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Effect of Temperature on Cooking Rate of Soybean

Sung-Kon Kim, Kwangho Cho and Jong-Goon Kim*

Department of Food Science and Nutrition, Dankook University, Seoul
** Department of Home Economics, King Sejong University, Seoul*

Abstract

The temperature dependence of the cooking rate of soybean cotyledon was investigated by cooking samples at 106°C-121°C and by measuring the maximum cutting force. The cooking of soybean followed a first-order reaction and the reaction rate constant was approximately doubled by increase of cooking temperature by 4 or 5°C. The z-value for softening of the soybean, which was calculated from the time-temperature combinations that gave the same degree of cooking, was 13.3°C.

Introduction

Soybean (*Glycine max*) has been effective protein source in many countries including Korea. It has been unique dietary culture in Korea in that soybean is commonly cooked with cereals, especially with rice.[1] However, cooking property of Korean soybean has not been fully understood.

Dry beans are usually hydrated prior to cooking. One of the main problems of the dry beans is that they require long cooking times to render them eating-soft.[2] The shear press is frequently used as an objective means of measuring the degree of cooking of beans.[2-4]

Sefa-Dedeh and Stanley[4] demonstrated that the thermal softening of legumes could be expressed as the first-order equation. They showed that soybeans had the lowest rate of softening, followed, in increasing order, by adzuki beans, blackeye peas, pinto beans and white beans. It was suggested[4] that the breakdown of the middle lamella may play a significant role in determining textural changes in cooked legumes. However, soybeans did not show a noticeable breakdown of the middle lamella during cooking at 100°C for 60 min,[4] which implies that the microstructure and chemical and/or physical changes occurring during cooking of soybeans may be different from other legumes.

Quast and da Silva[2] studied the temperature dependence of the cooking rate of dry legumes. They used the time-temperature combinations which gave the same texture to obtain z-values for softening of the beans. The z-value for soybean was 15.5°C, which was somewhat smaller than black beans (19°C) and brown beans (18°C).

The purpose of this study was to determine the temperature coefficient of the cooking rate of Korean soybean.

Materials and Methods

Materials

A variety of soybean, Jangyeob, was obtained from commercial market and kept at 4°C.

The average weight of grain was 0.2326*g*.

Cooking rate

Soybean was soaked in distilled water for 16hr at room temperature. The seed coat was removed and the cotyledons, which were halved, were used for cooking.

Cooking of soybean was carried out using an autoclave at temperature range of 106°-121°C. The come-up and come-down times at each cooking temperature were maintained for 3 and 10 min, respectively. After the predetermined cooking time, the soybean was cooled in a running water for 1 min prior to texture measurement.

Cutting force measurement

The cutting force of the sample was measured with a Rheometer (Sun Co., Japan) under the following conditions: chart speed, 120 *mm*/min; plate speed, 35.09 *mm*/min; and force, 200 or 400*g* full scale.

The maximum force of an average of 20-30 measurements was expressed as *g/g*.

Results and Discussion

Cooking rate

The relation between the reciprocal cutting force (softness) and cooking time of soybean cotyledons at each cooking temperature is shown in Fig. 1. Each curve showed a clear linear relationship. The reciprocal cutting force at each cooking temperature reached at a constant value after a certain period of cooking time, at which the bending of the curve occurred.

On the assumption that the reciprocal cutting force is directly related to the degree of cooking of soybean, the bending point was defined as the terminal point of cooking at each cooking temperature. As shown in Fig. 1, the cooking time to the terminal point was inversely related to the cooking temperature.

The degree of cooking at each cooking time was analyzed from the data in Fig. 1. The degree of cooking (α) can be expressed as follows:

$$\alpha = \frac{C_t - C_o}{C_L - C_o}$$

where C_0 and C_t are cutting force at cooking time 0 and t, respectively and C_L is the cutting force at terminal point of cooking. The values for C_o and C_L were 1,871 and 186 *g/g*, respectively, which indicate that the cutting force of soybean decreased approximately to one-tenth upon pressure cooking.

A plot of the rate of uncooked portion of soybean, expressed as 1-α, as a function of cooking time is shown in Fig. 2. The rate of uncooked portion of soybean decreased as cooking time increased. Sefa-Dedeh and Stanley[4] also reported that the thermal softening of soybean at 100°C logarithmically increased as a function of cooking time, indicating a single-stage process.

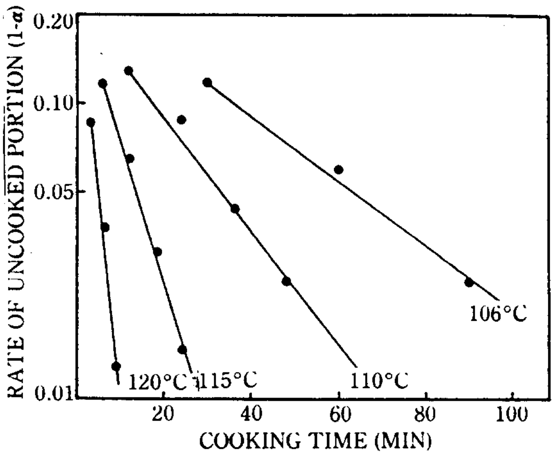

Fig. 2. The rate of uncooked portion of soybean as a function of cooking temperature

The results in Fig. 2, can be expressed as first-order equation:

$$\ln(1-\alpha) = -kt$$

where k is first-order reaction rate constant and t is cooking time. As can be seen in Fig. 2, the rate of uncooked portion at cooking time zero was not 1.0. It is well known[5,6] that the degree of cooking of rice follows the similar pattern to Figs. 1 and 2, but the rate of uncooked portion logarithmically decreased as function of cooking temperature with intersect of 1.0 at cooking time zero. The results in Fig. 2, therefore imply that the cooking process of soybean may be different from that of rice. The main constituent of rice is starch, while soybean has no starch.[7,8]

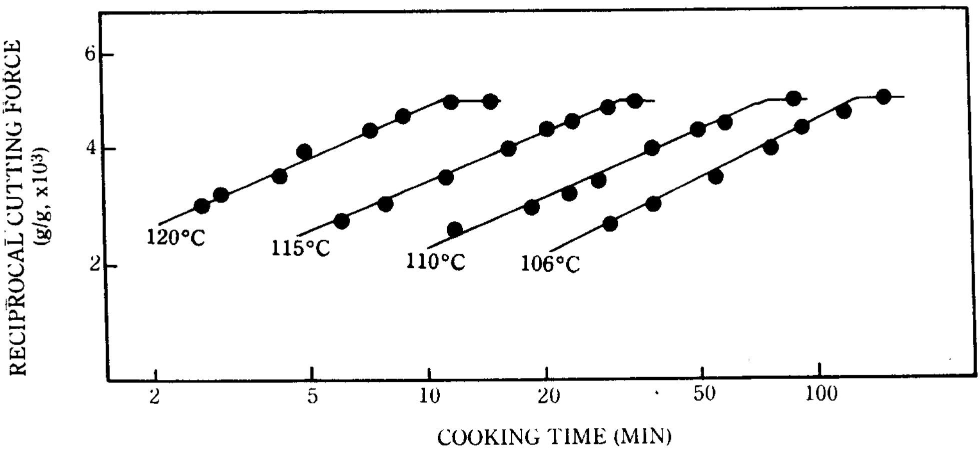

Fig. 1. Relation between the reciprocal cutting force and cooking time of soybean at various cooking temperatures

Table 1. Cooking rate constants of soybean

Cooking temperature (°C)	Cooking rate constant (min^{-1})
106	0.0108
110	0.0199
115	0.0496
121	0.1367

The reaction rate constants calculated from Fig. 2 are given in Table 1. The reaction rate constant was approximately doubled by increas of cooking temperature by 4 or 5°C. An Arrehenius plot of cooking rate constants is shown in Fig. 3. The activation energy calculated from Fig. 3 was 50,200 *cal/mole.*

Temperature coefficient

To investigate the temperature coefficient of the cooking rate, the time-temperature relations were analyzed from the results in Fig. 1. The effect of cooking temperature on cooking time is shown in Fig. 4. The straight lines in Fig. 4 represent the time-temperature

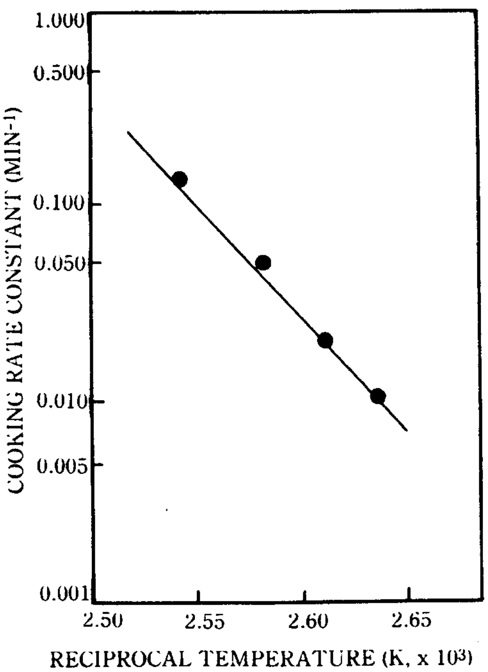

Fig. 3. Arrehenius plot of cooking rate constants of soybean

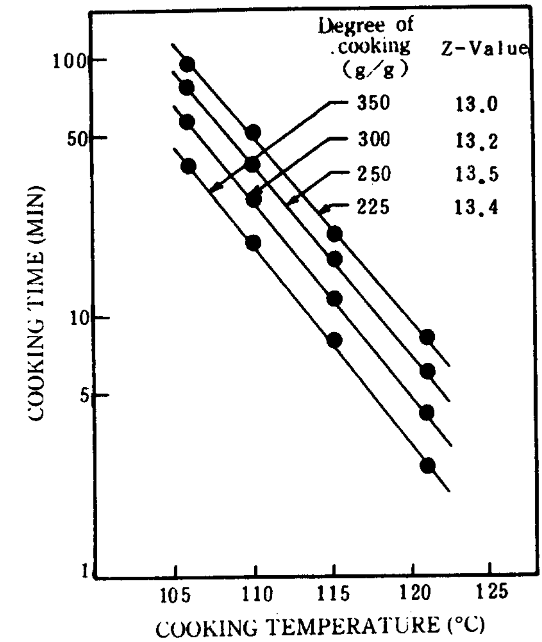

Fig. 4. Effect of temperature on cooking time

combinations that give the same degree of cooking. For example, 2.7 min at 121°C has the same effect as 38 min at 106°C to give the degree of cooking of 350 g/g.

The slope of the curve in Fig. 4 is related to the z-value.[2] As shown in Fig. 4, the z-values were not affected by the degree of cooking, which confirms the results of Quast and da Silva.[2] The average z-value indicates that cooking time is decreased by 10 times for each increase of 13.3°C in the temperature.

The relation between the z-value and Q_{10} coefficient is expressed as follows:[2,9]

$$\log Q_{10} = \frac{10}{z}$$

The value for Q_{10} was 5.65, which indicates that an increase of 10°C in cooking temperature causes a 5.65-fold reduction in the cooking time, for the same degree of cooking. Quast and da Silva[2] reported the z-value and Q_{10} coefficient for soybean were 15.5°C and 4.41, respectively, between cooking temperatures of 98°C–127°C.

The z-value (i.e., 13.3°C) indicates that the temperature dependence of the cooking rate of soybean was smaller than that of the death of microbial spores (typically z = 10°C or 18°F). It can be seen from Fig. 1, that soybean was assumed adequately cooked after 15 min at 121°C. The sterilization value of F_{121} = 18 min can also be considered adequate for commercial sterility.[2] Therefore, the results in this experiment may be used for the design of cooking operations of soybean.

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콩의 취반속도에 미치는 온도의 영향

김성곤 · 조광호 · 김종군*

단국대학교 식품영양학과, *세종대학 가정학과

콩을 106°~121℃의 가압조건에서 일정시간 조리하면서 최대 절단력을 측정하고 이로부터 조리속도를 계산하였다. 콩의 조리속도는 1차반응의 속도로 표시될 수 있었으며 반응속도상 수는 조리온도가 4 또는 5℃ 상승함에 따라 약 2배 정도 증가하였다. 동일한 조리도를 나타내는 온도-시간과의 관계로부터 계산한 콩의 연화에 따른 Z-값은 13.3℃이었다.