Antun Jozinović[1], Đurđica Ačkar[1], Ante Lončarić[1], Veronika Barišić[1], Stela Jokić[2], Jurislav Babić[2], Borislav Miličević[1], Drago Šubarić[2]*

Challenges Facing the Food Industry

[1]Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 18, 31000 Osijek, Croatia ([*]dackar@ptfos.hr)
[2]Croatian Academy of Engineering, Zagreb, Croatia

Abstract

Never before have so many demands been made on the food industry as today. In addition to producing safe and tasty food, the food industry faces the challenge of making food functional, easy to prepare and convenient, with a "zero waste" approach, both in the use of raw materials and in packaging. Food is not only fuel, but it has been given a role in preventing various diseases and improving human health, preferably finely tuned to personal needs and desires. For all these reasons, scientists are working with the food industry to solve problems associated with the consumption of unhealthy foods and to produce new products with increased nutritional value. Furthermore, several new strategies have recently been implemented to address the problem of negative environmental impacts and to maintain sustainability in the food industry. Therefore, the aim of this paper is to describe some of the contemporary challenges of the food industry and trends towards their solution.

1. Introduction

The food industry is one of the most important branches of the national economies, in the European Union as well as in the World in general, which plays a central role for the processing of agricultural raw materials and food supply (Bigliardi and Galati, 2013). This industry has changed and developed over the decades in order to satisfy customer needs and consumer behavior. It is characterized by a complex system of activities concerning supply, consumption and delivery of food products across the entire globe. While people in the past had to fight to find their daily meals and used to eat only local and seasonal products, nowadays people in the Western world are surrounded by different types, qualities and prices of food products (Recordati, 2015). Furthermore, the situation has changed drastically, especially in the 20th century, as a result of civilization, industrialization, technological innovations, mechanization, the economic growth as well as increasing the world's population. The world's population is now more than 7.7 billion persons, and this number is presently growing at a rate of around 1.07% per year (Fasolin et al., 2019), which generates a growing demand for food globally (Ramos et al., 2020). While on the one hand food industry must produce enough quantity of products, on the other hand it is well established that poor diet is a major contributor to many conditions including cardiovascular disease, obesity, type 2 diabetes, dental caries, and some cancers (Crawford, 2020). According to all the above, the aim of this paper is to highlight some of the challenges facing the food industry today and trends in addressing them.

2. Contemporary challenges of the food industry

Until the end of the 20th century, the prevalent policy was mainly to increase food production, without improving the efficiency of the food systems (Biglardi and Galanakis, 2020). This fact caused an increase in food loss and food waste, where the amount of lost or wasted food accounts 1.3 billion tonnes globally each year

(Galanakis, 2020). This situation has triggered a series of environmental challenges that could threaten human survival. Climate change, loss of biodiversity, accumulation of waste, resource depletion (water, fossil fuels, etc.), growing disease pandemics, and the modification of natural ecosystems, are some of the results of human activities (Khoo and Knorr, 2014; Ramos et al., 2020). One of the main manufacturing industries is the agri-food industry, which is responsible for 25% of the total emissions of greenhouse gases (Ramos et al., 2020). Therefore, improving food production systems is one of the major actions that needs to be done urgently to reduce the global impacts on the environment.

Recently, three main innovation directions for the future food systems were highlighted: 1) sustainability and higher efficiency – production at the lowest possible cost; 2) innovation opportunity – refer to new scientific and technical approaches in food processing, and to the introduction of novel foods; and 3) development of functional foods focused on the health and well-being after consumption (Fasolin et al., 2019).

2.1. Sustainability and higher efficiency

Sustainable food systems are those that ensure food security and nutrition for all in a way that economic, social and environmental sustainability is not compromised for future generations (Fasolin et al., 2019). Therefore, maintaining sustainability in food industry requires the maximum utilization of all raw materials and integration of activities throughout all the production-to-consumption stages. The production stage is the first one, where the efforts begin with activities of reducing postharvest losses and increment of waste valorisation. Furthermore, efforts are underway to ensure that the energy, water, and other resources are used most efficiently, and environmental impacts are minimized (Biglardi and Galanakis, 2020). One of the new strategies which could be used to reduce environmental impacts is Cleaner Production (CP) methodology, which in food industries focuses on minimization of resource consumption, reduction of the waste generation, a better use of food by-products looking for increasing the process efficiency (Ramos et al., 2020). On the other hand, future perspectives for the food industries is the application of Industry 4.0 concept, which proposes an interconnected production, through the information exchange (smart data) of all the links of the supply chain, connecting workers, devices, materials, processes, logistics or consumers. According to this strategy, the company could provide and receive information in real time about their own processes and the rest of the links of the value chain, adjusting their production to unforeseen events (**Figure 1**). This leads to the optimization of the inputs needed for the production and thus to the minimization of environmental impacts related to the efficiency of water, energy or raw material (Ramos et al., 2020).

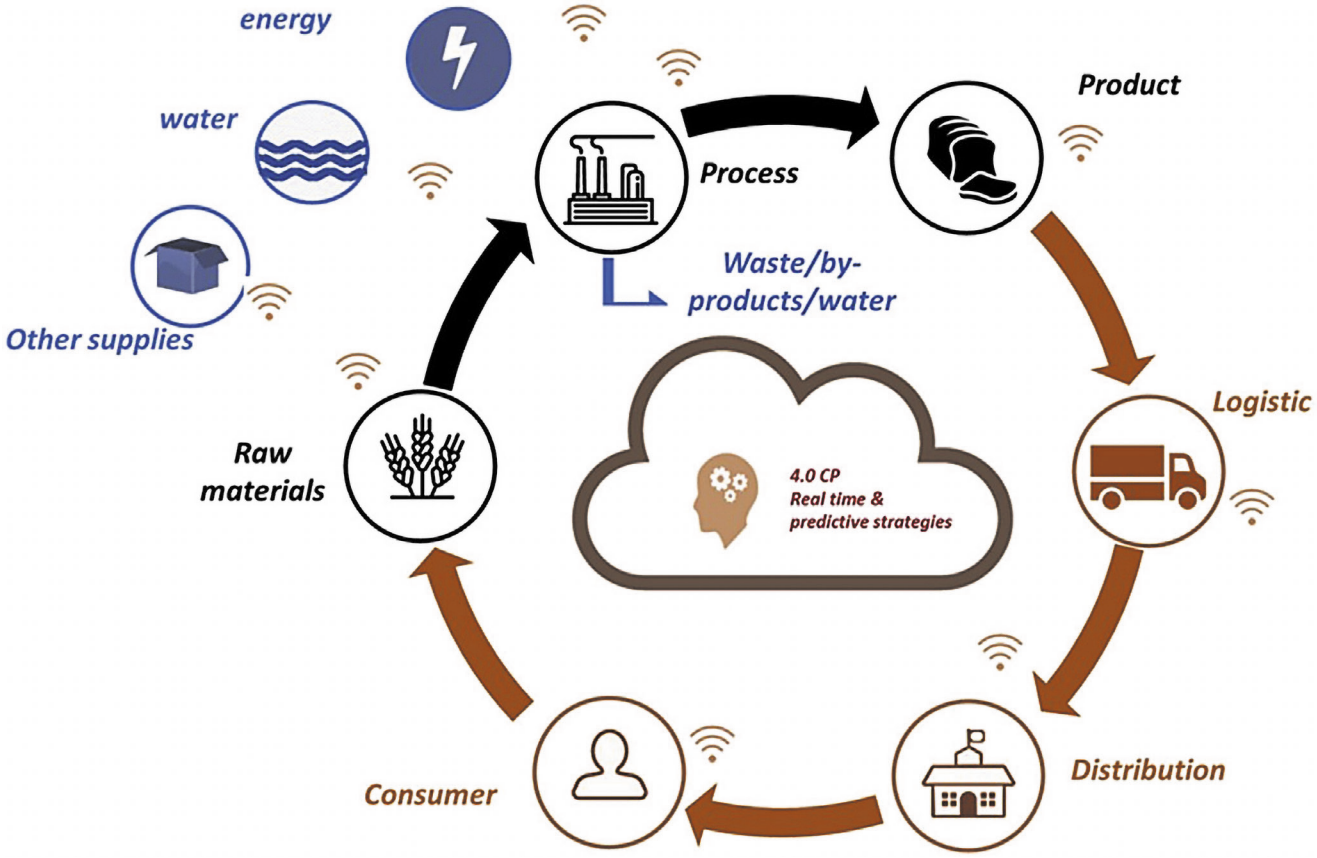

Fig. 1. Application of Industry 4.0 strategy in food industry (adopted from Ramos et al., 2020)

2.2. Innovation in the food industry

In the past, the food industry has traditionally focused on minimizing production line costs, giving little attention to the real needs of consumers. Thereafter, the food chain is reversed, the need for food, based on the offer was transferred to a concept based on demand. So consumers tell producers what they want to eat. According to this trend, modern innovations in food companies are implemented in various ways (Biglardi and Galanakis, 2020). Innovations can occur in all parts of the food chain and the possible classification of food innovations is as follows: (1) new food ingredients and materials, (2) innovations in fresh foods, (3) new food processing techniques, (4) innovations in food quality, (5) new packaging materials and methods, and (6) new methods of distribution or retailing (Bigliardi and Galati, 2013). However, most research follows the classification in process and product innovations. Process innovations represent the customization of existing production lines, as well as the installation of a completely new infrastructure and the implementation of new technologies that enable the creation of new products. Their main aims are to improve product quality and production process in terms of time, cost and flexibility (Biglardi and Galanakis, 2020). In this regard, so-called emerging (mainly non-thermal) processing technologies have been gaining interest among food researchers, due to their lower impact on nutritional and sensory properties of the products (Barba et al., 2016). The most popular emerging technologies examined in the of food science are: pulsed UV-light, pulsed electric fields (PEF), irradiation, cold plasma (CP), high hydrostatic pressure (HPP) and ultrasound (US) (Zhang et al., 2018), as well as radio-frequency drying, electro-osmotic dewatering, pressurized extraction, high voltage electrical discharge, nanoencapsulation and others (Biglardi and Galanakis, 2020). Another important example of innovations in the food industry is known as „food waste recovery“. This kind of innovations is based on valorisation of food industry by-products, as a source of high added-value micromolecules (e.g., antioxidants, polyphenols, carotenoids) and macromolecules (e.g., dietary fiber, pectin, β-glucan, proteins). In connection with this, it is important to highlight two recently published books: “Some possibilities for utilization of food industry by-products” (Šubarić, 2017) with 13 chapters and “Some possibilities for utilization of food industry by-products – Book 2” with 18 chapters (Šubarić and Babić, 2019), outlining the potential for utilization of various food by-products.

2.3. Development of functional foods

Although the food is primary fuel and one of the major human needs which is used to eliminate hunger and obtain energy for the body, in recent years the lifestyle of people and desire for a healthier life have changed the philosophy of food. Thus, the food has been given a role in preventing various diseases and improving human health. These foods are called *functional foods*. Functional foods are defined as the foods or food elements that provide additional benefits for human physiology and metabolic functions and help to reduce the occurrence of disease (Santeramo et al., 2018; Lule et al., 2019). Functional foods can be the foods which are natural, fortified, enriched, or contain functional ingredients (Guo, 2009). Functional foods have been developed almost in all food categories. However, among all the food products, functional foods are mainly launched in dairy, confectionery, soft drinks, bakery and baby foods (Bigliardi and Galati, 2013). There are different classifications of functional foods in the literature, whereby the classification from the product point of view includes the following types: 1) fortified products – food fortified with additional nutrients (vitamin C, vitamin E, folic acid, zinc, calcium, etc.); 2) enriched products – food with additional new nutrients or components normally not found in a particular food (probiotics and prebiotics); 3) altered products – food from which a harmful component has been removed, reduced or replaced by another with beneficial effects (dietary fibers as fat replacers); 4) enhanced commodities – food in which one of the components have been naturally enhanced (eggs with increased omega-3 content) (Bigliardi and Galati, 2013). Regardless of the type of functional food, it is important to emphasize that awareness for health benefits of some functional foods are gaining ground. Guo (2009) found that the sources of information about these benefits come primarily from different media, accounting for 72%, while medical sources ranked second with 44%, and 20% obtained from friends and family or self, while diet and health books represented 13%. Among the functional products that have been particularly attractive in recent times, a distinction could be made between products with an increased content of proteins, dietary fibres or active components such as polyphenols.

In the case of protein, when thinking about replacing conventional proteins (e.g., meat and egg proteins), the main groups of emerging and sustainable proteins are: vegetable proteins (seeds, legumes, nuts, fruits and vegetables or vegetable-based by-products such as apple pomace, orange pulp, oat bran, sugar beet pulp and brewer’s spent grain); insect proteins (*Coleoptera* (31%), *Lepidoptera* (18%), *Hymenoptera* (14%), *Orthoptera* (13%) and *Hemiptera* (10%) (Sun-Waterhouse et al., 2016)); microbial proteins (microalgae, fungi and bacteria) and milk proteins (whey proteins) (Fasolin et al., 2019).

It is known that the consumption of dietary fibers in sufficient quantity is necessary for the function of the gastrointestinal tract. Furthermore, the reductions in LDL-cholesterol, attenuating glycemic and insulin response, increasing stool bulk, and improving laxation have been associated with dietary fiber intake through the consumption of foods rich in this dietary component. It includes polysaccharides, lignin and associated plant substances, whereby as the most important components

in the production of new products can be highlighted: resistant starch, pectins, guar gum, gum arabic, fructans, galactooligosaccharides, lactulose and other wide variety of oligosaccharides (Guo, 2009).

The disease prevention and health enhancement of active plant-derived ingredients or plant-based foods have widely been examined and many of them have demonstrated positive effect on human health (Carrillo et al., 2019; Dimou et al., 2019; Pawlowska et al., 2019; Santamarina et al., 2019; Kalt et al., 2020). There have been a several attempts to enrich different food with polyphenols such as fruit smoothie enriched with polyphenols and fibre by adding high concentration of fruit, snack bars with added fruit fiber and polyphenols, a drinking yoghurt and functional breads enriched with fruit polyphenols etc. Some of the developed functional foods enriched with fruit polyphenols are shown in **Table 1**.

The food industry has also faced this challenge by recovering of polyphenols from the by-products of plant food processing with possible potential applications in the food, pharma and cosmeceutical industries (Ibrahim et al., 2017). In **Figure 2** a schematic representation summarizing key technical development factors and potential applications of plant by-products valorisation is provided. Fruit processing involves numerous phases, including peeling, trimming, deseeding, cutting and pressing which results in high amounts of by-products rich in polyphenols.

Fruit pomace is one of the most common by-products in the fruit industry. Some fruits such as apple, grape and/or berry pomace are known to possess high antioxidant activities. Today, these value-adding components are isolated and exploited as natural antioxidants for the formulation of functional foods or food ingredients (Ibrahim et al., 2017). However, future innovations in the field of functional foods enriched with polyphenols and other antioxidants should focus on exploring synergistic interactions between added bioactive substances and other food ingredients in selected products during processing and storage.

Table 1. Fruit-related functional foods (adopted from Sun-Waterhouse, 2011)

Fruit material	Food format	Bioactives or mechanism of interest
Blueberry	Blueberry fruit drinks	Not available
Berries	Blended berry fruit juices	Flavonoids
Fruit and vegetable juice powders	Enrichment for cereal products	Flavonoids, fibre and vitamins; Use as processing aids, colorants, flavorings.
Chokeberry, elderberry, blackcurrant redcurrant, red grape, cherry, strawberry, raspberry plum	Antioxidant functional juices	Anthocyanins, flavonols, flavan-3-ols, phenolic acids
Fruit powder (blueberry, cranberry, Concord grape, and raspberry)	Naturally colored breakfast cereals (extruded) in opaque bags	Soluble phenolics and anthocyanins (survive extrusion and retain some antioxidant activity)
Acerola extracts	An isotonic soft drink containing anthocyanin extracts from acerola and from acai	The highest stability was correlated to high flavonoid content and absence of ascorbic acid. The degradation of anthocyanins occurred in the presence or absence of light.
Citrus fruits, such as lemons or oranges	Fruit juice and skim milk mixtures	Antioxidant capacity of new fruit juice and skim milk

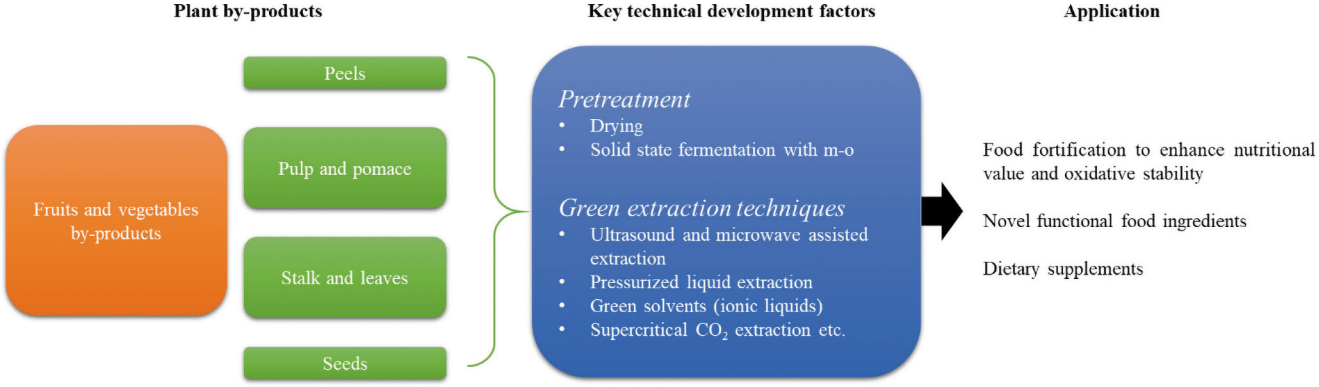

Fig. 2. Schematic representation summarizing key technical development factors and potential applications of plant by-products valorisation (adopted from Ben-Othman et al., 2020)

3. Conclusion

Health and nutrition are the most demanding and challenging field in this era and would continue to be in the future as well. During the last decades, the global dynamics in food production and consumption have changed significantly. While in the past the prevalent policy was mainly to increase food production, today the food industry is focused on the production in accordance with consumer demands as well as assuring the sustainability of the food sector. Finally, it can be concluded that there is an extensive need in food industries to introduce innovations associated with the implementation of emerging technologies, food waste recovery and production of new functional food products in order to survive market competition.

References

[1] Barba, F.J., Orlien, V., Mota, M.J., Lopes, R.P., Pereira, S.A., Saraiva, J.A. (2016) "Chapter 7. Implementation of emerging technologies", in: Galanakis, C.M. (Ed.) Innovation Strategies for the Food Industry: Tools for Implementation. London, San Diego, Cambridge, Oxford: Academic Press, Elsevier Inc., pp. 117-148.

[2] Ben-Othman, S., Jõudu, I., Bhat, R. (2020) "Bioactives from Agri-Food Wastes: Present Insights and Future Challenges", Molecules, (25): 510.

[3] Bigliardi, B., Galanakis, C. (2020) "10 – Innovation management and sustainability in the food industry: concepts and models", in: Galanakis, C.M. (Ed.) The Interaction of Food Industry and Environment. London, San Diego, Cambridge, Oxford: Academic Press, Elsevier Inc., pp. 315-340.

[4] Bigliardi, B., Galati, F. (2013) "Innovation trends in the food industry: The case of functional foods", Trends in Food Science & Technology, (31), 2: 118-129.

[5] Carrillo, J. Á., Zafrilla, M. P., Marhuenda, J. (2019) "Cognitive Function and Consumption of Fruit and Vegetable Polyphenols in a Young Population: Is There a Relationship?", Foods, (8), 10: 507.

[6] Crawford, P.B. (2020) "Nutrition Policies Designed to Change the Food Environment to Improve Diet and Health of the Population", Nestlé Nutrition Institute Workshop Series, (92): 107-117.

[7] Dimou, C., Karantonis, H.C., Skalkos, D., Koutelidakis, A.E. (2019) "Valorization of Fruits by-products to Unconventional Sources of Additives, Oil, Biomolecules and Innovative Functional Foods", Current Pharmaceutical Biotechnology, (20), 10: 776-786.

[8] Fasolin, L.H., Pereira, R.N., Pinheiro, A.C., Martins, J.T., Andrade, C.C.P., Ramos, O.L., Vicente, A.A. (2019) "Emergent food proteins – Towards sustainability, health and innovation", Food Research International, (125): 108586.

[9] Galanakis, C. (2020) "11 – Food waste valorization opportunities for different food industries", in: Galanakis, C.M. (Ed.) The Interaction of Food Industry and Environment. London, San Diego, Cambridge, Oxford: Academic Press, Elsevier Inc., pp. 341-422.

[10] Guo, M. (Ed.) (2009) Functional foods: principles and technology. London, New Delhi, Boca Raton: Woodhead Publishing Limited and CRC Press.

[11] Ibrahim, U.K., Kamarrudin, N., Suzihaque, M.U.H., Abd Hashib, S. (2017) "Local Fruit Wastes as a Potential Source of Natural Antioxidant: An Overview", in: Proceedings IOP Conference Series: Materials Science and Engineering, pp. 1-9.

[12] Kalt, W., Cassidy, A., Howard, L.R., Krikorian ,R., Stull, A.J., Tremblay, F., Zamora-Ros, R. (2020) "Recent Research on the Health Benefits of Blueberries and Their Anthocyanins", Advances in Nutrition, (11), 2: 224-236.

[13] Khoo, C.K., Knorr, D. (2014) "Grand challenges in nutrition and food science technology", Frontiers in Nutrition, 2014.

[14] Lule, N.O., Simsek, H., Yilmaz, S., Cavdar, U. (2019) "Functional food knowledge and use in individuals with type 2 diabetes and the relevant factors", Progress in Nutrition, (21), 4: 858-867.

[15] Pawlowska, E., Szczepanska, J., Koskela, A., Kaarniranta, K., Blasiak, J. (2019) "Dietary Polyphenols in Age-Related Macular Degeneration: Protection against Oxidative Stress and Beyond", Oxidative Medicine and Cellular Longevity, (2019): 1-13.

[16] Ramos, S., Etxebarria, S., Cidad, M., Gutierrez, M., San Martin ,D., Iñarra, B., Olabarrieta, I., Melado-Herreros, Á., Zufia, J. (2020) "1 – Cleaner production strategies for the food industry", in: Galanakis, C. (Ed.) The Interaction of Food Industry and Environment. London, San Diego, Cambridge, Oxford: Academic Press, Elsevier Inc., pp. 1-34.

[17] Recordati, G.B.P. (2015) "The food industry: History, evolution and current trends", Doctoral thesis. (https://tesi.luiss.it/15698/1/177941.pdf) (25.3.2020.)

[18] Santamarina, A.B., Jamar, G., Mennitti, L.V., Ribeiro, D.A., Cardoso, C.M., de Rosso, V.V., Oyama, L.M., Pisani, L.P. (2019) "Polyphenols-Rich Fruit (*Euterpe edulis* Mart.) Prevents Peripheral Inflammatory Pathway Activation by the Short-Term High-Fat Diet", *Molecules, (2):* 1655.

[19] Santeramo, F.G., Carlucci, D., De Devitiis, B., Seccia, A., Stasi, A., Viscecchia, R., Nardone, G. (2018) "Emerging trends in European food, diets and food industry", Food Research International, (104): 39-47.

[20] Sun-Waterhouse, D., Waterhouse, G. I. N., You, L., Zhang, J., Liu, Y., Ma, L., Gao, J., Dong, Y. (2016) "Transforming insect biomass into consumer wellness foods: A review", Food Research International, (89): 129-151.

[21] Sun-Waterhouse, D. (2011) "The development of fruit-based functional foods targeting the health and wellness market: a review", International Journal of Food Science & Technology, (46), 5: 899-920.

[22] Šubarić, D., Babić, J. (Ed.) (2019) Neke mogućnosti iskorištenja nusproizvoda prehrambene industrije – Knjiga 2. (Some possibilities for utilization of food industry by-products – Book 2). Osijek: Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno-tehnološki fakultet Osijek.

[23] Šubarić, D. (Ed.) (2017) Neke mogućnosti iskorištenja nusproizvoda prehrambene industrije (Some possibilities for utilization of food industry by-products). Osijek: Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno-tehnološki fakultet Osijek.

[24] Zhang, Z.H., Wang, L.H., Zeng, X.A., Han, Z., Brennan, C.S. (2019) "Non-thermal technologies and its current and future application in the food industry: a review", International Journal of Food Science and Technology, (54): 1-13.