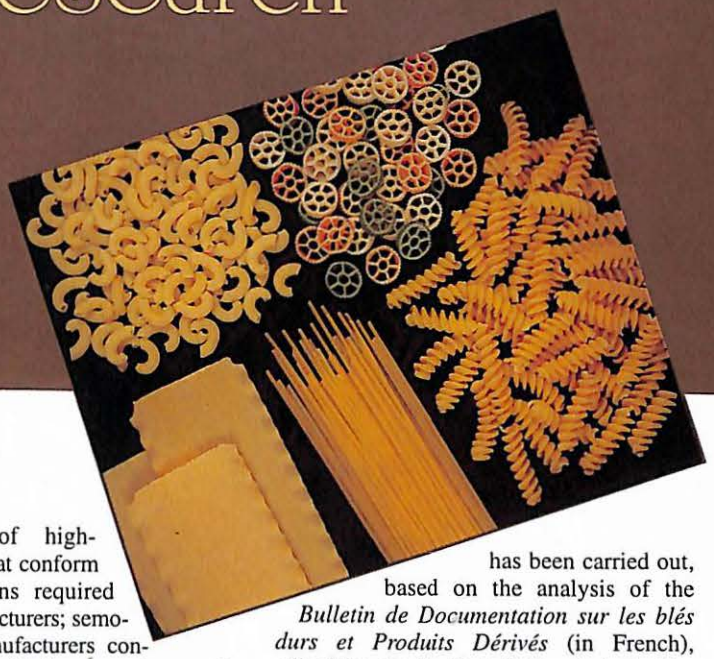
Past and Future Trends of Academic Research on Pasta and Durum Wheat



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Pasta has long been a favorite of Chinese and Mediterranean civilizations and is currently consumed and appreciated worldwide. It is simple to prepare, easy to transport, and has excellent storage properties. It is nutritional and healthy and can be prepared in a variety of ways. All of these factors contribute to its popularity.

The transformation of durum wheat into pasta is a straightforward operation, as can be seen in Figure 1. The endosperm of the grain is first extracted in the form of 150- to 500-µm particles of semolina that are then hydrated, mixed, pressed, and finally extruded and cut into the desired shape before being dried.

Those involved with the production of durum wheat, semolina, and pasta continue to want to improve product quality and to optimize methods of production. The principal agents of the pasta chain involved are: geneticists, breeders, and agronomists who create and produce durum wheats with the qualities required for semolina that can subsequently be used for the production of high-quality pasta and that conform to the specifications required by industrial manufacturers; semolina and pasta manufacturers concerned with the efficient running and optimization of their production lines, particularly with regard to the mixing, extrusion, and drying processes, as well as the conditioning and storage of their products; and machinery suppliers, who develop and manufacture the materials that contribute to productivity, quality, economy of energy, hygiene control, and ease of maintenance.

These are the progressive stages that constitute the durum wheat research sector (Fig. 2), with academic research occupying a central position. The role of research is particularly important to this sector, particularly in food science (knowledge of the physicochemical properties of products and the effect that transformation processes have on these), genetics (including the creation of varieties and molecular biology) and agronomy, and process engineering (fragmentation and separation of grain constituents, mixing and extrusion, drying). Research teams are also involved in the development of new methods of analysis (electrophoresis of proteins for varietal identification, detection of bread wheat products, control of semolina purity, and appreciation of the color and cooking quality of pasta).

PRINCIPAL TRENDS IN INTERNATIONAL RESEARCH

A bibliographic analysis of works published after 1980 (patents not included) has been carried out, based on the analysis of the *Bulletin de Documentation sur les blés durs et Produits Dérivés* (in French), edited by the Institut National de la Recherche Agronomique (France) with the backing of French durum wheat industry. (A detailed analysis can be found in AACC*net*.) Table I lists publications by theme. The general conclusions that can be drawn from this analysis follow.

Sixty percent of publications concern genetic, physicochemical, and analytically based research. Proteins are studied more than (86 publications) enzymes, lipids, and starch, which account for no more than 37 publications between them. Despite the importance for consumers of nutrition and hygiene control, these subjects have not inspired much in the way of academic research, and indeed there has even been a lessening of interest over the past five years.

The study of the processes used in semolina production has not attracted much interest, with only 5% of total publications being devoted to this topic. The production of pasta, however, has inspired 15% of the research effort. One important field that has been the subject of research, especially between 1980 and 1990, is high or very high temperature drying techniques, accounting for 7% of total publications.

It is only recently that the international scientific community has become interested in branching out into other products derived from durum wheat, in particular bread and couscous. The principal analyti-

Publication no. W-1996-0409-01F.

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cal research programs have focused on the following: the development of methods for determining the cooking quality of pasta, the addition of eggs to pasta, the detection of bread wheat products, the characterization of physical properties of grains, and the fractionation of proteins (chromatography, electrophoresis).

The majority of these works are carried out by a small number of laboratories, the most active being situated in Canada (Winnipeg), France (Montpellier), Italy (Milan, Rome, and Viterbo), and the United States (Fargo, ND).

In addition, the authors have identified what, in their opinions, are their most significant publications in different areas during the last 10 years (Appendix 1).

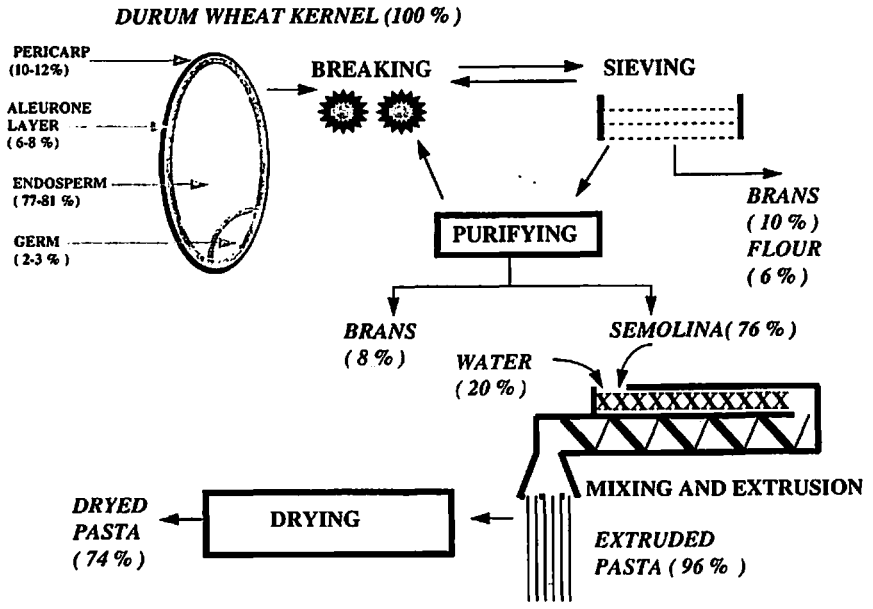

Fig. 1. Process of turning durum wheat into pasta.

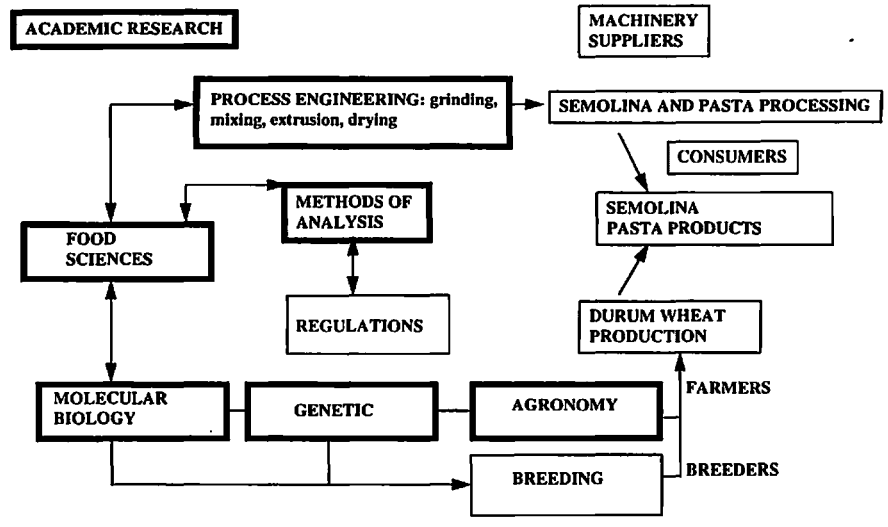

Fig. 2. Positions of academic research in the pasta food chain.

Table I. Publications by Fields (1980–1995)

Field	Number of Publications			Percentage of Total
	1980–1990	After 1990	Total	
Genetics and agronomy	83	81	164	19.2
Food science	134	68	202	23.6
(proteins)	(59)	(27)	(86)	(10.0)
Analytical	66	79	145	17
Milling	39	11	44	5.2
Pasta processing	82	41	123	14.4
Bread, couscous, bulgur	6	25	31	3.6
Storage	59	30	89	10.4
Nutrition and hygiene	37	19	56	6.6
Total	500	354	854	100

PRIMARY AREAS OF RESEARCH INTEREST

An international survey of 16 laboratories carrying out research into durum wheat and pasta was conducted. These 16 (listed in Fig. 3) represent most of the teams working in the fields of food science, study of production processes, and chemical analysis.

The results from these questionnaires have been evaluated. Based on the survey and analysis of the literature, the four main areas of research interest in the last 15 years have been as follows: high-temperature drying of pasta; genetic variability of the protein composition of durum wheat and its effect on cooking quality of the finished product; development of methods of detection and measurement of bread wheat products in pasta; and nutritional value of cooked pasta.

High-Temperature Drying

The first major change to revolutionize the production of pasta was the introduction of continuous presses. It is generally accepted that the second important change in this industry has been the introduction of new high-temperature drying techniques.

The drying process begins with elimination of moisture without modifying starch and protein components and later becomes more rigorous to meet two objectives. The first is to achieve the moisture content required for the end product. The second objective is to effect an important transformation in the physicochemical characteristics of the raw material, improving the appearance of the product, and giving it better cooking properties.

To fully understand the physicochemical phenomena involved, it has been necessary to dissociate the effects due to the transfer of moisture from those due to the transfer of temperature during the drying process. The various changes in starch composition, enzyme activity, and the degree of protein binding are now well known. In particular, it has been shown that the optimal quality of the finished product is achieved by an inactivation of oxidoreductases at the start of drying and an aggregation of proteins at the end of the process.

These studies have also shown that the protein content becomes a vital factor for cooking quality when pasta is dried at high temperature, whereas the "quality" of proteins is the important parameter for cooking performance when pasta is dried at 50–60°C.

The fact that Maillard reactions intensify at higher drying temperatures has

provoked concern for the nutritional consequences. This concern is probably unjustified, however, when one considers the place occupied by pasta in the overall diet.

Genetic Variability and Cooking Quality

A considerable number of publications address the genetic variability of durum wheat protein composition, modifications of protein structure during the transformation of semolina into pasta, and relationships between protein composition and cooking quality.

At the end of the 1970s, gamma gliadin-45 was identified as a "genetic marker" for gluten viscoelasticity and the cooking quality of pasta. From 1984 to 1995, the focus was on glutenins, particularly the low molecular weight subunit glutenins (LMW-SG).

Gamma gliadin-45 is a genetic marker only for the LMW-SG, which contribute to the formation of the protein network and give pasta its viscoelastic properties. Thus, a durum wheat or semolina of "good cooking quality" should have a high LMW-SG content. Despite analytical progress made in recent years (RP-HPLC, GP-HPLC, one- or two-dimensional electrophoresis), analysts have not yet managed to find a rapid and repetitive method for determining the respective proportions of the main protein components of durum (and bread) wheat: albumin and globulin, gliadin, LMW-SG, and HMW-SG (high molecular weight subunit glutenins).

Detection of Bread Wheat Products in Pasta

It is generally thought by many that durum is the only wheat fit to be used for the production of pasta. Because some may try to introduce bread flours into "durum wheat" pasta production for economic reasons, analysts have developed procedures for detecting the presence of bread flours in pasta. Indeed, many countries have banned use of bread flour in the production of pasta. The trade practices within the European Union have made it more important than ever to have reliable methods of detection, given the importance of informing consumers of the precise composition of products.

The first method developed in the 1960s was based on the detection of sitosterol palmitate, which should be absent from durum wheat but present in bread wheat. Unfortunately, large genetic variability has considerably diminished the reliability of this method, and it has now been abandoned in Europe. U.S. researchers have recently shown that it can still be used in the United States, due to the type of wheat grown there.

Methods based on the detection of proteins (albumins) and enzymes (peroxidases) specifically synthesized by genes of the genome D of bread wheat (durum wheat only contains genomes A and B) have proved their efficacy in the 1970s. However, the drying of pasta at very high temperatures distorts these results so that these methods should also be discon-tinued.

Under the aegis of the European Union, an important project has been undertaken by English, French, and Italian teams to address these new difficulties. Researchers have been able to identify protein constituents that are not, or only very slightly, modified by temperature and have proposed new methods, the repetitiveness and accuracy (that can in turn be influenced by variability of intervarietal composition) of which are today being studied. Detection of omega gliadins by electrophoresis and chromatography, combined with the detection of friabilin by immunochemical reactions, should hopefully provide the answers that will satisfy professionals and consumers alike.

Nutritional Value of Pasta

Pasta has traditionally been considered by many physicians as a "fattening" product, the consumption of which should be limited. Fortunately, nutritionists have countered this by showing that one of the most important qualities of pasta is that it liberates the sugars that the body needs progressively (pastas have a low glycemic index). What before might have been a criticism of "too many calories" can now be considered to be a desirable quality, because the calories satisfy the body's needs long after the pasta is consumed, according to demand.

It would be possible to draw attention to other important studies that have been investigated over the past 15 years: the better understanding of the ultrastructure of raw and cooked pasta, the composition of starch, the role of lipids, and the perfecting of extrusion and shaping processes. However, these studies tend to be too disparate and fragmented for them to be considered as having made a significant impression on research between 1980 and 1995.

RESEARCH PRIORITIES FOR THE NEXT FIVE YEARS

The production of pasta involves a set of constraints associated with the composition of durum wheat and semolina, the processing conditions needed to convert semolina into pasta, regulatory issues, and the requirements of consumers (Fig. 4) .

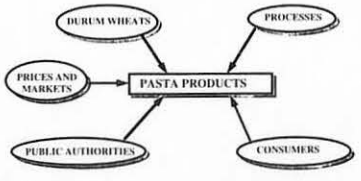

Fig. 4. Constraints on pasta processing and quality.

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In this context, we can consider the priorities identified by the academic research sector in our survey. Input from manufacturers and consumers on the pertinence of these priorities would be most valuable.

Production of High-Quality Durum Wheat

The first priority strongly expressed by numerous laboratories is to develop methods of analysis predicative of durum wheat quality that are rapid and can be applied to small quantities of selected grains. These methods should assess quality parameters to match the processing requirements, in particular high-temperature drying, that accelerates enzymatic browning and compensates for an insufficient "quality" of proteins.

A second research priority concerns the study of the genetic diversity of storage proteins, in particular LMW-SG and HMW-SG.

Research into the origin of black point and smudge, together with the development of methods to combat this, remains a priority concern for geneticists and agronomists from certain countries, France in particular.

Finally, and of particular importance for the future, long-term research based on the progress of molecular biology should enable the isolation of genes coding for proteins (and enzymes) of technological interest, in particular oxidoreductases and glutenins, prior to identifying their temporal and spatial regulation systems. The ultimate step will be to "transform" durum wheat varieties by transgenesis.

Optimization of Pasta Production Processes

Following the results of research into the drying of pasta at high temperatures and the effect of proteins on pasta quality, a new field of research examines the understanding and optimization of mixing and shaping of pasta by extrusion. A relatively recent approach in this sector of research, making use of concepts developed in process engineering, aims to determine the influence of the intensity and of the conditions of transfer of mechanical and thermal energy on all physicochemical reactions developing during the formation of the pasta.

The understanding of the mechanisms of transformation of grains into semolina has been of minor interest to research teams. At INRA, we have recently started a research project in this domain. Several laboratories have instead chosen to develop chemical (determination of ferulic acid) and physical (fluorescent microscopy) methods of detection and measurement of fragments of pericarp, aleurone, or endosperm in milling products.

Normative Research

The development and standardization of methods for analyzing physical (black point, smudge, yellow berry) and technological (color, cooking performance) characteristics remains a priority for many laboratories. Some laboratories consider the development of a method for detecting bread wheat flour in pasta subjected to high drying temperature to be an important research objective.

Satisfying Consumer Requirements

This large and varied field of research forms part of "food science." It touches on many domains relevant to biochemistry and physicochemistry (protein, lipid, starch, and enzyme composition), to rheology (textural properties and product viscoelasticity), to taste and aroma sciences, to nutrition and health.

It is striking to note the amount of research devoted to proteins. This is understandable given their influence on the production and quality of pasta, but at the same time it has to be pointed out that there are entire sectors of pasta science that remain unexplored. Two fields that merit more research, for instance, are that of nutrition and of grain microstructure in relation with the milling behavior.

CONCLUSIONS

The days when artisans and small entrepreneurs made excellent pasta using the gramola, the piston press, and the sun for drying, are long gone. The pasta manufacturers then knew nothing of physicochemistry, macromolecular networks, polyphenol-oxidases and lipoxygenases, carotenoids and tristimuli indices, process engineering, matter or temperature transfer, immunochemical techniques for the detection of bread wheat, slow or fast releasing sugars, molecular biology, genetic engineering, or transgenesis.

Despite all this, not only was the pasta delicious, but if our elders are to be believed, tasted even better than the pasta today.

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Fig. 3. Participating laboratories.

Is there a risk that scientific progress can be more harmful than helpful? This would not appear to be the case, at least in the food industries. The new demands made by economic competition, a heightened respect for hygiene conditions, and the urbanization of consumers has resulted in production conditions that have marked the end of the 20th century by a remarkable growth in productivity and quality control.

The evolution of production processes and need for increased productivity have resulted in new requirements for the constituents of semolina that did not exist in the time of the artisans. To match these processing requirements, it is important to understand the physicochemical factors contributing to the quality of the finished product and the effects of processing conditions. From the agronomic point of view, we must determine what methods of selection and production should be used to obtain a durum wheat that would satisfy the new demands of pasta producers, and at the same time assure a satisfactory income for farmers. To the scientists, the main questions of yesterday are still the questions of tomorrow.

Acknowledgments

Certain key figures played an important role in the early pioneering days of the 1960s, and it is fitting to conclude this report with an expression of thanks to the following who created the science of durum wheat and pasta: Keith Gilles of North Dakota University, Norman Irvine of the Canadian Grain Commission Laboratory, Michel Matveef of the Montpellier Agronomic National Research Institute, and Giuseppe Fabriani of the National Institute of Nutrition in Rome. We acknowledge the important contribution of all those who answered the questionnaire.

Appendix

Genetics and Agronomy

Proteins

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