Research on the evaluation of wheat quality

KNOWLEDGE TRANSFER FROM CEREAL SCIENCE LABS TO QUALITY CONTROL LABS OF THE INDUSTRY. DEVELOPMENT OF IMPROVED METHODS TO EVALUATE THE GLUTEN QUALITY OF WHEAT FLOURS

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Bread and bakery products are one of the most important staple foods in Germany, with a per capita consumption of more than 80 kg per year, providing the majority of the daily carbohydrate, protein and vitamin B requirements. These products are predominately produced from wheat. Wheat flour provides unique properties amongst cereal flours and is, therefore, the basis for the successful production of bread, cakes, cookies, biscuits, pasta and so forth, to name only a few.

Wheat flour is the most exceptional flour amongst all cereal flours, for it is able to form a unique cohesive dough with viscoelastic properties when mixed with water. This viscoelastic dough is capable of retaining gas and setting in the oven during baking. These properties are essential prerequisites for the production of products such as bread with a light and even crumb structure; they are obtained by the special properties of the wheat flour proteins to form gluten after hydration and during mixing.

The quality of the raw material wheat and subsequently the flour has therefore, by far, the greatest influence on the overall bakery product quality. Its quality is essentially dependent on the wheat's individual genetic predisposition, the agricultural practices used during cultivation and the environmental effects the plant was exposed to. These exogenous and endogenous factors have great influence on the individual constituents of wheat flour and, therefore, on its overall baking quality. The genes mainly regulate the fundamental potential or occurrence of different attributes, such as protein type or quality, starch properties, grain hardness, potential to produce grain with protein content in a specific range or with a high milling yield in the growing wheat grain. However, the second group of attributes are those that underlie intense fluctuations by external influences, such as seasonal or site specific factors. These are amongst others moisture content, actual protein content or milling yield, weather damage, and contamination by foreign seeds, material that cannot be milled or grain infestations (moulds, insects).

As it is only possible to sell high-quality bakery products, it is essential that raw materials with defined quality are available for their production. Thus, it is clear that the raw material properties and their determination are of direct economical importance for the wheat flour processing industry. Therefore, it is vital to provide the milling and flour processing industry (baking and bakery ingredient industry) with reliable methods to determine the flour and gluten properties, respectively. Representatives of the milling industry have in particular repeatedly pointed out, in the last few years, that the methods currently used in quality control for the determination of gluten quality in wheat flour have gained results with decreasing correlations with the baking test and hence new reliable methods are necessary.

New methods are needed

Reliable methods for assessing baking quality are, therefore, in the interest of the consumer, expecting high quality bakery products as well as providing mills and the baking in-

dustry with the possibilities of monitoring the quality of their raw materials more effectively. This is important for the industry, because there is not a company that can afford to take the risk of economical loss due to varying raw materials and product quality.

Amongst breeders, grain producers/merchants and millers the need for more consistent and reliable information on the effect their incoming wheat grain quality has on the end-use functionality has clearly risen in the last few years. They are now not satisfied with the presently available methods and standards to predict the dough and flour properties and hence the end-use quality. These have shown to be increasingly unreliable and, therefore, the classification of the different grain lots or varieties is unreliable.

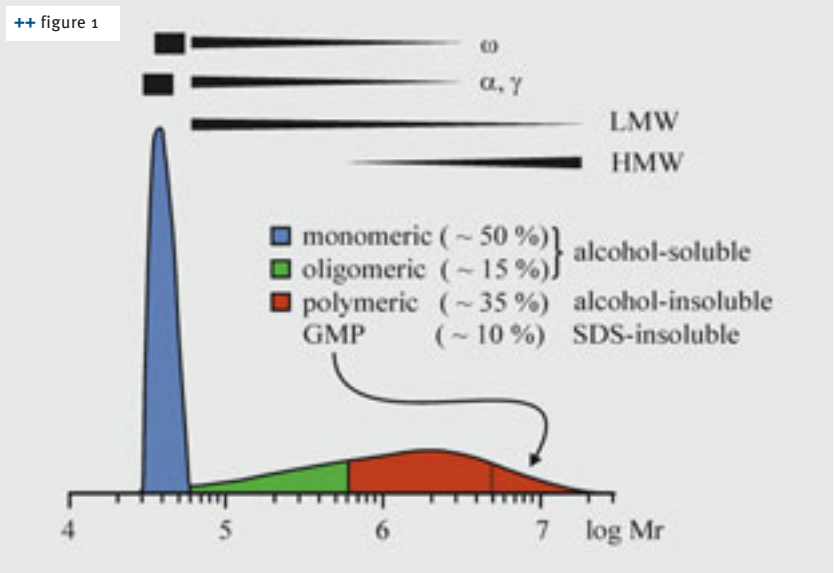
The general knowledge in cereal science regarding the different quality traits in wheat grain determining the end-use properties have enormously increased in the last few years. However, this knowledge and the determination of these quality traits are based on high priced equipment, only to be found in a few laboratories. Therefore this knowledge can only be effectively used, at the moment, by a small number of firms in the wheat chain production. Besides the high testing equipment cost, these determinations still take longer than the "old methods" and are, therefore, not practical for most companies.

Therefore, the aim of cereal science, besides increasing the basic knowledge on cereals, has to be the transfer of this knowledge cost-effectively and as quickly as possible into all those firms in the grain production chain needing new methods. This basic need for simple methods that indicate the flour, dough and baking quality characteristics by determining corresponding wheat quality factors will be the goal of our new project.

Flour characteristics

Wheat flour consists of starch (70 – 75%), water (ca. 14%), protein (10 – 13%) and minor components such as non-starch polysaccharides (arabinoxylans, 2 – 3%), lipids (ca. 2%) and enzymes (ca. 1%). All these components have an influence on the manufacturing process and the quality of the produced bread. However, the most overwhelming contribution towards the overall baking properties of wheat flour is made up by the so called wheat gluten, the biggest part of the wheat flour protein fraction (approximately 75%). The gluten content in wheat flour is a useful indicator for its quality, so the flour quality is influenced by the quantity and the quality of its gluten and its various components. Wheat gluten can be divided into two major protein fractions, the gliadins and the glutenins. They are both essential for the physical properties of the gluten network, the balance between the elastic and viscous properties. These depend on the ratio between glutenins and gliadins, on the molecular weight distribution of the glutenins, the presence of certain ▶

++ figure 1
Molecular weight distribution and presence of wheat gluten proteins



HMW glutenin subunits, and the plasticizing effect of the gliadins. The glutenin molecules are much larger than the gliadin molecules and are capable of forming an extensive three-dimensional network of molecules that provides strength (resistance to deformation) and elasticity for the dough. The glutenin subunits are linked together by intermolecular disulfide bonds to a huge polymeric glutenin molecule. Glutenins are physically resilient and not cohesive and therefore are thought to give the gluten network its elastic properties. However, gliadins also play an important role in this gluten network. When isolated they are very sticky and are therefore thought to be responsible for the cohesive property of gluten, providing the dough with plasticity/viscosity.

The gluten quality and hence the baking performance of the wheat flour is known to be well characterized by the gliadin/glutenin (Gli/Glu) ratio. Another gluten quality characteristic connected to the baking performance of wheat flour has been found to be the amount of glutenin macropolymer (GMP) present in the flour. GMP is defined as the amount of protein polymers that are insoluble in a sodium dodecyl sulfate solution (SDS) and form a gel-like layer after centrifugation. As can be seen in figure 1, GMP consists of those proteins showing the highest molecular weights in the polymeric protein group and of all the proteins present. GMP content in wheat flour is known to be highly correlated with the elastic properties of dough and bread volume.

Determination of protein parameters

However, up to now there have been no simple methods available to determine these two protein parameters. After all, the baking test is indeed still the only method that provides doubtless information on the quality of the wheat flour. However, the application of the baking test is time consuming and labor intensive, and is, therefore, scarcely used as a standard method in quality control. This is the reason why the baking activity of wheat flours is attempted to be correlated with protein parameters that can be determined easily, and from this to draw conclusions on the technological-baking properties of the flour. The amount of gluten is determined, on the one hand, empirically by estimation via the determination of the total protein content of the flour (near infrared spectroscopy (NIR), Kjeldahl method, Dumas method) and on the other hand through standard methods providing the amount of wet gluten after dough mixing and washing. Up to date, the gluten quality is determined by applying rheological (dough-mixing in the Farinograph; dough extensograms) and physical-chemical methods (Zeleny sedimentation test; sodium dodecyl sulfate (SDS) sedimentation volume). However, these methods only provide sum parameters and do not take into account the proteins or protein fractions respectively that are responsible for the gluten quality. Since breeding, nowadays, affects protein composition much more strongly than in previous times, protein quality is subject to change leading to larger discrepancies between traditional predictive analysis for quality and the baking test as compared to the situation ten years ago. In consequence this indicates clearly that there is a great need for implementing new methods to quickly and easily determine the Gli/Glu ratio and the amount of GMP in wheat flours.

Reliable methods are needed for the industry

For the industry, it is very important to have reliable methods to determine the quality of wheat flours so that they can permanently provide raw materials and food of high quality, respectively. The methods used presently do not represent the current state of the art in cereal science and are, therefore, not as reliable, especially with the newly developed wheat varieties, as they used to be. Therefore, the industry needs methods to quickly and easily determine the Gli/Glu ratio and the amount of GMP. Cereal science has known for years about the significance of the Gli/Glu ratio and the amount of GMP with respect to the gluten quality and the baking properties of wheat flours. The determination of these parameters is obviously possible. However, they cannot be determined with the equipment that the cereal grain industry uses routinely for their quality control, because there are no simple methods available yet. Up to date, it is not known to what extent ELISA, spectral-photometry and analytical combustion methods can be used to determine the Gli/Glu ratio and the amount of GMP.

The aim of the project is to develop methods that can be used to evaluate the gluten quality of wheat flours. The Gli/Glu ratio and the amount of GMP are to be determined. The new methods should thereby at least show an equivalent

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good correlation with the baking quality when compared with the existing ones. Special attention should be placed on the easy and quick feasibility of the new methods to guarantee a smooth transfer into the quality control of the industry.

On the scientific-technical side, the quantitative determination of the two parameters, the Gli/Glu ratio and the amount of GMP, which are crucial for the gluten quality, is already possible these days, albeit needing highly sophisticated and expensive equipment. The aim is to determine these parameters with the same accuracy, but with simpler methods. The new methods should be easily applicable and without great expense and be available in every quality control laboratory, e.g. in the milling industry, because the equipment used is already widespread throughout the industry.

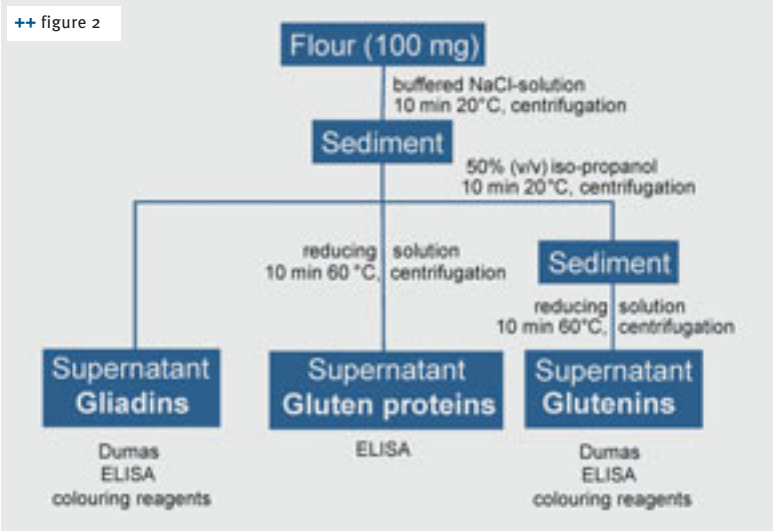
From an economical point of view the new methods will only deliver advantages to the companies, because for the first time the parameters directly connected with the gluten quality of the wheat flour are determined. The expectations are that the new methods show a better correlation with the baking quality than the existing methods. This will increase the effectiveness of the quality control and eliminate some of the inadequacies known from the existing methods.

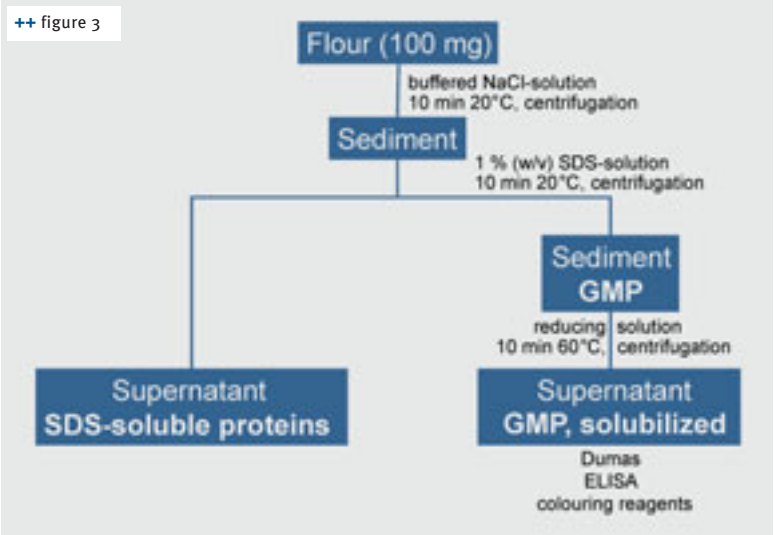
Innovative potential of the results

The quantitative determination of the gluten proteins with ELISA, as it has already been used for some years in celiac disease research, is accomplished by detecting gluten with the R5-antibody. However, it would be a novelty to use this analytical method to quantify protein fractions in gluten containing food such as wheat flour. The determination of the total protein amount has also been carried out for some time with spectral-photometry and combustion analysis; although up until now these methods have not been used for quantifying proteins in the gluten protein fractions. Since ▶

++ figure 2
Extraction procedure (based on the Osborne method) to determine the amount of gliadins, glutenins, and the ratio of gliadins/glutenins

++ figure 3
Extraction procedure to determine the GMP content of wheat flours





spectral-photometry and nitrogen determination, according to the Dumas method, are already commonly used, the existing equipment can be used to determine the Gli/Glu ratio and the amount of GMP.

Experimental design

Preliminary tests used five samples of wheat flour from kernels, grown in soil containing a different range of sulphur supply. The flours were well characterized in respect to their protein composition. The Gli/Glu ratio was between 1.49 and 2.30 and therefore more or less covered the range that can be found for the licensed wheat varieties in Germany. These flours were then examined for their technological properties. Mixing tests with the micro-Farinograph and extensibility tests with the dough and micro baking tests were conducted. The baking tests showed quite a range of different volumes of between 20 and 55 mL. The protein parameters, as found with the HPLC, were correlated with the obtained technological data. The results showed that the Gli/Glu ratio was highly correlated with the bread volume.

The research project

The research project is organized in five work packages (WP), which will be worked on simultaneously. In the first part of the project in Germany ten licensed wheat varieties will be selected. They will cover the range of baking quality groups and will be outstanding in respect to their cultivated area (acreage). The flours will be made from the kernels and then characterized by chemical-analytical as well as rheological-baking technological methods. In the second part, these flours will be used to develop new methods to determine the Gli/Glu ratio on the basis of the extraction procedure shown in figure 2 (based on the Osborne extraction procedure). To start with, a spectral-photometric method will be developed, followed by the analytical combustion method and the ELISA method. Additionally the extraction procedure will be mainly optimized in respect to the time needed for the testing procedure. The third part of the project will focus on developing methods to quantify the amount of GMP on the basis of the extraction procedure shown in figure 3, thereby using the methods developed in the second part and again mainly focusing on optimizing the procedure in respect to reducing testing time. The fourth part of the project will include the calculation of the correlation between the Gli/Glu ratio and the amount of GMP, as found with the newly developed methods, and the baking activity on the one hand and on the other with the data from the established methods. In the last step of the project the new methods will be used on a range of 20 wheat flours comprising licensed cultivars as well as new cultivars designated for licensing. The data obtained hereby will be correlated to the baking results found for these experimental flours.

The methods developed during the course of this project accommodate the needs of the industry in two aspects and are therefore of high economical importance. On the one hand, the methods detect the compounds of wheat flour which are truly responsible for the quality of wheat gluten and thereby raise the dependability of the quality measurements and allow the production of unvarying high quality of the raw materials as well as the bakery products produced thereof. On the other hand, they can easily be implemented, depending on the existing equipment, directly at the place of production or conducted cost-effectively by assigned laboratories. In the present difficult economic situation, in particular, this is a clear advantage. +++