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COMMENTARY

Foodomics: a new comprehensive approach to food and nutrition

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Abstract In the past 20 years, the scientific community has faced a great development in different fields due to the development of high-throughput, *omics* technologies. Starting from the four major types of *omics* measurements (genomics, transcriptomics, proteomics, and metabolomics), a variety of *omics* subdisciplines (epigenomics, lipidomics, interactomics, metallomics, diseasomics, etc.) has emerged. Thanks to the *omics* approach, researchers are now facing the possibility of connecting food components, foods, the diet, the individual, the health, and the diseases, but this broad vision needs not only the application of advanced technologies, but mainly the ability of looking at the problem with a different approach, a "*foodomics* approach". *Foodomics* is the comprehensive, high-throughput approach for the exploitation of food science in the light of an improvement of human nutrition. *Foodomics* is a new approach to food and nutrition that studies the food domain as a whole with the nutrition domain to reach the main objective, the optimization of human health and well-being.

Keywords Foodomics · Omics technologies · Food science · Human nutrition

Human nutrition science has greatly developed in the past decades, turning from the consideration of foods as simply energy sources to the recognition of their role in maintaining health and in reducing the risk of diseases.

The importance of food for human health is not a new concept, considering Hippocrates's sentence "Let food be thy medicine and medicine be thy food"; the recent progresses in analytical methods allowed scientists to demonstrate the role of food in human health, and not to simply hypothesize it. So, according to another Hippocrates's sentence "There are in fact two things, science and opinion; the former begets knowledge, the latter ignorance", nowadays we are not simply thinking that a good diet is important for health, but we can demonstrate it, evidencing the mechanisms underlying these health effects.

In recent years, food science greatly grew as well, developing new food products, designing processes to produce these foods, improving packaging materials, food shelf-life, and sensory characteristics. Food chemistry, devoted to the evaluation of the molecular composition of food and the involvement of these molecules in chemical reactions, food physical chemistry, which studies both physical and chemical interactions in foods, and food microbiology also took great advantages from the new analytical methods.

Even though the readers of this journal are supposed to be more than familiar with these terms, let us introduce what we mean by the term "new analytical methods".

New analytical methods are mainly related to the holistic *omics* approach, implemented by "high-throughput" technologies. High-throughput refers to a technology in which a large (or even exhaustive) number of measurements can be taken in a fairly short time period. "Ome" and "omics" are suffixes that are derived from "genome", a term created by Hans Winkler in 1920, although the use of ome is older, signifying a homogeneous set of items as a whole.

Although four major types of high-throughput *omics* measurements are commonly performed (genomics,

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transcriptomics, proteomics, and metabolomics), a variety of omics sub-disciplines (epigenomics, lipidomics, interactomics, metallomics, diseasomics, etc.) have begun to emerge, each with their own set of instruments, techniques, reagents and software.

Transcriptomics, proteomics and metabolomics are all dynamic domains, as affected by interactions between the organism and external stimuli. The human being (the organism) can be affected by the diet (the external stimuli), that can intervene in a positive or negative way on the risk of occurrence of certain human diseases. But the diet is made of foods, and foods originate from living organisms, and can in turn be affected by external stimuli such as different agricultural and transforming technologies. Thus, to reach the final goal of improving human health, we need to consider all these possible dynamic interactions in an *omics* approach.

Thanks to the *omics* approach, researchers are now facing a new science which in theory can connect food components, foods, the diet, the individual, the health and the diseases. In practice, we are still far from this connection, which needs not only technologies but mainly a broad vision of the problem, since there are many actors playing the comedy. A broad vision means not only a broad expertise and the application of advanced technologies, but also the ability of looking at the problem with a different approach, a "*foodomics* approach".

Foodomics received the interest of scientists with different cultural background since 2009, at the time of the first international conference held in Cesena, Italy (foodomics.eu). The purpose of that conference was to promote a multidisciplinary environment where specialists in *omics* sciences were invited to contribute to the holistic definition of food and to trace a possible way to exploit this view in the nutrition field.

Food is a highly complex mixture and, with such complexity, its definition cannot be based only on preselected components. Moreover, its conventional definition, performed by a compositional analysis, is often affected by the extractive methods that, in turn, may not resemble the physiological environment where the molecules will become bioavailable. In fact, paying attention to particular components or methods, some chemical characteristics could be emphasized more than others, even if the latter may be more important to the food-human interaction point of view and to the health perspective. Equally, focusing our attention on the effect of specific nutrients on defined metabolic pathways we are at risk of forgetting the effect of the whole food on the whole human organism. To overcome this limit, the food-human interaction needs a higher definition for both sides, and *foodomics* responds to the challenge to achieve this aim.

Thus, *foodomics* is not the food science-related counterpart of the nutrition science-related nutrigenomics. *Foodomics* is the comprehensive, high-throughput approach for the exploitation of food science in the light of an improvement of human nutrition.

Foodomics has been previously defined as a discipline that studies the Food and Nutrition domains through the application of omics technologies. In this context, nutrigenomics and nutrigenetics have been considered as a part of the more general *foodomics* term (Cifuentes 2009).

In our opinion, *foodomics* studies the food domain as a whole with the nutrition domain, applying the same advanced omics technologies to different samples, and integrates all results in order to have an overall vision allowing the improvement of health and well-being.

Indeed, food science and nutrition science can apply the same omics technologies to different samples. Besides the concept of biological sample in *omics* technology, already elucidated by Morrison et al. (2006), the same high-throughput analysis can be used in both food science and nutrition science. In human nutrition, genomics (the comprehensive analysis of DNA structure and function) is the scientific field of the genetic basis for the diverse responses to foods (and not the secret to personalizing diet and health; German et al. 2011); in food science it is the opportunity for improving our understanding of the history of plant domestication and to accelerate crop improvement (Morrell et al. 2011).

Transcriptomics allows to evidence the modulation of the global gene expression profile by different nutrients, correlating it to disease prevention (Bordoni et al. 2007), and to design microbial mitigation strategies for ready-to-eat food products (Soni et al. 2011). Proteomics can greatly contribute to food safety (D'Alessandro and Zolla 2012) as well to the prevention of cancer by food bioactives (Shukla and George 2011). Last but not least, metabolomics, the systematic study of the unique chemical fingerprints that specific cellular processes leave behind, is rapidly becoming a fundamental approach in food science (Hong 2011) and in nutrition science as well (Puiggròs et al. 2011).

Technologies such as mass spectrometry (MS) or nuclear magnetic resonance (NMR) spectroscopy, can be used to characterize genetically modified crops (García-Cañas et al. 2011) as well as in studies aimed to improve health of individuals through diet (Rezzi et al. 2007), but they can also give new answers to old, unraveling questions such as food digestibility (Bordoni et al. 2011).

In this respect, also the traditional investigation techniques are experiencing a new age, since their integration with bio-informatics tools are putting a new light on the experimental data. The optimization of algorithms for genome-, proteome- and metabolome-wide statistical analyses are crucial tasks to exploit fully the potentials coming from the omics information.

This holds particularly for NMR, which provides spectral data that could be considered, as a whole, the molecular profile of the sample and, for this, can mirror the whole metabolome present in the sample. Several applications of NMR metabonomics, recently appeared in literature, represent the opportunity to describe heterogeneity among food sources by looking at the effect of different production practices on the whole metabolic pattern, rather than focusing on specific metabolites (Savorani et al. 2010; Picone et al. 2011a, b).

The suitability of NMR metabonomics, as a general approach to evaluate the substantial chemical equivalence of wild type and GMOs grapes, emerges from a study which compared different cultivars of *Vitis vinifera* receiving a different number of the same exogenous gene, by looking at the changes occurring in the metabolic phenotype (metabotype; Picone et al. 2011a, b).

The increasing interest for the *foodomics* science encouraged the organizers to reiterate the same international conference on 2011, and four invited speakers are contributing with representative articles to the present special section hosted by Gene and Nutrition. Now, few words to introduce the contributions.

The article by Pérez-Massot et al. (2012) deals with the possibility of counteracting malnutrition by genetic engineering of staple crops, reviewing and discussing strategies for enhancing crop content of different nutrients. The authors also consider major constrains, that is, the risk assessments, that are at the basis of EU policies and regulation of GE crops. GE represents a “hot topic” not only in food science but also in human nutrition, and an *omics* view is surely needed to face all its implications.

The work by Valdés et al. (2012) describes the effect of rosemary extracts on colon cancer cells, and underlines the need of going behind the observational aspects, using omics approach such as transcriptomic profiling and functional enrichment analysis for elucidating signaling and metabolic pathways involved. This article highlights that all different aspects of *Foodomics* are, however, facing important challenges related to bioinformatics. Specialized bioinformatic platforms are essential to analyze and manage data in an efficient and reliable way.

The review authored by Cerdà and Manchado (2012) summarizes the use of comprehensive functional genomics, proteomics and metabolomics analyses aiming at better identifying the critical genes and molecules that control traits of commercial interest in aquaculture productions, such as growth rates, reproduction, larval development and disease resistance. An overview is given about the next-generation sequencing platforms which have drastically transformed the way researchers can address genomic questions on non-model fish species, allowing for a better optimization of production and management procedures in the industry.

Finally, the article by Montoliu et al. (2012) offers an overview on the opportunity offered by the determination of the system-wide (i.e., whole organism) biochemical effects of diets on individuals’ metabolism, by unraveling the interactions in the complex mosaic of both genomic and meta-genomic (i.e., gut microbiota) network. The evolution of gene-metabolism researches, from single-gene/single-metabolite studies to genome wide association studies (GWAS), made it possible to perform unbiased searches of the entire human genome to identify all common genetic factors that affect the holistic metabolomics phenotypes.

In conclusion, given that the development and application of advanced omics methodologies and bioinformatics has contributed to the investigation of topics considered unapproachable few years ago, they represent the tools and not the scope, and the *foodomics* is much more than a further application of analytical methods. *Foodomics* is a new approach to food and nutrition, *foodomics* is a new science and a challenge to be faced leaving old concepts apart. In the *foodomics* field, researchers working in food chemistry, analytical chemistry, biochemistry, microbiology, molecular biology, food technology, clinical sciences, and human can finally work together, with an *omics* approach, to reach the main objective, the optimization of human health and well-being.

Conflict of interest None.

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