

Interpretation of Do-Corder Curves. Identification of Flour Components Influencing Curve Characteristics

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ABSTRACT

Cereal Chem. 58(6):538-542

This study was designed to indicate the constituents of flour responsible for the peaks at 75 and at 85°C in the curve produced by the Do-Corder, an instrument for measuring the consistency of dough while it is heated. The protein fraction of flour appeared to be associated with a peak at 75°C, because urea (a protein-dispersing agent) and *N*-ethylmaleimide (a

sulphydryl-blocking agent) affected this peak. Starch was the main flour component causing the increase in viscosity at 85°C, judging from the evidence that the damaging of starch affected it. Removal of free lipid had no effect on the curve, but bound lipid was shown to play an important role in determining the Do-Corder characteristics of a flour.

In previous studies (Nagao et al 1981a, 1981b, 1981c; Tanaka et al 1980), the Brabender Do-Corder was used to investigate the rheological properties of doughs in the presence and absence of oxidants and other relevant reagents. The importance of fermentation in breadmaking was also demonstrated using the Do-Corder (Nagao et al 1981b). Do-Corder curves were shown to provide a good indication of the bread-making performance of a dough. The instrument distinguished between bromated dough (two peaks in the curve at 75 and 85°C), dough with added ascorbic acid (one peak at 75°C), and an untreated dough (one peak at 85°C). Most compounds so far tested in dough have had their effects, if any, on the Do-Corder curve in these two regions (75 and 85°C). To improve our understanding of the Do-Corder and consequently to increase its usefulness, we conducted experiments designed to identify the major components of flour responsible for the formation of these two peaks. For this purpose, the effects on Do-Corder curves of starch damage and premixing in various mixers were investigated in the presence of reagents such as urea, salt, and *N*-ethylmaleimide (NEMI). Do-Corder curves for starch and vital gluten isolated from the flour and for defatted flour were also obtained.

MATERIALS AND METHODS

The flour used in the present study was described in a previous article (Tanaka et al 1980). All chemicals used were reagent grade.

Starch and Vital Gluten

Starch and vital gluten were prepared from the flour according to the method described in the previous article (Tanaka et al 1980). The starch had a protein content of 0.6%, moisture of 12.9%, and an ash content of 0.21%. The vital gluten contained 75.3% protein, 7.4% moisture, and 0.49% ash.

Farinograph Operation

A Farinograph was operated by the procedure specified by the manufacturer. The thermostat was maintained at 30°C, and a large mixing bowl containing 300 g of flour was used. All farinograms were recorded at 70% water absorption.

Premixing of a Dough

Doughs were premixed with the following instruments for 2, 6, and 10 min. After premixing, 120 g of dough was taken for the Do-Corder investigations.

Farinograph. A Farinograph was used as a mixer in the manner described above.

Mixograph. A mixograph with a 35-g bowl (National Mfg. Co.) was used according to the AACC mixograph procedure (1962), except that 40 g of flour was mixed with 28 ml of water.

A Planetary Mixer. A Kantoh Mixer type SS (Kantoh Kongoki Kogyo C., Japan) was used in this study with a formula of 300 g of flour and 210 ml of water. Mixing was performed at high speed for the specified period.

Do-Corder Operation

A Do-Corder was operated as previously described (Tanaka et al 1980).

Diastatic Activity (Maltose Value)

Diastatic activity of dough was determined according to AACC methods (1962) after pulverizing it in granulated quartz so that it would be easily dispersed in the buffer solution. The result gives a good indication of the starch damage of a sample.

Preparation of Defatted Flour

Free lipids were removed from flour by exhaustive extraction with petroleum ether (bp 35–60°C) in a large Soxhlet. Total lipids were extracted from 100-g batches of flour with water-saturated butanol as described by Mecham and Mohammad (1955).

RESULTS

Effect of Vibrating Ball-Mill Treatment

Flour particles were gradually reduced in size with prolonged treatment in a ball-mill (Table I). Without this treatment, the quantities of particles with diameters of above and below 63 μ are almost the same. After a 5-min treatment, nearly all particles were reduced to less than 63 μ in size. At the same time, the level of damaged starch (expressed as maltose released) increased with prolonged treatment.

With prolonged ball-mill treatment, maximum consistency in the farinograph increased (Fig. 1). This change is due to the decrease in availability of free water caused by an increase in damaged starch, which absorbs more water than sound starch (Bushuk 1966). This is another indication that the vibrating ball-mill treatment was effective in increasing the degree of starch damage.

TABLE I
Size Distribution (%) and Diastatic Activity of Ball-Mill Treated Flour

	Ball-Mill Treatment (min)			
	0	1	3	5
Size Range (μ m)				
0–40	11	12	20	30
40–63	40	65	69	68
63–90	35	20	10	2
Over 90	14	3	1	0
Diastatic Activity ^a	175	385	512	560

^aIn milligrams of maltose per 10 g of flour.

Effect of Starch Damage

Figure 2 shows Do-Corder curves for doughs with different levels of starch damage in the presence and absence of bromate. The curve for untreated flour showed a clear peak at 85°C in the absence of bromate. As the period of vibrating ball-mill treatment increased, the major peak (higher consistency) shifted from 85 to 75°C. In the presence of bromate, untreated flour gave two peaks, at 75 and 85°C, as reported previously (Tanaka et al 1980). Starch damage, however, had little effect on Do-Corder curves in the presence of bromate.

Effect of Water Content

Do-Corder curves for isolated starch were obtained at 100 and 33% added water. The total amount of the mixture was 120 g (Fig. 3). The curve for starch at 100% hydration gave a peak at around 75°C, similar to that observed at 70% hydration in Fig. 4. At 33% hydration, the curve gave a peak at 85°C. In this case the lack of water delayed the peak formation by about 10°C.

Effect of Salt

Starch and vital gluten isolated from the flour gave peaks at about 75 and 65°C in the Do-Corder curve, respectively (Fig. 4), as reported previously (Tanaka et al 1980). The Do-Corder curve for reconstituted flour (60 g of starch and 10 g of vital gluten), gave peaks at about 70 and 85°C (Fig. 4), but this shape was quite different from the curve for the original flour (Fig. 2). The addition of 5% salt in these cases delayed peak formation from 75 to 80°C for starch and from 65 to 75°C for vital gluten. For reconstituted flour, the peaks at about 70 and 85°C disappeared in the presence of salt and were replaced by one peak at 80°C.

Effect of Premixing and Additives

A Farinograph, a Mixograph, and a Kantoh mixer (planetary mixer) were used to investigate the effect of premixing of dough on

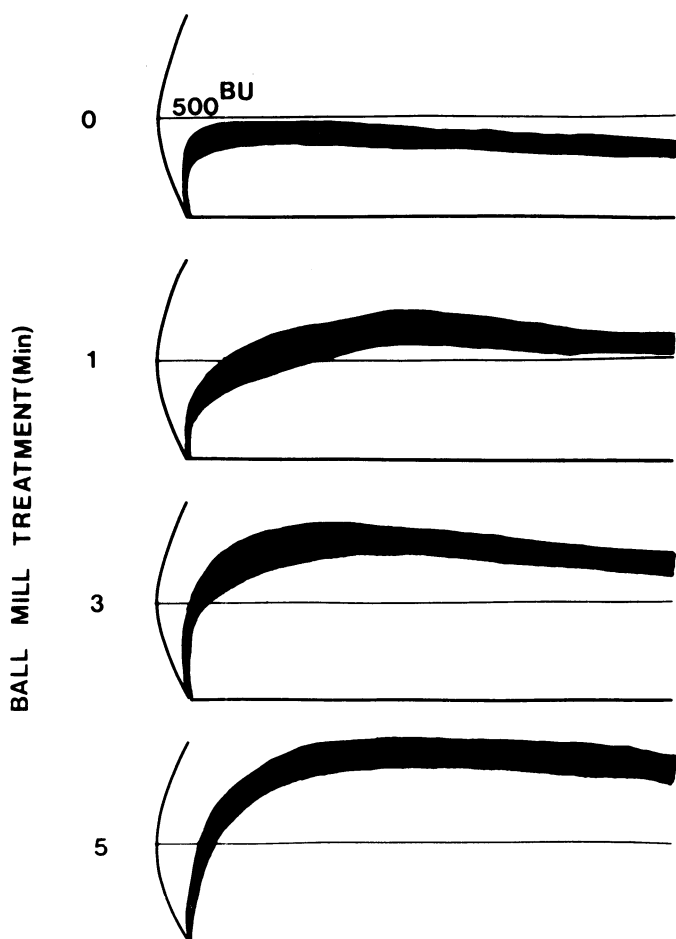


Fig. 1. Farinograms for flour samples ball-milled for various periods.

Do-Corder curves in the absence of any reagents. Prolonged premixing shifted the major peak from 85 to 75°C regardless of the type of instrument (Fig. 5). This result was produced more quickly in doughs mixed in the Mixograph and Kantoh mixer.

Mixing a dough might bring about a moderate increase in the degree of starch damage expressed as maltose values (Table II).

The Mixograph was chosen to investigate the combined effects of premixing and the addition of the reagents urea, salt, and NEMI on Do-Corder curves (Fig. 6). Each reagent was incorporated at a level of 1,200 ppm. In the presence of urea, a slight rise at 75°C was observed in the Do-Corder curve even without premixing. Following premixing, the major peak shifted from 85 to 75°C (Fig. 6) more rapidly than it did in the absence of urea (Fig. 5). On the other hand, the addition of salt without premixing eliminated the shoulder at 75°C observed in the Do-Corder curve for a control dough (Fig. 2). After prolonged premixing with salt (up to 10 min), the peak at 75°C became predominant. As reported (Tanaka et al 1980), a slight rise or plateau at 75°C was observed after adding NEMI. This disappeared with prolonged premixing. When both salt and NEMI were incorporated in a dough, the Do-Corder curve was very similar to that of a salted one and changed little with prolonged premixing.

Do-Corder Results with Defatted Flours

Figure 7 shows Do-Corder curves for doughs produced from flour defatted either with petroleum ether or with water-saturated butanol. Extraction of free lipid from the flour with petroleum ether had little effect on the curves for normal or bromated doughs.

Extraction of total lipid with water-saturated butanol produced a drastic effect on the curves for all the samples, so that only a peak

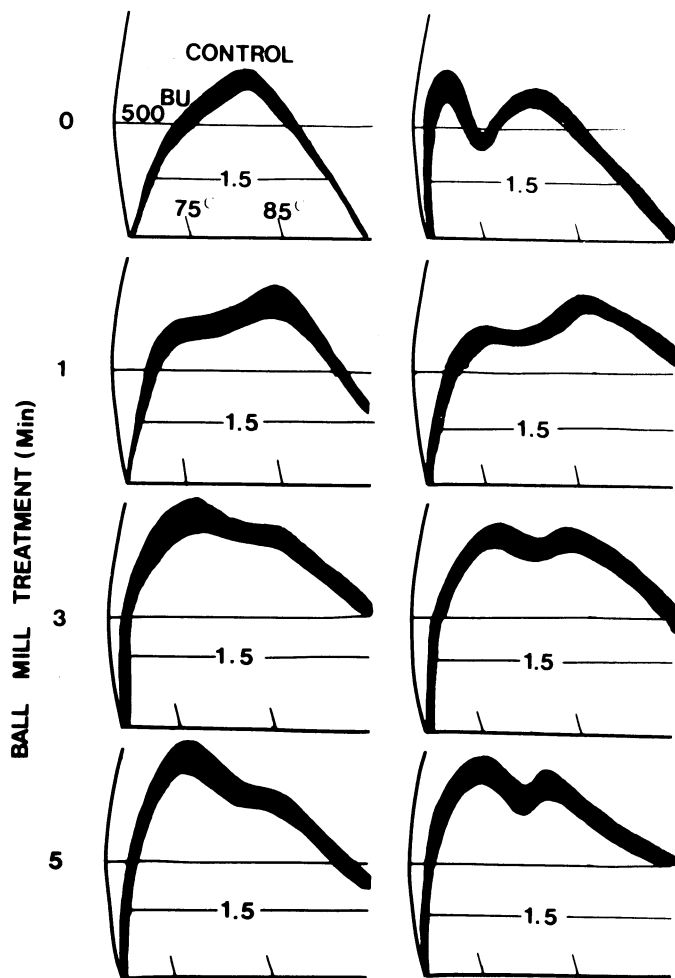


Fig. 2. Do-Corder curves for ball-milled flours in the absence (left) and presence (right) of bromate. The figure under each curve stands for the lever position of the instrument.

at 75°C was observed in each curve. This is very similar to that for starch (Fig. 3).

DISCUSSION

In the previous study (Tanaka et al 1980), we observed that with increasing water absorption, the main peak in the Do-Corder curve shifted from 85 to 75°C. We also postulated that the peak may result largely from the combined effects of starch gelatinization and thermal denaturation of gluten, because these two events govern

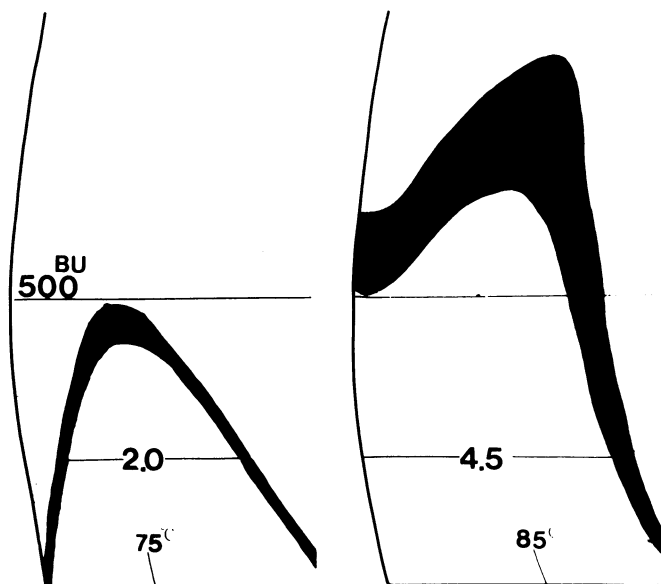


Fig. 3. Do-Corder curves for starch isolated from flour at two different hydration rates: **left**, 100% hydration (60 g of starch, 60 g of H₂O); **right**, 33% hydration (90 g of starch, 30 g of H₂O). The figure under each curve stands for the lever position of the instrument.

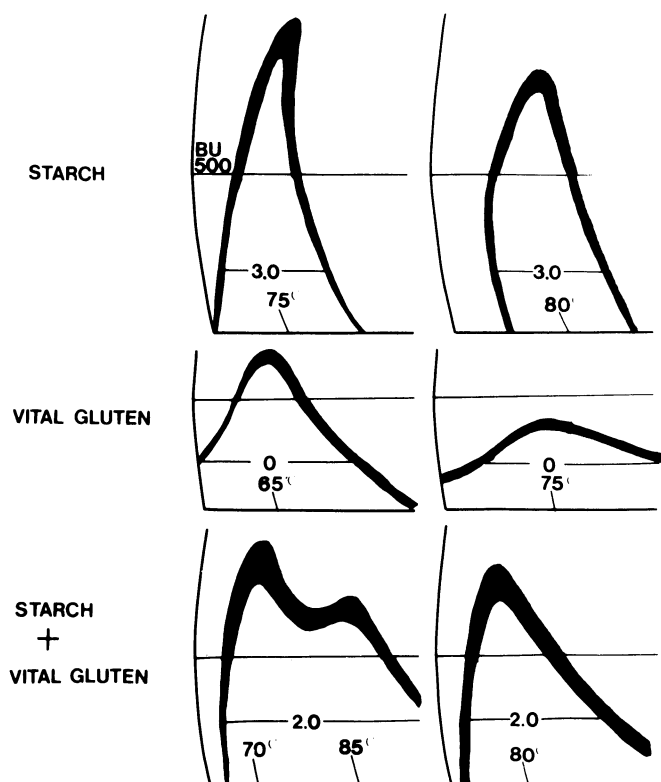


Fig. 4. Do-Corder curves for starch and vital gluten isolated from flour and recombined in the absence (**left**) or presence (**right**) of 5% salt. The figure under each curve stands for the lever position of the instrument.

the distribution of dough water between starch and gluten.

The present study gave some indications that flour components cause the peaks at 75 and 85°C. Two major components, starch and gluten, showed different intrinsic characteristics during separate heat treatments with the Do-Corder. A large increase in viscosity was observed at 75°C for starch and at about 65°C for vital gluten (Fig. 4). Flour reconstituted from starch and gluten showed peaks at about 70 and 85°C, similar but not identical to those observed in the original flour.

The presence of salt delayed the increase in viscosity by about 5°C for starch and 10°C for vital gluten. Salt shifted the major peak of recombined starch and gluten from 70 to 80°C. This may be because the hydration capacity of starch and vital gluten is decreased in the presence of salt. The overall effect of salt addition may thus be similar to the effect of water removal, which reduces starch gelatinization.

The amount of damaged starch in a flour is also important in gelatinization. Absorption of water by any particular flour depends mainly on the degree of starch damage. For example, Greer and Stewart (1959) obtained a water uptake value for undamaged starch of 0.44 g/g compared to a water uptake of 2.0 g/g of damaged starch. The Farinograph consistency of flour rose when the amount of damaged starch was increased by the ball-mill treatment (Fig. 1). Do-Corder investigations on the same flour showed that the major peak shifted from 85 to 75°C with ball-mill treatment (Fig. 2). This change may be because the importance of starch in determining consistency in the Do-Corder is increased following damage. On the other hand, decreasing the amount of water added to starch isolated from flour delayed the gelatinization of the starch from 75 to 85°C in the Do-Corder curve (Fig. 3). In the presence of bromate, two peaks (at 75 and 85°C) were observed for all samples regardless of ball-mill treatment (Fig. 2). The increase in damaged starch had little effect on bromate response.

Pomeranz et al (1965) reported that small amounts of polar lipid substantially improved the bread quality of untreated flours. Nonpolar components, however, had little effect. According to Tsen and Hlynka (1962), the effects of lipids may depend on their peroxidation by oxidant and subsequent reaction with protein sulfhydryl groups.

TABLE II
Maltose^a Values for Flour and Premixed Doughs

Mixing Time (min)	Dough Premixed in			
	Flour	Farinograph	Mixograph	Kantoh Mixer
0	175
2	...	235	235	214
6	...	226	243	235
10	...	221	245	240

^aIn milligrams of maltose per 10 g of dry dough.

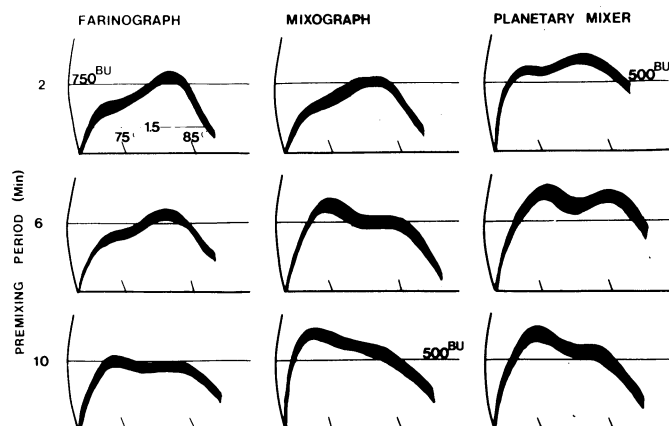


Fig. 5. Do-Corder curves for powdered freeze-dried doughs premixed in various mixers for a range of times. All curves were obtained with the lever position at 1.5.

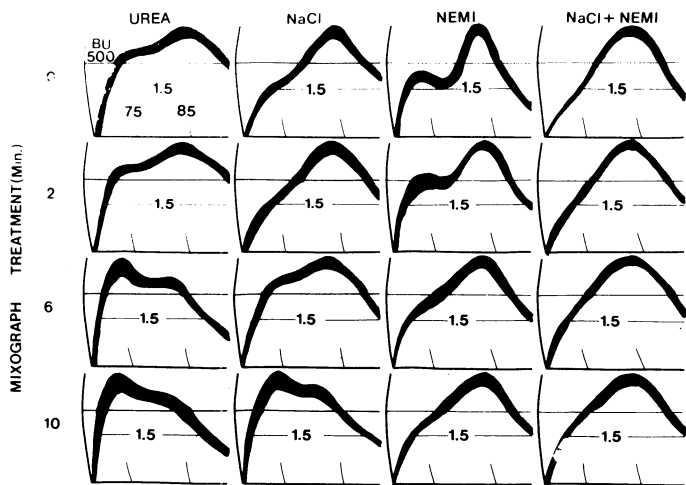


Fig. 6. Do-Corder curves with urea, NaCl, *N*-ethylmaleimide (NEMI), and NaCl + NEMI added to powdered freeze-dried doughs premixed in a Mixograph mixing bowl for various periods. The figure under each curve stands for the lever position of the instrument.

Lipid is also involved in the bromate reaction according to some workers (Bloksma 1963, Cunningham and Hlynka 1958, Narayanan and Hlynka 1962, Pomeranz 1967). Hoseney et al (1972) reported that defatted flour extracted with petroleum ether gave essentially no bromate response at a level of 30 ppm. On the contrary, in the present study such flour still showed a partial bromate response, as observed in Fig. 7, but we used a higher level of bromate than did Hoseney et al (1972). Only flour that had been totally defatted with water-saturated butanol gave essentially no response to oxidants (Fig. 7). This agrees with the report that bound lipid plays an important role in bread-making performance (Pomeranz et al 1965).

We observed that the major peak of the Do-Corder curve for the samples with the prolonged premixing gradually shifted from 85 to 75°C (Fig. 5). This may be attributed to a progressive movement of water from hydrated gluten to starch, mainly because mixing the dough brought about a slight increase in the amount of damaged starch (Table II). However, other factors may also be involved; a much greater extent of starch damage was needed to produce a similar change in the Do-Corder curve when starch was damaged in the ball-mill.

The results obtained in this study suggested that the 75°C peak or shoulder of the Do-Corder curve (Fig. 2) was associated with the protein (gluten) fraction in the dough, because urea (a protein-dispersing agent) and NEMI (a sulfhydryl-blocking agent) had their effects on the consistency at this temperature. This suggestion was supported by the observation that, in the presence of NEMI, the addition of bromate had no effect on the curves, whereas the normal bromated dough gave a distinct peak at the same temperature, presumably by the oxidation of all sulfhydryl to disulfide bonds (Tanaka et al 1980) and as no sulfhydryl group was found in the bromated dough at 75°C (Nagao et al 1981b).

The previous paper suggested that the increase in viscosity at 85°C was mainly brought about by starch gelatinization, as indicated by the fact that, in the presence of NEMI, each dough showed a distinct peak in the Do-Corder curve at 85°C. This is further confirmed by the finding in the present study that the major peak shifted from 85 to 75°C with an increase in the degree of starch damage in ball-milled flour or premixed dough. The peak at 85°C is therefore probably largely due to the increase in consistency associated with the rupture and gelatinization of intact starch granules. Damaged granules, on the other hand, would be expected to gelatinize at a lower temperature (contributing to consistency at 75°C) because their rupture has already been partly achieved by mechanical means.

However, the results with isolated starch (a single peak at 75°C, Fig. 4) appear to conflict with this conclusion, and the peak for gluten occurred at an even lower temperature (65°C) when it was

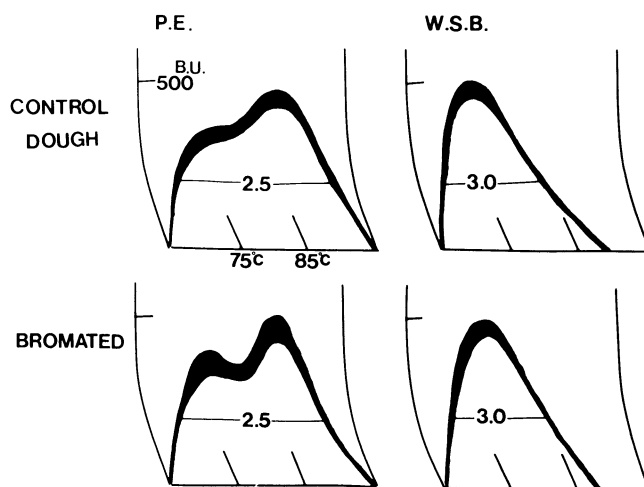


Fig. 7. Do-Corder curves for flours defatted with petroleum ether (P.E.) or water-saturated butanol (W.S.B.). The figure under each curve stands for the lever position of the instrument.

examined by itself. Testing of a simple combination of starch and gluten gave a Do-Corder curve with peaks at 70 and 85°C. This lack of agreement with the testing of starch and gluten separately suggests that the two may interact, making their separate testing atypical and invalid for the present purposes. Furthermore, the lack of complete agreement between the curve for normal flour and that for the starch-gluten mixture indicates that other constituents (eg, lipids) may play a minor part in determining the shape of the curve. Making these comparisons at equivalent levels of water addition is also a problem.

ACKNOWLEDGMENTS

We gratefully acknowledge the expert technical assistance of H. Hara and K. Okano and the advice of C. W. Wrigley of the Wheat Research Unit of the Commonwealth Scientific and Industrial Research Organization (Australia) on the preparation of the manuscript.

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[Received March 17, 1981. Accepted June 23, 1981]

Methide Structures of Amino Acids from Cereals

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ABSTRACT—Methide structures of amino acids from cereals were determined by mass spectrometry. The structures were compared with those of the corresponding amino acids from other sources. The results show that the methide structures of amino acids from cereals are similar to those of the corresponding amino acids from other sources. The results also show that the methide structures of amino acids from cereals are different from those of the corresponding amino acids from other sources.

INTRODUCTION—The methide structures of amino acids from cereals have been reported (1,2). The results show that the methide structures of amino acids from cereals are similar to those of the corresponding amino acids from other sources.

EXPERIMENTAL PROCEDURES—The methide structures of amino acids from cereals were determined by mass spectrometry. The results show that the methide structures of amino acids from cereals are similar to those of the corresponding amino acids from other sources.

RESULTS AND DISCUSSION—The results show that the methide structures of amino acids from cereals are similar to those of the corresponding amino acids from other sources. The results also show that the methide structures of amino acids from cereals are different from those of the corresponding amino acids from other sources.

CONCLUSIONS—The results show that the methide structures of amino acids from cereals are similar to those of the corresponding amino acids from other sources. The results also show that the methide structures of amino acids from cereals are different from those of the corresponding amino acids from other sources.

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