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EFFECT OF POLYDEXTROSE AND K-CARRAGEENAN ON INITIAL FREEZING POINT OF CHICKEN SURIMI

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SUMMARY

Initial freezing points (T_i) of chicken surimi samples mixed with sodium tripolyphosphate (w = 0.3%), κ-carrageenan (w = 0.5 %) and different mass fractions of polydextrose (w = 1 -10%) were determined by use of differential thermal analysis (DTA). Chicken surimi was produced following a modified procedure of Dawson et al. (1988.) from broiler (Sasso, 12 weeks, 1.73 kg live wt.). Water content in chicken surimi was 84.05% before mixing with added substances. Relations between decrease of the initial freezing point (T_i) as function of mass fractions (w) of the polydextrose were determined by linear regression. Coefficients of determination R^2 = 0.90 were obtained. There were differences in the T_i values for samples of chicken surimi and water solution of polydextrose as a function of the mass fraction of polydextrose calculated on the total mass of water. These findings support the assumption that polydextrose interacts with chicken surimi proteins, resulting in an increase in the mass fraction of bound water, which depresses T_i. The results are compared with results for chicken surimi with added different mass fractions of polydextrose (w = 1 -10%) but without κ-carrageenan and with Pham model for prediction T_i.

Key-words: initial freezing point, DTA, chicken surimi, polydextrose, κ-carrageenan

INTRODUCTION

The most important food's thermal property in frozen state is initial freezing point (T_i). Most mathematical models for predicting thermal properties of frozen food are based on equation for freezing point depression, T_i (Heldman, 1982; Schwartzberg, 1976; Chang and Tao, 1981; Chen, 1985; 1986; Fikiin, 1998; Miles et al., 1997; Pham, 1996; van der Sman, 2004, James et al., 2005) which states that, $\Delta T = K_k \cdot \gamma$, where ΔT is the temperature decrease, K_k is cryoscopic constant, and γ is molality. The lower the initial freezing point, the more microbiologically stable the food, the lower the water activity, the higher its boiling point and the slower the ice content increases as the temperature is lowered (Miles et al., 1997). To protect myofibrillar proteins from freeze-denaturation during frozen storage, cryoprotectants were generally added (Park et al., 1996). The most effective cryoprotectants for myofibrillar proteins carbohydrates, such a sucrose, sorbitol, maltodextrins and polydextrose (Tomaniak et al., 1998; Herrera and Mackie, 2003). All sugars interact strongly with water and participate in the water lattice through hydrogen bonds, this presumably led' to formation of extended region of hydrogen-bondend structured water in the vicinity of the cryoprotective molecule , which may stabilize surface hydration of protein and protect them from freeze injury (Auh et al., 2003).
Polydextrose is a highly branched polysaccharide prepared by the thermal polymerization of glucose. The cryoprotective effects of polydextrose may be attributed to the numerous hydroxyl groups available for hydrogen bonding with proteins, leading to increased protein hydration, reduced surface tension of water and decreased aggregation (denaturation) (Smolinska et al., 1995; Park et al., 1993). In this research, laboratory design of DTA apparatus was applied to determine the relative effects of different mass fractions of polydextrose on the T_i of samples of chicken surimi with 0.5% κ-carrageenan.

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MATERIAL AND METHODS

Samples of chicken surimi were prepared in the laboratory from broiler (Sasso, 12 weeks, 1.73 kg live wt.) by the modified procedure of Dawson et al. (1988.). Samples were mixed with sodium tripolyphosphate (w = 0.3%), κ-carrageenan (w = 0.5 %) and different mass fractions of polydextrose (w = 1-10%). Mass fractions were determined as percent of total mass. Moisture content was 84.05% and ash content was 0.27% determined by the A.O.A.C. method (1980) for meat products before added components. Total protein mass fraction was 15.12% determined with samples by the Kjeldahl method; (Kjeltec System, model 1002 Distilling Unit, Tecator Inc., Boulder, CO, U.S.A.). Samples were packed in polyethylene bags and fast frozen in liquid nitrogen and stored at - 25 °C. Average storage time was 1 week before DTA experiments.

DTA apparatus was constructed in the laboratory (Kovačević and Kurtanjek, 1993) and used for measurement of initial freezing point T_i. Thermocouples were made from Alumel-Chromel wire (0.07 mm diameter). The thermocouples were calibrated using a standard platinum resistance thermometer, Pt-l00 (Riddle et al., 1976) at a temperature ranged -30 to 25 °C. The instruments were interfaced with a standard PC and a sampling rate of 3.5 kHz was used. All data were prefiltered with at +/-3σ rule for noise rejection prior to data analysis (Mendenhall and Sinchic, 1988). From statistical analysis of the measurement signal, the calibration error of 50 mK and sensitivity of 10 mK were estimated. An aqueous solution of $CaC1_2$, $w(CaC1_2)$ = 30%, was used as reference substance for DTA measurement. Distilled water was used as a calibration substance for the static correction of the initial freezing point.

RESULTS AND DISCUSSION

DTA measurements of samples of chicken surimi mixed with the added substances were conducted at a temperature ranged from -25 to 5°C. Results of DTA are presented in Fig. 1. The DTA curves have a low level of measurement noise, which is a result of statistical data filtering and rejection of outliers by +/-3σ rule, as well as high frequency of data sampling. Drift from the base line at a the temperature ranged from 0 to 0.2°C occured due to difference of thermal properties of samples and the reference substance. The peak points were read off as the initial freezing points from DTA diagrams. Systematic shifts of the initial freezing points toward lower temperatures with increased concentration of polydextrose can be observed data for the initial freezing points T_i are given in Table 1. ln Fig. 1. Below the initial freezing points DTA diagrams for all samples show systematic increase in the temperature difference with increased level of the polydextrose. Each DTA diagram is corrected only for constant error of +0.1235355°C being determined from calibration with distilled water. The parameters of the regression equation were determined by the method of linear correlation of T_i with mass fraction of the polydextrose:

$$T_i = -0.0607 \cdot x_s - 0.277 \qquad /1/$$

were standard errors $e(T)$ = 0.0838 coefficient of determination R^2 = 0.90. The most effect of cryoscopic depression of initial freezing point T_i is exhibited by the samples of chicken surimi with 0.5% κ-carrageenan with added 9% of polydextrose.

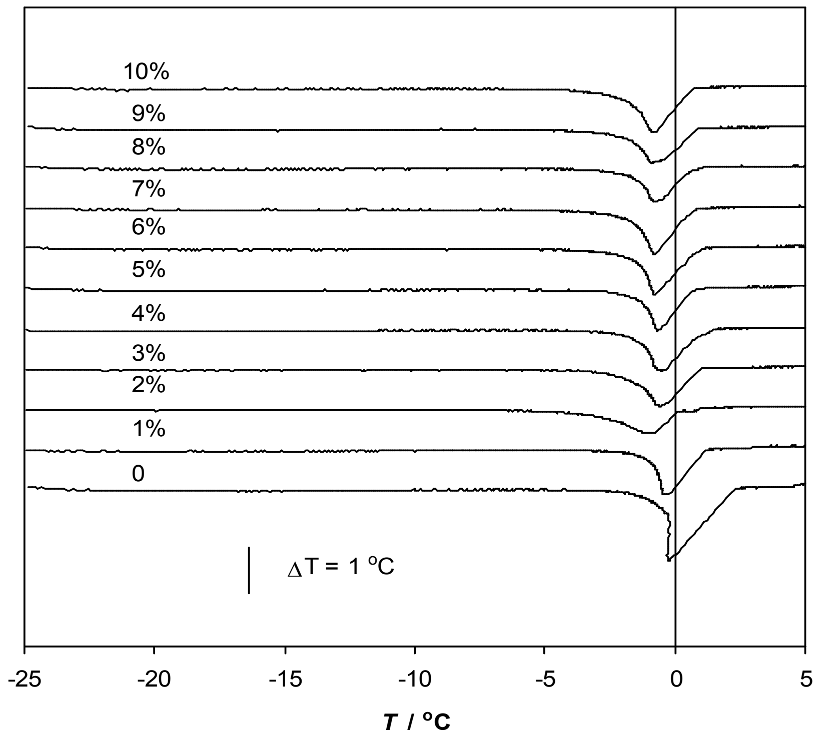

Figure 1. DTA curves of chicken surimi with 0.5% κ-carrageenan as a function of w (%) of polydextrose ΔT is temperature difference between sample and reference substance

Table 1. Experimental data of initial freezing point (T_i) of chicken surimi with 0.5% κ-carrageenan

Mass fractions of polydextrose (%)	T_i (°C)	
	Experimental data	Linear regression
0	-0.40	-0.38
1	-0.48	-0.45
2	-0.33	-0.53
3	-0.64	-0.60
4	-0.69	-0.67
5	-0.80	-0.74
6	-0.88	-0.81
7	-0.94	-0.88
8	-0.94	-0.95
9	-1.04	-1.02
10	-0.99	-1.09

The observed values of T_i are presented in Fig. 2 along with the values predicted by the Pham model (Pham, 1996), given by the regression equation with respect to the mass fraction of water (w_w), ash (w_a), other components (w_o) and mass fraction of added component (x_s),:

$$T_i = -4.66 w_o / w_w - 46.4 w_a / w_w \qquad /2/$$

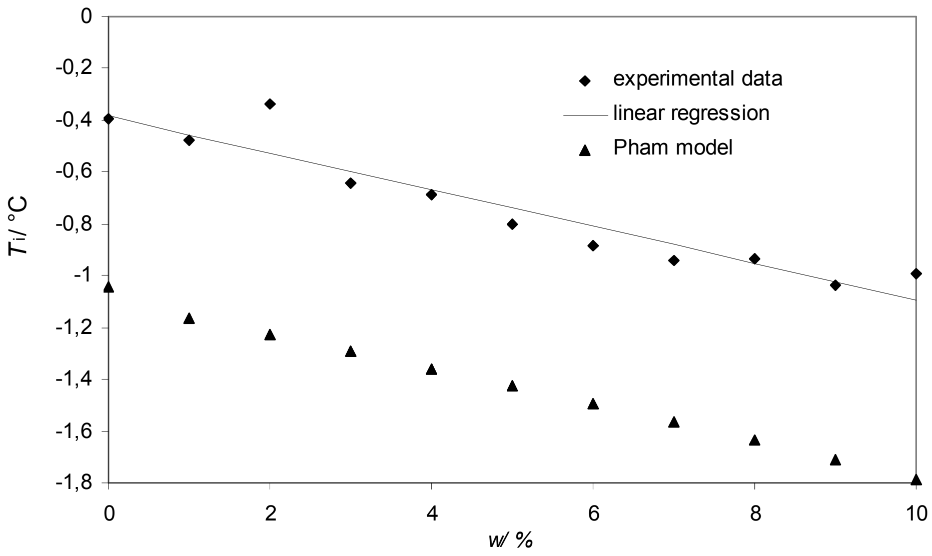

Figure 2. Initial freezing point (T_i) of chicken surimi with 0.5% κ-carrageenan as a function of mass fraction (*w*) of polydextrose

The experimental value for T_i and results by the Pham model /2/, show large deviations. It can be concluded that the effect of mass fraction is not the only parameter, but also specific components are important. A deviation of initial freezing points T_i approves that polydextrose acts in accordance with the cryoprotecting mechanism and interacts with protein in surimi. Therefore it increases the amount of bound water and decreases the initial freezing point (Sych et al., 1995; Wang and Kolbe, 1991).
Fig. 3 shows comparison of dependencies of T_i for chicken surimi and chicken surimi with 0.5% κ-carrageenan. Deviations of initial freezing points T_i shows that κ-carrageenan also lowers T_i and interacts with protein in chicken surimi.
Comparison of dependencies of T_i for chicken surimi with 0.5% κ-carrageenan and water solution of polydextrose on mass fraction of polydextrose calculated on total mass of water is presented in Fig. 4. Deviations of initial freezing points T_i approve that polydextrose acts in accordance with the cryoprotecting mechanism and interacts with protein in surimi.

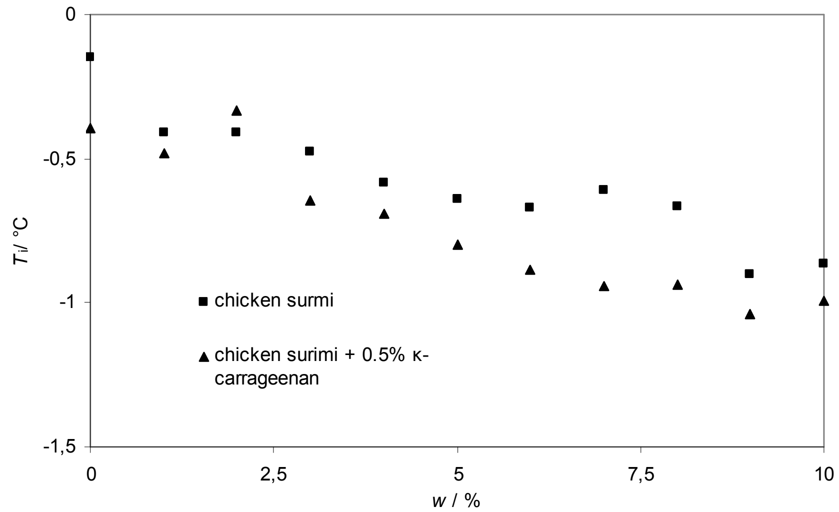

Figure 3. Initial freezing point (T_i) of chicken surimi and chicken surimi with 0.5% κ-carrageenan as a functions of mass fraction (*w*) of polydextrose

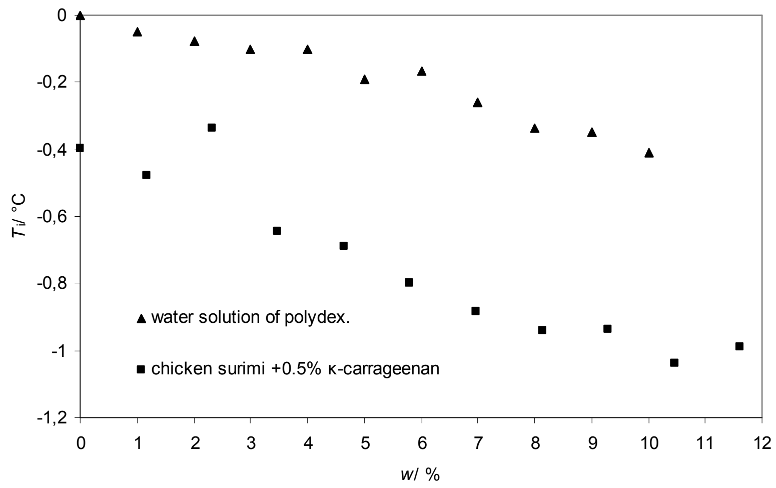

Figure 4. Comparison of dependencies T_i for chicken surimi with 0.5% κ-carrageenan and water solution of polydextrose on mass fraction (*w*) of polydextrose calculated on total mass of water

CONCLUSION

Freezing point depression of chicken surimi with 0.5% κ-carrageenan is a linear function of the increased mass fraction of polydextrose. Deviations of experimental value for initial freezing points T_i, and results by the Pham model approvethat polydextrose acts in accordance with the cryoprotecting mechanism and interacts with protein in chicken surimi. The T_i values for samples of chicken surimi and chicken surimi 0.5% κ-carrageenan as a function of the mass fraction of polydextrose show deviations. It can be concluded that κ-carrageenan also interact with chicken surimi proteins and lowers T_i. The T_i values for samples of chicken surimi with 0.5% κ-carrageenan and water solution of polydextrose as a function of the mass fraction of polydextrose calculated on the total mass of water were different for all the samples. The results support the assumption that polydextrose interacts with the protein of chicken surimi by increasing the mass fraction of bound water and lowering the T_i.

REFERENCES

1. AOAC (1980): Official Methods of Analysis. 13th ed. Association of Official Analytical Chemists, Arlington,Virginia. USA, p.153.
2. Auh, J.H., Kim, Y. R., Cornillon, P., Yoon, J., Yoo, S. H., Park, K. H. (2003): Cryoprotection of protein by highly concentrated branched oligosaccharides. I.J. Food Sci. and Tech. 38:553.
3. Chang, H.D., Tao, L.C. (1981): Correlation of enthalpies of food systems. J .Food Sci., 46:1493.
4. Chen, C.S. (1985): Thermodynamic analysis of the freezing and thawing of foods: Enthalpy and apparent specific heat. J. Food Sci., 50:1158.
5. Chen, C.S. (1986): Effective molecular weight of aqueous solutions and liquid foods calculated from the freezing point depression. J. Food Sci., 51:1537.
6. Dawson, P.I., Sheldon, B.W., Ball, H.R. (1988): Extraction of lipid and pigment components from mechanically separed chicken meat. J. Food Sci., 53:1615.
7. Fikiin, K.A. (1998): Ice content prediction methods during food freezing: a survey of the Eastern European literature. J. Food Eng., 38:331.
8. Heldman, D.R. (1982): Food properties during freezing. Food Technol., 36:92.
9. Herrera, J.R., Mackie, I.M. (2003): Cryoprotection of frozen-stored actomyosin of farmed rainbow trout (Oncorhynchus mykiss) by some sugars and polyols. Food Chem., 81:91.
10. James, C., Lejay, I., Torosa, N., Aizpurua, X., James, S. J. (2005): The effect of salt concentration on the freezing point of meat simulants. I. J. of Refigeration, 28 : 938.
11. Kovačević, D., Kurtanjek, Ž. (1993): Enthalpy determination of frozen surimi by differential thermal analysis. Food. Technol. Biotechnol., 31:157

12. Lanier, T.C., Akahane, T. (1986): Method of retarding denaturation of meat products. U .S. patent No. 4,572, 838.
13. Mendenhall, W., Sinchic, T. (Ed.). (1988): "Statistics for Engineering and Computer Sciences", 2nd ed. Collier MacMillan Publishing, London.
14. Miles, C.A., Mayer, Z., Morley, M.J., Houška, M. (1997): Estirnating the initial freezing point of foods from composition data. Int. J. Food Sci. Technol., 32 : 389.
15. Park, S., Brewer, M.S., McKeith, F.K., Bechtel, P.J., Novakofski J. (1996): Salt, cryoprotectants and preheating temperature effects on surimi-like material from beef or pork. J. Food Sci., 61:790.
16. Park, J.W., Lanier, T.C., Pilkington, D.H. (1993): Cryostabilization of functional properties of pre-rigor and post-rigor beef by dextrose polymer and/or phosphates. J. Food Sci., 58:467.
17. Pham, Q.T. (1996): Prediction of calorimetric properties and freezing time of foods from composition data. J. Food Eng., 30:95.
18. Riddle, J.L., Furukawa, G.T., Plumb, H.H. (1976): Platinum resistance thermometry. In "Measurements in Heat Transfer". Springer Verlag, Berlin. p.25.
19. Smolinska, T., Gawronska, B., Malecha, M. (1995): Effect of cryoprotectants and frozen storage on ultrastructural and electrophoretic picture of MDTM proteins. Arch. Geflügelk., 59: 257.
20. Sych, J., Lacroix, C., Adambounou, L.T., Castaigne, F. (1990): Cryoprotective effects of lactitol, palatinit and polydextrose on cod surimi proteins during frozen storage. J. Food Sci., 55: 356.
21. Schwartzberg, H.G. (1976): Effective heat capacities for the freezing and thawing of foods. J. Food Sci., 41:152.
22. Tornaniak, A., Tyszkiewicz, I., Komosa, J. (1998): Cryoprotectants for frozen red meats. Meat Sci., 50:365.
23. Van der Sman, R.G.M., Boer, E. (2004): Predicting the initial freezing point and water activity of meat products from composition data. J. Food Eng., 66:469.
24. Wang, D.Q., Kolbe, E. (1991): Thermal properties of surimi analyzed using DSC. J. Food Sci., 56:302.

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