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Consumers' attitudes and change of attitude toward 3D-printed food

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ABSTRACT

3D printing, also known as additive manufacturing, offers a wide range of new possibilities within the food industry. From the realisation of complex food designs to the automated preparation of personalised meals, 3D printers promise many innovations in the food manufacturing, retail and catering sectors. Because the successful launch of foods made using a novel technology needs to be accompanied by targeted communication, a careful assessment of consumers' perception, needs and apprehensions is required. The present study aims to explore consumers' attitude formation and evolution toward this technology and resulting food concepts. Data were collected through a postal survey sent out to a sample of 2047 German-speaking residents from Switzerland, yielding a final sample size of N = 260. Participants' attitudes were assessed at the beginning and end of the survey. Three consecutive multiple regression analyses helped analyse the initial attitude, the final attitude and the attitude change determinants that were assessed. Participants' self-assessment revealed a varied but overall relatively low initial knowledge level of 3D-printed food. Because the first impression has been proven to be decisive in attitude formation, this lack of knowledge allowed us to test the effect of targeted information, and we succeeded in overcoming food neophobia and convincing consumers that this technology can support them in the preparation of healthy and individualised meals while adding a playful dimension to food preparation. The information given, however, failed to overcome food technology neophobia. Avenues for the development and testing of adapted communication concepts are discussed.

1. Introduction

3D printing, or additive manufacturing, is defined as a technology with which computer-aided design (CAD) software instructs a digital fabricating machine to shape 3D objects by the successive addition of material layers (ISO, n.a., Lupton & Turner, 2016). This technology, which originated in the 1980s and was primarily intended for use in the prototyping industry (Savini & Savini, 2015), began to be used in food processing a decade ago. Although many technological challenges related to the use of a food matrix have been tackled, very little research has been conducted on how people perceive food produced with 3D printing and how they form their opinion on this topic. Elsewhere, the food industry, well known for its competitive and innovative nature, is also characterised by a high share of product failure and market withdrawals (Bruhn, 2007; Dijksterhuis, 2016). Although the reasons for the high failure rate are numerous, the lack of importance given to consumer research appears to be one of the most crucial points upon which to work (Dijksterhuis, 2016; Popa & Popa, 2012).

Food innovations can be classified into different categories according to their degree and type of novelty (Grunert et al., 1997); novel foods and their technologies together represent the most disruptive category and are particularly susceptible to instigating mistrust and being rejected by consumers (Cardello, 2003; Cox & Evans, 2008; Ronteltap, van Trijp, Renes, & Frewer, 2007; Ueland et al., 2012). Hence, early investigations about consumers' perceptions, needs and fears are particularly relevant when it comes to marketing these types of innovations (Frewer, 1998; Frewer et al., 2011). By introducing a recent and alien technology for processing food, 3D printing is by essence a novel food technology. In-depth investigations on consumers' attitude regarding the use of this new technology in food processing are therefore recommended prior to the market launch of devices, services or products linked to or derived therefrom. A targeted study on current consumers' opinion toward 3D-printed food and their opinion-formation processes will allow for an evaluation of the potential of new food concepts, help identifying potential early-adopting customers and contribute to the development of an appropriate communication strategy.

1.1. 3D food printing

In 1984, 3D printing technology was invented by Charles Hull, who patented the stereolithography, the first technology to enable the

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creation of 3D objects from digital data. Originally developed for prototyping in the industry, several university-driven initiatives contributed to making this technology accessible to the general public and to democratise its domestic use in the 2000s (Savini & Savini, 2015). In 2001, Nanotek Instruments Inc. patented a 'rapid prototyping and fabrication method for 3D food objects' (US6280785 B1, 2001). This was the very first concept of a 3D food printer; however, further attempts from the appliance specialists Electrolux and Philips suffered from several technical shortfalls, and they found neither industrial nor domestic applications for 3D food printing (Sun et al., 2015). Inspired by the Massachusetts Institute of Technology FabLab project, in 2007, two researchers from Cornell University presented the Fab@Home Model 1, the first functioning and replicable 3D printing system compatible with food (Malone & Lipson, 2007; Sun et al., 2015). Since then, numerous projects have been conducted to refine and adapt this technology to different food matrixes (Godoi, Prakash, & Bhandari, 2016). After a decade of research, scientists have produced a sizeable range of 3D-printed food samples on a laboratory scale, with different technologies and from a variety of raw materials, but have faced several technological challenges along the way (Godoi et al., 2016; Lipton, Cutler, Nigl, Cohen, & Lipson, 2015; Sun et al., 2015). Pizzas, chocolate creations, cookies and dumplings are only a few examples of foods that can be designed by 3D printers.

1.2. Consumer perception toward 3D food printing

Although the advantages and numerous possible uses of 3D food printing are already widely discussed (Izdebska & Zolek-Tryznowska, 2016; Sun et al., 2015), very little research has been conducted on consumers' attitudes, perceptions and acceptances toward food produced by 3D printing. To the best of our knowledge, the contribution from Lupton and Turner (2016) is the first and only attempt to understand how consumers might respond to food produced with this technology; the study's online focus group discussion highlights that public knowledge about both the technology and the characteristics of the food produced with it was fairly inexistent and very speculative. Several participants feared that food produced with a printer would be inedible, unsafe or at least nutritionally depleted, and the word printer itself, commonly associated with the non-food industry, seemed to have a negative impact on participants' acceptance. Neither the display of pictures of 3D-printed food and meals, nor the arguments that this technology might contribute to food waste reduction and world hunger alleviation were successful in overcoming most participants' scepticism. Nonetheless, a small minority, describing themselves as adventurous eaters, indicated being open to consuming 3D-printed food.

1.3. Factors influencing consumers' attitude and perception toward novel food and novel food technology

Consumers generally view novel food technologies and their resulting foods with suspicion (Popa & Popa, 2012); however, not all new food technologies and food trigger the same reactions. Both the technology itself (Cardello, 2003; Frewer et al., 2011) and the individual experience and knowledge background play a determining role in the evaluation process (Greehy, McCarthy, Henchion, Dillon, & McCarthy, 2013; Olsen, Grunert, & Sonne, 2010). Some general fostering or stifling factors can nonetheless be drawn from the literature: improved flavour, increased convenience, health-enhancing properties and the proximity to or imitation of natural processes are the arguments most susceptible to enhancing consumers' acceptance of novel foods (Bruhn, 2008; Cox, Evans, & Lease, 2007; Rollin, Kennedy, & Wills, 2011; Siegrist, 2008; Siegrist, Stampfli, & Kastenholz, 2009). Repeated exposure to different types of novel food and visual representations of them (Bruhn, 2007; Cardello, 2003; Cardello, Schutz, & Lesher, 2007; Frewer et al., 2011; Jaeger, Knorr, Szabó, Hámori, & Bánáti, 2015) can also contribute to making new techniques imaginable and new food more familiar to consumers, which in turn positively affects consumers' attitudes (Lyndhurst, 2009). In contrast, suspecting the presence of harmful by-products and, more generally, any potential health risk associated with the consumption of novel food will undoubtedly pre-empt consumers' acceptance of and interest in consumption (Bruhn, 2008; Cardello et al., 2007; Siegrist, 2008). Chemical transformation (e.g., modification of the food composition) is an additional factor that similarly jeopardises people's acceptance of new foods and new technologies (Cardello et al., 2007; Lyndhurst, 2009; Siegrist, 2008). The literature remains inconclusive and partially contradictory regarding the effect of consumer communication and education (Rollin et al., 2011). Indeed, researchers agree that unilateral and technology-driven information fails to convince consumers of the benefits of novel food (Cox et al., 2007; Scholderer & Frewer, 2003). Yet a segment-specific communication (Rollin et al., 2011) addressing both the top-down and bottom-up attitude-forming pathways (by contributing to the development of consumers' trust and faith in relevant public institutions while providing sufficient information about the risks and benefits of the technology) (Jaeger et al., 2015) using lay terminology, referring to comparable and more familiar technologies (Bruhn, 2007, 2008; Jaeger et al., 2015; Ronteltap et al., 2007; Siegrist, 2008) and addressing the major consumer questions, which are product safety and tangible end-user benefits (Bruhn, 2007, 2008; Cardello, 2003; Lyndhurst, 2009; Siegrist, 2008), has the potential to contribute to the broader acceptance of novel foods and novel food technologies. Consumer trust in the industry, the media, the scientists and the government also plays a decisive role in opinion formation, especially when the opinion-making process follows a top-down pathway, which seems to be the most probable process when it comes to evaluating particularly controversial technologies (Søndergaard, Grunert, & Scholderer, 2005). In Europe, consumer organisations, health professionals and independent scientists belong to the most trusted sources and therefore should be involved in the debate (Rollin et al., 2011; Siegrist, 2008). Taking all this into consideration, the best communication strategy might still fail to change the public's view about a novel food when its content does not match pre-existing knowledge and values (Greehy et al., 2013; Lyndhurst, 2009). Finally, studies on the impact of socio-demographic determinants have yielded contradictory results (Lyndhurst, 2009); moreover, the explanatory power of these factors has been shown to disappear when competing with cognitive and attitudinal determinants (Verbeke, 2005). The consistently more reserved attitude expressed by women toward several novel foods and novel food technologies is a notable exception (Lyndhurst, 2009).

1.4. The present research

The purpose of the current study is to fill the current knowledge gap by conducting a quantitative study on consumers' attitudes toward 3D-printed food. To this aim and based on the initial insights obtained by Lupton and Turner (2016), we developed a consumer survey and used a drivers analysis. Constructs identified to be related to consumer acceptance toward novel foods and novel food technologies according to the above literature review and that were assessable by means of a paper and pencil survey were included in the questionnaire, including *food neophobia*, *food technology neophobia*, *previous knowledge*, *convenience orientation*, the importance of both a healthy diet (*health*) and *natural* food *content* (see Table 2). Socio-demographic variables were also included. Other insights from the literature review were used to develop the information content delivered to the participants in the questionnaire. Finally, we complemented the survey with a selection of additional factors, which we hypothesised to be involved in the opinion-forming process toward 3D-printed food specifically. *Benefit perception*, the *willingness to consume*, *fun to use*, *cooking creativity*, *food involvement*, a preference for familiar foods (*familiarity*) and an affinity toward digital tools (*digital native*) are in this group of factors (see Table 2). The collected data enabled us (a) to evaluate existing public