Using near infrared spectroscopy to assess dough development during mixing

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Introduction

Near infrared (NIR) spectroscopy is widely used for the measurement of parameters such as protein and moisture contents of wheat and flour. As instrumentation and data processing capabilities have developed, new applications for the technique have been proposed. Recently, a novel method of following dough mixing, using a Perten DA-7000 spectrometer, was reported.[1] This instrument uses diode array technology which leads to rapid data acquisition. Traces derived from the NIR spectra of dough during mixing showed minima which were thought to relate to points of optimum dough development. The process of dough mixing is of fundamental importance to the quality of the bread produced[2] and a number of methods have been used to evaluate the process. Prior to the use of NIR spectroscopy, however, it has not been possible to investigate the chemical changes occurring in a dough as it mixes. By developing this technique, therefore, a means of assessing the mixing process for individual batches of dough may be envisaged.

Method

A number of UK-grown wheats from the 1995 and 1997 harvests, covering a wide range of gluten properties, were assessed. The wheats were Bühler milled and the resultant flours were included in a standard bread recipe using two types of CBP z-blade mixers. Preliminary work employed 50 g flour samples on a small scale DoCorder mixer, while later trials used 1400 g flour samples on a Morton mixer. To obtain a measure of the functional properties of the flours studied, rheological measurements on their gel protein fractions were carried out.[3] NIR spectra were collected using a Perten DA-7000 spectrometer via a fibre-optic interactance probe. The probe was suspended 4 cm above the average position of the dough surface. Spectra (400 nm–1700 nm) were acquired, smoothed, treated to produce second derivative traces and integrated using the dedicated Perten and GRAMS/32 software. Dough from the Morton mixer was test-baked and the bread was assessed according to a standard method. Bread crumb texture was also assessed using image analysis.

Results and discussion

The NIR spectra gathered showed significant baseline variation due to movement of the dough as it mixed. To overcome this problem and to allow the spectral peaks to be more easily resolved, spectra were transformed to second derivative traces. Following pre-processing, all the spectra from each dough (approximately 300) were evaluated, using Principal Component Analysis, to determine the spectral areas which changed most during mixing (Figure 1).[4] Two areas (1125–1180 nm and 1375–1525 nm) were found to be significant. Traces for 1375–1525 nm seemed to indicate a v-shaped

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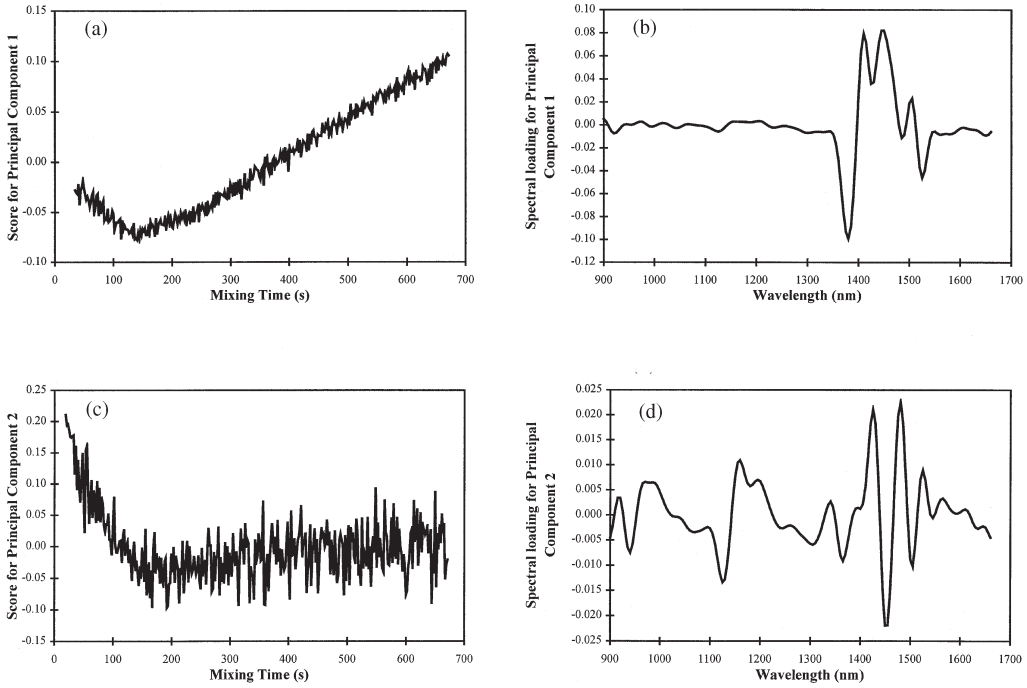

Figure 1. Principal Component Analysis for Hereward dough.

trace, while the 1125–1180 nm trace was different, showing a period of change only at the beginning. Due to the number of NIR absorbing materials in dough and the overlapping of absorbance bands in the regions of interest, it is difficult to assign the spectral patterns observed to particular chemical changes during mixing. However the region 1375–1525 nm is known to be associated with hydrogen bonding and has previously been used to investigate starch–water interactions.[5] In each case, the dough was allowed to mix for approximately ten minutes which would be sufficient to ensure that it had begun to break down. It is thought that this process occurs due to a progressive reduction in the chain length of the protein macromolecules and their solubilisation. In turn, this would result in sites becoming available for hydrogen bonding between these proteins and water. Given the shape of the mixing curves obtained for the first Principal Component, it would seem logical to propose that it relates to the development and subsequent breakdown of the gluten proteins during mixing. The spectral pattern associated with the second Principal Component only changes during the early stages of mixing, after which it seems to achieve a relatively constant state. One of the areas in the spectral pattern associated with Principal Component two (1160 nm), has previously been associated with water.[1] It seems, therefore, that Principal Component two may be related to the change from free to bound water during hydration of the flour components.

The results were investigated further using the area under the peak of interest (Figure 2)[6] to allow for future evaluation of dough during mixing. This showed that the area under the curve, in the region 1125–1180 nm, gave the most consistent results for a range of samples and so further work concentrated on this area. The minimum for each trace was derived using a hyperbolic cosine function and

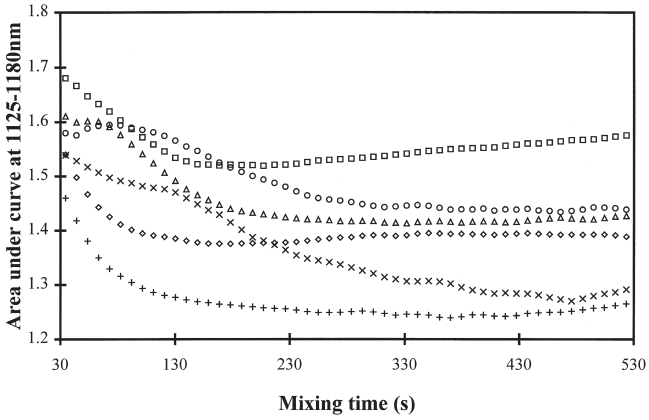

Figure 2. NIR mixing traces using the area under the region 1125 nm–1180 nm.

□ Hereward △ Rialto ○ Soissons + Riband ◇ Consort × Fresco

was compared to rheological properties of the gel protein fraction of the relevant flour (Figure 3).[4] The latter has previously been shown to relate well to functional properties of the gluten proteins and breadmaking performance. The linear relationship between the NIR and gel protein results indicates that the 1125–1180 nm region of the NIR spectrum of dough during mixing contains relevant information for the evaluation of flour functionality.

To investigate the effect of mixing time on breadmaking performance, doughs were mixed to a range of different work inputs using a Morton mixer. NIR and mixer torque traces were gathered and compared with loaf volume and crumb structure as measured by image analysis (Figure 4).[6] Flour

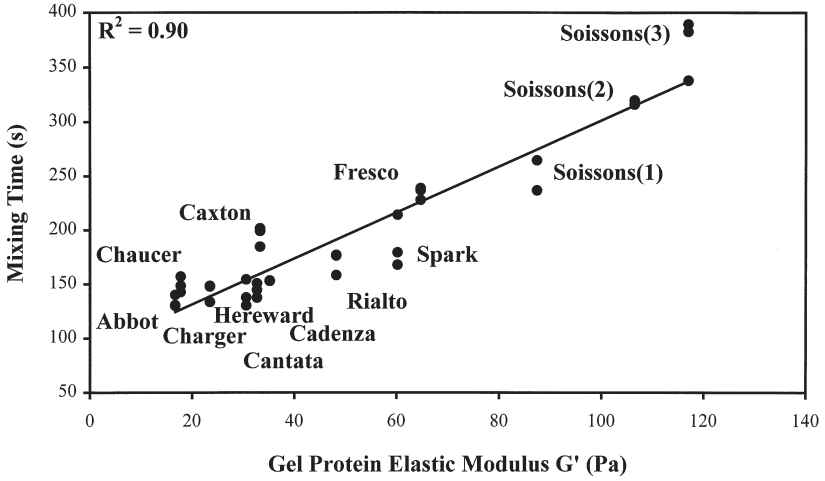

Figure 3. The relationship between the elastic moduli of the gel protein fractions and NIR mixing traces using the area under the region 1125–1180 nm.

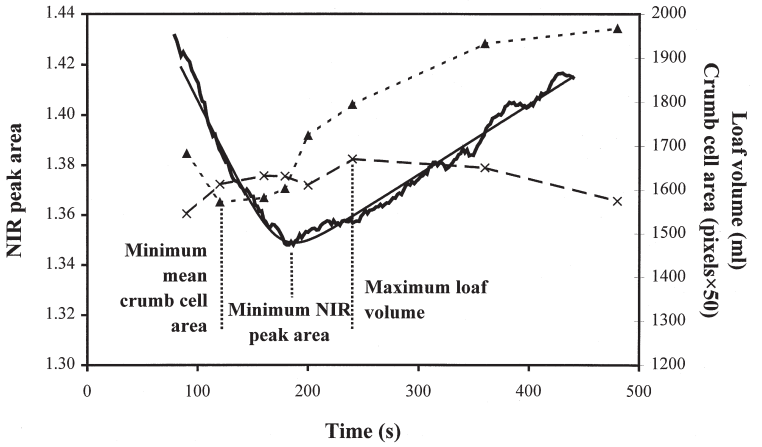

Figure 4. Effect of dough mixing times on bread properties.

milled from five wheat varieties, covering a range of gluten properties from very weak (suitable for biscuit making) to very strong (used to improve breadmaking grists), was evaluated. Again the stronger varieties had longer mixing times as determined by NIR. In each case the point at which optimum crumb texture was achieved was relatively early in the mixing process although, again, this took longer for the stronger varieties. Maximum loaf volume occurred at longer mixing times than optimum crumb texture, indicating that a degree of breakdown of the gluten proteins was necessary to allow this to occur. The minima on the NIR traces came after the point at which the finest crumb texture was achieved but before the point at which maximum loaf volume was achieved. This indicated that the NIR method could be used to determine a point of optimum mixing which offered a compromise between crumb structure and loaf volume.

Conclusions

An NIR method for assessing bread dough development has been investigated using a range of wheat varieties for two CBP mixers. The results indicate consistent relationships between NIR mixing curves, functional properties of the flour as determined by rheological studies and final bread quality. This methodology could form the basis of an on-line control system for mixing bread doughs to ensure optimum processing and final product quality.

Acknowledgement

This project is funded jointly by **nabim** (National Association of British and Irish Millers) and CCFRA Membership subscriptions.

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