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Mismatch between food sustainability and consumer acceptance toward innovation technologies among Millennial students: The case of Shelf Life Extension

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ABSTRACT

The academic interest towards food products produced with innovative technologies has increased and a specific attention has been paid on the factors that could explain consumer acceptance or skepticism with regard to these new technologies. In this frame, the aim of this work is to analyze the factors that affect consumer acceptance towards new technologies in food with a special focus on Shelf Life Extension, which is considered to be one of the most sustainability-driving food innovations. The target group for the analysis is represented by the Millennial Generation (MG) students (n = 1027), recruited through a face to face survey.

The results evidenced that higher levels of food knowledge led to an increase in acceptance whereas, in contrast, a greater interest in sustainability led to technology rejection. As the main scope of these technologies is to increase the overall sustainability of food products by reducing food loss and chain fails, the mismatch evidenced by the rejection of Shelf Life Extension technology by eco-friendly individuals outlines that the innovation technologies in food products is perceived by consumers as risky *per se*, regardless of the specific technology. In a nutshell, individuals characterized by high sustainability concerns fail to recognize, in science and technology, a possible contribution for a more sustainable world.

1. Introduction

In the last decades, modern food systems have been faced with a challenge to accelerate the shift towards sustainable development and production; identifying solutions that are able to enhance productivity and sustainability along the supply chain while helping the sector cope with climate change issues (OECD, 2012). The transition towards new models of food production and consumption will depend on the sector's capacity to introduce innovative approaches and strategies at any level of the supply chain (Schiefer and Deiters, 2016). Nonetheless, compared to other manufacturing sectors, the food and drink sector in Europe is less innovative and only the 1.9% of the EU patent applications were related to such products (Eurostat, 2012).[1] In the food sectors, ready-made meals are the most innovative, with 8% of the total European food innovation, followed by dairy products (7.5%), soft drinks (6.3%) and savory frozen products (6.2%) (FoodDrinkEurope, 2016). Moreover, in addition to patent data, research and development (R&D) expenditures can also be used as a measure of innovation. Data revealed that the low levels of R&D expenditures at an aggregate level and the low propensity for the development of new knowledge led to considering the European food and drink sectors as low-tech industries (Costa et al., 2016).

The capacity to innovate represents a strategic tool for firms to maintain a competitive position in the marketplace (de Jong and Marsili, 2006; Laforet and Tann, 2006). This is particularly relevant in the Italian market, where small and medium enterprises (SMEs) represent a greater part of the food industry (Spillan and Parnell, 2006; Banterle et al., 2016): the introduction of new

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[1] Several indexes have been employed to measure the technological changes based on patents (Daim et al., 2006). Indeed, the number of patents reflects inventive activity and innovation and could be considered a good proxy for evaluating the evolution of technology in a particular area (Frisio et al., 2011; Pantano et al., 2017). A patent is described as a 'source of technical and commercial knowledge about technical progress and innovative activity' (Park et al., 2005) and is the most used tool to protect inventions (Archibugi and Pianta, 1996).

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ideas, processes and products allows SMEs to survive alongside big enterprises and to face the growth of competition due to globalization processes (Traill and Grunert, 1997). On the demand side, consumers are increasingly careful about what they eat, as a consequence of problems related to food intolerance, allergies and episodes of food poisoning and scares (McEachern and Schroder, 2004; Grunert, 2005; European Commission, 2007), along with the increased awareness of the existence of a direct link between diet and health (Banterle and Cavaliere, 2014; Bui and Fazio, 2016; Cavaliere et al., 2016, 2017). In this context, despite the fact that technological innovation in the food chain can play a strategic role in coping with the evolution of the consumers' needs and choices, evidence suggests that consumers tend to appreciate technology applications in general and, conversely, find food technologies risky (Lusk et al., 2014).

As a consequence, the academic interest towards food products produced with innovative technologies has increased and a specific attention has been paid on the factors that could explain consumer acceptance or skepticism with regard to these new technologies (Magnusson and Hursti, 2002; Biltekoff, 2010; Verneau et al., 2014; Ferrazzi et al., 2017). Moreover, for the specific case of Italy, Eurobarometer data showed the lowest percentage of respondents who think that both science and technological innovation as well as people's actions and behavior will have a positive impact on the availability and quality of food (European Commission, 2014). In addition, the highest proportion of respondents who consider food origin as important can be found in Italy. Indeed, almost 70% of the respondents were aware and interested in the Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) logos (European Commission, 2012). This is the peculiarity of the Italian population, which translates to a great preference for high quality, typical, and niche food productions and a high adherence to 'Made in Italy' products (European Commission, 2012).

In this frame, the purpose of this paper is twofold: first, to analyze consumer acceptance towards new technologies in food and, second, a special focus on Shelf Life Extension, which is considered to be one of the most sustainability-driving food innovations. Plenty of studies have focused on new innovation technologies in the food sector, such as bio-fortified food, nanotechnology, and transgenic food, but, to our best knowledge, the acceptance of Shelf Life Extension technologies has been scarcely investigated (Magnusson and Hursti, 2002; Stevens and Winter-Nelson, 2008; González et al., 2009; Vandermoere et al., 2010; Bieberstein et al., 2013; McFadden and Lusk, 2014; Stranieri and Baldi, 2017).

The target group for the analysis is represented by the Millennial Generation (MG), in particular, the college student category of the MG, aged 20–25 years old. The MGs are considered more knowledgeable than others with respect to the environment, and they are more global and community oriented and less brand-loyal (Harris et al., 2011). They are also more concerned about the environment and the ethical attributes of products (Schubert et al., 2010; Lozano et al., 2013; Vicente-Molina et al., 2013; Zsóka et al., 2013; Gustin and Ha, 2014; Sloan, 2014).

This paper is structured as follows: the next section presents the main characteristic of Shelf Life Extension technology, and Section 2 describes the conceptual framework followed in this study. Moreover, the third section explains the details of data collection and the methodology applied; the fourth section provides the results and discussions. Finally, the study's conclusions and limitations are presented in the fifth section.

1.1. New food technologies: why the Shelf Life Extension?

Shelf life is the period of time before a food product is considered unsuitable for consumption or sale. During the last several years, reliable methods have been developed to extend the shelf life of food products through formulation, processing or packaging innovations (Soliva-Fortuny and Martı;n-Belloso, 2003; Deegan et al., 2006; No et al., 2007; Banerjee et al., 2016; Odueke et al., 2016). Active packaging and modified atmosphere packaging are widely used as a supplement to refrigeration to delay spoilage and extend the shelf life of fresh products while maintaining a high-quality end-product. The most recent innovation in this sector introduced the adoption of 'mild' technologies that are able to preserve the nutritional and organoleptic characteristics of food products. In these recently developed innovations, antimicrobial compounds can be incorporated into the packaging films or coatings in order to maintain high concentrations of preservatives on the surface of foods for a longer storage time (Chouliara et al., 2007; Yuan et al., 2016). Natural food preservatives can help in ensuring protection from both spoilage and pathogenic microorganisms by using low concentrations of essential oils in combination with other preservation technologies, such as low temperature (Scandamis and Nychas, 2001), low dose irradiation (Farkas, 1990; Chouliara et al., 2007), high hydrostatic pressure (Devlieghere et al., 2004) and modified atmosphere packaging (Marino et al., 1999).

The extension of the shelf life of food products is considered to be one of the most strategic tool to improve the overall sustainability of a food product along its entire supply chain. Indeed, this technology can help in counteracting food waste, which is responsible for 17% of direct greenhouse gas emissions and 28% of material resource use (Priefer et al., 2013). A recent EU Resolution (European Commission, 2010) stated that food gets wasted in approximately 89 million tons per year throughout the entire food system from households (42%), manufacturers (39%), retail (5%), and catering (14%): there is a potential for the spoilage of food products at any stage of the supply chain when the products reach their 'best before' or 'saleable date'. As a key strategy to tackle the problem of food waste, there is a trend towards developing Shelf Life Extension solutions that are intended to facilitate supply chain management by reducing the production and delivery lead times, thus increasing the low predictability and stability of the supply logistic strategies (Amani and Gadde, 2015). For consumers, the positive impact of Shelf Life extended products relies on improved convenience attributes in response to consumer demands for less time spent on shopping and cooking. Moreover, the longer shelf life period should increase the consumer's ability to manage food provision, storage and preparation and, consequently, minimize domestic food waste.

2. Consumer acceptance of new food technologies

Consumer's perception and acceptance of Shelf Life Extension is a quite new topic of investigation, although new food technologies have already been intensively investigated. Summarizing the main topics driving the controversies around new food technologies, *trust* represented one of the main important factors (Costa-Font et al., 2008; Vandermoere et al., 2010). Indeed, food neophobia, described as the propensity to avoid new foods, can also be a consequence of the lack of social trust. Another factor that can influence the benefit-risk perception was *media coverage* (Fox et al., 2002; Roosen et al., 2011): food scares and worries are examples of how the media can sway the public's perceptions of risk. Nevertheless, it would be erroneous to blame the media for the public's unbalanced responses to such events, even though their influence is important and sometimes detrimental to the public's understanding (Ventura et al., 2017). Also, *cultural cognitions* and *worldviews*, including food values (in particular, naturalness) have been studied in relation to the acceptance of new food technologies (Lusk and Briggeman, 2009). Indeed, the consumer's general cultural and political attitudes toward the world influence how technologies are perceived by individuals and how the individuals evaluate them (Douglas, 1990; Dake, 1991; Slovic, 1999; Peters et al., 2004).

This work focused only on those factors that could be associated with the acceptance of the specific case study of Shelf Life Extension technology and on those that characterize the Millennial student sample: the interest in sustainable practices, food knowledge, familiarity and education.

The *consumer interest in sustainable practices* could lead to the acceptance of food technology, such as Shelf Life Extension, because of its sustainability implications. For example Niva et al. (2014), found that sustainable food consumption is related to interests in cooking and healthy food choices, confirming that an environmental attitude is acquiring great influence on consumers' food-related behaviors and that, in some cases, the association between health and environmental concerns can exist (Cavaliere et al., 2014). Matin et al. (2012), revealed an inverse relationship between environmental attitudes and nanotechnology acceptance, as confirmed by Vandermoere et al. (2011), who stated that public perceptions of technologies in the food domain significantly relate to universalistic values (Grunert and Juhl, 1995; Thøgersen and Ölander, 2002; de Boer et al., 2007). Among these values, 'naturalness' is identified as a choice motive that motivates a consumer's preference for unaltered foods (O'Connor et al., 2005; Ares and Gámbaro, 2007; Rozin et al., 2012) over innovative and new products.

Also, *food knowledge* can play an important role in driving the perception of Shelf Life Extension products. Several studies stated that knowledge represents a useful tool for helping consumers make more informed and aware food choices, leading to higher levels of acceptance. Thus, food knowledge could be essential to shape consumer attitudes (Boccaletti and Moro, 2000; Vilella-Vila et al., 2005; Allum et al., 2008; Simon, 2010) and their dietary choices by having a direct effect on the performance of complex tasks (Campos et al., 2011; Bonsmann and Wills, 2012; Hieke and Taylor, 2012; Wills et al., 2012; Lähteenmäki, 2013; Spronk et al., 2014; Miller and Cassady, 2015). In this sense, a higher level of food knowledge could mean a higher level of understanding of technology and, consequently, a greater level of acceptance.

A further aspect is referred to the concept of familiarity. The literature showed a proven relationship between the *familiarity* with the new technology (Macoubrie, 2004; Bieberstein et al., 2013) and consumer acceptance, as variations in familiarity about a risk have some effect on information processing across individuals (McFadden and Lusk, 2014).

Another factor that could increase acceptance is represented by *education*. Indeed, education is considered one of the most important determinants of public attitudes. Bak (2001) evidenced that levels of education and levels of scientific knowledge make independent contributions to public attitudes toward science. A further contribution is provided by the university curricula, as noted by the work of Rodríguez-Entrena and Salazar-Ordóñez (2013), who evidenced some differences in behavioral intentions towards GM food between scientific-technical and social-humanistic literacy fields.

3. Materials and methods

3.1. Sampling and data collection

Data were collected during April and May 2016 through a face-to-face survey of the Millennial Generation students, using an ad hoc questionnaire. To evaluate the role of different university curricula, student samples were composed of 50% social sciences and 50% applied sciences. The master degrees of the University of Milano were listed in order to identify and group the social and applied science degrees. Moreover, the head of the teaching board of each degree was contacted to ask for the willingness to participate in the survey. Within the offered degrees, in order to consider different levels of food knowledge, applied science students belonging to Food Science ($n = 184$), Pharmacy ($n = 162$) and Engineering ($n = 206$) degrees were recruited. Within the social sciences, the degrees in Humanities ($n = 197$), Law ($n = 171$) and Political Science ($n = 183$) were selected. Excluding all incomplete observations from the analysis, the final sample was composed of 1027 respondents. The sample size was decided following the criterion explained by Mazzocchi (2008) for the determination of the relative accuracy of a mean estimator according to both the sample and population sizes (choosing a level of error of approximately 3%).

The respondents were assured of anonymity and confidentiality. The data were collected from the students during the university class hours in order to reduce the refusals to participate. Students who declined participation were replaced by other students. The answering time for the questionnaire was approximately 15–20 min. The questionnaire consisted of 65 questions and is structured in different sections. The order of appearance of the sections has been randomized to avoid the potential bias resulting from the order of items in the questionnaire.

The first question that the respondents were asked to answer related to their shopping habits, namely, if they are the main person responsible for food purchases, and only respondents who answered positively to this question were recruited for the survey, in order to test the interest for this new technology amongst real food purchasers.

3.2. Questionnaire and variables description

The first section of the questionnaire focused on individual attitudes toward food technology applications in general. A validated scale on Food Technology Neophobia, developed by Cox and Evans (2008), was employed in order to determine the respondents' fear of novel technologies in food products (pasteurization, high pressure, genetic modification). The Food Technology Neophobia Scale (FTNS) represents an evolution of the previous Food Neophobia Scale (FNS) proposed by Pliner and Hobden (1992). In a further work of Evans et al. (2010), the FNTS is confirmed as a reliable and predictive measure of responses to novel food technologies. Two bilingual translators converted all of the original items from English to Italian. Subsequently, a third bilingual translator back-translated the Italian version of the scale into English. The differences found were resolved by discussion, with all the translators agreeing on the final versions of the two scales (Sousa and Rojjanasrirat, 2011; Schnettler et al., 2016) (Annex A). For the 13 items of the FTNS, respondents had to indicate their level of agreement using a Likert 7-point scale (Cox and Evans, 2008).

Moreover, this section contained also two questions extracted from the Eurobarometer survey on the public perception of science, research and innovation (European Commission, 2014). These questions have been used as a proxy for the level of the respondent's confidence in both the impact of people's action (Ebs_people impact) and science (Ebs_sci&tech impact) on the quality and availability of food in the next years.

The second section of the survey contained questions meant to elicit the respondent's level of food knowledge, adapted from Parmenter and Wardle (1999). This validated scale collects information on knowledge about nutrient content, diet related diseases, dietary recommendations and choices in everyday foods. For each question, a correct answer was assigned the value of 1 and a wrong answer was assigned a value of 0, with a total score ranging from 0 to 30.

The third section was dedicated to elicit the consumer's degree of sustainability in food consumption (SFC) through the index developed by Niva et al. (2014). The scale represents a summative index of 6 statements concerning the consumption of locally produced foods, seasonal fruits and vegetables, organic foods and the consumption of meat, products with excessive packaging and food products imported by airplane. This measure was employed as a proxy to measure the consumer's environmental good practices in food consumption.

Section 4 addressed a focus on consumer acceptance toward the new technology of Shelf Life Extension. It contained a preliminary question on familiarity with the specific technology to understand the level of awareness with regard to this food technology without any kind of information received. Furthermore, to avoid potential knowledge bias, a brief description of the main characteristics of this technology has been provided: '*Shelf life of a food product can be defined as the time in which the product remains acceptable on the shelves. There are a set of technologies under development that will allow the extension of the shelf life of food products, thus reducing the frequency of provisions and waste.*' After the information, students were asked to answer questions about their willingness to try shelf life extended food products. A set of questions focused on specific case studies (poultry meat, bread, fresh-cut salad, mozzarella cheese, and fish fillets[2]) were provided, meant to elicit, for each of them, the degree of consumer preferences for two different Shelf Life Extension time ranges. For each product, the students were asked to respond on a graphical continuous rating scale from 0 (not at all) to 7 (very much) by making a sign on a bar. The investigation was about the general acceptance of the effect of SLE technology on food products, namely an extended shelf life, and irrespective of the specific technology used to extend it. This entails the fact that the specific features of a certain technology (i.e. packaging vs process modification) could partially influence SLE acceptance. Nevertheless, given the great heterogeneity of these group of technologies and their seminal state of development, the emphasis of the work was on the global acceptance of what consumers could find on the supermarket shelves in the next years, i.e. products with extended shelf life.

The last part of the survey focused on socio-demographic characteristics (age, gender, education).

Table 1 presents the descriptive statistics of all the variables mentioned above.

3.3. Data analysis

A multiple-level data analysis was employed: first, an explorative analysis of the characteristics of the sample has been performed considering the *Food Technology Neophobia Scale* and *Sustainability of Food Consumption Index* variables. To summarize the information on the statements composing the FTNS scale, a principal component factor analysis with a Varimax rotation was performed to allow the extraction of components that are highly correlated and, thus, obtain more interpretable factors. Second, for each specific food product, a paired *t*-test was estimated to analyze if technology acceptance is influenced by the rate of Shelf Life Extension (low and high extension period).

Third, a set of OLS regressions (11 models) were performed. More specifically, Model 1 investigated the acceptance of food technologies in general. The dependent variable was the Food Technology Neophobia Scale, the validated index for food technology rejection. This variable represented the sum of all the values of the 13 statements that compose the scale (with the pro-technology statements reversed before summing). Models two to eleven have been performed to analyze the acceptance of shelf life extended products. They were OLS regressions where the dependent variable was represented by the willingness to try a specific food product (mozzarella, poultry, sea-bream, fresh cut salad, white bread) with two different ranges of shelf life extension. All models employed the same independent variables: food knowledge, education, sustainability of food consumption index, familiarity with Shelf Life Extension, Eurobarometer questions on people impact and Eurobarometer question on science and technological innovation impact (transformed as dummy variables). The variance inflation factor (VIF) was calculated in order to avoid multicollinearity problems among the explanatory variables. In the analysis, the VIFs were always far below the problematic value of 5, meaning the absence of multicollinearity (Hair et al., 2011, 2016). Fourth, a k-means cluster analysis (MacQueen, 1967) was estimated to determine the segmentation of respondents and to profile the consumers in order to verify the existence of different groups based on food technology perception. All reported analyses were conducted in IBM SPSS Statistics.

4. Results and discussion

4.1. Exploratory data analysis

With respect to the distribution of the Food Technology Neophobia, results evidenced that the sample is notably similar to the original scale proposed by Cox and Evans (2008), and the value for Cronbach's alpha is 0.76, showing good internal reliability. The millennial student sample showed slightly lower mean values (49.5 vs 55 on the original scale), probably due to their intrinsic characteristics. Indeed, the selection of students as a target group needs to take into account their greater familiarity with innovation and technology in general (Chung et al., 2010). Nevertheless, items 7 (*new food technologies are unlikely to have long term negative health effects*, reversed) and 13 (*the media usually provide a balanced unbiased view of new food technologies*, reversed) revealed an opposite trend, characterized by higher levels of concern for the potential impact of food technologies on health and a general mistrust about the quality of media information. The principal component factors analysis of the 13 items composing the scale was performed (Table 2) and the results of the Kaiser-Meyer-Olkin[3] test and Bartlett's sphericity test showed adequacy of the sample for factor analysis. The four factors resulting from the analysis explained the 56.8% of the total variation of the data and reflect the output of Cox and Evans (2008); thus, the same names for each of them have been used. The first factor called, 'New food technologies are unnecessary,' included all statements that are related to the feelings and worries about the risks of new food technologies and their uncertainty. The second factor, labelled 'Healthy choice,' was positively associated with the health-related benefits of new food

[2] The choice of the products is linked to the project on which this paper was developed. Indeed, the project, titled 'Long Life, High Sustainability,' analyses specific case studies in order to combine the technology of Shelf Life Extension with a possible increase in the global sustainability of a food product from farm to fork.

[3] The Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity test are measures of how data fitted for Factor Analysis. The KMO test measures sampling adequacy for each variable in the model and the proportion of variance among variables that might be common variance. KMO values between 0.8 and 1 indicate the sampling is adequate. Also, the Bartlett's Test of Sphericity relates to the significance of the study and thereby test the homogeneity of variances (Mazzocchi, 2008).

Table 1
Descriptive statistics and variables description.

Variable name	Scale	Description	Min	Max	Mean	Range	Freq
Education_curricula	Dummy	University degree	0	1			
Social							537
applied science							490
Age	Discrete numerical		21	29	24.21		
Gender	Dummy		1	0			
Male							381
Female							646
FTNS	Categorical	Food Technology Neophobia Scale	19	91	49.46	13–91	
FKN	Categorical	Food Knowledge Scale	2	29	20.29	0–30	
SFC	Categorical	Index of Sustainability of Food Consumption	0	12	7.28	0–12	
Ebs_people impact		15 years from now, what impact do you think people's actions and behaviour will have on availability and quality of food?	0	3			
Do not know	Dummy		0	1			227
Negative	Dummy		0	1			565
Neutral	Dummy		0	1			27
Positive impact	Dummy		0	1			208
Ebs_sci&tech impact		15 years from now, what impact do you think science and technological innovation will have on the availability and quality of food?	0	3			
Do not know	Dummy		0	1			221
Negative	Dummy		0	1			85
Neutral	Dummy		0	1			17
Positive impact	Dummy		0	1			704
Familiarity SLE	Dummy	Have you ever heard about Shelf Life Extension technology?	0	1			
No							509
Yes							518
Mozzarella Low SLE	continuous	Would you be willing to try a mozzarella cheese whose shelf life has been extended 2 days?	0	7	2.33		
Mozzarella High SLE	continuous	Would you be willing to try a mozzarella cheese whose shelf life has been extended 5 days?	0	7	1.62		
Poultry Low SLE	continuous	Would you be willing to try poultry meat whose shelf life has been extended 2 days?	0	7	2.45		
Poultry High SLE	continuous	Would you be willing to try poultry meat whose shelf life has been extended 5 days?	0	7	1.71		
Sea bream Low SLE	continuous	Would you be willing to try a sea bream whose shelf life has been extended 2 days?	0	7	1.83		
Sea bream High SLE	continuous	Would you be willing to try a sea bream whose shelf life has been extended 4 days?	0	7	1.31		
Fresh cut salad Low SLE	continuous	Would you be willing to try a fresh cut salad whose shelf life has been extended 3 days?	0	7	2.73		
Fresh cut salad High SLE	continuous	Would you be willing to try a fresh cut salad whose shelf life has been extended 9 days?	0	7	1.66		
White bread Low SLE	continuous	Would you be willing to try a white bread whose shelf life has been extended 10 days?	0	7	2.07		
White bread High SLE	continuous	Would you be willing to try a white bread whose shelf life has been extended 20 days?	0	7	1.45		

Note: SLE is the abbreviation for Shelf Life Extension. Observations n = 1027.

Table 2
Food Technology Neophobia Scale: factor descriptions and loadings, item means and standard deviation.

Factor	Description	Item	Loading	Mean	Std. Dev.
1	New food technologies are unnecessary	There is no sense trying out high-tech food products because the ones I eat are already good enough	0.709	2.27	1.555
		New food technologies are something I am uncertain about	0.588	3.981	1.867
		New foods are not healthier than traditional foods	0.729	3.422	1.810
		The benefits of new food technologies are often grossly overstated	0.608	3.907	1.667
		There are plenty of tasty foods around, so we do not need to use new food technologies to produce more	0.724	2.656	1.751
		New food technologies decrease the natural quality of food	0.646	3.552	1.841
2	Healthy choice	New food technologies are unlikely to have long-term negative health effects®	0.673	4.481	1.549
		New food technologies give people more control over their food choices®	0.818	3.870	1.605
		New products using new food technologies can help people have a balanced diet®	0.765	3.712	1.578
3	Perception of risks	New food technologies may have long-term negative environmental effects	0.738	3.844	1.613
		It can be risky to switch to new food technologies too quickly	0.779	4.453	1.799
		Society should not depend heavily on technologies to solve its food problems	0.601	3.633	1.984
4	Information/media	The media usually provide a balanced, unbiased view of new food technologies®	0.914	5.681	1.478

Kaiser-Meyer-Olkin measure of sampling adequacy: 0.84—Bartlett test of sphericity $\chi2(78)$ 2608.79(p = .000); Loadings > 0.5 are reported. Percentage variance explained 56.8%. (R) indicates reverse scored items.

technologies. The third component added different nuances to the aversion to new technology in food products. In this factor, labelled ‘Perception of risks,’ the aversion was associated with expected environmental impacts. Finally, the fourth component was strongly associated only to the statement, ‘The media usually provide a balanced and unbiased view of new food technologies.’ This factor was labelled ‘Information/media.’ Among the studies that have described the FTNS with a principal component factor analysis, the

Table 3
Sustainability of Food Consumption – Items description.

Items	I am doing this already (%)	I would like to do this (%)	I am not doing this and I am not willing to (%)
Buy regional (local) food	71.08	18.70	10.22
Avoid products with excessive packaging	44.40	28.43	27.17
Buy organic food	49.17	21.32	29.50
Eat only seasonal fruit and vegetables	46.93	39.05	14.02
Eat meat at most twice a week or a little at a time	49.37	20.55	30.09
Avoid food products that were imported by airplane	23.95	30.19	45.86

Cronbach's alpha = 0.72.

most similar results are those of Verneau et al. (2014), which equally referred to an Italian sample.

Regarding the index of Sustainability of Food Consumption for five out of the six activities considered almost half of the respondents reported practicing them already, showing a quite high level of environmentally fair practices among the sample (Table 3). This could be explained by different factors: first, the Italian population shows a growing appreciation for agriculture with less environmental impact or are practiced with methods that ban synthetic chemicals (like organic) and are very attentive toward food products with schemes of geographical indications (like PDOs and PGIs). Second, the fact that millennials have been already identified as a more sustainable and environmentally friendly generation. Third, the role of education level could contribute to explaining this positive attitude toward sustainability. Indeed, as noted by Niva et al. (2014), people with a master level education stand out as being more active than those with only a basic education. Thus, the Italian millennial student sample effectively synthetized the above mentioned characteristics.

4.2. Shelf Life Extension–case studies

As for the acceptance of the specific SLE technology, data revealed that among the different food products analyzed, the highest level of acceptance was for fresh-cut salad, probably due to the high consumer familiarity with this type of product, which is characterized by strong convenience gains. On the other side, the lowest level of acceptance was for seam-bream, since freshness in fish products is normally perceived as a prioritized factor, influencing purchasing behaviors.

In addition, Table 4 showed the results of the paired *t*-test[4] comparisons that were used to determine whether the willingness to try specific food products (mozzarella, poultry meat, sea-bream, fresh-cut salad, white bread) is influenced by Shelf Life Extension time. The results revealed different degrees of acceptance for the specific case studies analyzed. In particular, the food products with lower Shelf Life Extension (mozzarella 2 days, poultry meat 2 days, sea-bream 2 days, fresh-cut salad 3 days, white bread 10 days) showed a higher mean value, and this difference between the two alternatives was always statistically significant. This implies that the acceptance of Shelf Life Extension technologies is affected by the extent to which shelf life is prolonged: the longer the time period, the ‘less natural’ the product is probably perceived. Together with naturalness, product freshness can have also played a role in influencing willingness to try SLE products. Thus, in this case, the lack of acceptance could be partially due to freshness concerns rather than to SLE technology acceptance: the positive effect of innovation cannot be disentangled from

Table 4
Differences between products through Paired *t*-test.

Product	SLE	Mean	SD	Corr.	Sig.
Mozzarella	2 days	2.33	2.11	0.76	***
Mozzarella	5 days	1.62	1.87		
Poultry meat	2 days	2.45	2.11	0.73	***
Poultry meat	5 days	1.71	1.91		
Orata	2 days	1.83	2.01	0.81	***
Orata	4 days	1.31	1.74		
Fresh cut salad	3 days	2.73	2.26	0.70	***
Fresh cut salad	9 days	1.66	2.03		
White bread	10 days	2.07	2.19	0.80	***
White bread	20 days	1.45	1.95		

Significance at $p < .05^{*}$, $p < .01^{**}$, $p < .001$ ***.

the negative effect of the probability of having older products on shelves.

4.3. Factors affecting technology acceptance: estimation results

To analyze the factors that are related to the food technology acceptance in general and in the specific case of Shelf Life Extension technology, 11 models were performed. The regression outputs highlighted no significant results for the variables Ebs_people impact or Ebs_sci&tech impact (all values showed p-values >0.05). A further regression was performed with the remaining variables and the final restricted estimation model (n = 4) is shown in Table 5.

Model 1, having the FTNS as dependent variable, confirmed the recent literature revealing the important role of food knowledge on the acceptance of innovation food technologies. The association between the two variables was significant and negative (−0.321); in other words, people with a high level of food knowledge are those more prone to accept new technologies in food products, or less neophobic.

The results concerning the role of education revealed the strongest relation with FTNS (−3.115), suggesting that those students attending applied science faculties are, *per se*, more inclined to accept innovation in foods than humanities students. This probably means that the type of university education can be interpreted as a proxy for a more general disposition toward science and technology and their applications. This relationship is in line with recent studies (Priest, 2000; Saher et al., 2006; Rodríguez-Entrena and Salazar-Ordóñez, 2013) where behavioral intentions towards innovative-product acceptance displayed some differences between the scientific–technical and social–humanistic literacy fields. A direct relationship exists between the consumer literacy fields and behavioral intentions, since science and technology students tend to be more positive about the application of technology to food.

The sustainability of food consumption is confirmed to be associated with the FTNS (+0.486). More specifically, the more sustainable the food consumption practices are, the higher the level

[4] The paired *t*-test is used to compare two population means. The paired *t*-test is a statistical procedure used to determine whether the mean difference between two sets of observations is zero. In a paired *t*-test, each subject or entity is measured twice, resulting in pairs of observations (Mazzocchi, 2008).

Table 5
OLS results.

	FTNS	Mozzarella LowSLE	Mozzarella HighSLE	Poultry LowSLE	Poultry HighSLE	Fresh cut salad LowSLE	Fresh cut salad HighSLE	White bread LowSLE	White bread HighSLE	Sea-bream LowSLE	Sea-bream HighSLE
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Food Knowledge	−0.321	0.049	0.024	0.045	0.045	0.042	0.053	0.065	0.039	0.034	0.035
	*(0.089)****	*(0.017)***	*(0.015)**	*(0.017)***	*(0.015)***	*(0.018)**	*(0.016)****	*(0.018)***	*(0.016)***	*(0.016)**	*(0.014)***
Education_Curricula *(Applied science = 1)*	−3.115	0.434	0.413	0.410	0.487	0.196	0.431	0.457	0.375	0.494	0.430
	*(0.731)****	*(0.139)****	*(0.124)****	*(0.139)***	*(0.124)****	*(0.149)*	*(0.133)**	*(0.144)***	*(0.129)***	*(0.132)****	*(0.114)****
Sustainability food consumption	0.486	−0.059	−0.049	−0.105	−0.123	−0.120	−0.113	−0.077	−0.092	−0.113	−0.096
	*(0.346)****	*(0.025)***	*(0.023)**	*(0.025)****	*(0.023)****	*(0.027)****	*(0.024)****	*(0.026)***	*(0.024)****	*(0.024)****	*(0.021)****
Familiarity SLE	−1.894	0.434	0.293	0.335	0.236	0.404	0.162	0.205	0.110	0.362	0.229
(Yes = 1)	*(0.694)***	*(0.133)****	*(0.118)***	*(0.132)**	*(0.118)**	*(0.142)***	*(0.127)**	*(0.136)*	*(0.122)*	*(0.125)***	*(0.108)**
Cons	54.846	1.341	1.153	1.926	1.336	2.460	1.130	0.998	1.089	1.533	0.973
	*(1.860)****	*(0.353)****	*(0.316)****	*(0.353)****	*(0.317)****	*(0.379)****	*(0.339)****	*(0.366)****	*(0.328)****	*(0.335)****	*(0.290)****
Obs	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027
R2	0.164	0.145	0.131	0.144	0.162	0.135	0.149	0.144	0.134	0.154	0.152
R2 adj	0.161	0.141	0.127	0.141	0.158	0.131	0.145	0.140	0.130	0.150	0.148
F	17.546***	11.967***	8.117***	11.873***	16.824***	9.156***	9.156***	13.149***	9.062***	14.461***	13.915***

Note: Standard error in parentheses, significance at $p < .05^{*}$, $p < .01^{**}$, $p < .001$ ***; SLE is the abbreviation for Shelf Life Extension.

of neophobia is for technologies in food; This result is in line with recent literature about the consumer preference and demand for natural attributes in food, which are perceived as unaffected by human technological advances and thus not interfering with Mother Nature: naturalness is regarded as conflicting with innovation (Lusk et al., 2014).

Concerning the familiarity with Shelf Life Extension technology, the models revealed that its relation with Food Neophobia was significant and negative, in accordance with Slovic (1987) who suggested the familiarity hypothesis: a lack of familiarity with a technology may be an underlying cause for lay people's reluctance to accept the use of new food technologies.

Models 2 to 11 analyzed the factors associated with consumer acceptance for SLE technology, having as dependent variables the willingness to try SLE products with two different Shelf Life Extension time ranges. The models showed that the relationships within the variables under consideration are stable and moderately independent from the type of product considered.

Although the same set of independent variables have been employed, it must be said that in these models the dependent variables measured a degree of acceptance (expressed as willing to try) rather than a level of rejection, as expressed by the Food Technology Neophobia. Nevertheless, regardless of the inverted signs of the relationship, models 2–11 tended to confirm the relationships among the dependent and independent variables of model 1. More specifically, the positive role played by food knowledge as well as by previous familiarity with this type of technology in shaping technology acceptance is confirmed. Also, education showed a direct link with a willingness to try different Shelf Life Extension technologies, as well as for the role of sustainable food consumption: the higher the attention to the environmental sustainability of food consumption, the lower the willingness to try products with Shelf Life Extension.

As the main scope of these technologies is to increase the overall sustainability of food products by reducing food loss and chain fails, the mismatch evidenced by the rejection of Shelf Life Extension technology by eco-friendly individuals outlines that the innovation technology in food products is perceived by consumers as risky *per se*, regardless of the specific technology. In a nutshell, individuals characterized by high sustainability concerns fail to recognize, in science and technology, a possible contribution for a more sustainable world.

4.4. Cluster analysis

Table 6 displays the cluster analysis results that were used to determine the segments of individuals who present different food technology acceptance levels. A four-cluster solution grouped the participants based on their food technology neophobia, familiarity with Shelf Life extended products and the type of university curricula.

Cluster 1, called the *Confident Scientist* group, was the least likely to be technology neophobic (mean FTNS = 34). They were characterized as being more receptive to extended Shelf Life products as well as being applied science students, with a relatively higher value of Food Knowledge and previous familiarity with Shelf Life Extension. They presented the highest level of acceptance for extended Shelf Life product case-studies. Not surprisingly, they were also the group that revealed the lowest degree of sustainable food consumption.

Cluster 2 (n = 355), called the *Cautious Scientists* group, though having a positive attitude to the application of technologies in food, were hardly familiar with the specific case of Shelf Life Extension. Compared to Cluster 1, they were characterized by lower level of food knowledge and a greater sustainability of food consumption.

Cluster 3, named the *Convinced Humanists*, can be distinguished by Cluster 1 and 2 mainly because of the type of curricula, which is Social Science in this case. Moreover, this cluster of respondents was defined as more food neophobic and more involved in sustainability issues. Nevertheless, they were familiar with Shelf Life Extension and willing to try this technology.

Cluster 4, named the *Skeptical Humanist*, was the most likely to refuse food technologies, having the highest level of neophobia, no familiarity with Shelf Life Extension technology, and no willingness to try Shelf Life extended food products. As expected, the highest food technology neophobia was coupled with a greater degree of sustainability of food consumption and low food knowledge. Cluster analysis identified this market segment as those who remarkably rejected the use of this technology in food products.

Table 6
Cluster analysis results.

	Cluster 1 (n = 183)	Cluster 2 (n = 355)	Cluster 3 (n = 372)	Cluster 4 (n = 117)
Food Technology Neophobia Scale	34.0	44.7	55.2	69.8
Willing to try SLE product	Yes	Yes	Yes	No
Food Knowledge	21.8	20.6	19.5	19.5
Education Curricula	Applied	Applied	Social	Social
Sustainability of Food Consumption	6.8	7.2	7.5	7.5
Familiarity SLE	Yes	No	Yes	No
Mozzarella Low SLE	3	2	2	1
Poultry Low SLE	4	2	2	2
Fresh Cut Salad Low SLE	4	3	3	2
White Bread Low SLE	3	2	2	1
Sea Bream Low SLE	3	2	2	1

5. Conclusions

This study investigated consumer acceptance of new technologies in food by focusing on the specific case studies of Shelf Life Extension. The results evidenced that higher levels of food knowledge led to an increase in acceptance whereas, in contrast, a greater interest in sustainability led to technology rejection. The knowledge-acceptance relationship is still an important concern in communicating with citizens in a more efficient way. If knowledge represented one of the main barriers to consumer acceptance, in this direction, policies such as information campaigns or educational programs could be recommended to make the consumers more knowledgeable and informed about food choices. At the same time, the data revealed that, in this specific study, people with a higher level of sustainability of food consumption practices were those less prone to accept new technologies in food products.

This raised some cues of reflection and suggested the presence of a sustainability paradox. Indeed, the main purpose for the development of Shelf Life Extension technologies is the achievement of a more sustainable food chain, by improving the efficiency of logistics operations and reducing food waste. Nevertheless, the consumers more concerned with sustainable consumption were still those who most severely refused such technologies. The presence of this paradox first suggested that, in the food domain, the risk perception related to the use of technologies is able to overcome environmentally driven benefit perceptions. Second, that the consumer perception of sustainability issues in food is strongly associated with the idea of 'ancient naturalness'; purchasing food products is sustainable only when they are local, organic, and traditional: innovation and sustainability simply cannot match. In other words, although the experts are aware that the achievement of sustainability goals can only be addressed through a combination of 'back to the past' and 'towards the future' strategies, lay people have probably not been sufficiently informed on this issue to date.

This study had some limitations. The face-to-face survey raised the issues of social desirability bias and under/over estimation of responses due to stated preferences, which can partially affect the results of the present study. The second issue was related to the sample, Millennial Students, which represented a very specific population and, consequently, did not allow the generalization of the results. Third, the consumers' willingness to try SLE products could be partially affect by other product attributes (i.e. freshness), thus, a more comprehensive framework is required. Moreover, the analysis referred to the case of Italy, and further research is needed to verify the outcomes in other countries with different characteristics.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jclepro.2017.12.087.

Annex A
Food Technology Neophobia Scale, Italian translation

Item	English	Italian
1	New food technologies are something I am uncertain about	Non ho certezze sulle nuove tecnologie applicate ai prodotti alimentari
2	New foods are not healthier than traditional foods	I prodotti alimentari nuovi non sono più sani di quelli tradizionali
3	The benefits of new food technologies are often grossly overstated	I benefici delle nuove tecnologie alimentari sono spesso fortemente sopravvalutati
4	There are plenty of tasty foods around, so we do not need to use new food technologies to produce more	Esistono già molti cibi gustosi e non è necessario usare nuove tecnologie per produrne altri
5	New food technologies decrease the natural quality of food	Le nuove tecnologie applicate al cibo riducono la naturale qualità di un alimento
6	New food technologies are unlikely to have long-term negative health effects®	Le nuove tecnologie alimentari non avranno effetti negativi sulla salute nel lungo periodo
7	New food technologies give people more control over their food choices®	Le nuove tecnologie alimentari consentono ai consumatori un maggiore controllo delle proprie scelte alimentari
8	New products using new food technologies can help people have a balanced diet®	Nuovi prodotti sviluppati con nuove tecnologie possono aiutare ad avere una dieta bilanciata
9	New food technologies may have long-term negative environmental effects	Le nuove tecnologie alimentari possono avere un impatto ambientale negativo nel lungo periodo
10	It can be risky to switch to new food technologies too quickly	Può essere rischioso passare a nuove tecnologie alimentari troppo velocemente
11	Society should not depend heavily on technologies to solve its food problems	La società non dovrebbe dipendere fortemente dalle tecnologie per risolvere i propri problemi alimentari
12	There is no sense trying out high-tech food products because the ones I eat are already good enough	Non ha senso provare alimenti innovativi perché quelli che mangio sono già buoni
13	The media usually provide a balanced, unbiased view of new food technologies®	I mezzi di comunicazione normalmente forniscono un punto di vista bilanciato e obiettivo sulle nuove tecnologie alimentari

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