Wheat Gluten: A Glassy Polymer[1]

To the Editor:

A number of workers (Arntfield and Murray 1981, Eliasson and Hegg 1980, Schofield et al 1984) have shown that wheat gluten gives only extremely small or no denaturation peaks (T_d) when heated in a differential scanning calorimeter (DSC) within the temperature range of 30–130° C. Two of the small endotherms observed were shown to be from residual starch. Schofield et al (1984) showed no peak with purified gluten.

Arntfield and Murray (1981) suggested that the thermal denaturation of gluten involved both endothermic and exothermic events that cancelled each other. If that is true, then changing the polarity of the solvent would not be expected to change the enthalpy of both events to the same extent and should result in a denaturation peak. We added glycerol to water (30:70, glycerol:H_2O), and added three parts of the mixture to one part gluten, but still found no denaturation peak for gluten (Fig. 1). Thus, it appears that the cancelling of endothermic and exothermic events is an unlikely explanation for the lack of a denaturation peak.

Perhaps a better explanation is that gluten does not have a long-range order. If that is true, the only order in gluten would be the orientation caused by the bond angles between adjacent amino acids. This would mean that gluten is an amorphous random polymer. Most, if not all, random polymers will show a glass transition. Therefore, we examined commercial wheat gluten with a Perkin-Elmer DSC-2. The gluten contained 11.3% moisture and clearly gave a glass transition (T_g change in heat capacity) at 50° C (Fig. 1). Cooling and reheating the sample gave the same transition but without the stress relief peak, as would be expected (Hoeve 1977). A laboratory-isolated gluten gave a similar curve (Fig. 1) but with a lower T_g value (11.4% moisture, 38° C). Also, as would be expected, the glass transition varied with the water content of the polymer (Ferry 1961). This is shown in Figure 2. The T_g of dry, hand-washed gluten appears to be above 160° C. It cannot be determined with accuracy, because the polymer decomposes at higher temperatures. At water contents above 13%, the transition occurs at room temperature. Thus, at lower moistures, the polymer is glassy at room temperature. At higher temperatures or water levels, the polymer is rubbery.

Similar results have been reported for other proteins. Kakivaya and Hoeve (1975) reported the T_g of elastin, which proved to be a cross-linked amorphous polymer. Yannas (1972) has demonstrated the glass point of gelatin and how it is depressed by glycerol.

From this work we concluded that wheat gluten has essentially no long-range order, which explains the absence of a denaturation peak when examined in a DSC. Wheat gluten appears to be an amorphous random polymer. This view, of course, is not consistent with the beta-turn conformation recently suggested for wheat gluten (Tatham et al 1985). Their model is based on a proposed structure of elastin which is also not universally accepted.

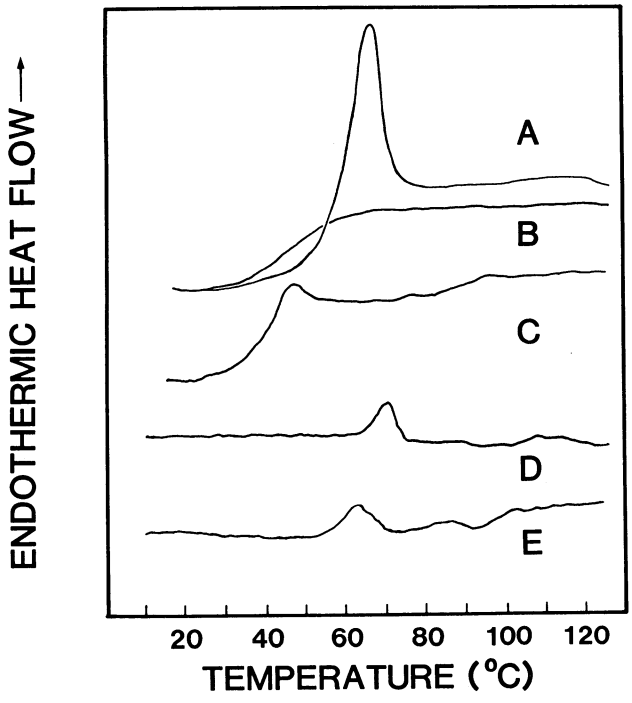

Fig. 1. Differential scanning calorimeter thermograms at 10° C min for: **A,** commercial wheat gluten (3.98 mg, 11.3% moisture); **B,** the same sample as A cooled and reheated; **C,** a gluten hand-washed from flour and lyophilized (3.29 mg, 11.4% moisture); **D,** hand-washed gluten (2.70 mg, 7.66 mg 30% glycerol); peak is presumed to be caused by starch as the endotherm for starch in 30% glycerol occurs at this temperature; **E,** hand-washed gluten (2.52 mg, 7.56 mg water); peak is presumed to be caused by starch as the endotherm for starch occurs at this temperature.

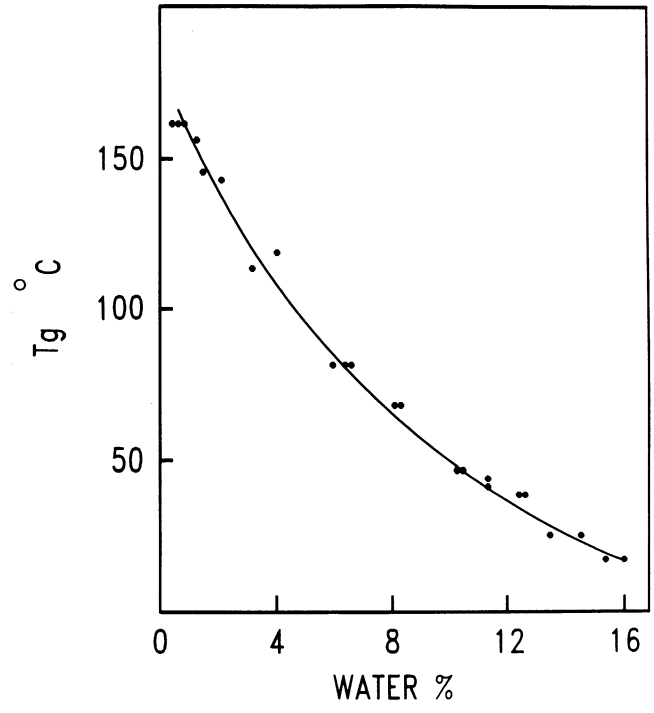

Fig. 2. Change in T_g as a function of moisture for a hand-washed and lyophilized gluten. Moisture was adjusted by weighing approximately 3 mg of gluten (6–7% moisture) into a differential scanning calorimeter sample pan of known weight. That pan containing the gluten was then placed into a chamber to be dried over P_2O_5 or tempered over water. The lid was applied before removing the pan from the chamber, sealed immediately, and reweighed. The moisture was then calculated from the known weights. All samples and pans were weighed using a Cahn 21 electrobalance.

[1]Contribution no. 86-158J, Kansas Agricultural Experiment Station, Kansas State University, Manhattan, KS 66506.

R. C. HOSENEY
K. ZELEZNAK
C. S. LAI

Department of Grain Science and Industry
Manhattan, KS 66506

LITERATURE CITED

ARNTFIELD, S. D., and MURRAY, E. D. 1981. The influence of processing parameters on food protein functionality. I. Differential scanning calorimetry as an indicator of protein denaturation. J. Inst. Can. Sci. Tech. 14:289.

ELIASSON, A.-C., and HEGG, P.-O. 1980. Thermal stability of wheat gluten. Cereal Chem. 57:436.

FERRY, J. D. 1961. Chapter 16 in: Viscoelastic properties of polymers. John Wiley and Sons: New York.

HOEVE, C. A. J. 1977. The elasticity in the presence of diluents from a symposium. Elastin and elastic tissue. In: Adv. Exp. Med. Biol. Vol. 79. L. B. Sandberg, W. R. Gray, and Carl Franzblau, eds. Plenum Press: New York.

KAKIVAYA, S. R., and HOEVE, C. A. J. 1975. The glass point of elastin. Proc. Nat. Acad. Sci. USA. 72:3505. Biophysics.

SCHOFIELD, J. D., BOTTOMLEY, R. C., LEGRYS, G. A., TIMMS, M. F., and BOOTH, M. R. 1984. Effects of heat on wheat gluten. Page 81 in: Proc. 2nd Internat. Wkshp. on Gluten Proteins. A. Graveland and J. M. E. Moonen, eds.

TATHAM, A. S., MIFLIN, B. J., and SHEWRY, P. R. 1985. The beta-turn conformation in wheat gluten proteins: Relationship to gluten elasticity. Cereal Chem. 62:405.

YANNAS, I. V. 1972. Collagen and gelatin in the solid state. In: Rev. Macromol. Chem. Vol. 8. G. B. Butler, K. F. O'Driscoll, and M. Shein, eds. Marcel Dekker: New York.

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