คุณสมบัติด้านความร้อนและฟิสิกส์ของเจลจากหนังสัตว์
Thermo-physical Properties of Gelatine from Cattle Skin

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ABSTRACT

Gelatine extracted from cattle skin is widely used in food industries such as the manufacture of confectioncry, jelly crystals, packaged desserts, icecream, canned ham and many other food products. Concerning thermal process of these products, thermophysical properties of gelatine are essentially required for identifying the process conditioin. Thermal conductivity, specific heat, viscosity, density and boiling point were studied on as a function of temperature, pH and the concentration of gelation. The results are presented in the form of mathematical model.

บทคัดย่อ

เจลที่สกัดได้จากหนังสัตว์ซึ่งเป็นของเหลือจากโรงฆ่าสัตว์ถูกนำมาใช้ประโยชน์ในอุตสาหกรรมอาหารหลายประเภท เช่นใช้ในอุตสาหกรรมผลิตลูกกวาด แยม เยลลี่ ไอศครีม แฮมกระป๋อง และอื่น ๆ และเนื่องจากขบวนการผลิตอาหารเหล่านั้นเกี่ยวข้องกับการใช้ความร้อน คุณสมบัติเชิงความร้อน และฟิสิกส์ (thermo-physical property) ของเจลจึงเป็นสิ่งสำคัญที่ต้องคำนึงถึง เพื่อใช้ในการออกแบบสภาวะการใช้ความร้อนในขบวนการผลิตให้เหมาะสม คุณสมบัติเชิงความร้อนและฟิสิกส์ของเจลที่ได้ศึกษาคือ ค่าการนำความร้อน (thermal conductivity) ค่าความหนาแน่น (density) ค่าความร้อนจำเพาะ (specific heat) ค่าความหนืด (Viscosity) จุดเดือด (boiling point) คุณสมบัติเหล่านี้ได้ถูกศึกษาในเทอมของปัจจัยต่าง ๆ เช่น อุณหภูมิ ความเป็นกรดเป็นด่างและความเข้มข้นของเจล และสามารถอธิบายได้โดยแบบจำลองทางคณิตศาสตร์

INTRODUCTION

It is known that gelatine and certain kinds of glues can be peoduced from animal tissues. These products are formed from the collagen material in animal tissues. The extraction of gelatine from collagen-bearing materials such as ossein and skins is almost universally performed in tanks with a steam coil under a perforated false bottom. After extraction, the gelatine liquor is filtered, concentrated, dried and ground to powder. Gelatine is widely used in the food industries such as in the production of jelly crystals, ice-cream, confectionery and packaged desserts. Its functions are as a gelling agent, as a surface acting sol and as a film forming substance. Concerning thermal process of these products, thermophysical properties of gelatine which involved in the process condition are essentially known. Consequently thermo-physical properties of gelatine were studied in this work.

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METHODOLOGY

specific heat measurement

The method of mixtures was used to measure the specific heat of gelatine. A sample of known mass and temperature was mixed into a calorimeter of known specific heat containing water of known temperature and mass. The specific heat was then calculated from a heat balance equation between the heat gained or lost by the water and calorimeter and that lost or gained by the sample. The equation for calculating the average specific heat of the sample was given by Mohsenin (1980).

$C_s = C_w(W_w+E_w)(T_c-T_m)/W_s(T_m-T_{si})$ ...(1)

Where C_s = average specific heat of sample in the temperature range T_s To T_m (kJ/kg K)

C_w = average specific heat of water in the temperature range T_c to T_m (kJ/kg K)

W_w = weight of water (kg)

E_w = water equivalent of the system (kg)

T_c = initial temperature of calorimeter (K)

T_m = final temperature of the mixture (K)

T_{si} = initial temperature of sample (K)

W_s = weight of sample (kg)

Measurement procedure

The measurement procedure was similar to Putranon et al. (1980). The calorimeter was a vacuum thermos flask fitted with a small magnetic stirrer. The thermocouple (type K) was placed through the lid to the midpoint of the calorimeter to record the mixing temperature. A sample of gelatine at various concentration from 2% to 30% solid content (35 g) was placed in a glass bottle and heated to a temperature of 70°C in a controlled temperature bath. The water (75mL) at room temperature was poured into the calorimeter and left until the temperature of the system was equilibrated. The sample was then rapidly added to the calorimeter. The temperature of the mixture was recorded at 1 min intervals initially, then at 5 min intervals, using a digital thermometer which had an accuracy of ± 0.1°C. The equilibrium temperature was determined as described by Mohsenin (1980) and Putranon et al. (1980). the water equivalent of the flask was determined by using 40 gm of water at a known temperature. The method was calibrated by measuring the specific heat of water (C_w = 4.18 kJ/kg K). The standard error was 3.5% for water.

Thermal conductivity

The method for measuring the thermal conductivity of gelatine was developed by Rahman (1991), based on the modified Fitch method (Fitch 1935, Zuritz et al. 1989). The apparatus consisted of a thermos bottle with a stopper and an insulated copper disc. the thermos bottle was sealed by a cork stopper, pierced through the centre by a 19-mm solid copper rod. A polystyrene disc was glued to the top of the cork stopper. A 15-mm diameter copper disc was held in a polystyrene disc which had a compartment for placing the sample. Two thermocouples were fixed on the surface of the copper rod and disc.

Measurement procedure

The gelatine sample and the copper disc were left to equilibrate to room temperature. The thermos bottle was filled with crushed ice and water. The lest duration was always 240 s and temperature was recorded at 10 s intervals by a digital thermometer (a precision of ± 0.1°C)

Thermal conductivity calulation

The calculation of thermal conductivity was based on the quasi-steady conduction heat trasfer through a disk shaped product sample (Fitch 1935 and Mohsenin 1980).

$$\frac{A_C k_{f'}(T-T_{cu})}{l} = W_{cu}C_{pcu}\frac{dT}{dt} \quad ......(2)$$

Where A_c = contact area of samply and discs (m^2)

k = thermal conductivity of sample (W/m K)

T = temperature (K)

l = compartment thickness (m)

W = mass (kg)

C_p = specific heat (J/kg K)

t = time (s)

Subscripts

cu = copper

f' = modified Fitch method

Rahman (1990) evaluated the precision of the modified Fitch method. He found the correction factor, which was the ratio of true thermal conductivity over measured thermal conductivity, correlated with the sample thickness and measured thermal conductivity as follow :

correction factor = $3.95 + 97.91 - 5.3k_{f'}$...(3)

The maximum percentage error for this apparatus was ± 5% at temperautres above freezing.

Apparent viscosity

The apparent viscosity of the gelatine samples was measured by a Brookfield Small Sample Adapter viscometer (Brookfield Engineering Laboratories, Soughton). The measurements were made at 50, 60, 70 and 80°C.

Boiling point

The biling point of the gelatine sample was measured at atmospheric pressure by heating gelatine in an oil bath until the liquid started to boil. When the liquid boiled (bubbles of vapour were generated at the heating surface, rose through the mass of liquid and disengaged from the surface of the liquid) the temperature was recorded.

RESULTS AND DISCUSSION

Thermal conductivity

Thermal conductivity of gelatine was measured and modelled with respect to concentration. From the results obtained as a result of the experiments described in methodology section, the thermal conductivity of gelatine decreased from 0.599 to 0.411 W/m K with varying concentration of gelatine at 28°C (figure 1). By using a statistical analysis package (SAS 1985), the thermal conductivity of gelatine was correlated with solid contents by a linear form of equation as follows:

K = 0.59 - .009 X ...(4)

r^2 = 0.96

SEE = .001

SEE = standard error of estimation

= $\sqrt{(\Sigma(Y_i-Y_{eqn})^{42} / (n_t-n_m))}$

Where

K = thermal conductivity (W/m K)

X = solid content of gelatine (%)

Y_i = actual value
Y_{eqn} = predicted value by the equation
n_t = number of data points
n_m = number of constants

Usually thermal conductivity varies linearly within small concentration ranges (Mohsenin 1980). The high r^2 and low standard error of estimation indicated that the thermal conductivity of gelatine varies linearly with concentration over the measured range.

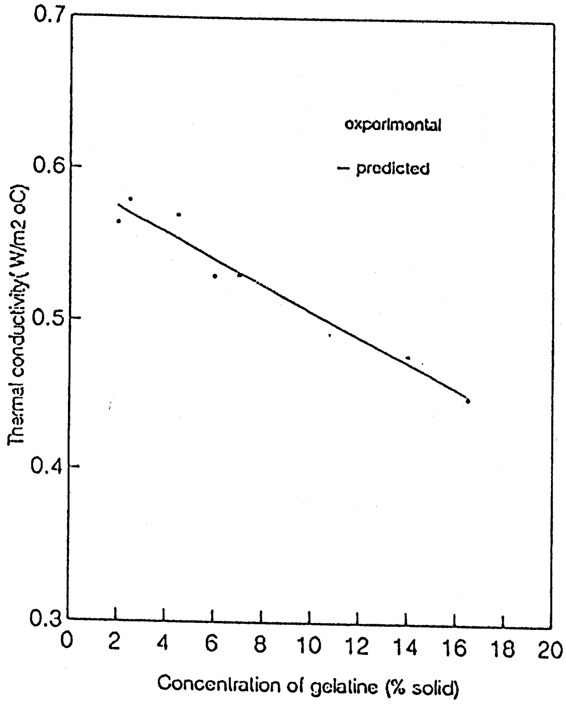

Figure 1. Thermal conductivity of gelatine at 28°C

Specific heat

From the experiments described in methodology section the specific heat of gelatine varied from 2.99 to 4.36 kJ/kg K (figure 2), and correlated with the empirical equation below:

$$C_p = \frac{3.32 + 4.186\, X_w}{1 + X_w} \qquad \ldots(5)$$

r^2 = 0.99
SEE = 0.41

Where

C_p = specific heat of gelatine (kJ/kg K)
X_w = moisture fraction of gelatine

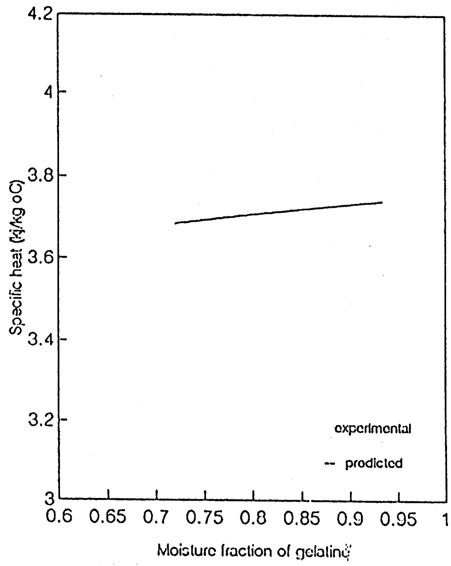

Figure 2. Specific heat of gelatine at 28°C

Boiling point

Boiling point of gelatine samples was 101°C at atmospheric pressure, an insignificant increase over 100°C for pure water. Consequently, a constant boiling point was used for the entire concentration range in the simulation program.

Viscosity

The measured viscosity of gelatine was platted in figure 3 as a function of temperature and concentration. Finch and Jobling (1977) reviewed the relationship of viscosity of ossein gelatin with temperature and concentration. The viscosity data were fitted using an Arrhenius form of equation at different concentrations. S-shaped log (viscosity)-concentration isotherms were found.

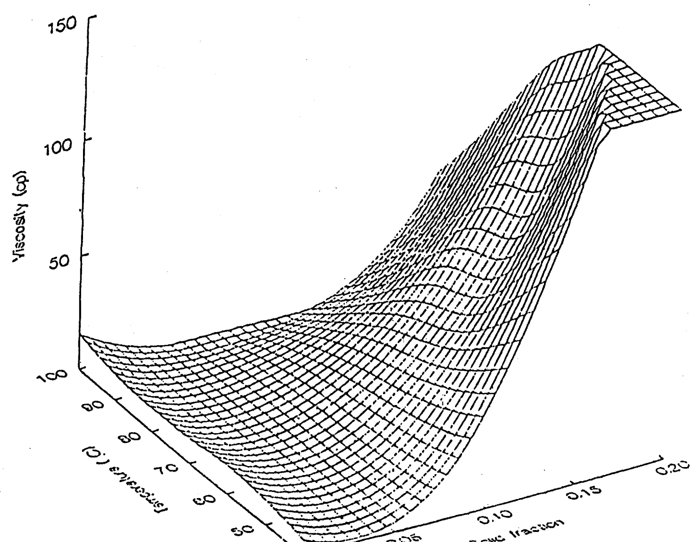

Figure 3. Effect of temperature on viscosity of gelatine at various concentration

The viscosity of gelatine was modelled as a function of temperature and concentration. It was difficult to get a good correlation when considering the whole range of concentration, so the concentration was divided into two ranges. Multiple regression equations were then fitted as follows.

For the low range of gelatine mass fraction :
(0.02 - 0.165)

μ = exp [-69.66 + 20.16exp (X_s) + 49.44exp(1/T] x 10-3 ...(7)

r^2 = 0.92

SEE = 0.33

Where μ = viscosity of gelatine (Pas)

x_s = solid fraction of gelatine

T = temperature of gelatine (°C)

For the high range of gelatine mass fraction
: (0.165-0.30)

μ = exp [-9.86 + 10.93exp(X_s) + 91.38/T] X 10-3 ...(8)

r^2 = 0.98

SEE = 0.11

Figure 4 shows the relationship between pH and viscosity of gelatine at various bloom strength. The effect of pH on viscosity of gelatine similarly behaved for all bloom strength. It was found that pH in the range of 4 to 9 did not significantly affect on viscosity but a small increase of viscosity at pH below 4.

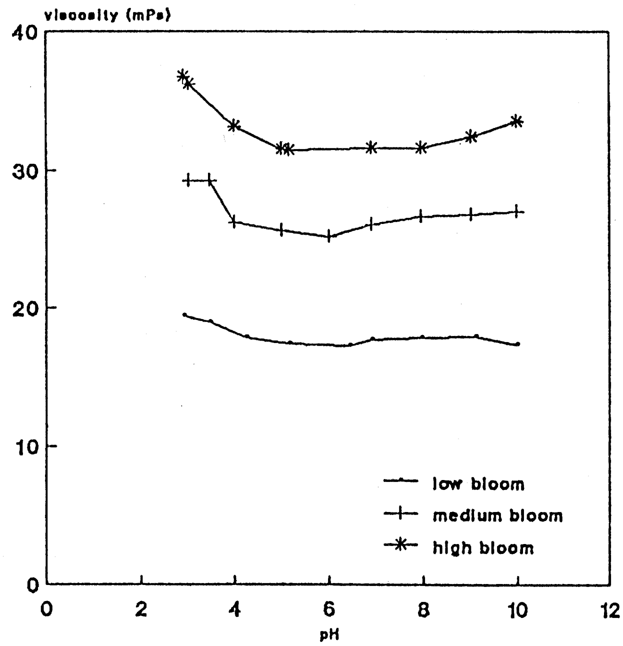

Figure 4. Effect of pH on viscosity of gelatine at various concentration

The effect of pH and temperature on viscosity of gelatine was illustrated in figure 5. Increasing temperature reduced the viscosity of gelatine while changing of pH from 3.2 to 6.2 did not alter the viscosity. Temperature factor more influenced on viscosity of gelatine than pH factor.

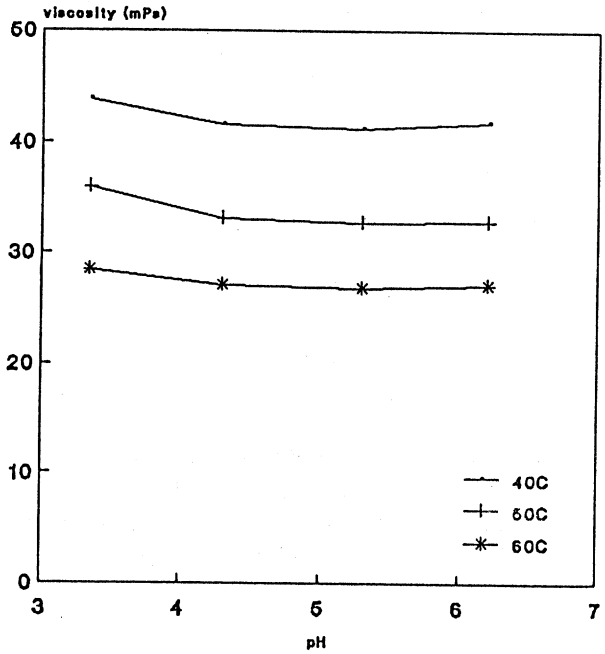

Figure 5. Effect of temperature and pH on viscosity of gelatine

CONCLUSION

Thermo-physical properties of gelatine extrated from the cattle skin were studied and graphically presented. The prediction of thermo-physical properties chaning on temperature, pH and moisture content of gelatine was clearly shown in mathematical models. The benefit of this work is that it facilitates any thermal process design for production of gelatine contining food. However this study is still limited to the certain range of the parameters.

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