Tackling the gluten network structure to anticipate dough mechanical behavior in baking industry

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Understanding the mechanical behavior of the wheat flour dough is a crucial step for the baking industry, not only to optimize end product quality, but also to save time and cost by producing a processable dough. Dough behavior is determined by its rheological properties, which are obtained at mixing, the first step of the process. However, today, baking industry often use only the Alveograph (Chopin, France), an empirical test of dough bubble inflation, to try to predict dough behavior. Thus, the objective of this work is to accurately and simply determine the dough processability in the production line. In this purpose, we have (i) analyzed dough structure and rheological behavior for different mixing conditions, (ii) assessed dough elongational properties with the relationship between the Alveograph curve and a rigorous rheological test, and (iii) investigated the effects of dough elongational properties on the mixing power curve P(t).

Four commercial wheat flours were selected according to their distinct mixing behavior, determined by P(t). Doughs were then prepared in the Farinograph, at different mixing times (3, 9, 12 min) and at different hydration levels (50%, optimal value determined in the Farinograph, and 66% by weight of flour). The thermo-viscoelastic behavior of the dough at small deformation was determined by dynamic thermomechanical analysis (DMA) and the bi-extensional properties (at large deformation) by the lubricated uniaxial compression test (LSF). In addition, confocal scanning laser microscopy (CSLM) was used to investigate the gluten microstructure of the 20-conditions dough samples and the Alveograph test (hydration level = 50%) was carried out for the four flours.

DMA results are followed by the ratio E'max/E'min, where the variations of the storage module between 55 - 70°C mainly reflect the gluten cross-linking: the higher the ratio, the less the network is developed after the mixing step. At constant deformation ε_b, the bi-extensional viscosity of doughs follows a power law, for which the consistency index K decreases exponentially with the dough hydration ($R^2 = 0.8$) from 47 to 10 kPa.s^n ($\varepsilon_b = 1$), for all flours, whereas, at constant hydration, the variation of K during mixing is related to the flour tolerance during mixing, defined by P(t) curve. Therefore, dough consistency (K) values also reflect gluten network structuring. Furthermore, the stress-strain curve derived from the Alveograph was well fitted by the power law defining bi-extensional stress determined by LSF ($R^2 > 0.9$).

In complement, results from spectroscopic method (TD-NMR) showed that four dough hydration states exist which correspond to different structuring gluten network, and hence specific intervals of K values. In line, the main gluten network structural factors obtained by CLSM confirm the relations between hydration states and gluten network structuring.

So, once integrated, these results will allow predicting the gluten network structuring from the mixing curve P(t) and help implement the necessary on-line settings for bakery production.