Effect of ingedients and mixing energy on the rheological properties of wheat dough*

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The meaning of the term rheological properties of dough is considerably broad. It is necessary to define well which way we want express the rheological properties of dough in case we try to measure them.

Viscoelastic properties of wheat dough are well known. Momentary rheological behavior depends on the momentary conditions (stress, speed of deformation) but also on the deformational history of dough. This is the reason, why there is no simple description of rheological properties of dough, and why we cannot express the relation of most important factors in dough manufacture to the complex rheological properties, i.e. elasticity and viscosity or their combination.

In the present study, the Hoeppler falling ball principle of viscosity measurement was applied to dough. Owing to variations of shear stress and shear rate over the ball surface, and because of complex deformation, it is not possible to determinate the actual values for shear stress and shear rate over the total surface of ball. Despite the empirical character of such measurements for non-Newtonian substances, the conditions of measurement are well defined and reproducible (1). The stress or shear rate may be expressed in terms of acting force or velocity of ball. These results are not directly comparable to that obtained from rotational viscometer, which may be expressed in proper physical units. However the deformational graph with Hoeppler consistometer (fig. 1) is easier to evaluate, as it is very similar to simple one-dimensional deformation (elongation). The evaluation of the curves from most of commercial rotational viscometers is not so simple.

In our study only part of the curve representing a viscous flow was considered. Speed of ball was calculated from the curve (fig. 1B). Consistency, calculated from the linear part of that speed is numerically comparable to the coefficient of viscosity, which is used as a measure of viscosity of Newtonian matters. It was calculated using the empirical formula recomended by the manufacturer of consistometer. The flow properties of dough are evaluated this way under the conditions of stabil speed of deformation. Elasticity of dough is not considered at that moment.

To make the conclusions about the factors that affect the dough consistency, we would be able to figure more than ten of them. At the first approach to the problem we tried to choose only most important factors from the technological point of view. All factors, that use to be held constant at the actual dough manufacturing (e.g. temperature, oxygen action), were not considered as variables des-

* A III. Nemzetközi Élelmiszeranalitikai Módszertani Szimpoziumon elhangzott előadás. Szentendre 1975. október 8–11.

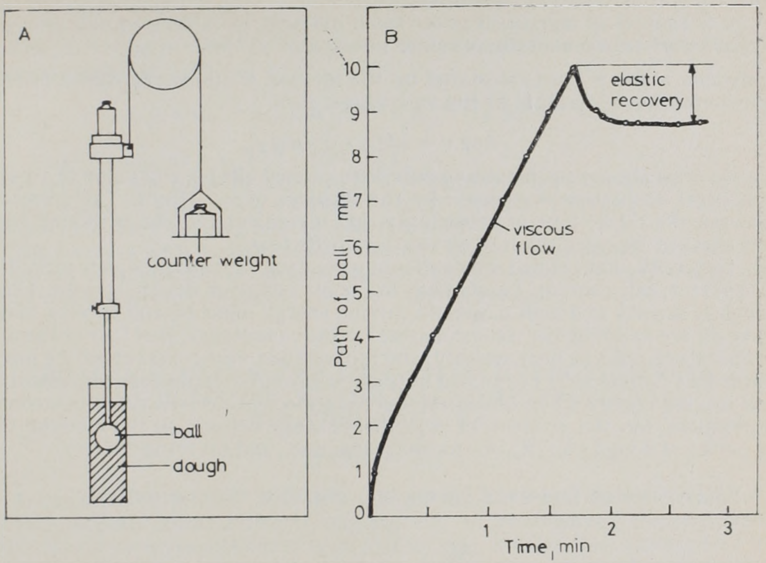

Fig. 1.

pite the considerable effect on the consistency of dough. Some of them were considered in final formula as the constants.

Four variables, which affected the consistency, were picked. Three of them were the basic ingredients: water, salt, and fat. The fourth was mixing energy which varied by the changes of the motor drive input.

Middle values of variables were given by the "basic formula" of dough. The basic levels of ingredients for any flour were: 50 grams of flour, 2% salt, and 5% fat (in per cent based on flour weight). Basic level of water added to any flour was chosen according to the farinographic absorption.

The mixing energy was controlled by the changes of motor drive input. Conseqently, the rotations of mixing element were changing in the range approx. 62-74 r.p.m. of slower arm of farinographic mixing bowl "Junior". Since the mixing time was held constant for 5 minutes and middle value of r.p.m., the basic dough was defined by means of middle value of r.p.m., the basic mixing energy for different flours was varying due to different properties of flour.

The ranges of variations of every factor were chosen to find out its effect on the consistency. The experiments were arranged so that the dough was mixed according to the basic formula with varying only one factor in that ranges.

Method of dimensional analysis was used to reach the survey about the complex effect of all ingredients on the consistency of dough. Its use is justified when the relations between variables are not known exactly. A rough evidence based on our former results showed that the relation between the consistency and the ingredients could be written:

$$\eta = b \times y^{b}, \quad (1)$$

where η is consistency (< viscosity) in Pa.s,

y is content of ingredient in optionali units,

a, b, are experimentally obtained constants.

Constants a and b were calculated by the method of linear regression after the transformation of formula to the logarithmic form:

$$\log \eta = \log a \times b \times \log y \,. \tag{2}$$

At least six paralel measurements were carried out for any value of variable. Statistical evaluation was made by the analysis of variations. The correlation between the logarithms of consistency and ingredient content or mixing energy was checked by calculation of correlation coefficient.

Generally, eight main factors affecting the dough consistency were picked: water content, salt content, fat content, the temperature of dough, specific heat of dough c, density of dough ϱ, specific mixing energy input N, and mixing time τ. They all are undoubtedly determinative for the consistency. But four of them, the temperature, specific heat, density, and mixing time vere constant during mixing. These four factors were comprised in the dimensionless expessions for consistency and mixing energy when dimensionless equation was derived (2). Dimensionless expressions for the content of ingredients were defined as the amount of in-kg per kg of dough (A_W, A_S, A_F for the water, salt, and fat respectively).

Dimensionless factors of energy and viscosity were respectively:

$$A_N = \frac{N \times \tau}{c \times T}, \tag{3}$$

and

$$A_\eta = \frac{\eta}{T \times c \times \tau \times \varrho}. \tag{4}$$

Then the general form of the equation for 5 dimensionless factors was solved:

$$F(A_w,\ A_s,\ A_f,\ A_N,\ A_\eta) = 0 \,. \tag{5}$$

When numerical experimental constant z was involved and consistency η expressed from $A\eta$, the equation had form:

$$\eta = T \times c \times \tau \times \varrho \times f(A_w,\ A_s,\ A_f,\ A_N) \times z \,, \tag{6}$$

or

$$\eta = \varkappa \times f(A_w,\ A_s,\ A_f,\ A_N) \times z \,. \tag{7}$$

Numerical constants are included to the constant *H*.

Provided the general form of the function f is the equation l, we can write final form of the equation:

$$\eta = \varkappa \times A_W^{\alpha} \times A_s^{\beta} \times A_f^{\gamma} \times A_N^{\delta} \times z \,. \tag{8}$$

The exponents of this equation are that found for every varialle by the method of linear regression.

Since the measurement was made with only factor carying the experimental constant a from eq. 1 or 2 have comprised constants $\varkappa$, z, and all three factors that were just held constant. The value of $\varkappa$ is known as well as the values of dimensionless factors which were constant. Consequently, the value of z could be calculated from the experimental data, when equations were solved. The constant z represents the properties of flour.

The final form of complex formula for one of czechoslovak standard flours is shown as example!

$$\eta = 1.35 \times 10^{-30} \times \varkappa \times A_w^{-28.68} \times A_s^{-0.91} \times A_f^{-0.67} \times A_N^{1.93} . \qquad (9)$$

The value of $\varkappa$ is 2.17×10^{11} Pa.s.

So far only few types of flours were investigated. There is already evidence, that the value of z has been varying from 10^{20}; to 10^{-39}, However, the other exponents has been varying also to a certain part.

The formula with experimental constants give us a possibility to calculate consistency of dough for an optional change in ingredients or mixing energy, provided these values do not exceed the expermental ranges.

ADALÉKANYAGOK ÉS A DAGASZTÁSI ENERGIA HATÁSA A BÚZALISZTBŐL KÉSZÜLT TÉSZTÁK REOLÓGIAI TULAJDONSÁGAIRA

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A búzalisztből készült tészták viszkózus tulajdonságai kerültek tanulmányozásra Köppler konzisztométer segítségével. Az eredmények alapján Szerző meghatározta az egyes adalékanyagok mennyisége, a dagasztási energia és a hőmérséklet, valamint a konzisztencia közötti korrelációt. Az összefüggések segítségével olyan empirikus formula állítható fel, amely alkalmas a tészták közelítő konzisztenciájának számítására a technológiai paraméterek ismeretében.

ВЛИЯНИЕ ДОБАВОЧНЫХ ВЕЩЕСТВ И ЭНЕРГИИ ЗАМЕСА НА РЕОЛОГИЧЕСКИЕ СВОЙСТВА ТЕСТА ИЗ ПШЕНИЧНОЙ МУКИ

Й. Прихода

Автор с помощью консистометра Кёпплера изучал свойства вязкосcти теста изготовленного из пишеничной муки. На основании результатов автор определил корреляцию между количеством некоторых добавочных веществ, энергией замеси и температурой, а так же консистенцией. Помошью зависимостей возможно установить такую эмпирическую формулу на основании которой зная параметры техно логии возможно провести приблизительный расчет консистенции теста.

L'EFFET DES ADDITIFS ET DE L'ÉNERGIE DE PÉTRISSAGE SUR LES PROPRIÉTES RHÉOLOGIQUES DES PÂTES PRODUITES À PARTIR DE FARINE DE FROMENT

J. Prihoda

On a étudié, à l'aide du consistomètre Hoeppler, les propriétés visqueuses des pâtes produites à partir de farine de froment. A partir des résultats, l'auteur a établi des corrélations entre la quantité de quelques matières d'addition, de l'énergie de pétrissement et la température, ainsi que la consistence. Ces corrélations permettent d'établir une formule empirique qui se prête, en connaissance des paramètres téchnologiques, de calculer la consistance approchée des pâtes