Thermal Stability of Wheat Gluten

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ABSTRACT

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The thermal behavior of gluten was studied with differential scanning calorimetry in the temperature range 30–115° C. Four endothermic peaks were registered. The peaks at 64.6 and 111.8° C were assigned to thermal transitions in starch, whereas the peaks at 88.4 and 101.4° C were assigned to transitions in the gluten proteins. The apparent enthalpies of the protein transitions were, however, very small. These small enthalpies do not support the idea of protein denaturation as an important factor in the baking process.

The texture of bread is reputed to be the result of starch gelatinization and protein denaturation during the baking of fermented dough (Parker 1960, Ponte 1971). In the baking process, the temperature is raised from the fermentation temperature to about 95° C in the center of the bread. The influence of this thermal treatment on the different dough constituents is poorly understood. Starch has probably been examined in most detail, especially in diluted solutions (Stevens and Elton 1971). Gelatinization of potato starch (Donovan 1979) and wheat starch (Wootton and Bamunuarachchi 1979) in concentrated systems was recently studied also. The thermal behavior of the protein part of a dough, ie, the gluten proteins, is still unknown, however. Gluten is defined as the part of a dough remaining when starch and other water-soluble components have been washed away with excess water. The water content of gluten is 60–70%. Dry gluten is composed of 75–80% protein, 5–15% starch, 5–10% lipids, and small quantities of mineral salts (Pyler 1973).

Differential scanning calorimetry (DSC) is a method well suited for the study of thermal denaturation processes (Hegg et al 1978). So far DSC has not been used much either in the study of the baking process or in the examination of dough constituents during a thermal treatment (Donovan 1977).

In this investigation, the thermal behavior of gluten is reported and an attempt is made to identify the different peaks in the DSC thermogram. The thermal transitions of gluten are also compared with those of a dough.

MATERIALS AND METHODS

Materials

Gluten, starch, and dough were prepared from the Swedish winter wheat STARKE II. This flour contained 9.6% protein on a dry weight basis. Gluten was prepared using a semiautomatic gluten washer (Glutomatic, Falling Number, Stockholm, Sweden). The moisture content of the gluten was 63%, determined as described in AACC method 44-19. Starch was obtained by centrifugation of the washing water from the gluten washer and was dried in air at room temperature overnight. Doughs were prepared at 25° C from 10 g of flour and 5.5 ml of water and were mixed for 5 min at a speed of 62 rpm in a 10-g farinograph (Brabender, Duisburg, Germany) mixing bowl. Newly prepared doughs were used in all experiments.

Differential Scanning Calorimetry

Thermal transitions were measured by DSC performed on a

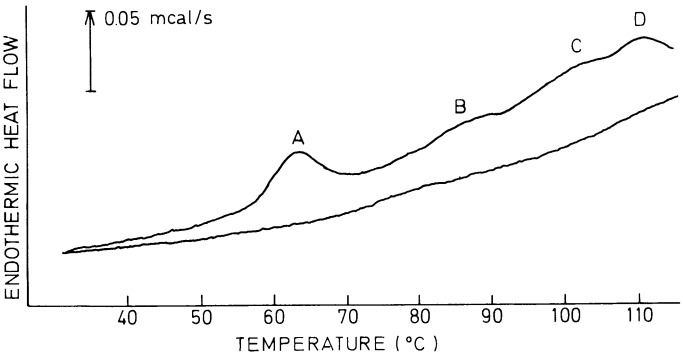

Fig. 1. The differential scanning calorimetry thermogram of gluten. Upper curve, gluten when heated at 10° C/min; lower curve, same gluten sample reheated after rapid cooling in the differential scanning calorimeter. Endothermic peaks **A** and **D** are probably the result of starch transitions, peaks **B** and **C** of protein denaturation.

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Perkin-Elmer DSC-2. Aluminum sample pans (Perkin-Elmer No. 219-0062) were used. The amount of gluten, dough, or starch-water mixture was 10–15 mg in all experiments. A sealed sample pan enclosing a piece of silver of appropriate heat capacity was used as reference. The experiments were conducted at a scanning rate of 10° C/ min. At lower scanning rates the peaks in gluten could not be observed because of a low signal to noise ratio.

Transition temperatures were defined as the intersection of the extrapolated lower temperature side and the extrapolated higher temperature side of the DSC peak. Calibration of the DSC and calculation of apparent transition enthalpies have been described earlier (Hegg et al 1978). All reported values are the means of three to six independent replicates.

RESULTS AND DISCUSSION

Figure 1 shows the DSC thermogram of gluten. Four endothermic peaks are observed when the temperature is linearly increased from 30° to 115°C. The corresponding transition temperatures and apparent transition enthalpies are given in Table I.

Donovan (1977) has reported that wheat starch gelatinization occurs near 65° C; the endotherm registered at 64.6° C (peak A) must therefore be caused by gelatinization of starch remaining in the gluten. The gelatinization process could be distinguished from protein denaturation by an estimation of the enthalpy of the two processes. The area of the gelatinization peak, ie, the enthalpy of the process, is dependent on the ratio of water to starch (Donovan 1979). Thus, to elucidate the influence of starch gelatinization on peak A, DSC thermograms of starch-water mixtures with the same water content as that of gluten were recorded, and the energy per milligram of starch was estimated. The energy of peak A in the gluten thermogram was calculated and compared with the energy per milligram of starch. A starch contamination of 7% in the gluten preparation corresponded to the observed area of peak A. Because this degree of starch contamination is conceivable, the conclusion is reasonable that peak A is due to gelatinization of starch in the gluten preparation.

A second endothermic peak has been observed on potato starch at higher temperatures at certain water contents (Donovan 1979). Endothermic changes also occur on wheat starch at higher temperatures (Eliasson 1980). Consequently, from these DSC-recordings at different water to starch ratios, peak D in the thermogram of gluten can reasonably be assigned to transitions in starch also.

In contrast to peaks A and D, which thus could be explained by starch transitions, peaks B and C are more difficult to account for. The lipid part of gluten could not give rise to these transitions, because the thermogram of separated wheat lipids gave no peaks. The lipids were prepared as described by Carlson et al (1978). Consequently, assignment of these peaks to the gluten proteins is tempting. In protein denaturation, however, large enthalpies usually are involved (Donovan et al 1975, Hegg[1]). The apparent enthalpies corresponding to peaks B and C, given in Table I, are about 100 times less than that of an ordinary protein denaturation process. In spite of this, these peaks must be assigned to the proteins in gluten because separated gluten proteins gave enthalpies of the same magnitude. Further investigations on separated gluten proteins are in progress to elucidate whether peaks B and C could be assigned to any specific protein or class of proteins in gluten. Of the two peaks registered, only peak B (88.4° C) is of any interest in the baking process; peak C occurs at too high a temperature (101.4° C). The amount of ordered structure of the gluten proteins is uncertain (Kasarda et al 1976, Pyler 1973). The low endothermic heat flow registered in the thermal denaturation process could be interpreted either as lack of ordered structure or as stability of ordered structure towards heat. In any case, the gluten proteins seem to be marginally influenced by heat, and the term "thermal denaturation" might in this connection be misleading. However, small changes crucial to the final baking result might occur during the heating process without a large endothermic heat flow.

[1] Unpublished results.

TABLE I.
Transition Temperatures and Transition Enthalpies of Gluten

Peak	Temperature (°C)	Apparent Transition Enthalpies (cal/g)
A	64.6 ± 1.6	0.35 ± 0.25
B	88.4 ± 1.8	0.06 ± 0.03
C	101.4 ± 1.6	0.03 ± 0.01
D	111.8 ± 0.8	0.08 ± 0.02

To examine whether the four peaks in gluten could also be distinguished in a baking process, some experiments were performed on the complex system of dough. Two endothermic peaks of about equal size were registered. (Two peaks were observed earlier by Donovan (1977).) One peak was at 67.6 ± 0.4° C and the other at 90.6 ± 1.7° C. These two peaks and peaks A and B in gluten show rather good correlation, although the transition temperatures in dough are somewhat higher than those of gluten (Table I). Considering only the temperatures, the first peak in dough seems to be the result of starch gelatinization and the second to protein transitions. However, an estimation of the enthalpy for the second peak in dough reveals about 1 cal/g compared to 0.06 cal/g for peak B in gluten (Table I). Apparently, the thermal behavior of the gluten proteins cannot explain the second peak in the thermogram of dough. Further studies must be performed before any conclusions can be drawn about this second peak in the baking process, but DSC thermograms may possibly arise not only from denaturation of a single component but also from interactions between components.

In conclusion, thermal transitions of proteinous material appear to occur in gluten, but the enthalpies involved are very small. These small enthalpies do not support the idea of protein denaturation as an important factor in the baking process.

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