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The pattern of wheat flour dough linear viscoelastic behaviour

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Abstract

Dynamic measurements and retardation tests are combined to characterise the linear viscoelastic behaviour of wheat flour dough over a 7 decades frequency range. Analysis of the data provides the main viscoelastic constants. On the one hand, the water content of dough from a commercial flour was varied from 42.5 to 50.7 percent of dough weight. On the other hand, doughs from near-isogenic wheat lines differing in their high molecular weight glutenin subunits compositions, grown in three locations, were compared at the same water content (46.1 %). Both factors affected dough viscoelasticity in a similar and remarkable way. In particular, the same inverse relationship between steady-state viscosity and compliance, and the same power law relationship between steady-state and plateau compliances, were found to hold wether variability was of endogenous origin or was due to dough water content. The terminal relaxation time was nearly the same for all doughs, whereas the upper frequency limit of the viscoelastic plateau showed a large range of variation with dough hydration.

Key words: *Wheat Flour dough; Linear Viscoelasticity; Hydration; Glutenin Composition*

Introduction

Although dough rheology is thought to control to a large extent dough technofunctional characteristics and the texture of the end products, it remains ill understood in many of its aspects (Dobraszczyk and Morgenstern, 2003). This applies even to the linear viscoelastic behaviour of dough since in most of the numerous studies on the subject the experimental time window was quite limited compared to the time-scale of the viscoelatic response. In particular, the steady-state rheological properties of dough have been seldom investigated.

The purpose of our work was to analyse the linear viscoelastic behaviour of dough in shear over a large time-scale extending up to steady-state flow, and to study the effect of dough water content and of high molecular weight glutenin subunits (HMWGS) composition on the main intrinsic rheological constants.

Materials and methods

The effect of water content was studied using a commercial flour in the 42.5 to 50.7 % hydration range (on dough basis). To investigate the effect of HMWGS composition, doughs from near-isogenic wheat lines differing in their high molecular weight glutenin subunits compositions, grown in three locations (Sweden, France, England) and displaying a large range of technological characteristics, provided by Svalöf-Weibull, were compared at the same water content (46.1 %). Dough were mixed with a 2 g Mixograph during 10 min.

Rheological measurements were performed at 20°C using two stress-controlled rheometers with cone-plate geometries. Each experiment consisted in the sequence of a frequency sweep (0.06-100 rad/s) and a creep (3 h)-and-recovery (12 h) test. For each mixing condition or for each wheat line, the sequence was repeated on at least 3 dough preparations. The strain amplitude of dynamic measurements (0.001) and the value of the creep stress (1 to 6 Pa according to the dough) were chosen so as to remain within the linear domain.

Results and discussion

The data from the dynamic and the retardation tests were analysed and combined as explained previously for gluten (Lefebvre et al., 2003). Figure 1 shows as an example the mechanical spectrum over 7 frequency decades thus obtained for one of the experimental lines dough.

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We cannot expound here the complete set of results and discuss them in details. Figures 2-4 show a few remarkable relationships linking some of the intrinsic rheological characteristics of dough. The steady state viscosity η_o varies with the steady state compliance $J_e°$ according the same inverse relationship (Fig.2), whether the change is controlled by dough hydration (commmercial flour), by HMWGS composition or by agro-climatic conditions (experimental lines). Similarly, all the data fall on the same line when the plateau modulus $G_N°=1/J_N°$ is

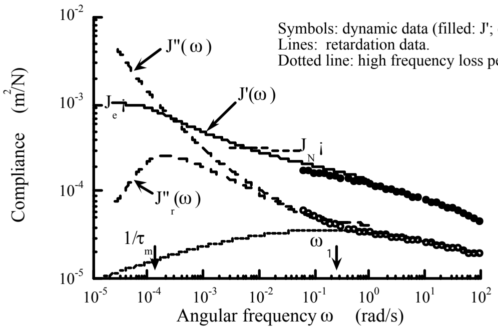

Figure 1: Example of composite mechanical spectrum of dough

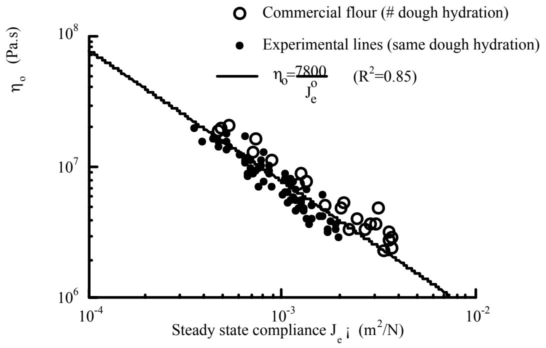

Figure 2: The relationship between the steady state constants

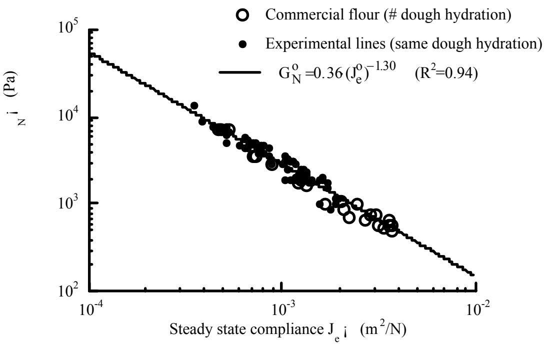

Figure 3: The plateau modulus *versus* steady state compliance relationship

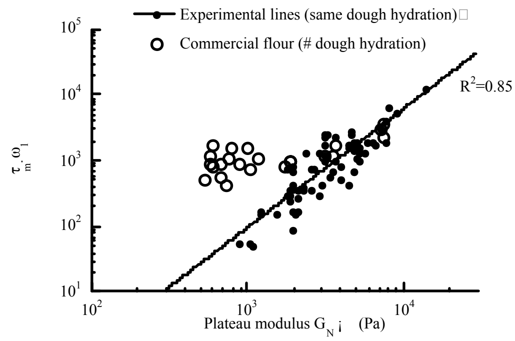

Figure 4: The relationship between the width and the modulus of the plateau

plotted against $J_e°$; they are fitted by a power law with an exponent of –1.3 (Fig. 3). The ranges of variation of η_o and $J_e°$ are surprisingly narrow, about one logarithmic decade; that of the plateau modulus is larger (2.6 decades), due to the sharp decrease of $G_N°$ when dough water content increases. The intrinsic link between the viscoelastic constants illustrated by figures 2 and 3 is no longer observed when one considers the width of the viscoelastic plateau defined as $\tau_m \cdot \omega_1$, $\tau_m = \eta_o \cdot J_e°$ being the terminal relaxation time and ω_1 the central frequency of the high frequency loss peak (see Fig. 1). As shown in Figure 4, in this case dough hydration and HMWGS or environment factors act differently; however, one still observes a power law relationship (exponent 1.8, R^2=0.85) between $G_N°$ and $\tau_m \cdot \omega_1$ for all the experimental lines. Since $\tau_m = \eta_o \cdot J_e°$ is nearly constant, the large variations of the width of the plateau are due to ω_1, and thus reflect probably differences in the structure of the building blocks of the gluten network.

References

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