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Inside-outside view on the international recognition of cereal research of the Department

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1. SUMMARY

The author summarises the research and teaching work in food chemistry at the Budapest University of Technology, now known as the Budapest University of Technology and Economics. The manuscript is based on a lecture given at the University's "100+10" anniversary celebrations (*the Ed.*).

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2. Introduction

The rather unusual title of this paper requires some explanation: The author started to work as a demonstrator during his last semester of his chemical engineering studies in 1972 at the Department of Biochemistry led at that time by professor Telegdi-Kovats. He was employed as a sponsored postgraduate in July 1972 under Professor Lásztity, two weeks after the change of leadership of the department. He carried out research and was involved in undergraduate teaching, moving ahead on the academic ladder, achieving university doctorate and PhD till 1987 when he was invited to join the Wheat Research Unit of CSIRO (Commonwealth and Industrial Research Organization) in Sydney, Australia. Being involved cereal research there he had a permanent and a continuous relationship with the staff of the Department in Budapest, he was not only a witness but also a participant of the ongoing research there, meanwhile he had the opportunity to directly perceive the recognition of the Departments' research activity on the international platform.

3. Early history

Before covering the story of cereal research carried out at the department, it is worth to mention an episode happened 50 years earlier than the establishment of the department but had and even has nowadays strong effect on its spirit and strategy.

The last quarter of the 19th century is the era of success of the Hungarian milling industry, when the chilled-iron roller mills equipped with planar sieves, manufactured by the factory of Abraham Ganz spread around the world. A functioning model-mill, to demonstrate the revolutionary new technological solutions of the Ganz mills, with all their novel features, have appeared in Australia. The mill was capable to mill some kilogram grain for evaluating its quality. This equipment, representing one of the superior products of the Hungarian manufacturing industry of the XIX century is also a valuable symbol of the Australian grain industry developing in same time. However, the mill has an important role in the birth of cereal chemistry as scientific discipline, too **[1].**

In the 1890ies the Australian wheat breeder William Farrer and Fredrick Guthrie, the chemist working with Farrer introduced the concept that the *quality of wheat* also should be considered together with harvest yield as a criterion used during wheat breeding. Guthrie's concept was to evaluate quality by applying identical methodologies and scaled down equipment and in the laboratory as the milling and baking industry practice in large scale **[2]**. So, it was inevitable that Guthrie should turn to this form of milling when he was asked to evaluate the milling qualities of a series of cross-bred lines of Farrer, in 1894. Guthrie took the model mill to his laboratory and started to evaluate Farrer's wheat line on it: The Ganz mill became the very first test equipment to evaluate the milling quality wheat – the discipline of grain science born **[3].**

Guthrie's model mill – after several decades of vicissitude – was taken back to Hungary in 2011 and now it shown as a part of the permanent exhibition of the history of the Ganz mills in Budapest at Foundry Museum of the Hungarian Technical and Transport Museum.

4. The beginnings

Cereal science is one of the most important research directions at the Department since its establishment under in the 20ies under the leadership of Miháyl Vuk. In the first quoter of the the XX. century, the Hungarian grain science was internationally well-recognised László Karácsonyi achieved internationally known results in investigations of bread staling, published in the then established American journal, Cereal Chemistry **[4, 5],** the Pekár flour colour measuring method, became widely known and applied in several countries **[6]**, internationally one of the very first detailed information about the chemical composition of the Hungarian wheat and wheat flour was published **[7]**. Hankóczy's dough rheology equipment had been developed in this period, revolutionising the wheat chemistry: he discovered the farinometer in 1905, the very first equipment which was capable to determine the extensibility of dough and gluten. After further development he established the Farinograph, for the simultaneous determination of the water absorption of the flour, the quality of the gluten and the dough development time **[8,9]**. His method and his invention has been spread around the world. He proposed the establishment of Hungarian wheat cadastral leading to quality-based wheat selection in breeding [**10,11**].

Under the leadership of Vuk Mihály, the department played important role in the development of methodologies for Hungarian food analytics and quality control. He published the first Hungarian food chemistry textbook with his co-workers, Zoltán Sándor and Károly Vas **[12]**, he is the author of the first Hungarian wheat chemistry book **[13]**.

5. Radomir Lásztity, the “Hungarian Pomeranz”

A new, internationally well recognised era started in 1951 when Radomir Lásztity joined to the department and especially from 1972 when he took over the leadership at the department. The number of staff doubled; the average age dropped by 30 years. In addition to his research activity, Lásztity had essential role in shaping the educational structure of the Chemical Engineering Faculty by establishing the bioengineering division, he had a mentor role of for the teaching and research stuff of Department. His teaching passion is best illustrated by the fact that throughout his carrier he always has found time to write numerous much-needed textbooks in English and Hungarian language as well as books for undergraduate and postgraduate students in co-authorship with colleagues from The Department or from other institutions. Since its publication in 1984 by CRC Press under the title “The Chemistry of cereal proteins”, it has become one of the most frequently mentioned handbooks in the literature worldwide. Radomír Lásztity’s most important works on this subject are presented in ***Figure 1*** without claiming to be exhaustive.

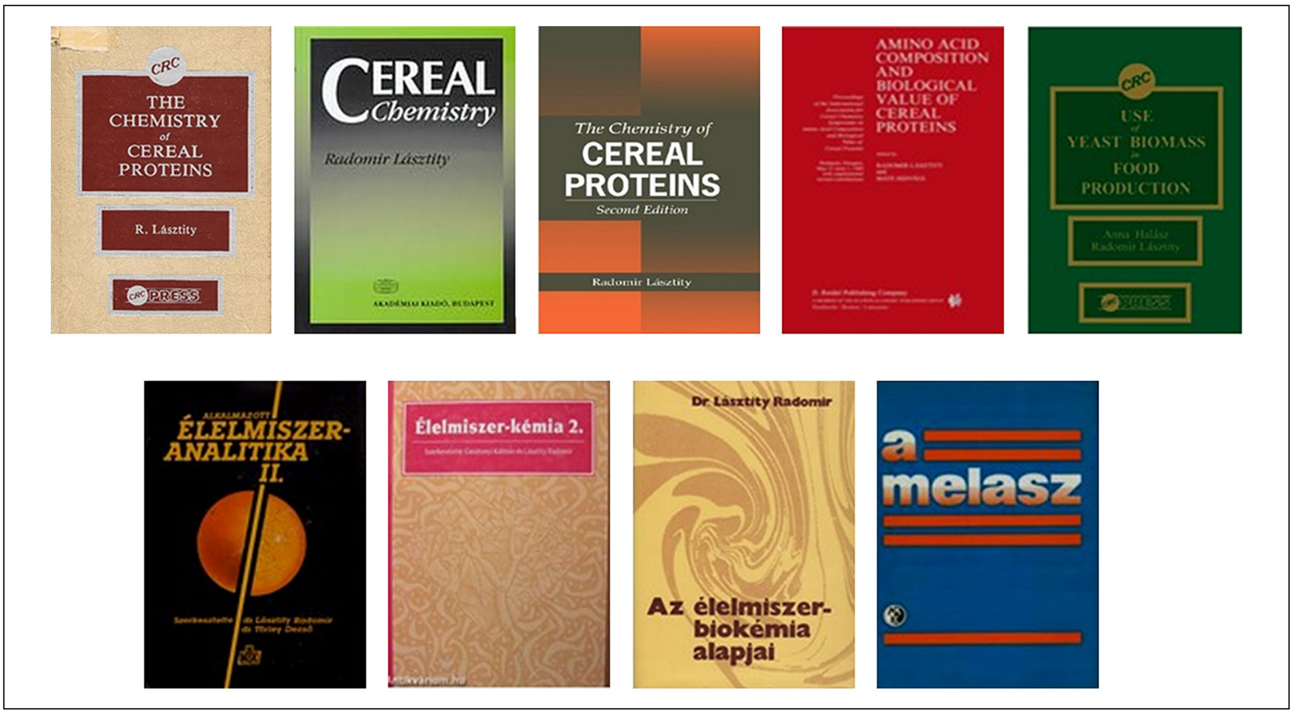

Figure 1/a. Some important book publication of Professor Lásztity (reference books)

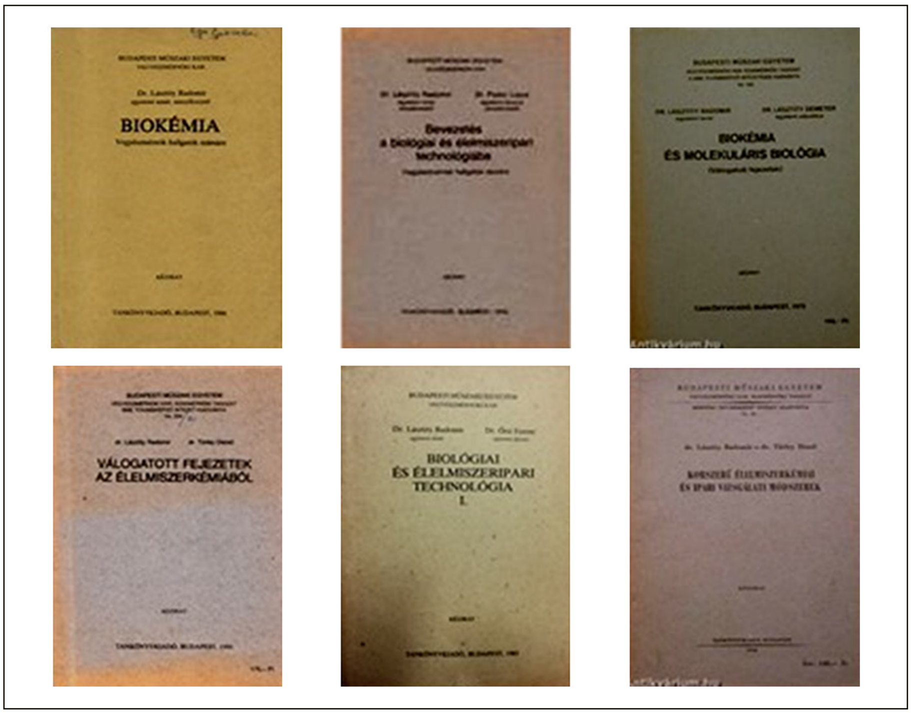

Figure 1/b. Some important book publication of Professor Lásztity (university notes)

The openness for new ideas of Lásztity is best demonstrated by the fact the Ganti’s Chemoton-theory on the principles of life has been part of the curriculum of bioengineering students at the faculty first time around the world as a part of a facultative subject of “Selected chapters of Biochemistry” under the name of Lásztity. Several awarded student works, thesis have been written on the related subject, and a self-study small group called “Kinetic Club”, sponsored by the MTESZ, has actively worked on topics related to pre-biology evolution, not only with students from the BUTE, but from SOTE and ELTE.

From the very beginning, Professor Lásztity’s personal research focused on the investigation od structure and rheological properties of dough and on the development of new apparatus and methodology for this task **[14, 15, 16, 17, 18]**. The most important groundbreaking result of his work was the development of a linear structural model of wheat glutenin **[19]** (***Figure 2***), which made his name one of the greatest of the era (*Bloksma, Evans Ewart, Pomeranz*).

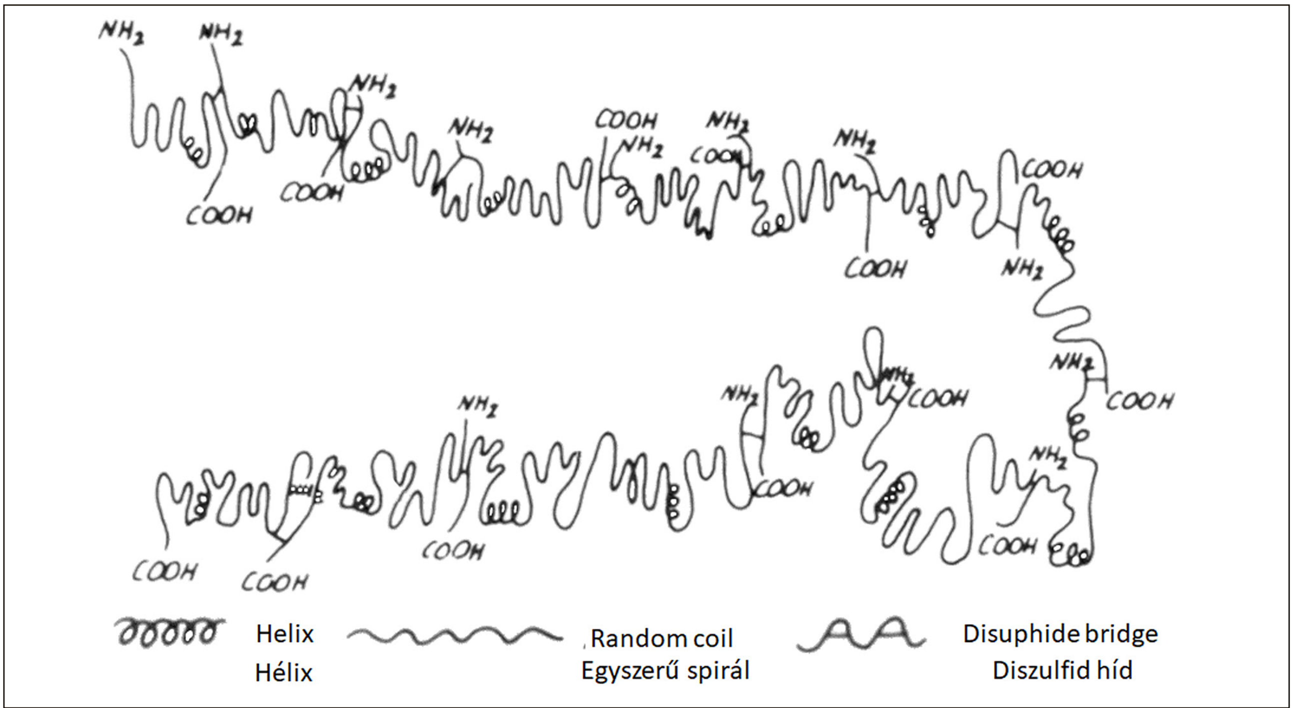

Figure 2. The linear polymeric structural model of wheat glutenins developed by Lásztity [19]

Lásztity’s place and role in the world grain science pantheon was most succinctly articulated by *Colin Wrigley,* a world-renowned Australian representative of the profession, when he introduced Lásztity, who was an invited speaker at the annual Australian Grain Chemistry Conference in the 1990s, as the “Hungarian Pomeranz” before his presentation (Pomeranz is the greatest figure of our profession of all the time, who, in addition to his own research, has enriched the field of cereal science with over 500 publications, teaching, educating generations of students at several universities in the USA as a scientific organizer. F. Bekes).

6. Priority research directions

Lásztity’s definition of wheat gluten is the most accurate description to date of this complex food constituent with an extremely intricate structure: Wheat gluten is a protein-lipid-carbohydrate complex formed during dough making when, as the results of mechanical input, several specific covalent and non-covalent interactions are formed among the hydrated components of flour. This definition illustrates Lásztity’s lifelong interest in the complex structure of foodstuffs, which has ultimately defined one of the most frequent areas of cereal research in the Department to date, the study of the composition and structure of protein-lipid and protein-carbohydrate interactions and their relationships to functional properties of dough.

6.1. Research on complex proteins in wheat

The Department’s numerous publications on this topic **[20, 21, 22, 23, 24],** and not least the methods for estimating baking properties based on these complex chemical interactions **[25, 26]** have generated considerable international interest. The Department has been recognised as one of the most important centres of research in this field. This area also includes the research on thionins, a lipoprotein of cereals with a particular composition and small molecular mess **[27, 28],** which resulted in two publications cited more than a hundred times in the international literature: one on the detailed structural model of the lipid complex of wheat purothionin **[29]**, and the other on the amino acid sequence of the oat thionin, avenothionin **[30].** The study on complex wheat proteins is still an active area of research in the Department trough international collaborations, in particular in on arabinoxylane and its interactions with wheat storage proteins **[31, 32, 33, 34, 35, 36].**

6.2. Cereal laboratory instrument development, collaboration with LaborMIM

Another very important research area of the Department, initiated by Lásztity, is the development of testing equipment and methodologies for the cereal industry. This activity has been carried out in the framework of a decades-long collaboration between the Department and the engineers of the Laboratory Instrumentation Works (LaborMIM) **[16, 17, 18].** To quote the 1971-72 Yearbook of the Faculty of Chemical Engineering of the BUTE: "The department regularly carries out the determination of parameters for the design of new laboratory grain and flour testing instruments, as well as the measurement and expert evaluation of equipment and instruments for complete laboratories. In 1970, the Department carried out a study on the design of a micro-baking and moisture measuring equipment, an elastograph, a bread-crumb investigating apparatus, a hydrolysis equipment for rapid protein content determination. Contractor: the company named LaborMIM."

Contributions to the creation of numerous grain testing instruments, in addition to a large number if scientific publications and patents, have significantly enhanced the reputation of the Department both in Hungary and abroad. For decades, Valorigraph was the basis for grain classification in Hungary, so the expert level of knowledge of the instrument provided a direct link woth the industry namely with the Department of Quality Control of the Hungarian Grain Trust, headed by Pál Kézdy, and the two relevant industry research institutes (Grain Research Institute, Baking Research Institute). Through these contacts, the Department has been able to obtain first-hand information on the development ideas of the cereal industry and to contribute to the solution of problems that arise. Two examples of these latter are worth mentioning here, because both topics, which were originally industrial problems, developed into basic research projects at the Department, which have been internationally acclaimed for several years. The severe mycotoxin infection appearing in the Hungarian cereal chain lad to start to deal with analytical problems of mycotoxin-contaminated grain, which activity later extended in the direction of mycotoxin detoxification **[37, 38, 39, 40].** The Department's research on in vitro biological value evolved from its expert advice on feed optimalisation activities for the Grain Trust, resulting in the development of a non-linear optimalisation methodology using novel chemical indices **[41, 42]**, as an objective methodology for the formulation of both human food (e.g., baby food) and feedstuff **[43, 44, 45].**

LaborMIM's grain analysers were widely used not only in domestic applications but also in contries behind the Iron Curtain: their purchase, unlike comparable analysers in Western countries, did not require "hard currency" in these countries. This was one of the reasons for close cooperation between the Department and researchers from neighhouring countries, especially the former Yugoslavia and Czechoslovakia.

In terms of content, the LaborMIM relationship has far exceeded the decades of cooperation based on grain industry instruments, with the Department actively involved in the development of other products of the company, such as liquid chromatographs and electrophoretic equipmint. One of the success stories of these activities was the BNW's grand price-winning complex seed testing laboratory, which produced a world-class gel-electrophoresis apparatus and a computer program package for variety identification tasks based on a pattern recognition algorithm written under DOS environment **[46].** An improved version of the program, converted to Windows, is still in use today by many research and breeding institutions worldwide under the name "PatMatch" **[47].**

7. Gluten workshops

In 1980, researchers from the Department were invited to participate in a exclusive International Wheat Gluten Workshop organised by INRA (Nantes, France), which was attended by the world's leading wheat research institutions. The "International Workshop on Gluten Proteins" has become the highest level professional forum in the field, traditionally held every 3 years since 1980. The Department has been represented at all 13 Gluten Workshops held so far, and we organized the 3rd Workshop in Budapest in 1987. The 3rd Gluten Workshop in Budapest has been rated by the profession as one of the highest quality and best organised meetings to date **[48].**

8. The 80s, wheat research at the crossroads

The 2nd Gluten Workshop held in Wageningen in 1984 was an important milestone in the history of the field: it was here that a Lásztity-Shewry polemics on the use of the word prolamin took place, raising much more general questions. Until then, cereal chemistry had classified cereal proteins according to the classical nomenclature laid down bt Osborne, based on their solubility.

It was the early 80s that plant molecular biology and genetics came to interpret the genetics of this complex croup of compounds, leading the British research group led by Miflin to formulate a genetically based grouping and new nomenclature for wheat proteins **[49]**, (***Figure 3***). This provides a more precise designation/definition of the different protein groups in all respects, but it contains a serious problem -not at all important from the view of content – but with consequences: the *prolamin* designation of the alcohol -soluble proteins of the Osborne nomenclature is by Miflin et al with a completely new content to designate a different concept, causing a great deal of confusion in the literature published over the last 50 years.

Following Shewry's presentation, Lásztity, recognizing the problem, made a comment that led to a long and substantive discussion, pointing out the great dilemma of that era of cereal chemistry: until then, cereal chemistry had focused on wheat and wheat flour as the *raw material for bread-making*, but with the advance of molecular biology/genetics, *wheat as a biological object* came to the fore. This meant that while the former approach focused on the properties of flour and in particular dough, based on complex interactions, latter focused entirely on the components, i.e. the individual genes representing the genetic make-up of the wheat plant, completely ignoring the fact that the techno-functional properties of wheat flour is manifested through the *interactions* between the products of these genes.

We reported on the Workshop in an article entitled "At a crossroad in wheat protein chemistry?" in the magazine, Food Industry **[50].** Unfortunately, the evolution of the field over the next 10 years has proven our fears to be well founded, and even showed signs of splitting. Although both camps have achieved epoch-making results – an era when biochemical and then molecular markers have been introduced in plant breeding, NIR technique become routine method for the quantitative analysis important grain and flour components, when MacRitchie and his co-workers developed the reconstitution technique, the production of unique wheat proteins become available bacterial expression, wheat protein genes have been genetically altered – but at the same time the gap between basic research I cereal chemistry and applied research that can directly serve practical applications has widened considerably. The results of biotechnology, in particular following the successful solution of wheat transformation, have led to articles by leading experts predicting that in the near future genetic engineering will take over the function of plant breeding and that new genetically modified varieties will be created to meet the various needs of cereal technology. Of course, their prediction did nit come true at all.

It is no accident it was Peter Shewry, Olin Anderson and Rudi Appels, the most prominent pioneers in the application of molecular biology in crop science, who were first realize that the unprecedented potential of molecular approaches and tools could only be fully exploited, if we can not only manipulate the gene and detect its product in wheat, but also - using the tools and experience of traditional cereal science – we can follow and interpret their effect in wheat-based products. This realisation has opened a new chapter in cereal science, in which the Department has played a key role.

9. Development and application of small- and micro-scale dough-testing equipment and methodology

At the turning of 1980s and 1990s, British and American researchers solved the problem of isolating genes coding various gliadin as well as glutenin proteins and producing the encoded proteins at mg scale by bacterial expression. Around the same time, the 2g Mixograph, the first micro-scale dough tester, originally developed for early selection in wheat breeding, was found to be an excellent basic research tool: by adding a few mg of protein to the flour during dough mixing, its effect on mixing characteristics could be monitored and recorded in a sensitive and reproducible way **[51].** By means of a consecutive reduction/oxidation process carried out directly in the mixing bowl, supplemented glutenin subunits could be incorporated into the polymeric structure of glutenin polymer and their effect on the rheological properties of the dough could be studied **[52]**. These novel test methods opened the way to investigate the relationship between the dough properties and the structure of added/incorporated natural and/or genetically modified proteins **[53, 54].**

The characterisation of wheat transformed with modified wheat genes **[55]** and the above-mentioned *in vitro* methodologies had two fundamental shortcomings: we did not have the means to mill gram quantities of transgenic seed into flour and there was no micro-scale equipment for the determination of one of the fundamental properties of wheat flour: water absorption, the parameter what is actually measured on macro scale using the Hankóczy Farinograph.

It was the time when members of the Department and the staff of two small Hungarian companies, engineers from the then defunct Labor MIM, joined forces with Australian CSIRO researchers **[56]** to create the world's smallest laboratory micro-mill, capable of grinding even a single grain of wheat to flour **[3, 57]** and micro-version of Hankóczy's Farinograph (micro-Z-arm mixer), capable mixing 4 gram of flour and determining mixing properties, including water absorption **[58, 59, 60]**.

These developments are an integral continuation of the Department's activity in this field, which has been carried out in the spirit of Guthrie and are the culmination of decades of cooperation with LaborMIM. The micro-mixer is a joined intellectual property of BUPA and CSIRO, the manufacturing rights were purchased by Newport and its successor, Perten. And which is now being further developed, manufactured and marketed under the name of Micro DoughLAb. More than 200 units are in operation in 41 countries worldwide. Nowadays, wheat transformation for research purposes, research on structure/function relationships of wheat proteins, QTL analysis on large sample population, molecular marker development, all basic and applied research areas where sample size is limited, are unthinkable without the use of Z-arm micro mixer.

The Department has been/is involved in a large number of international collaborations in various areas of cereal science using its micro-scale test equipment **[61, 62, 63, 64, 65, 66].** Instrument development, development of new micro-scale equipment and methodologies is still an important area of research in the Department. Recent developments include a micro Zeleny sedimentation apparatus **[26, 65, 66]**, a micro scale apparatus for gluten-washing with starch isolation options **[67]** and a complete micro scale test baking facility and methodology **[68, 69, 70].**

The significance of the Hungarian-Australian cooperation on micro-scale testing was perhaps most succinctly expressed by *Harry Sapirstein*, a Canadian researcher, who introduced the authors of a paper on micro scale studies (Tömösközi, Gras, Varga, Rath, Nánási, Salgó, Békés) at a conference in the USA with these words: " They were the *traitors* to traditional cereal science who made contact with the *gene-jokies* – opening a new chapter in cereal science by their joined achievements.

10. Other international contacts

This overview of the Department's international relations would not be complete without mentioning the activities of the Department's staff in various international associations. Professor Telegdy-Kováts became a member of the Executive Committee of the ICC (Interntionl Ceral Chemistry Association, Vienna) as early as the 1960s, and was replaced by Professor Lásztity in 1978, even serving as President of the ICC for one election cycle. The Department, through Dezső Törley and András Salgó, was actively involved in the work of the FAO/WHO Codex Alimentarius. Budapest has been the venue for several highly successful ICC events, on one of which in 2002 András Salgó received the ICC's prestigious Harold Perten Award as a recognition of his work in the field of near infrared (NIR) technique in cereal science **[71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 84]**.

As a member of several largescale international collaborations organised by the ICC and the EU, including the MoniQA **[81, 82, 83]** and HealthGrain **[84, 85, 86]** projects the staff of the Department have worked and published results with researchers from numerous countries in europe. Among these links, a special place is occupied by the cooperation with the sister department of BOKU in Vienna, which has been established over several decades and includes not only research but also the training of chemical engineering students **[33, 34, 87, 88, 89, 90, 91, 92]**.

11. Conclusion

The broadening concept of cereal quality, such as the need to study nutritional and health related properties, continues to reinforce the interdisciplinary nature of food science. New disciplines and new methodologies are being integrated int traditional research/development processes.

As illustrated above, the research palette of the Department has been enriched accordingly with new colours. Large-scale instrumentation techniques, indirect methods for online control have been added to the research topics, as well as the study of allegenic/toxic components of food materials, including cereals.

Building on the Department's long tradition, these are carried out on an international scale, often in the framework of international cooperation.

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