaamylose does not inhibit hydrolysis of soluble starch, nor does it completely inhibit enzyme binding to and hydrolysis of starch granules at concentrations used here and, therefore, increase in amylograph paste viscosity was small.

The effects of CHA on wheat flour amylograph viscosity cannot be explained solely on the basis of increased starch swelling and solubility, nor on inhibition of starch granule hydrolysis.

TABLE I
Amylograph Viscosity[a] of Wheat Starch and Flour in the Presence of Cycloheptaamylose (CHA)

		CHA Concentration (%)			
System	α-Amylase	0	0.5	1.0	1.5
Wheat starch					
(13.7%)[b]	−	840	845	850	855
(13.0%)[b]	−	700	700	700	700
(13.7%)[b]	+[c]	320	355	380	390
(13.0%)[b]	+[d]	305	345	380	380
Sound wheat flour (14.4%)[b]	−	960	995	1,020	1,020
Wheat flour (14.4%)[b]	+[e]	380	480	500	500
	−[f]	840	870	895	900

[a] Brabender units (BU); mean value of duplicate determinations.
[b] Dry basis (w/w).
[c] 990 IDC units of α-amylase was added.
[d] 825 IDC units of α-amylase was added.
[e] Wheat flour with endogenous α-amylase.
[f] Wheat flour with endogenous α-amylase inactivated by acid treatment.

TABLE II
Falling Number[a] of Wheat Starch and Flour in the Presence of Cycloheptaamylose (CHA)

System	α-Amylase	CHA Concentration (%) 0	0.5	1.0	1.5
Wheat starch (14.9%)[b]	–	445 ± 2	394 ± 1	386 ± 2	367 ± 5
	+[c]	350 ± 6	337 ± 4	330 ± 1	309 ± 2
Wheat flour (14.4%)[b]	+[d]	295 ± 4	274 ± 1	260 ± 2	248 ± 1
	–[e]	216 ± 1	204 ± 2	196 ± 6	184 ± 3

[a] Seconds; mean ± standard deviation for three determinations.
[b] Dry basis (w/w).
[c] 330 IDC units of α-amylase was added.
[d] Wheat flour with endogenous α-amylase.
[e] Wheat flour with endogenous α-amylase inactivated by acid treatment.

TABLE III
Farinograph Characteristics of Wheat Flour Dough in the Presence of Cycloheptaamylose (CHA)

CHA (%)	Farinograph Absorption (%)	Development Time (min)	Mixing Stability (min)	Mixing Tolerance (BU)
0	64.8	4.2	11.3	10
0.5	65.2	5.5	22.3	17
1.0	66.0	6.8	19.5	10
1.6	67.0	6.5	12.0	10

Cycloheptaamylose increased the amylograph viscosity of a sound wheat flour, whereas it had little effect on amylograph peak viscosity of a starch preparation (Table I). The release of solubilized starch exudate can be delayed by other flour components, either through complex formation and/or limiting the amount of water available for starch hydration (Olkku et al 1978). This delay may be alleviated by CHA through complexing with these components.

Falling Number

Table II shows the effect of CHA on the falling number of wheat starch and wheat flour. As the concentration of CHA was increased, the falling number declined. A similar effect was noted even when α-amylase was inactivated in the flour preparation. At a CHA concentration of 1.5%, falling number was reduced 15–16%, regardless of whether α-amylase was present in wheat flour. Cycloheptaamylose had a similar effect on wheat starch.

The amylograph and the falling number apparatus have been used widely to estimate α-amylase levels in wheat flour. The methods differ in several properties, notably rates of heating, flour concentration, and rates of shear during mixing and during sensing of viscosity (Meredith 1970). One or all of these factors could account for the differences observed in the effects of CHA on amylograph viscosity or falling number of wheat starch/flour systems. Cycloheptaamylose lowers the temperature at which amylose is leached and starch granules swell (Kim and Hill 1984). This would, in effect, increase the time during which starch granules are exposed to shear in the falling number test, consequently lowering the falling number. Also, increased breakdown of the swollen gel which is exposed to shear could be equivalent to increased setback observed in the amylograph test (Fig. 1).

Whereas in the amylograph, maximum viscosity increased when CHA was added to starch or flour containing α-amylase, no such increases were observed in falling number of α-amylase containing starch or flour. This is undoubtedly due to the short time during which α-amylase could bind CHA during heating in the falling number test. As noted by Hlynka (1968), the rate of gelatinization and the rate of heat inactivation of enzyme are considerably different in the two tests.

Farinograph Characteristics and Loaf Volume

All farinograph characteristics of a wheat flour dough were altered by addition of CHA to the dough system (Table III). As CHA concentration is increased to 1.6%, farinograph absorption increased by 2.2%. Development time increased to 6.8 min at 1.0% CHA, then declined slightly to 6.5 min at 1.6% CHA. Mixing stability was considerably increased by 0.5% CHA compared to the control. Then, upon further additions of CHA, mixing stability declined. At 1.6% CHA, the mixing stability was similar to that of the control. Mixing tolerance also increased upon addition of 0.5% CHA compared to the control but showed no effect at higher CHA concentrations.

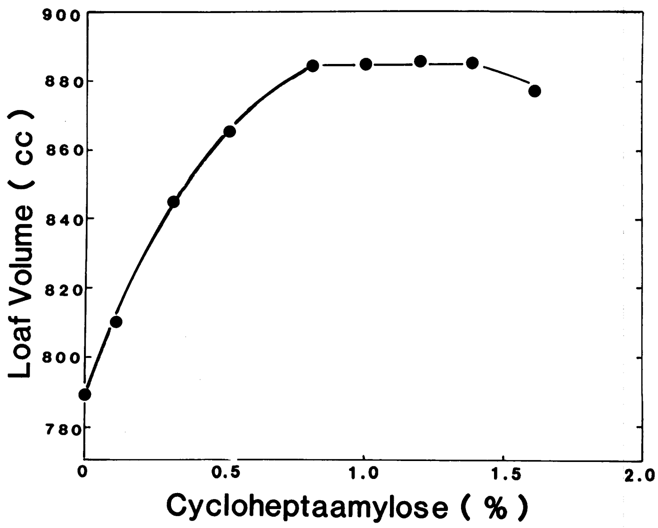

Fig. 2. Loaf volume of bread prepared in the presence of cycloheptaamylose.

Loaf volume of bread prepared by the GRL Remix method increased as CHA was added up to a concentration of 0.8% CHA (Fig. 2). Between 0.8 and 1.4% CHA, there was no further change in loaf volume. At optimum CHA concentrations, loaf volume increased by 12%.

The increase in the stickiness of the dough, which tends to increase dough consistency (Bloksma 1964), is probably due to the increased concentration of hydrophilic substance in the water phase. This hypothesis is supported by the increased water absorption observed in the farinograph curve upon addition of CHA. The increase in development time with addition of CHA would be expected as water absorption increased (Bloksma 1964). Previous work (Kim and Hill 1984) suggested that CHA interacted with lipid to affect viscosity of starch pastes, and a similar interaction could affect farinograph characteristics by increasing surface tension. The results obtained by the amylograph viscosity of sound wheat flour or of wheat flour with inactivated α-amylase (Table I) also suggest some interaction between CHA and a component other than starch granules in the wheat flour dough.

Gluten, composed mainly of protein, is the major component affecting viscoelastic properties of dough (Bloksma 1964), and some interaction of CHA with protein to produce the effect observed in the farinograph characteristics cannot be discounted. Indeed, carbohydrate polymers have been shown to affect both farinograph characteristics (Wilham et al 1959, Jones and Erlander 1967, Huebner and Wall 1979) and loaf volume (Cawley 1964).

Further work is clearly needed to establish the major interaction in this complex dough system.

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