INTEGRATED KNOWLEDGE OF GLUTEN QUALITY: GROWTH CONDITIONS AS WELL AS GENETIC ASPECTS

J.-C. Autran

INRA Cereals Technology Research Unit, Montpellier, France

Gluten proteins govern the bread-making quality of wheat flours, and gluten quality can be defined as a desirable combination of gliadin monomers and large glutenin polymers. Gluten quality varies as a function of genotypic and environmental factors, as well as the interaction of both (Graybosch, 1993).

In contrast to the considerable research effort directed on understanding of genetic bases of gluten quality, the effects of environmental factors (soil, climate, agronomic practices, diseases, etc.) have received only minor attention.

Because controlling the stability of the expression of quality is an objective long yearned for in the Western European context, I personally think that it is essential to intensify efforts with the aim of better understanding the effects of environment. As I have the role of providing an introduction of this session, I will very briefly review what has been done to understand and possibly control the effects of environmental factors, basing my argument on the situation in Western Europe.

In Western Europe, the consistency of the quality of the greater part of existing wheat is insufficient due to
(i) the relatively small size of productive areas, compared to North America or Australia,
(ii) a strong seasonal effect resulting in variable quality, and
(iii) too great a sensitivity to agronomic and climatic factors (Autran, 1989).

In Southern Europe, the climate is often the factor limiting both yield and quality; in the coastal regions of Northern Europe, where the crop can be cultivated intensively, sprouting puts a severe strain on both yield and quality (Autran *et al.*, 1995).

A review of the main recent investigations of the effects of environment shows that research strategy has been based on both conventional and novel approaches.

Conventional approaches have consisted of:

- Multi-site experiments aimed at quantifying the respective effects of genotype (G) and environment (E), and G X E interaction. The changes in relative proportions in glutenin, gliadin, soluble proteins were determined upon environmental modification, and analysis of variance was used to partition variation in measured responses into G and E. The results of such multi-site trials were used for attempting selection of cultivars which provide consistency in grain quality (Branlard *et al.*, 1991).

- Optimisation of fertilisation regimes (early/late dates, amounts and fractionation of nitrogen supplies) were optimised, essentially in view of controlling total protein content.

  It turned out that early supplies penalised protein content and adversely affected the environment, whereas staggering fertiliser use, with several applications over a period of time, was recommended for higher protein content, although it increased gliadin/glutenin ratios (Martin, 1987).

- Following the changes in proportions of the main protein fractions (using selective extraction) during the filling and dehydration steps of grain development (Galterio *et al.*, 1987; Robert *et al.*, 1994).

- Studies of the influence of sulfur deficiency/fertilisation. Late N applications where no S treatment was included tended to reduce breadmaking potential. Such samples were found to contain reduced levels of glutenin with increased quantities of the S-deficient omega-gliadins (Byers *et al.*, 1987; Landry *et al.*, 1991).

On the other hand, several novel approaches can be pointed out:

- In experimental designs, it was strongly recommended to better specify the origin of variation of protein content (Rousset *et al.*, 1985). [Inconsistent conclusions of many reports resulted from the insufficiently clear distinction between agronomic variation (agronomy trials) and genetic variation (inter-station trials) for the protein content of the wheat-grain samples].

- SE-HPLC was used to monitor the protein composition throughout grain development until dehydration (Benetrix *et al.*, 1994). The consequences of respective availability of gliadin, LMW or HMW subunits in the developing grain on the extension/termination of glutenin chains and functionality of polymers were discussed. Attempts were made to assess cultivar tolerance (stable cultivars could have glutenin aggregates that undergo less changes in function of nitrogen level) (Scheromm *et al.*, 1992).

- The dynamics of the accumulation of dry matter and proteins in the kernel in relation to temperature, water and nitrogen supplies were investigated, indicating that the length of the filling period (and not the nitrogen availability in the plant) was the limiting factor (Tribo, 1990).

- The effect of high temperatures during grain filling on the amount of insoluble or polymeric proteins in both bread wheat and durum wheat were studied, confirming the lower quantity of insoluble proteins and weakness of dough in heat stressed samples, but (without excluding the influence of high temperatures on gliadin synthesis), an alternative hypothesis to Blumenthal's was formulated, putting forward a lower degree of polymerisation of glutenin subunits with an effect of temperature on the mechanism by which intermolecular S-S are formed during the deposition (Ciaffi *et al.*, 1994, 1995).

- To select for a better sprouting resistance, a bioassay was developed to monitor inhibitors of germination and fractions containing inhibitors were characterised biochemically (Van Laarhoven *et al.*, 1993).

Perspectives for future research about effects of environments have to take into account the new challenge in the EU, which comes from the need to preserve the environment and to reduce chemical inputs. For wheat, this means to design more adapted fertilisation regimes, and to develop new cultivars with equal yield and quality but which will use nitrogen more efficiently.

In this perspective, nitrogen supplies can be now optimised using the new prediction balance method JUBIL® (based on a comparative study of soil nitrogen and nitrate content in the sap of the lower part of the stem). This makes it possible to supply the exact amount of nitrogen for the yield objective of the farmer, to insure a given level of quality and to avoid under-supply (loss of yield) or over-supply (pollution, lodging). This should also help in the decision-making processes: determination of an optimum harvest date, and earlier prediction of quality for the new harvest.

There is also a need to investigate further the whole wheat plant, specifically to identify agro-physiological markers of its functioning, so as to better understand and control its N metabolism in various temperature/water/nitrogen situations. For instance, to unravel the complex relationship between root absorption of nitrogen, its remobilisation from leaves (using 15N mass spectrometry), biosynthesis of specific subunits (with éffects on gluten functionality, biosynthesis of carbon and cell division or elongation). In the longer term, considering that expression of quality traits might originate in the interactions between the kernels and the whole plant, this should permit control of the expression of specific quality traits (and not only total protein content) through adapted nitrogen regimes.

Finally, we should be aware of likely evolution in the concept of gluten quality. So far, its definition has been based on functional properties in baking. In the future, because of new developments in wheat technology, it may be important to tailor new wheats with different protein composition and other gluten functionalities based on e.g. emulsifying properties, filming properties, taking into account glass transition, interaction with specific polysaccharides, etc., which will require new types of cultivars as well as totally different fertilisation regimes.

REFERENCES

Autran, J.C. (1989) Cereal Foods World 34, 667-676.
Autran, J.C., Hamer, R.J., Plijter, J.J., and Pogna, N.E. (1995) To explore and improve the industrial use of EC wheats. ECLAIR Programme AGRE 0052. Final Report from 1-01-1991 to 31-03-1995, Commission of the European Communities, Brussels, 134 p.
Benetrix, F., Kaan, F., and Autran, J.C. (1994) Crop Sci. 34, 462-468.
Branlard, G., Rousset, M., Loisel, W., and Autran, J.C. (1991) J. Genet. Breed. 45, 263-280.
Byers, M., Frankin, J., and Smith, S.J. (1987) Aspects of Applied Biology, 15, 337-344.
Ciaffi, M., Tozzi, L., Cannarella, E., Borghi, B., and Lafiandra D. (1994) In: Proceedings of the International Meeting "Wheat Kernel Proteins: Molecular and Functional Aspects", September 28-30, Viterbo (Italy), pp. 277-281.
Ciaffi, M., Lafiandra D., Tuechetta, T., Ravaglia, S., Bariana, H., Gupta, R., and MacRitchie F. (1995) Cereal Chem. 72, 465-469.
Galterio, G., Biancolatte, E., and Autran, J.C. (1987) Genet. Agr. 41, 461-480.
Graybosch, R., Peterson, C.J., Shelton, D.R., and Seo, Y.-W. (1993) In: 'Gluten Proteins 1993, Proc. 5th International Gluten Workshop'. Assoc. of Cereal Research, Detmold, Germany. P. 280-291.
Landry, J., Legris-Delaporte, S., and Feron, F. (1991) Phytochemistry 30, 729-732.
Martin, G. (1987) Perspectives agricoles 115, 114-122.

Robert, N., le Blevennec L., and Tribo, E. (1994) In: Gluten Proteins 1993, Proceedings of the 5th International Gluten Workshop, June 7-9, 1993, Association of Cereal Research, Detmold (Germany), pp. 105-109.
Rousset, M., Tribo, E., Branlard, G., and Godon B. (1985) Agronomie 5, 653-663.
Scheromm, P., Martin, G., Bergoin A., and Autran, J.C. (1992) Cereal Chem. 69, 664-670.
Tribo, E. (1990) In: Proc. Colloque INRA "Glutenines de haut poids mol,culaire et qualit, des bles", Paris, 4 Decembre, pp. 59-76.
Van Laarhoven H.P.M., Kelfens, M., and Hamer, R.J. (1993) In: Pre-harvest sprouting in Cereals 1992. (K.K. Walker-Simmons and R.L. Ried, eds.), pp. 280-287.