Rapid Quality Measurements of Flour and Wheat in the Milling industry.

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Introduction:

Human consumption of protein is sourced from meat, eggs, fish, nuts, pulses, fruit, vegetables and cereals grains. For much of the world, cereal grains provide a substantial portion of protein intake. Bread, pasta, biscuits, cake, noodles and pastries are made from wheat flour which has protein concentrations between 8 and 15%. The nature and the concentration of the protein in the flour are major determinants of the dough making and baking characteristics of the finished food. The type and variety of the wheat used to produce flour determine the application for the flour. Protein in wheat is a major quality parameter that determines the strength of the dough and thereby the application of the flour. Starch and water content also affect the application of the flour. As such measurement of these and other parameters in wheat and flour are very important to the milling industry. This article describes the use of Near Infrared Spectroscopy (NIRS) as a means of performing rapid quality measurements in wheat and flour.

Near Infrared Spectroscopy:

In the mid 1960's, an agricultural engineer, Karl Norris, USDA, Beltsville, Maryland, USA, was given the challenge to develop a rapid means of measuring protein, oil and moisture in soybeans. Mr. Norris is credited as being the father of NIR because he was the first person to use multiple linear regression analysis to develop mathematical models to relate the Near Infrared Reflectance spectra ground soybeans to the protein, moisture and oil concentrations. In the last 50 odd years, Near Infrared Spectroscopy has evolved to become a mainstay measurement tool for many food and agricultural products. Almost all of the world grain is traded based on the use of NIR analysers to rapidly measure protein and moisture in wheat, corn, barley, rice, pulses, oats, rye, sorghum and protein, oil and moisture in oil seeds such as canola, soybeans, sunflower, safflower, linseeds and others.

Figure 1. shows a schematic of the basic optics that is used in NIR analysers to generate spectra of flour and whole wheat grains. Light from a tungsten halogen lamp passes through a sample of either flour or whole grains. Energy is absorbed at specific frequencies by the chemical bonds in protein (N-H), water (O-H), oil (C-H) and carbohydrates (C-O-H). An optical element called a Diffraction Grating separates the light into individual frequencies from 720-1100nm. The dispersed light is detected by a silicon photodiode array detector, similar to that used in a flat bed scanner or a laser printer. The amount of light absorbed by the sample at the resonant frequencies that correspond to protein, moisture, oil and carbohydrate is proportional to the concentration of each component in the sample. Figure 2. shows the NIT spectra of wheat, durum, flour and semolina.

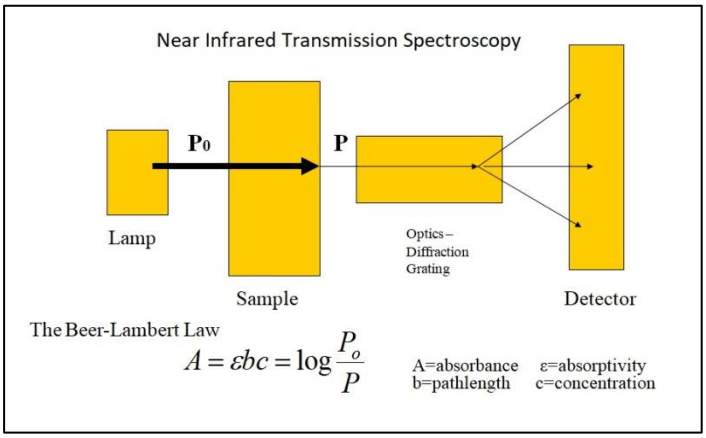

Figure 1. Near Infrared Transmission Spectroscopy

Applications for NIR Spectroscopy in the Flour and Wheat Milling Industry:

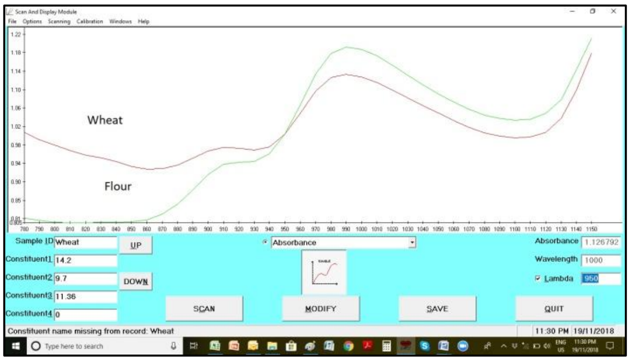

Figure 2. NIT Spectra of Wheat and Flour

The starting point for the production of flour and semolina is wheat and durum. Typically NIR analysers measure the protein and moisture in whole grains of wheat and durum as basic trading parameters, however for millers the measurement of gluten, falling number, hardness, sedimentation and Zeleny are important. Gluten is the major group of protein found in wheat. Gluten consists mostly of two protein, i.e., Glutenins and Gliadin. The question is whether the NIR spectra contains specific information that allows the analyser to measure gluten as part of the total protein compliment. The answer is no. The spectra of wheat grains are made up of a few broad absorption bands which are related to N-H bonds that are common to all proteins. The correlation between gluten and total protein is generally high and as such, the measurement of gluten using NIR is simply a proportional relationship to the total protein. Nonetheless, calibrations for gluten are commonly found in NIR analysers supplied to the flour milling industry. Likewise the physical parameters such as falling number, hardness, sedimentation and Zeleny are not directly measured form the NIR spectral but moreover indirect correlations to one or several of the chemical parameters, i.e., protein, moisture, oil and carbohydrates. The accuracy of NIR to measure these components in whole wheat grains is often poor. Grinding the grains into a powder and collecting the Near Infrared Reflectance spectra from 1000 to 2500nm, will improve the accuracy. Particle size of the powder is commonly correlated with measurements such as hardness, sedimentation and Zeleny and thereby explains why NIR Reflectance analysers are better for performing these measurement over NIR Transmission analysers.

Falling Number is a measurement of the extent of germination in a seed. Low Falling Number, i.e., less than 250 seconds, indicates a high degree of germination where the enzyme Amlyase is released and starts the breakdown of the starch in the endosperm. NIR spectroscopy measures total starch and thereby should provide a means of measuring Falling Number. However Falling Number is a viscosity analysis technique that relates the reduction in viscosity due to the breakdown in starch. The starch content as measured by NIR does not correlate well with the viscosity measurement and at best can be used as a rough estimate of the true Falling Number value.

Wheat and durum can exhibit white or yellow spots in the seeds due to high starch levels. In durum there is a measurement called Vitreousness that measures the transparency of the seeds. Starch spots inside the seeds decreases the transparency and are considered a negative quality parameter. High vitreousness measurement is associated with hardness and exhibits higher yield in semolina than low vitreousness durum. NIR Transmission analysers are capable for measuring Vitreousness. Although Vitreousness is related to the protein and starch content of the seeds, the actual measurement is related to the transparency of NIR light through the seeds.

There are more NIR measurements of quality parameters in flour and semolina than for whole grains. These include; Protein, Moisture, Starch, Ash, Water Absorption, Starch Damage, Dough Strength, and Dough Stability. Protein, Moisture and Starch measurements using NIR are straight forward. Ash which is a measure of the minerals in the flour, have no direct spectral bands in the NIR region. There are indirect measurements of Ash using the Visible spectral region, i.e., 520nm, which relates to the brand content of the flour. Several NIR analysers provide a wider spectral coverage in order to collect the 520nm band. The brand content can also measured in the NIR region using the 700-720nm region which captures the tail of the red absorption bands from the Visible spectral region, i.e., 350-680nm. Ash content is a good indicator of the degree of milling of the grain and separation of the non endosperm components of the grains. It is arguable whether Ash content of the flour directly affects the baking qualities of the flour, where as the inclusion of non endosperm components in the flour do affect baking quality. The reference method for Ash is weight of the residual after placing a sample in an Ashing Oven for many hours. Although a slow method as compared to NIR, the Ashing Oven method is highly sensitive and data is expressed as 0.001%. The NIR method for Ash is generally measured to only 0.01%.

Starch Damage, Water Absorption, Dough Strength and Dough Stability are parameters that are measured using a Farinograph, Extensiograph and Amylograph. These analysers are all based on measuring the rheometry or viscosity of a flour water mixture. As the mixture forms a dough, the strength of the dough is measured. Typically these procedures take 30 minutes to perform and can only be done one at a time. Flour millers use the data as guides to the baker as to the water take up and mixing performance of the flour when made into a dough. These are all physical measurements that at first thought should not be measured by NIR analysers. However calibrations for all four parameters have been developed across many brands of NIR analysers. The reason is that these parameters are Influenced by the protein, starch and water content of the flour. NIR chemometric calibration software uses multi variable linear regression processes to develop mathematical models to describe chemical components in food and agricultural products. As such, NIR calibrations for these four parameters can be rationalised due to the multi component interactions that exist within flour from protein, moisture and starch. Figures 3 and 4 show NIR calibration plots Water Absorption and Starch Damage using a NIR Transmission analyser.

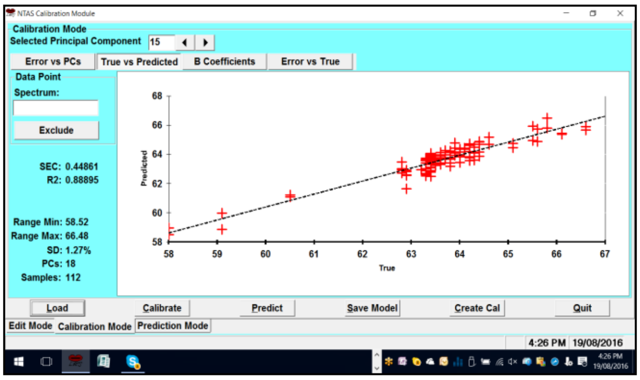

Figure 3. NIR Calibration Plot for Water Absorption in Flour

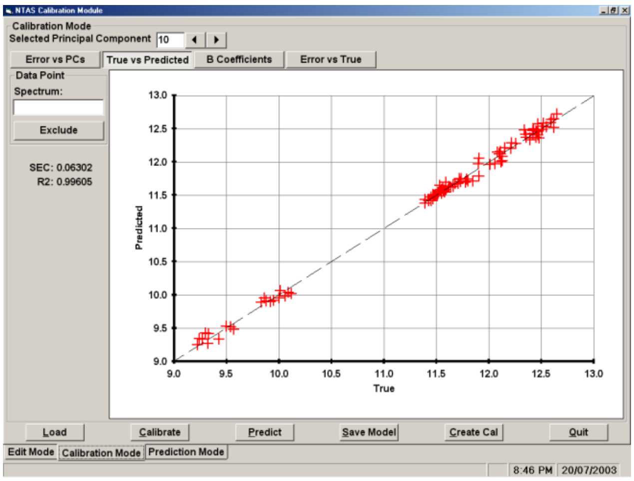

Figure 4. NIR Calibration Plot for Starch Damage in Flour.

Semolina is used to make pasta. The Protein, Moisture and Ash are critical parameters that are measured by pasta manufacturers. Figure 5 shows a typical calibration plot for protein in semolina is a NIR Transmission analyser.

In Line NIR Measurements in the Flour Milling Industry

NIR technology lends itself to in line measurements due to the ruggedness of the hardware and the fact that analysers can operate unattended for long periods with little or no need for maintenance. There are many locations within a flour mill to place NIR In Line analysers, i.e., incoming grain, tempering, milling streams and final products. Typically protein and moisture are the major parameters measured in line, however other quality and physical parameters can also be measured. Figure 6 shows an example of an in line NIR analyser installed in an Australian flour mill to monitor the protein and moisture in wheat as it is received into the plant. Figure 7. Shows the trend plot of Moisture as measured by the in line NIR analyser as compared to the laboratory NIR analyser.

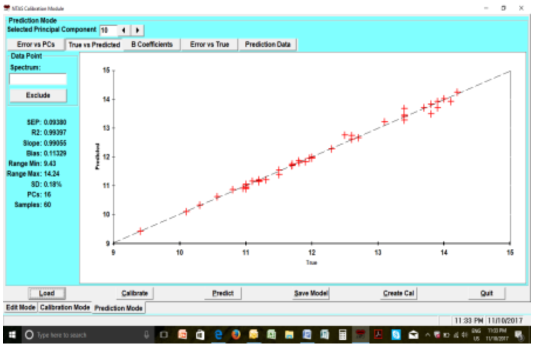

Figure 5. NIR Calibration Plot for Protein in Semolina

Figure 6. NIR In Line Analyser installed in an Australian flour mill

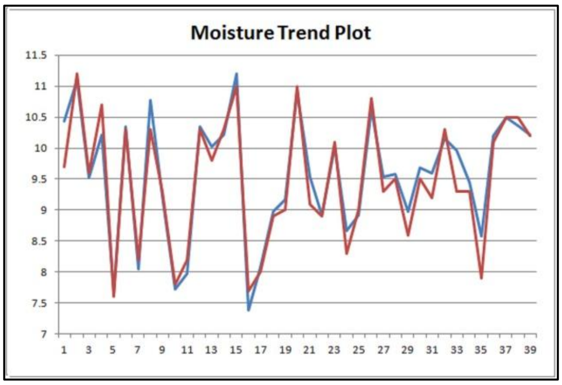

Figure 7. Trend Plot for Moisture in Whole Wheat

Discussion:

The use of NIR in the flour milling industry is well established. The benefits of NIR over traditional testing procedures lie in the speed of analysis, the simplicity, the ease of operation and the ability to measure several components simultaneously.