In 2015, AACC International is celebrating 100 years of dedication to the advancement of cereal grain science. As part of this centennial celebration, AACCI is exploring the future of grain science. In this series coordinated by Dilek Austin on behalf of the Centennial Planning Committee, experts from around the world will provide global perspectives on the opportunities and challenges that will propel grain science into the future.

Future of Grain Science: Italy

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Italy occupies a distinct postion within the framework of the food sector in Europe, and some of the unique issues that characterize the Italian food market and its legislation are reflected in the cereals and grains field. Italy has possibly the most stringent rules in the world when it comes to selection of raw materials for use in food products and to food safety issues. In Italy, the balance between "conservative" approaches to food production and consumption (focused on traditional processes and materials) and "innovation" is strongly biased, with the general attitude leaning very much toward doing things "the old fashioned way," or the way in which "grandma did it." This holds true at the industrial, political, and cultural levels, which, of course, also affects research approaches.

Fortunately, this imbalance does not prevent researchers in Italian businesses and institutions from recognizing that a number of changes are occurring, both locally and on a global scale, and that these changes call for solid scientific foundations to be established in an appropriate and timely way. The progress of Italian cereal science as a whole is evidenced by the steady increase in the number of Italian contributions to international research journals and by the exponential increase in the attention they are receiving from the science community (Fig. 1).

Also, "molecular minded" young graduates from the many food science schools scattered all over Italy are progressively climbing the ladder of responsibility in the Italian food community (both in the food industry and in research institutions). This, along with pressure from the international markets, will hopefully lead to changes in the present conservative attitude in the not-too-distant future. Admittedly, addressing the bias of Italian consumers against anything "novel" on the table will take some effort, although there are lessons that can be learned from different sectors of the food industry, for instance from the dairy industry.

In the following subsections, which are arranged by types of products, we summarize some of the main topics of current Italian research in the cereal-based food sector and offer some perspectives on directions Italian research may take in the near future. This overview will focus mainly on academic and institutional research, which in Italy is supported in almost equal parts by industrial and public funds. Public support is often offered through programs that address issues that are relevant from an industrial standpoint (e.g., related to the introduction of new products aimed at emerging markets or to sustainability issues) but that involve academic and institutional research focused on understanding and governing, whenever possible, underlying fundamental aspects.

In general, research in Italy often suffers from poor dialogue among different disciplines and from the paucity of attempts to enhance possible synergies between groups that may be looking at the same problems from different points of views or using different approaches, as exemplified by a protein chemist and a food technologist or a microbiologist and a sensory scientist, in the case of food science at large. The situation may evolve in the near future, as recent efforts aimed at promoting the aggregation of food-related and -relevant competencies into institutions of adequate size (both in universities and other public research centers, including those responding to the National Research Council, the Ministry of Agriculture, and the Ministry for Economic Development) are expected to be conducive to the development of comprehensive approaches in the case of cereal-related scientific challenges as well.

Typical Italian Products: Pasta and Bread

Pasta is associated worldwide with the "Italian way of life." Although pasta for the Italian market can be produced only from durum wheat semolina, fresh pastas and countless varieties of ravioli and other kinds of fresh, stuffed pastas, which are often aimed at local markets, represent an exception to this rule. Similarly, Italian

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bread also may be seen as unique in its sensory traits compared with standard/common leavened breads consumed in most of the Western world (32). Once again, the many local variations in shape, texture, size, ingredients, and so forth make any generalization next to impossible.

It should be noted that Italian legislation forbids the use of several flour "improving" agents (in particular, chemical additives) that are allowed in other countries within and outside the European Union. In response to these restrictions, genetic studies in Italy have been aimed at naturally improving the content of specific performance-related macromolecules (39) in wheat kernels, as well as yield and other traits relevant to agronomic and sustainability issues outside a country-specific framework. Italian research groups are currently among the leaders of programs that are addressing some of the common needs in the Mediterranean region, including emergent issues related to the availability and accessibility of water resources. This is expected to be a prominent field of study in the immediate future and seems to deserve adequate support from national and supranational agencies. However, appropriate coordination of these efforts likely will require some stabilization of the political situation in southern Mediterranean countries.

The protein content in wheat flour or semolina and the glutelin/gliadin ratio in wheat flour commonly are considered key parameters for predicting their best possible use (42). The relationships between these parameters and product quality are often elusive (19), however, and predictions made solely on this basis have proven unreliable in many cases when environmental and agronomic parameters that may affect protein expression or structure at the posttranslational level have not been considered as well (1,21). Italian scientists have conducted a number of proteomics-based studies that have contributed to our current understanding of the protein patterns in wheat and have provided the basis for many attempts to find possible correlations among the nature and amount of cereal proteins and the processing performance of flour or semolina (12,27,36,37).

Despite these efforts, the correlation with technological performance sought in proteomics and genetic studies has not always been evident, and increasing consideration has recently been given to structural issues related to grain biopolymers (7). These issues have been addressed by several groups of Italian food biochemists who have developed or implemented novel methodologies for determining: 1) the role of noncovalent (mostly hydrophobic) interactions in network formation among cereal proteins (6,8); 2) the availability of thiols and disulfide for exchange reactions, as determined by overall and local protein flexibility, which, in turn, is related to protein solvability and physical deformation (22); and 3) the possible role of low molecular weight thiols and limited quantities of thiol-rich proteins in facilitating thiol–disulfide exchange reactions.

Novel methods capable of evaluating protein surface hydrophobicity in systems made up of water-insoluble proteins also have been developed in Italy and have been applied to protein characterization in cereal-based raw materials and products (8,21) without resorting to protein separation that necessitates the use of solvent systems that affect protein structure and interactions. Protein solubility in the absence or presence of chaotropes (molecules in a water solution that unfold proteins, destabilize hydrophobic aggregates, and increase the solubility of hydrophobes) and in the absence or presence of disulfide reductants has been used to study hydrophobic interactions among proteins and their impact on the rheological properties of dough (6). The accessibility of thiols to common colorimetric or fluorescent reagents also has been studied as a function of added chaotropes and reaction time to assess overall and local rigidity of proteins in either the raw material or finished products (6,21).

It may seem self-evident that many interesting prospective applications could be developed from further and deeper integration of the information derived from molecular-based approaches with the information derived from standard and innovative approaches aimed at assessing the technological performance of

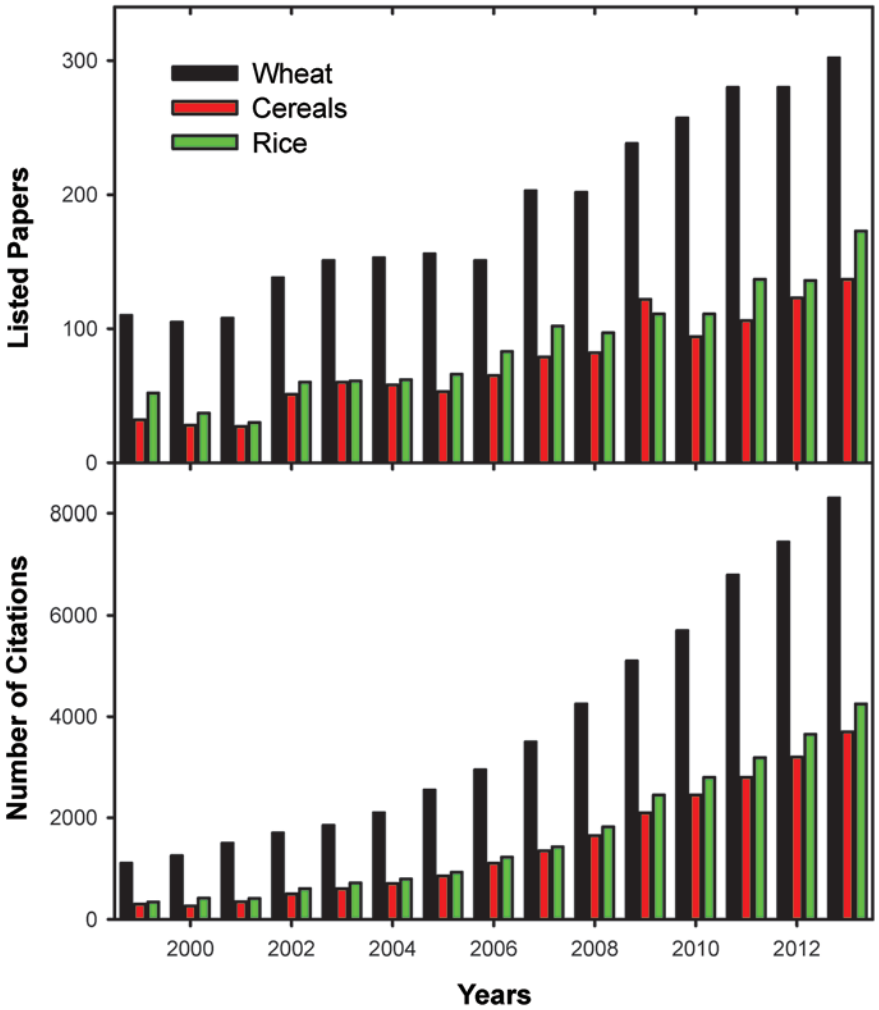

Fig. 1. Cereal science activity in Italy during the last 15 years, as indicated by the number of papers (top panel) and number of citations (bottom panel) listed in the *Web of Science* online database. Figures were obtained by entering "Italy" as the address in the search engine and the given topics as an additional entry.

products. In the case of Italy, these synergies are currently being exploited, for example, to address issues related to energy requirements in the pasta industry and/or to minimize process-related damage to products. As for bread, most country-specific investigations are being focused on the characterization of sourdough processes typical of various Italian locales (18), with the final goal of transferring these products and processes from artisanal to large-scale production while preserving the distinctive sensory traits of the products (16,31).

However, these studies need to be expanded to prove their significance beyond the specific needs of the Italian market. It also is easy to foresee that the molecular approaches described above may offer useful hints for studies aimed at a more thorough understanding of the determinants of interactions among various classes of biopolymers and structures in grain-based products. Attempts are currently underway to develop methods and tools suitable for analyzing the determinants and roles of starch–protein interactions, as well as the effects (mostly in baked products) of the interactions between various types of lipids and the dominant types of polymeric grain biomolecules (protein, starch, and nonstarch polysaccharides) and their relevance for applications in the fast-growing gluten-free products market (discussed below). In this area, there have been interesting recent developments concerning issues related to modulation of starch structures in grains used for production of either pasta (38) or bread (24).

Grain-Related Safety and Tolerance Issues

Safety Issues. As stated earlier, Italian legislation is very strict regarding contaminants in food materials. This applies to both biotic and abiotic contaminants, including heavy metals, aflatoxins, and other toxic metabolites. This has led to the establishment of dedicated laboratories that have developed excellent synergies with academic centers and contributed significantly to progress in detection methodologies and the implementation of appropriate protection plans, including the implementation and optimization of dehulling and debranning practices (9). These are especially important in Italy because a great deal of the transformed grains used (both cereals and pseudocereals) is imported, often from countries with widely differing safety standards. Italian legislation also does not allow the use of most of the chemical pretreatments that are commonly used elsewhere to minimize risk.

New research related to grain-related safety will likely investigate the possibility of applying novel analytical methodologies (3), including some that today may appear a bit unorthodox but that could represent a great deal of simplification with respect to current procedures (33). One of the goals is to develop methodologies that allow more extensive and thorough screening, thus improving the current safety standards and reducing nonconformity by avoiding a single contaminated parcel that spoils an entire shipment of grains. Another promising field of research with respect to food safety issues involves the development of integrated strategies for preventing or limiting fungal infection under locale-specific conditions (4,5,26), as well as studies on the microorganisms responsible for this type of contamination (34).

Tolerance Issues. Grain-related tolerance issues are also of great practical relevance in Italy. Italy has a very high prevalence of individuals with celiac disease, and other forms of gluten intolerance have been suggested for the first time recently by Italian scientists (11). Clinically oriented research groups are very active in this field (25), but the interactions among them and groups that consider these issues from the viewpoint of the food scientist remain limited. This creates further challenges for food scientists dealing with gluten-free foods in Italy because of the high expectations of Italian consumers, who expect gluten-free products to be similar in their sensory traits to those prepared from gluten-containing grains and to have the lowest possible content of ingredients that are perceived as not natural.

Because of the demand for "genuine tasting" foods from a growing population of individuals with celiac disease, Italian scientists are among the leaders in the use of microbial species and strains for fermentation of baked products (14) and in the use fo combinations of lactic-acid fermentation and enzymes of fungal origin to lower the gluten content in foods, including pasta (13). The results are encouraging, and this appears to be a field worth further exploration. In addition, considering the current ban on GM crops in Italy, a strategy based on selective microbial and/or enzymatic transformation of toxic fragments of proteins in existing celiacogenic grains is more likely to be implemented, in the near future at least, than strategies based on genetic manipulation and deletion of the offending sequences at the genome level.

With regard to gluten, it should be noted that, once again, Italy has implemented very strict limits for gluten content in gluten-free foods. This has contributed to increased research in the field of detection and quantitative estimation of celiac-related peptides and proteins. Results have been interesting, especially considering the fact that the generalized bias against GM crops in Europe has promoted use of wheat-derived starch in place of the corn commonly used elsewhere, prompting public concern about residual gluten in syrups and starch derivatives. Activities stemming from these issues have resulted in a number of analytical studies in the recent past (35), although further improvement in this specific area in the immediate future may be limited.

Nutritionally Enriched Products

There are two major current trends in the Italian scientific community that are focused on improving the nutritional value of grain-derived foods, and both take into account the specific requirements of the local market, with the hope of introducing a more general trend in consumer habits worldwide. The first approach relies on the association of "genuine" with time-proven materials and procedures and is best exemplified by Italian research on "ancient" or "traditional" grains, such as *Triticum monococcum*, and the many pigmented grain varieties (wheat, rice, and corn—either native or foreign in origin). *T. monococcum* is presented as a "natural," highly tolerated alternative to common hard and soft wheats (20) and pigmented grains as a "natural" source of antioxidants (17). In spite of substantial previous research, there is abundant room for studies on these systems, particularly related to performance and optimal processing. In the case of pigmented grains, for example, it is expected that future studies will address the issue of the solubility of bioactives (a source of losses during processing), as well as their stability and bioavailability, as dictated by their origin and chemical nature and by the type of product in which food processors wish to incorporate them. It is likely that progress in this particular field will require both optimization of physical treatments (e.g., dehulling for selective recov-

ery of bioactive-rich kernel fractions) and basic biotechnology (e.g., use of enzymes for modulating the solubility and bioavailability of bioactive species).

The second approach relies on the use of bioactive fractions (e.g., fiber) for enrichment of common Italian food staples (41). Appropriate synergies among research activities and approaches, in particular integration of molecular and processing aspects as discussed earlier, also could help processors to overcome some of the technical problems related to the introduction of these "new" products in the Italian market, where the expectations of the consumer are "crystallized." In this regard, fiber- and legume-enriched breads and pastas (15,23) may epitomize the unique problems encountered when trying to introduce new processes or products to Italian consumers who expect enriched pasta products (and enriched products at large) to be as close as possible to "traditional" ones in sensory attributes, cooking behavior, and so on. This may be tricky to achieve in view of the different solvation behavior of the added materials with respect to ingredients used in "conventional" nonenriched products, as well as other differences.

Research trends in this field likely will need to bring together studies in the field of food technology and other more fundamental branches of science. Food technologists will address the selection and processing of individual components of the final formula (28,29), as well as the parameters most suited for processing and preprocessing of the product to be commercialized, whereas food chemists or biochemists will contribute knowledge on what the properties of individual components will contribute to specific functions in the consumer-ready food product and on how bioprocesses (fermentation, germination, or use of specific enzymes) may be used to modulate specific, positive properties of individual ingredients. With this in mind, it will be of interest to monitor the progress of ongoing metabolomic studies (2), which may offer additional information with respect to pioneering studies on markers of quality in grain-based products (37).

Rice and Other Cereals without Gluten

Rice is a very important cereal crop grown extensively in the north and some of the coastal plains in central Italy. As in many other countries, a great deal of attention is being paid by Italian researchers to sustainability issues related to rice in terms of resistance to adverse conditions (10) and as a consequence of the increasing role of dry farming in rice production.

Rice and other cereals without gluten are being extensively studied in Italy as a source of raw materials for gluten-free foods. Of particular interest are ongoing studies aimed at addressing the production of gluten-free pasta without the addition of noncereal ingredients (such as extenders, emulsifiers, etc.). This will necessitate use of a combination of improved and/or novel processes and a better understanding of the factors governing the formation and maintenance of the required structure in pasta. Substantial progress has been made in this field, as discussed in a recent review by Marti and Pagani (30), but several issues remain to be addressed.

In particular, future research must consider the key role that starch plays in these processes, including modifications resulting from various types of preprocessing. A more comprehensive understanding of the kinetics of structural rearrangement of starch under various conditions, how such rearrangements are affected by other components in mixtures, and the impact on processing and nutrition also is required. This will be especially important when trying to improve the nutritional quality of rice-based gluten-free products, as has been found, for instance, when using other grains without gluten as ingredients in pasta. These advancements will likely require the development of specific methodological approaches, which are currently the subject of research by a handful of Italian teams and may find more widespread application when appropriately validated.

Conclusions

The Italian food industry is focused on creating products using traditional processes and natural ingredients that meet both stringent government regulations and high consumer expectations. In cereal grain science, major areas of research interest include genetic studies aimed at naturally improving the content of specific performance-related macromolecules, as well as other traits relevant to agronomic and sustainability issues; research investigating novel analytical methodologies that allow more extensive and thorough screening for contaminants; increased research in detection and quantitative estimation of celiac-related peptides and proteins; and research into nutritional enrichment of cereal-based products through use of natural ingredients and optimized processing. To succeed the food science community in Italy must improve the dialogue among different disciplines and enhance possible synergies between different groups looking at the same problems. Ultimately, any new products must meet consumer expectations that new product qualities and characteristics be as close as possible to their traditional counterparts.

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