Investigation of the Effects of Different Concentrations of Sucrose on the Thermal Properties of Porcine Proteins using DSC.

Solina, M., Baumgartner, P., Skurray, G., and Bergan, J.
Muscle Foods Research Unit.
University of Western Sydney, Hawkesbury.

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Introduction

Asian style processed meats are formulated with significantly larger amounts of sucrose compared to western style processed meats. Studies on NaCl have shown it to be a great influence on the conformational structure of food proteins (Barbut and Findlay, 1991; Quinn *et al.*, 1980). Similar studies of sucrose on plant (Sheard *et al.*, 1986; Sessa, 1992) and egg proteins (Back *et al.*, 1979; Ma *et al.*, 1986) have shown that sucrose is also an influencing factor in this environment. Thus, the effects of sucrose on meat may be of great importance to the functional properties of proteins. At present there are no published papers on the effects of sugars on meat proteins. This work aims to determine the effects of differing sucrose concentrations on the thermochemical properties of porcine tissue proteins.

Materials and Methods

M. *longissimus dorsi* was collected from 160-168 day old Large White pigs that were slaughtered by normal commercial practices. The pork was minced through a 5 mm plate. Three different sucrose levels relative to the percentage of total meat was used. The concentrations of sucrose used were 3.0%, 6.0%, and 12%. The minced porcine muscle was mixed for approximately 10 minutes with the appropriate sucrose concentration. Each treatment was allowed to equilibrate for 12 hours at 4°C.

DSC analysis was performed on a Perkin-Elmer DSC 7. The instrument was calibrated for temperature with samples of Indium and water. The machine constant that was used in the determination of enthalpy of denaturation was obtained from thermograms of weighed amounts of indium using a value of 28.46 J/g for its heat of melting. A baseline was established using two empty aluminium pans and was subtracted from each sample thermogram. Accurately weighed samples (10 - 15 mg) of non-fat components of the equilibrated sample were sealed in Perkin Elmer 50 µl aluminium pans (Part No. B016-9321) and then hermetically sealed with a crimper. An empty Perkin Elmer 50 µl aluminium pan was used as a reference. The samples were then analysed in a Perkin-Elmer DSC 7 using a programmed heating rate of 10°Cmin^{-1} over a temperature range of 7 to 107°C. A minimum of four replicates was used. Tmax (temperatures of maximum heat input) and ΔH (total enthalpy of denaturation) were recorded for each sample.

Results

The thermogram for minced porcine muscle (Figure 1: Curve A) in the absence of sucrose is an example of the porcine protein system which served as a point of reference when comparing the effects of sucrose on the protein. The addition of different sucrose concentrations resulted in varying effects on the Tmax and ΔH values of the different proteins. Curves B, C, and D in Figure 1 are typical curves for porcine muscle with 3.0%, 6.0% and 12% sucrose.

The sample containing porcine muscle alone produced three major peaks which were observed to have an average Tmax ± standard deviation values of 55.9°C±0.3°C (Peak I), 64.8±0.8°C (Peak II), and 77.4±0.2°C (Peak III). Increasing the concentration of sucrose frequently increased the denaturation temperature of the porcine proteins (Table 1). Furthermore, an increase in sucrose concentration did not cause a disappearance of either Peak I, II or III as observed in samples with added NaCl (Quinn *et al.*, 1980; Barbut and Findlay, 1991). The increase observed in all three transitions were significantly different ($P<0.01$) from the control (no sucrose) at all three sucrose levels indicating an apparent linear response for Peak I (Figure 2: y (Peak I)), Peak II (Figure 2: y (Peak II)) and Peak III (Figure 2: y (Peak III)).

Changes in denaturation temperatures of proteins were accompanied by corresponding changes in enthalpy (ΔH). Upon addition of sucrose, the enthalpy of the system significantly decreased (Table 1). The greatest decrease in enthalpy upon addition of sucrose was observed in the sample with 3.0% sucrose, followed by 6.0% and 12.0% sucrose respectively. There was no significant difference between the enthalpy values of the treatments containing sucrose. Thus, these curves indicate that although the addition of 3.0% sucrose did cause a significant decrease in enthalpy, no further decrease was observed by increased sucrose concentrations.

Discussion

Back *et al.*, (1979) explained that proteins may be stabilised generally by a combination of hydrogen bonding, electrostatic interactions, hydrophobic interactions, and with particular proteins cross-linking, metal complexing, and specific binding of ions and cofactors. Hydrophobic interactions are generally considered to be the major single factor in stabilising the three-dimensional structure of plant (Sessa, 1992) and egg proteins (Back *et al.*, 1979; Ma *et al.*, 1986) in the presence of sugars and polyols. Therefore, the stabilising effect that was observed (increased Tmax) in the samples containing sucrose may be due to the action of sucrose strengthening the hydrophobic interactions.

The study by Back *et al.*, (1979) explains that the effects of sugars on hydrophobic interactions and consequently on the thermal stability of proteins, should also depend upon how they affect the structure of water. These authors showed that hydrophobic groups are stronger in sucrose solutions than in pure water. These authors argued that it therefore seems likely, that this is the mechanism by which sugars in general may stabilise proteins to heat denaturation.

Slade *et al.*, (1989) showed that food materials containing sugars show typical behaviour of amorphous materials, for which the Glass transition theory may be applied. Sucrose, which has a crystalline structure, may according to this theory, reduce the amount of free water and volume within the porcine system (Sperling, 1986). This may add rigidity to the otherwise amorphous system or may result in a decrease in the mobility and rate of reactions occurring within the protein system. Thus, the resultant higher Tmax values obtained in our study upon the addition of sucrose, is most likely due to the greater amount of heat energy required to thermally denature the now more rigid porcine proteins. This would be consistent with the generally accepted concept that increased

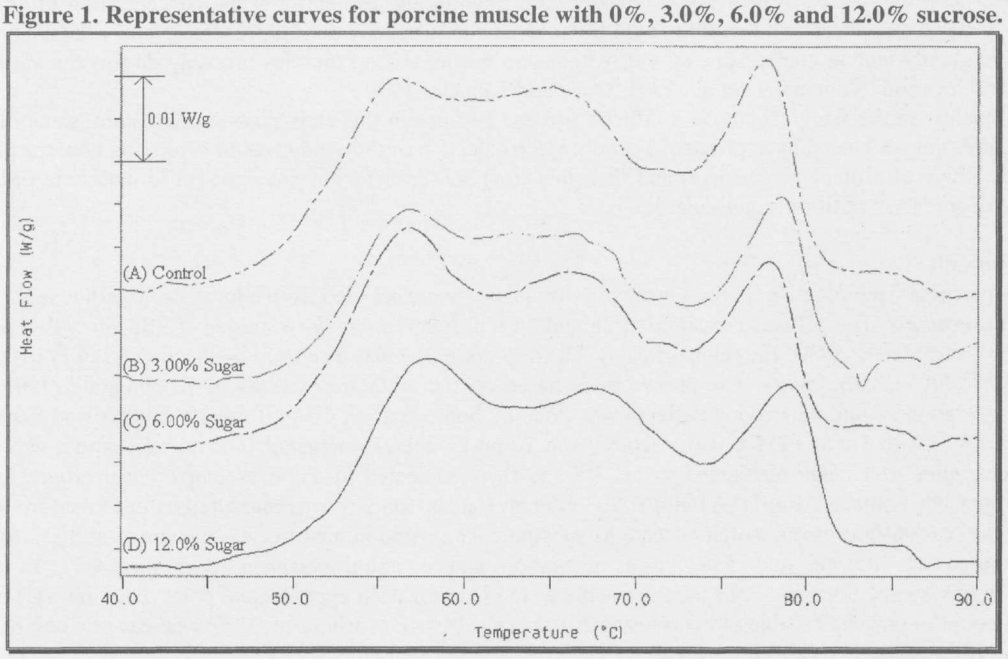
conformational rigidity of proteins would increase their thermal stability (Hageman, 1992; Bell & Hageman, 1996).

The observed enthalpy decrease may be due to the decrease in secondary structure of the protein (Koshiyama *et al.*, 1981) which may occur due to protein aggregation and the break-up of hydrophobic interactions (Arntfield and Murray, 1981).

Conclusion

Sucrose caused a strong linear increase in the denaturation temperature of the porcine myofibrillar proteins and was found to significantly decrease the enthalpy of denaturation of the porcine proteins. There was no significant difference in increasing the sucrose concentration from 3 to 12% for the enthalpy. Further work has been carried out to determine the effect of combinations of differing sucrose and NaCl concentrations and the effect of thermal processing treatments such as drying on the thermal properties of the minced porcine proteins. These results are to be correlated to final product quality attributes such as texture.

Figure 1. Representative curves for porcine muscle with 0%, 3.0%, 6.0% and 12.0% sucrose.



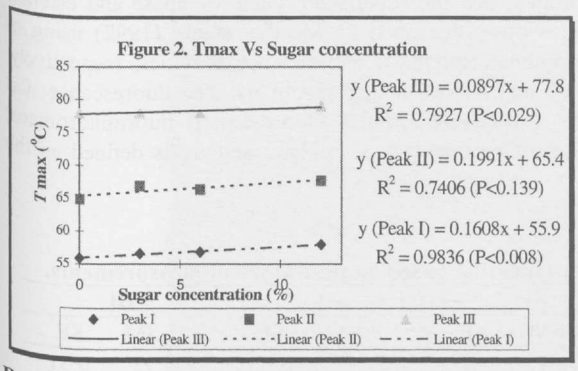


Table 1. *T*max and ΔH values for Peak I, II, and III at different concentrations of sucrose

	Temperature of maximum heat input (*T*max °C)			Total Enthalpy (ΔH J/g)
Sucrose %	**$Tmax_I$**	**$Tmax_{II}$**	**$Tmax_{III}$**	**ΔH_{Total}**
0%	55.9 ± 0.3°C	64.8 ± 0.8°C	77.4 ± 0.2°C	3.8 ± 0.3°C
3.0%	56.6 ± 0.2°C	66.8 ± 0.6°C	78.0 ± 0.4°C	2.8 ± 0.6°C
6.0%	56.8 ± 0.1°C	66.3 ± 0.6°C	78.0 ± 0.2°C	2.8 ± 0.2°C
12.0%	57.9 ± 0.1°C	67.7 ± 0.1°C	79.0 ± 0.04°C	2.9 ± 0.4°C

Note: Results are presented as means ± standard deviation.

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