



Grand Challenges in Sustainable Food Processing

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Sustainability is, unquestionably, a main driver for social, technological, and economic development toward the creation of a circular economy. This is even more important in the food industry as this issue of sustainability also demands that we are able to provide consumers with, not only high quality food, but, above all with food that complies with safety and security.

WHO estimates that, every year, more than 600 million people—this means 1 out of 10 people—get ill by ingestion of contaminated food and that the number of casualties is estimated as 420,000¹. Moreover FAO estimates that one-third of the food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year (FAO, 2011). This inevitably also means that huge amounts of the resources used in food production are used in vain, and that the greenhouse gas emissions caused by production of food that gets lost or wasted are also emissions in vain. It is also interesting to note that, on a per-capita basis, much more food is wasted in the industrialized world than in developing countries.

Having said this, it is clear that sustainability (Ehrenfeld and Hoffman, 2013) is a key driver for the food industry. However, a successful food industry sector, cannot be supported by safety and security considerations, only. Consumers are more and more demanding and, in particular in developed countries, are also linking food with health, thus demanding food industry and food technologists to provide foods that, in complement to their nutritional and organoleptic properties, can also contribute to a healthier life.

Although suggesting that these issues raise difficulties in fulfilling the consumer needs, it is also clear that new business opportunities are created and, as shown throughout this document, opportunities for raising value from wastes are now a great challenge that will also contribute for the development of healthier foods as well as for the implementation of a circular economy in the sector.

In order to answer satisfactorily to these demands, the food industry must evolve processing technologies that are effective not only in processing food materials in a way that minimizes the degradation of the components that are relevant for health and well-being, but are also able to incorporate materials in the processed foods that allow for an increase in these properties.

Moreover, these objectives must be fulfilled by complying with another key issue in food (and industrial) processing—sustainability—in such way that circular economy² becomes a reality in the food industry. This demands more efficient and environmentally friendly food processing technologies and process integration together with waste minimization and recovery and incorporation of food by-products in the food processing chain. New solutions on packaging are also required as 335 million tons of non-biodegradable/non-compostable plastics are produced annually, with the food sector being responsible for a large percentage

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¹WHO (2017). <http://www.who.int/mediacentre/factsheets/fs399/en/>

²www.ellenmacarthurfoundation.org/

of the release of these wastes (mostly plastics)³. With the new solutions being proposed, food packaging will extend its use beyond its traditional application and will have a decisive contribution to answering several of the challenges of the food sector.

Safety is also an issue that must be dealt with the development of more efficient processing technologies. Processing must comply with extremely rigorous food safety challenges and this demands the development of rapid and high throughput safety evaluation techniques for effective risk management in the food industry.

It is clear that the main issue(s)/challenge(s) facing the field of Sustainable Food Processing today are:

- development of efficient and environmentally friendly food processing technologies
- process integration as a key to more efficient and environmental friendly food processing
- wastes minimization
- recovery and incorporation of food by-products in the food processing chain
- incorporation of materials/compounds relevant for well-being
- development of efficient technologies for the adequate delivery (i.e., maintain the bioactivity) of the nutrients to the food consumer
- evaluation and development of correct strategies for the use of wastes and by products generated throughout the food value chain with the Circular Economy concept.
- development of new packaging materials and new packaging formulations that are environment friendly, as fully consumed or biodegradable and recyclable
- development of new packaging solutions that will act not only as a protection barrier but will also be active and intelligent.
- implementation and development and implementation of precise and fast food safety evaluation methodologies
- immediacy on the response to the consumer's demand
- assumption that food is a key issue on individual's health and development of food processing methodologies that are consumer groups oriented (elderly people, pregnant women, children)
- food personalization

All these challenges demand the industry to be in the frontline of knowledge and Sustainable Food Processing wants to make an effective contribution on this and become a reference source for scientists, academy, industrial, and other professionals engaged in food processing.

The section will highlight the current knowledge regarding the most recent innovations on emerging technologies and strategies based on food design on a sustainable level. Innovative technologies are expected to be described, characterized, and its application highlighted. These will include emerging technologies, sensor technology, cold plasma technology, sustainable packaging and refrigeration climate control, non-thermal pasteurization and sterilization, nano- and micro-technology, healthy product composition, development of

novel preservation alternatives, extending the shelf life of fresh products, alternative processes requiring less energy or water, plant-based meat alternatives, innovative processes/bioprocesses for utilization of by-products and information and knowledge transfer.

Although being clear that different technologies can have a significant impact in the development of a Sustainable Food Processing, there is no doubt that nanotechnology will be a key driver on the answer to several of the food industry challenges presented. However, the increasing concern about human produced nano-particles entering the environmental and being detrimental to living systems (including humans) must not be forgotten as relevant sustainability issues can be raised (Jurgilevich et al., 2016).

Nanotechnology is a fast-developing tool, with applications in virtually all areas of scientific and technological research. The advantages and impact of the nanotechnology-based systems are very significant, justifying the growing attention from both academy and industry. It is thus not surprising that also food & agricultural engineers, scientists and technologists are dedicating their attention to nanotechnology, in the search for specific advantages in agriculture, foods formulation, and processing.

In particular, the applications related with e.g., nanoencapsulation of functional ingredients are seen as very promising. This is not an easy task, though: on top of the difficulties inherent to nanotechnology (e.g., finding adequate characterization methods, quantification of products, etc.), there are two other issues which may dictate the success or failure of the research and development efforts in this area: (1) ingredients must be either bio-compatible or food-grade and (2) safety of the consumers & environment must be guaranteed. If these two issues are not conveniently addressed, no industrialist will be available to even consider using nanotechnological solutions in the products of the company. The production of and characterization of nanotechnology-based structures, their applications and safety concerns are therefore hot topics that must be addressed by the scientific community and be one of the main topics to be included in this journal.

Packaging is also, as mentioned before, a relevant topic to be considered within Sustainable Food Processing, due to the high amounts of non-recyclable plastics being disposed. However, it is clear that sustainability is to be addressed not only by solving the issues related with the development of biodegradable packaging materials. The development of edible films and coatings will contribute decisively to extend the functions to be played by packaging in the food industry. Edible packaging, apart from being environment friendly and so reduce the waste and solid disposal problem, are fully consumed or biodegradable and in this way its contribution to sustainable food processing is obvious. However, its functions are to be extended and may include the enhancement of food organoleptic properties and nutritional value, act as a carrier for anti-microbial or antioxidant agents and be used as a matrix for the micro encapsulation of flavoring agents.

The new packaging are to be active and intelligent and this can also be achieved by adding some of these functions to already available materials. Moreover, by-products from the food

³www.plasticseurope.org

processing industry can be applied in the development of these materials.

Finally, it is important to highlight the importance of the development and implementation of a circular economy in the food industry. Although being clear that there are an increasing number of papers describing the recovery and incorporation of food by-products in the food processing chain, there are still numerous challenges to be addressed. These challenges are both on the application of the obtained products on the food chain (although its use on other industrial sectors must be considered) and on the extraction/separation/purification technologies to be applied. Nowadays, most of the technologies applied are still largely based on energy, solvent and water-intensive processes and have a low energy efficiency. For instance, the solid-liquid extraction step is mostly based on the use of organic solvents what raises concerns on environmental safety, human toxicity and sometimes financial feasibility. Novel technologies based on the use of greener and higher efficiency solvents (ionic liquids, deep eutectic solvents) or the use of aqueous extraction processes intensified by the application of pressure and electric fields are alternatives that are being developed.

Considering the statements made previously, the publication of Sustainable Food Processing (specialty section of Frontiers in Sustainable Food Systems) will be an important contribution for

the technological development of the food industry. Innovative and cutting-edge research will be published in the following subjects: novel technologies for food processing and preservation, functional foods, active and functional packaging, process integration in food processing, novel technologies for food waste and by-product processing, food waste and by-products for the production of bioactives, food processing for increased food safety, food processing for healthier and more nutritive products, personalized food and risk management in food processing.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

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