Title	大豆及び 2, 3 の添加物を加えた小麦紛生地のレオロジー的挙動(農業工学科)
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Rheological Behavior of Wheat Flour Dough Fortified with Soy Flour and Some Additives*

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I INTRODUCTION

Soy bean is very important protein source, easpecially in developing countries, and many researchers have reported how to utilize it for traditional foods. For example, Tsen and Chung tried to bake bread and cooky from wheat flour fortified with soy flour, and found 12% of soy flour could be added keeping their custom texture if some additives were added. However, enough oven springe was not obtained without additives. The object of this study was to determine how three additives altered the dynamic visco-elasticity of wheat dough fortified with soy flour. Customary methods to measure baking performance, for example, the Farinograph, Extensograph and so on – do not provide information about basic rheological properties of dough. So, in order to determine the effectiveness of certain additives, it is necessary to describe the process by which the additives actually altered the visco-elastic properties of dough.

II EXPERIMENTAL

1 Samples

Eight samples were prepared as shown in Table 1 from commercially available flour, Hard Red Winter. Used additives were sodium stearoyl-2 lactylate (SSL), sucrose monopalmitate (SMP) and ethoxylated monoglycerides (EMG). Soy flour used here was defatted, and 3 g of it was 12% of the sample weight. The ammount of water to add was decided according to baking absorption that gave the best oven springe.

3 Method

Each sample was mixed for three minutes in a small mixing bowl which had a capacity of 25 g. A few of the samples were mixed six minutes to make comparison study. Three minutes was adopted as the best physical properties were obtained by the three minutes of mixing in the Alveograph test.

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Table 1. Component of Samples

Sample No.	1	2	3	4	5	6	7	8
Wheat flour	25.0	25.0	25.0	25.0	22.0	22.0	22.0	22.0
Soy flour	0	0	0	0	3.0	3.0	3.0	3.0
SSL	0	0.125	0	0	0	0.125	0	0
SMP	0	0	0.125	0	0	0	0.125	0
EMG	0	0	0	0.125	0	0	0	0.125
Water	15.70	15.05	15.35	15.30	16.20	16.20	16.45	16.20
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35

SSL : Sodium Stearoyl-2 Lactylate
SMP : Sucrose Monopalmitate
EMG : Ethoxylate Monoglycerides

Visco-elasticity of the samples were measured by the linear oscillation phase difference method as shown in Fig. 1 according to the papers reported by Hibberd (1966) and Kohda(1979). The equipment was designed in our laboratory (Dept. of Grain Science & Industry, Kansas State Univ.) and was made in the machine shop in Dept. of Physics, Kansas State University.

Mixed dough was placed in the sample holder by a spatula and then fixed on the equipment. The height of the sample holder was 1.2 cm and the arear was 1.0 x 2.0 cm. Eight steps of oscillation speed from 0.11 to 5.1 Hz were given to the sample, and the temperature in the sample room was controlled into four steps of 25, 30, 35 and 45°C.

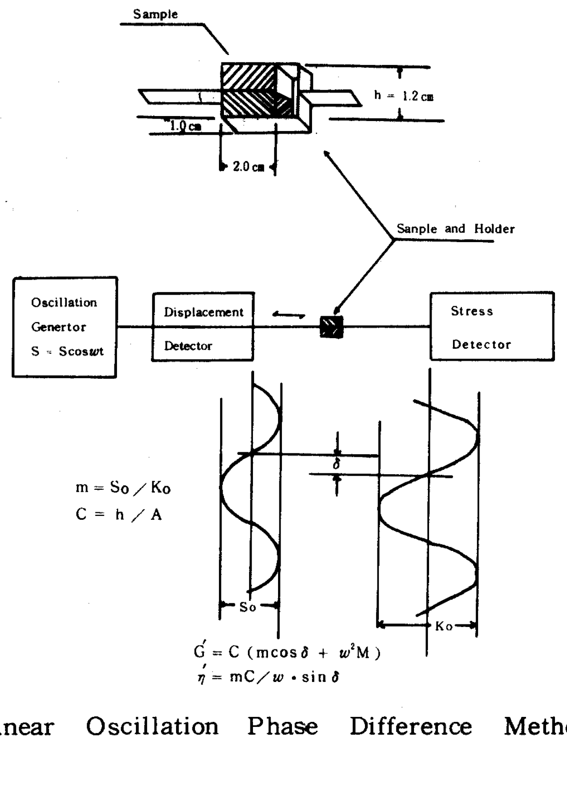


Fig . 1 Linear Oscillation Phase Difference Method.

Procedure of calculation was as follows. From the recorded wave shape of the two curves on the oscillogram, amplitude ratio m and angle of phase difference δ was obtained, and G' and η' was calculated by a computer from these m and δ according to the following equations.

$$G' = C\,(m \cos\delta + \omega^2 M) \quad (1)$$

$$\eta' = mC/\omega \sin\delta \quad (2)$$

where $m = S_0/K_0$

$C = h/A$

S_0 : Amplitude of displacement

K_0 : Amplitude of Stress

h : Height of the sample

A : Area of shear plane

ω : Angular velocity of the oscillation

Besides above mentioned samples, dough of varied absorption of 12.0 ml(48%), 13.25 ml(53%), 14.5 ml(58%) and 15.7 ml(63%) were prepared, and relation between visco-elasticity and quantityof added water were also tested along with effect of the additives to the visco-elasticity.

Each measurement was made 20, 45, and 60 minutes after mixing.

III RESULTS AND DICUSSIONS

1 General Behavior

Fig. 2 and Fig. 3 show relationship between visco-elasticity and oscillation speed of the samples, controll, dough with soy flour, and with SMP. In these figures, measured values are plotted on full logarithmic graph paper, and real line, broken line and chain line mean measured value 20, 45 and 60 minutes after mixing respectively. Mark ∘ shows dynamic viscosity η' and mark • shows dynamic elasticity G'. Most of these lines were on straight lines in the chart, namely, they are distributed on curves given by the following equations.

$$G' = Bg\ N^{Ag} \quad (3)$$

$$\eta' = Ag\ N^{Bg} \quad (4)$$

Where, N : Oscillation speed (Hz).

From the slope of these straight lines at N = 1, or from the solution of normal equation of logarithm of G' and N, and η' and N, indexes Ag, Bg, Ae and Be can be decided. Equations decided according to above mentioned process are shown in each of the figures, and these equations express the relationship between visco-elasticity and the motion speed.

These results agree with Kohda's former reports (1969, 1977, 1979). Namely, visco-elasticity of wheat dough can be expressed by four indexes Ag, Bg, Ae and Be. So, this study intends to explain how these indexes will change when above mentioned additives and soy flour are added to wheat dough. This information will be usefull when indicating the effectiveness of additives.

(1) $G' = 0.200\ N^{0.217} \times 10^5$
$\eta' = 0.368\ N^{-0.690} \times 10^4$
(2) $G' = 0.266\ N^{0.214} \times 10^5$
$\eta' = 0.556\ N^{-0.703} \times 10^4$
(3) $G' = 0.275\ N^{0.241} \times 10^5$
$\eta' = 0.662\ N^{-0.731} \times 10^4$

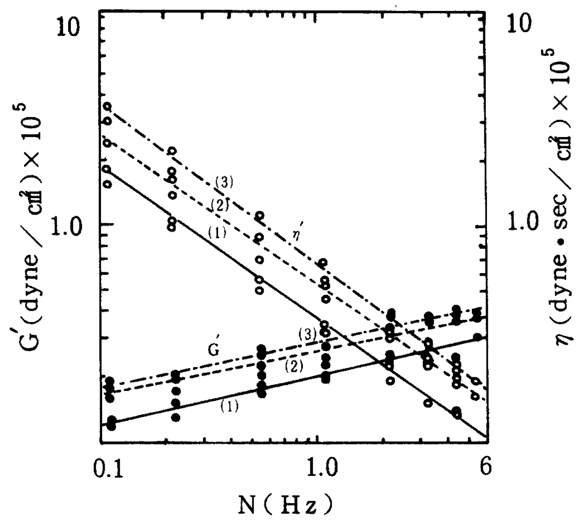
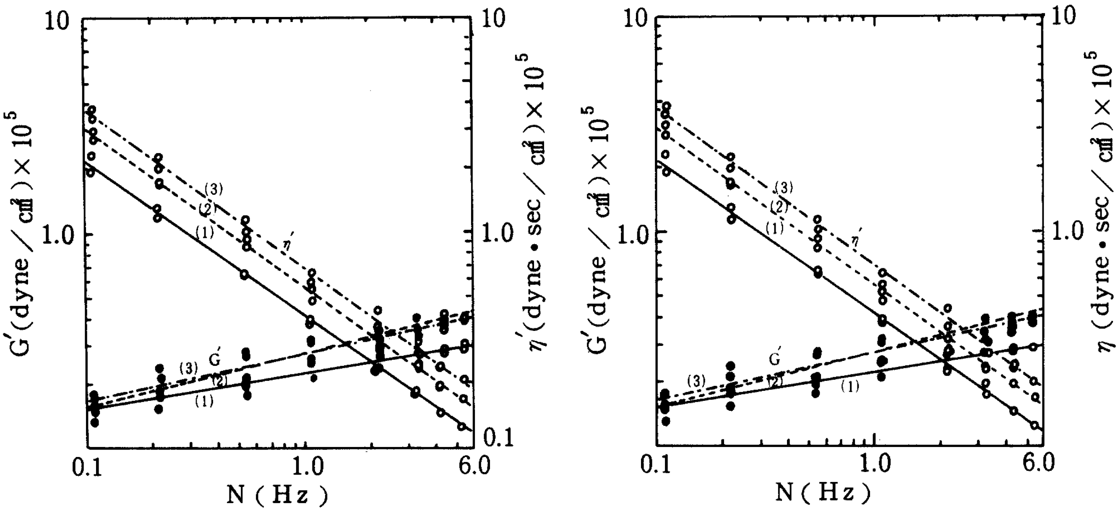


Fig. 2 —Relaticnship between Oscillation Speed and Dynamic Visco - elasticity of Wheat Dough (Control).
(1)— 20 min. (2) — 45 min. (3) — 60 min. after Mixing.



(a) Control + Soy flour　　(b) Control + Soy flour + SMP

(a)

(1) $G' = 0.218\ N^{0.169} \times 10^5$
$\eta' = 0.420\ N^{-0.719} \times 10^4$
(2) $G' = 0.272\ N^{0.245} \times 10^5$
$\eta' = 0.566\ N^{-0.736} \times 10^4$
(3) $G' = 0.269\ N^{0.202} \times 10^5$
$\eta' = 0.701\ N^{-0.731} \times 10^4$

(b)

(1) $G' = 0.218\ N^{0.169} \times 10^5$
$\eta' = 0.420\ N^{-0.719} \times 10^4$
(2) $G' = 0.272\ N^{0.245} \times 10^5$
$\eta' = 0.565\ N^{-0.736} \times 10^4$
(3) $G' = 0.269\ N^{0.202} \times 10^5$
$\eta' = 0.701\ N^{-0.731} \times 10^4$

Fig. 3 —Relationship between Oscillation Speed and Dynamic Visco - elasticity of Wheat Dough with 12% of Soy Flour.

2 Effect of Added Water

At first, effect of water to visco-elasticity of dough will be discussed. Namely, relationship between visco-elasticity coefficients of dough without any additives except salt and water ammount of which was changed from 12 ml/25 g of flour to 15.7 ml/25 g of flour are shown in Fig. 4. As, shown in the figures, indexes Ag and Ae changed their value little according to change of water. Their values are Ag = 0.22 and Ae = −0.73.

On the other hand, Bg and Be decreased gradually as water increased, and reached at a plateau near 14.5 ml of added water. The phenomena that more water makes dough softer and decreases Bg and Be was observed. The chemical meaning of these indexes are left for the further study, but it is interesting that usual baiking absorption of this dough 15.7 ml/25 g of flour is just on this plateau. This fact suggests that doughs are traditionally mixed, proofed and oven springed at the point mixing registance is the smallest.

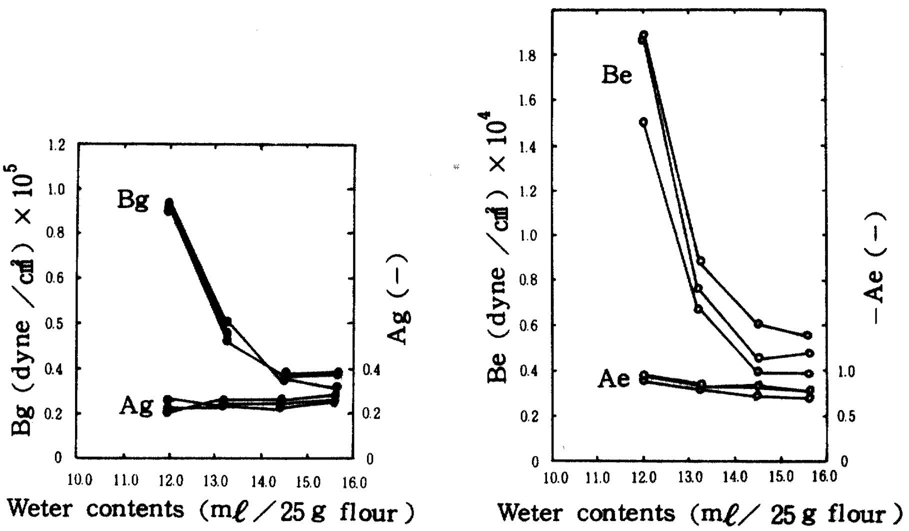


Fig . 4 −Effect of Water Content to Coefficient of Elasticity and Viscosity in Equations.
$G' = Bg\ N^{Ag}$ and $\eta' = Be\ N^{Ae}$.

However, these curves, that show a relationship between added water and G′ or η', can not be always expected to be expressed in only one term exponential function if water content is higher or lower than that tested in this study. In other words, lines on full logarithmic paper can not be always straight lines when water is added more or less than experimented here. However, such doughs that contain much more or less water will not be suitable for bread baking.

In the above area, as Ag and Ae of dough are almost constant, namely, as the gradient of straight lines are constant, they can be superimposed by parallel shift. It means that Bg and Be, or the value of the visco-elasticity at N = 1 Hz, are enough to know the visco-elasticity of normal dough, and visco-elasticity at other oscillation speed can be predicted.

3 Effect to the Relation between Temperature and Visco-elasticity

Relationship between visco-elasticity indexes of each sample and temperature are shown in Fig. 5, 6 and 7. First, we will discuss on the control, wheat flour dough without additive (Fig. 5 (a)) and a sample with soy flour (Fig. 5 (b)). The control has a maxinum value of Be at 35°C, and its Bg did not show a big change below 35°C and then increased gradually above that temperature. On the other hand, Bg of dough with soy flour had minimum value at 35°C, and its Be decreased continuously. The former is termed wheat flour type and the later soy flour type. How these properties will change by additives will be discussed.

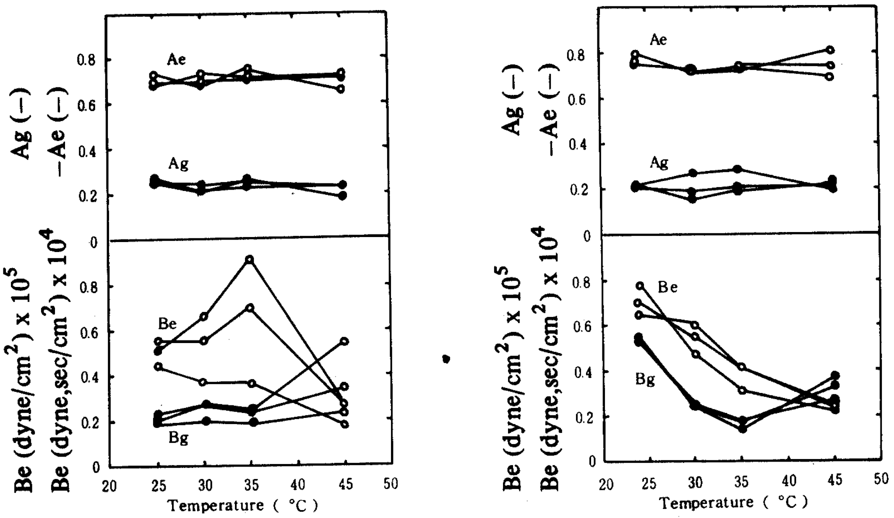


Fig . 5 −Relationship between Temperature and Visco - elasticity Coefficient of Dough without Additive

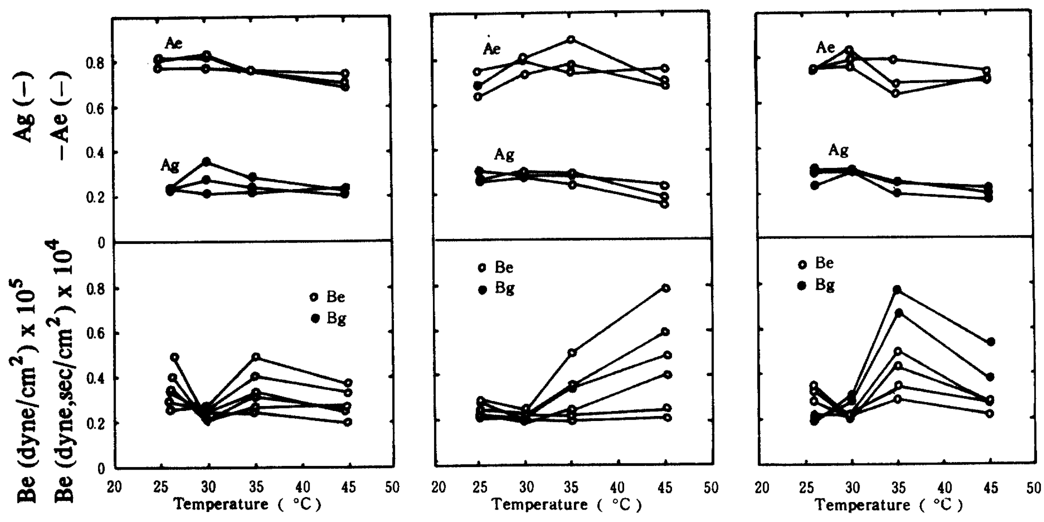


Fig . 6 −Effect of Additives to the Relationship between Temperature and Visco - elasticity Coefficient of Wheat Dough .

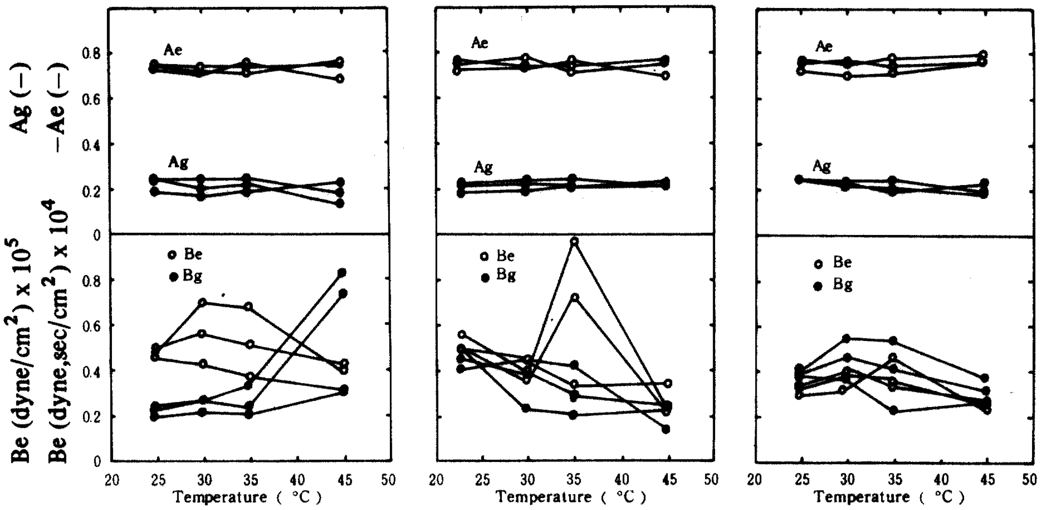


Fig . 7 −Effect of Addtives to the Relationship between Temperature and Visco - elasticity Coefficicnt of Wheat Dough with Soy Flour .

SSL, SMP or EMG added to the control had minimum value of both indexes Bg and Be near 30°C, and maximum value of Bg at 35°C except SMP, though the minimum value of Be was smaller than that without additive. Though indexes Ag and Ae were almost constant in the case of the control, they changed their values when additive was added. Especially in the case of SMP, its change of those values was remarkable. This means that graphs of G′ and η' becomes difficult to be superimposed upon others by parallel shift.

Secondly, we will discuss about the samples soy flour was added. In the sample with SMP added (Fig. 7 (b)), Be had clear maximum value at 35°C, and Bg had no minimum value. Its behavior is very similar to that of the control, that is to say, it was found that these rheological properties had changed from a soybean type to wheat type after SMP was added. It means that SMP had a very clear improving effect. In other words, SMP changed visco-elasticity of dough with soy flour, which is the most fundamental physical property, to have almost the same value and performance with that of the sample without soy flour. SSL also changed the sample with soy flour to wheat flour type, as shown in Fig. 7(a) though it was not clear as SMP. Moreover, EMG also made it clearly.

As mentioned previously, all additives used in this study had an improving effect to rheological properties of wheat dough with soy flour. Fundamental physical properties of dough with soy flour were converted to those close to dough without soy flour by adding these additives. The effect of SMP was remarkable. On the other hand, when additives were added, Ag and Ae without soy flour changed their value according to change of temperature, while those with soy flour changed less than those without additives and showed behaviors close to the control. We expect further study would explain these phenomena from the chemical side.

SUMMARY

In order to know the effect of additives, SSL, SMP and EMG on rheological properties of wheat dough with 12% of soy flour, dynamic elasticity G′ and dynamic viscosity η' which act as fundametanl physical properties of dough were measured by the linear oscillation method. Results were as follows.

1. The relation between logarithm of G′ and η' and that of oscillation speed N were linear, and were expressed by following equations. $G' = Bg \times N\ exp(Ag)$, $\eta' = Be \times N\ exp(Ae)$.
2. Index Bg and Be of wheat flour dough without soy flour decreased as water content decreased, and were led to plateau at the best baking absorbance, while Ag and Ae did not altered as amount of water.
3. Behaviors of indexes according to change of temperature could be devided into wheat flour type and soy flour type. Dough with soy flour acted as wheat flour type when an additive was added. This is a clear improving effect of additives to dough with soy flour. The effect was most remarkable when SMP was added.

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大豆及び2，3の添加物を加えた小麦粉生地のレオロジー的挙動

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要 約

12%の大豆粉を加えた小麦粉生地に物性を改良する目的でSSL，SMP及びEMGを添加し，生地の動的粘性η'及び動的弾性G'の挙動を求めてその効果を調べ，次の結果を得た。

1. G'，η'と振動数Nの各対数値は直線関係であり，次式で表わすことができる。

$G' = Bg \times N\exp(Ag)$，$\eta' = Be \times N\exp(Ae)$

2. 指数BgとBeは加水量の減少と共に減少し，ついには製パンに際しては最良の加水量を示す所で定値になった。

3. 各指数の温度変化に伴なう挙動は小麦粉型と大豆粉型に分けることができた。大豆粉でタンパク質強化をした小麦粉生地でも添加物を加えると小麦粉型の挙動をした。これは大豆を加えた小麦粉に対するすぐれた改良効果であり，特にSMPの効果がすぐれていた。

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