Innovative agriculture and sustainable food production
Applications of the Aquaponics system

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Abstract. The present global scenario shows a twofold consumers' behavior: on one hand, there is evidence of a growing demand for modern food; on the other one, it is easy to observe an increasing desire for natural foods. As far as innovations in the food industry are concerned, they often originate a lack of acceptance by the market, partly as a consequence of a phenomenon known as food neophobia; this involves the unwillingness to try new foods, as well as implies consumer reluctance with regard to emerging technologies in processing and producing food, known as food technology neophobia. As a consequence, in order to support marketing research, it is fundamental to analyse population segments that show food technology neophobic attitudes, as well as those groups regarded as early adopters of such innovative technologies. With reference to a specific application of the mentioned discourse, related to innovation in agriculture, the present contribution proposal aims at analyzing the potential of Aquaponics, defined as "the combination of aquaculture (raising fish) and hydroponics (the soil-less growing of plants) that grows fish and plants together in one integrated system". This technology is considered at institutional level as "a resource efficient and environmentally friendly food production system"; aquaponics products are locally produced and attract an increased attention among consumers. The present contribution proposal will outline factors related to the mentioned food neophobia and applications of the Aquaponics system, responding to diverse ecological and social challenges related to efficient and sustainable forms of agricultural production. In particular, the case study of Agricoltura 2.0, in Italy, will be discussed as a best practice to reach relevant development objectives with specific reference to peri-urban areas.

Keywords. Aquaponics - Innovative agriculture - Food technology neophobia - Food technology neophilia - Sustainable agriculture.

I - Introduction

New food technologies are increasingly and constantly introduced, especially in developing regions. Although, in general, end consumers are aware of the risks associated with food innovations and applications, massive food researches are carried out in order to analyse consumers' fear of novel food, defined as "food neophobia", as well as consumers' increasing attention towards sustainable practices along the whole support chain (Siegrist *et al*., 2007; Siegrist, 2008).

Apart from being a personality trait, food neophobia has also been studied as a form of behaviour (Choe and Cho, 2011; Barrena and Sánchez, 2013); in order to foster new food technologies market success that, in turns, depends on consumers' behavioural responses, it is essential to focus on population segments that are food technology neophobic as well as early adopters of such innovative technologies. Generally speaking, there are three key reasons for rejection of food by humans: (a) aversion to sensory characteristics, (b) danger, a fear of negative consequences of eating a specific food or (c) disgust, arising from the idea of nature or origin of food. As mentioned, consumers are also paying an increasing attention to issues related to environmental sustainability and production methods aimed at safeguarding both qualitative and ethical aspects (Frewer *et al*., 2011; Fenko *et al*., 2015).

Moreover, consumers' hesitation to try foods produced by new food technologies hinges on some main factors such as: functional barriers connected to simple use, benefits and risks

feelings, knowledge and attitudes, socio-demographic and lifestyle factors and psychological barriers; conversely, neophilics people perceive unusual foods in a positive light and embrace situations involving new foods, especially when these foods are produced according to sustainable methods, capable of creating opportunities for local development and environment safeguarding (Urala and Lähteenmäki, 2007; van Trijp and van Kleef, 2008; Tuorila *et al*., 2011; Verneau *et al*., 2014).

Different works have shown that the Food Neophobia Scale (FNS), developed by Pliner & Hobden (1992) to measure willingness to taste novel foods, predicts responses to novel or unknown food can provide a standardized measurement to evaluate the connection between appetite and food aversion; nevertheless, it does not properly work to examine the acceptance of foods produced by novel technologies. As a matter of fact, food neophobia is also linked to the acceptance of new technologies used in food production and processing. Thus, the Food Technology Neophobia Scale (FTNS) was developed, with the aim of having more precise and concise measurements, as accurately described in Cox and Evans (2008) and Evans *et al*. (2010).

In general, scientific and technological innovations have contributed to the enhancement of man's quality of life, as well as to the sustainability of production processes; within the food area some relatively recent technology-based innovations have been adopted easily, while others essentially rejected by consumers.

As argued, one of the reasons for such interest in new food technologies is the anticipated range of benefits they can bring to consumers and to the food sector. The reported advantages include safer, healthier more nutritious foods using less energy, water and chemicals and producing less waste. However, the toxicological nature of hazard, likelihood of exposure and risk to consumers from some new food technologies are largely unknown.

In the area of food and nutrition, various technological applications have emerged, related to different aspects of the supply chain; among them, aquaponics can be considered as a relatively new approach to safe and sustainable production of food. The present contribution aims at analysing the different aspects of this technology, with particular reference to the case study of Agricoltura 2.0, a best practice in Italy.

The case of aquaponics is analysed in relation to its being significant to the main theme of this paper, and to the investigation of neophobia/neophilia forces (Koster, 2009; Vidigal *et al*., 2014).

II - Materials and Methods

As to the OpenAgri Project from ImpattoZero, with the support of Agricoltura 2.0, it aims at fostering the diffusion of the Aquaponic technology and sustainable cultivation, all by means of the establishment of partnerships and the participation in regional, national and European initiatives (Gaskell, 2000).

Among the projects of major importance and institutional resonance, it is fundamental to cite "Open Agri: New Skills for New Jobs in Peri-urban Agriculture".

The project was conceived as part of the first call for the European initiative called "Urban Innovative Actions", art. 8 of the ERDF - European Regional Development Fund (EU Regulation n.1303 / 2013), aimed at identifying and testing new solutions to address issues related to sustainable urban development, relevant at the European level.

ImpattoZero participates in partnership with the City of Milan (leader), the University of Milan, the Milan Polytechnic and private individuals, including: Avanzi, Cineca, Future Food Institute, La Strada Società Cooperativa Sociale, Sunugal, Poliedra, Ifoa, Mare Social

Enterprise, Food Partners. The project started on the 1st of November 2016 and will end on the 31st of October 2019.

The specific objectives are related to:

- building a sustainable food chain that goes from promotion to consumption, in order to respond to the emerging needs of the agri-food sector;
- addressing young entrepreneurs and innovative SMEs in the agri-food sector and supporting experimental solutions that could emerge from their collaboration;
- create an innovative ecosystem, a hub that will connect all the stakeholders at territorial level, in relation to the themes of economic development and social inclusion, and which will favor the creation of new skills;
- contributing to the improvement of urban resilience;
- bringing agricultural policy closer to other innovative policies at local level;
- building a sustainable food supply chain, using innovative approaches along all steps.

ImpattoZero participates in the mentioned Project in all those aspects related to the design and the construction of aquaponic systems, in which different cultivation environments will cohabit, to be used for local varieties (e.g. aubergines, salads, tomatoes) as well as for tropical ones and for ancient seeds.

The aquaponic greenhouse, in addition to becoming an evocative place where it is possible to carry out specially dedicated educational activities, will represent a significant experimentation of the agri-food sector: peri urban agriculture will help to ensure the availability of food, especially fresh products, contributing to the increase in food security and good citizens' eating habits. All this will contribute effectively to a positive image related to aquaponics as a dare technology for food production, thus helping to fight against the mentioned food neophobia.

The expected results deriving from the project concern mainly the capacity for the agri-food sector to attract investments for the production of further innovative processes, the contribution to the increase of urban resilience and biodiversity, and the promotion of the territory through culture, food education and youth entrepreneurship.

III - Results and discussion

In recent years, many of the new food technologies and food innovations have been targeted at the promotion of both good health and environment safeguard.

Consumer acceptance is driven by risk perception and by the perception of the potential benefits, both at personal and societal level; a lack of perceived benefits leads the majority of people to question the need for, and usefulness of, novel food technologies, and may even accentuate perceived risks and moral concerns.

Starting from the conceptual framework developed by Ronteltap *et al*. (2007), the present contribution aims at analysing the different factors related to consumers' acceptance of food technologies; the aim is twofold: on one hand, the mentioned comprehensive conceptual framework will be broadened through the investigation of the most recent literature regarding neophobia/neophilia forces (Ritchey et al., 2003; Rollin et al., 2011); on the other hand, in addition to past reviews in the mentioned field, the analysis of the primary and secondary determinants is integrated with an in depth illustration of the different aspects related to measurement tools such as the Food Technology Neophobia Scale (FTNS) (Cox and Evans, 2008; Evans *et al*., 2010; Caracciolo *et al*., 2011; Coppola *et al*., 2014).

Significant are the innovations in the agricultural sector, more or less recently conceived and developed, such as the realization by the Research Area of Pisa of the National Research Council (CNR) of a prototype of drone, called "Hephaestus", to be used widely in the so-

called precision agriculture, thanks to innovative multi-sensory systems conceived and developed by the Institute of Information Sciences and Technologies (ISTI-CNR), the Institute of Biometeorology of Florence (Ibimet-CNR) and the Refly group of the CNR of Pisa.

The advantages are linked to the possibility of acquiring data from several sensors simultaneously and from being able to process them simultaneously; all this in order to minimize the environmental impact of production systems, mainly through the adjustment of sowing parameters, the modulation of fertilizer doses, the site-specific application of water, pesticides and herbicides. This is a notable evolution compared to the first applications of precision agriculture, based mainly on satellite image processing, GPS systems and geographic information systems (GIS).

The use of the drone, it is noted, allows the acquisition of "visible thermal and multispectral georeferenced images and the post-flight processing of data for the mosaic [...] data and images that can be integrated into a network and provide information in real time thanks also to the recent advances in radio transmission technologies and the possibility that these have to interface with the Internet". It is fundamental to note how this integrated system of methodologies and technologies allows to increase vegetable production, quality and productivity of a farm; the benefits are relative to several aspects: from the most efficient production, to the protection of the environment, with the early evaluation of the onset of diseases and pests, the reduction of production costs and, above all, the guarantee of greater sustainability in terms of environmental and product quality, thus impacting on the entire supply chain.

In this context, characterized at the regional level by the need to innovate the business model of the agricultural sector, the combination of the following three elements is very interesting:

- the technique of domotic culture (behavioral algorithms of ecosystem management) with the Internet of Things (IoT) in Aquaponics;
- the economic model of the franchise
- the digital economy, with the sale of agricultural products on direct and customized consumer demand (on-demand cultivation and sales of existing biodiversity).

Through this combination the franchisee uses the short supply chain and the final consumer has the possibility to choose any agricultural product outside the schemes imposed by the large production. The Aquaponic culture, i.e. the combination of aquaculture with hydroponic technology, is a relatively new method of technological production, receiving considerable attention from Europe and beyond, by virtue of the strong sustainability potential that characterizes this system. Considerable attention comes from various sources at the European level, and from FAO, in support of the validity of the method in question.

In summary, the business model provides a Franchisor, which offers a service/product, or the sale of aquaponic systems measured to the needs of the manufacturer (Franchisee); the latter manages to obtain an economic return thanks to the on-demand sale, mediated by technological tools such as APP or e-commerce platforms, which allow the final consumer to order agricultural products (including those of floriculture) of his choice.

The project is based on 4 pillars:

1. Food safety: cultivation with the ground-based technique in Aquaponics, 100% organic with cultivation materials of a higher standard even compared with those used in organic farming.
2. Food sovereignty: through the use of technologies related to the digital economy, the end customer (B2B/B2C) is able to choose a cultivation plan from the existing biodiversity catalogue.
3. Short supply chain: cultivating in inhabited places, in disused warehouses, on roofs, in greenhouses as in indoor cultivation with controlled temperature and photoperiod,

allows, together with modern technologies, to have 100% organic crops close to consumers.
4. Low carbon footprint: the mentioned system allows a 90% reduction in use of water, no combustion engine, no chemical, renewable energy and energy efficiency.

The technology out of the ground in Aquaponic is a scalable, vertical and adaptable technology that allows 80% less human work and can bring agriculture to a new profitability. The project, offering food safety and sovereignty, short supply chain and low carbon footprint, aims to create a network of farmers using the technology in Aquaponic, with the aim of allowing customers to develop a plan of cultivation on demand from the existing biodiversity. It is interesting, if not fundamental, to broaden the regional boundaries of the project, so as to consolidate the offer of so-called "urban farms", organic horticultural productions, in disused warehouses, on roofs or in greenhouses, as close as possible to the final consumer. Alongside the aforementioned urban farms, the technology in question is expected to provide interesting applications to promote the rebirth and development of rural areas. With regard to the close link with the Digital Economy, each company operating in this sector uses digital tools; the creation of the Farming on demand offer, through an online catalogue of biodiversity (e-commerce) allows to have a complete digital on demand agriculture service. Moreover, the management of the ecosystem through sensors and water analysis allows to have an IoT system that, through decision-making algorithms, manages the ecosystem itself remotely or independently, making the offer and the market penetration easier and more efficient. With a view to achieving goals, it is useful to cite:

1. Relaunching industrial areas (regional and national), often abandoned.
2. Allow anyone to become a virtual grower. The final consumer digitally chooses what to grow, for example through an ad hoc APP. Starting from a complete catalogue (containing also little used and unmodified seeds) and a description of the properties of foods, the consumer chooses what to grow, possibly thanks to the advice of a nutritionist (nutraceutical) or simply for personal needs and references. Being a virtual farmer allows consumers to hold food sovereignty.
3. To obtain products qualitatively and quantitatively superior to the current cultivations off the ground, such as those obtained from hydroponics. In this regard, it is recalled that many of the products that reach large-scale retail trade (GDO) are already produced off the ground, which reflects the need to create high quality and organic products.
4. The need to feed a growing population (9 billion people expected by 2050). Both the scientific studies and the data of the producers, about the quality and the production through the technique of the aquaponic culture, suggest that the latter is much more efficient than the traditional cultivation methods, through a maximization of the potential of plants.

Application and transferability of the technology.

Of considerable interest is the possibility that this technology could be also used to cultivate genetically modified organisms to produce a molecule of interest (for example an active ingredient). As a result, the aquaponic technology makes it possible to cultivate different plant species in optimal conditions, in a wide range of applications:

- in the food sector, for the cultivation of 100% natural food products in manufacturing, for the production of fabrics and raw materials (e.g. Cannabis);
- in the pharmaceutical field, for the production of organisms with a high concentration of active ingredients;
- in the construction industry, for the production of plants used for insulation and construction products;
- in the cosmetic sector, to obtain 100% organic nutrient-rich raw materials.

The benefits in terms of food waste reduction are noticeable, thanks to the described creation of an on-demand agriculture, characterized by the satisfaction of more stringent and targeted needs and requirements.

IV - Conclusions

As argued, in recent years, the number of new foods has increased as a result of new food technologies; the advantages of such technologies are multifarious and include safer, healthier and more nutritious foods using less energy, water and chemicals and producing less waste, the enhancement of environmental sustainability, and the growth of food productivity (Matin *et al*., 2012). Moreover, nowadays consumers are more and more aware of their food selection, especially novel foods (Cardello, 2003). They are more demanding for the quality of the products and health benefits they produce, in fact, they are aware of the effects of nutrition on health and well-being. Thus, food market must create new competitive products, nutrient-enriched, or produced by using new technologies in order to satisfy consumers (Chaudry *et al*., 2008); future researches on new technologies should include a psychology dimension to investigate and identify the real factors that determine consumer behavior, so as to predict their choice of specific food (Chen *et al*., 2013).

As firms attempt to put in place effective product development strategies and processes, it is vital to recognize how newness "per se" does not guarantee positive market performance; this occurs if newness itself provides real and meaningful differentiation to consumers in the market place (Gielens and Steenkamp, 2007). Food marketing and food New Product Development face the challenge to find an optimal level of "newness", high enough to induce curiosity and willingness to try the new food, but low enough not to cause neophobia (Koster, 2009). Future research is needed to set this optimal level and to investigate how market success and performance are related to product newness.

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Sitography

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