REA | ITALIAN REVIEW OF AGRICULTURAL ECONOMICS

Firenze University Press
www.fupress.com/rea

Citation: Francesco Marangon, Stefania Troiano, Matteo Carzedda, Federico Nassivera (2021) Consumers' acceptance of genome edited food and the role of information. *Italian Review of Agricultural Economics* 76(3): 5-21. DOI: 10.36253/rea-13115

Received: October 06, 2021

Revised: November 23, 2021

Accepted: December 20, 2021

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

Consumers' acceptance of genome edited food and the role of information

Francesco Marangon[1], Stefania Troiano[1], Matteo Carzedda[2], Federico Nassivera[3]

[1] *University of Udine, Department of Economics and Statistics, Italy*
[2] *University of Trieste, Department of Economics, Business, Mathematics and Statistics, Italy*
[3] *University of Udine, Department of Agricultural, Food, Environmental and Animal Sciences (DI4A), Italy*

Abstract. The application of biotechnology and genetics to plant science and agronomy is at the basis of the new breeding techniques, including Genome Editing (GE). A choice experiment was undertaken to investigate Italian consumers' preferences for bread made with gene-edited wheat. Respondents were randomly assigned one of the two versions of a questionnaire, including either a neutral or negatively biased definition of GE. Results demonstrate that the information effect is limited, which confirms that consumers are struggling to understand new breeding techniques. The scientific community should therefore develop better communication strategies for society to comprehensively understand biotechnologies and support policymakers in the definition of informed regulations.

Keywords: NBTs, choice experiment, genome editing, bread, consumer preferences.
JEL codes: Q01, Q10, Q16, Q18.

1. INTRODUCTION

In spite of over a half century-long global agricultural productivity growth (FAO, 2017), food security is still an issue, as almost 800 million people are undernourished and more than 150 million children under the age of five face stunted development (FAO, 2016). The scenario is indeed expected to worsen, as food systems experience growing pressure due to climatic and demographic changes. While the demand for food is expected to perpetuate its positive trend, production is experiencing growth constraints, as a consequence of the physical limitations of land, water and fisheries, as well as global, often anthropogenic, climate change and extreme weather events (Myers *et al.*, 2017).

Scientists and practitioners worldwide are involved in the development of new, innovative strategies and technologies to adapt to, and mitigate, the vulnerability of food systems, and stem food insecurity. Agricultural reorientation and transformation, together with global and national policies to support fair distribution of resources, are now mandatory to ensure food security, which is the fundamental presupposition of sustainable development (Pecl *et al.*, 2017). On the one hand, holistic and agroecological approaches propose to overcome the conventional, industrial paradigm, in favour of alternative and resource-conservative approaches, such as permaculture, urban agriculture, precision agriculture, digital farming (Pigford *et al.*, 2018). On the other hand, the application of biotechnology to plant science, as in conventional genetic modification (GM) and new breeding techniques (NBTs) provides methods and tools to accelerate breeding and domestication, thus allowing the selection and transmission of specific genetic traits to obtain resistant and resilient plant varieties (Østerberg *et al.*, 2017). Among the NBTs, Genome Editing (GE) is a genetic engineering method which enables modification, replacement, insertion and deletion of genetic material in specific locations of the genome of a living organism, thus generating changes in specific physical traits. To be more specific, while GM is based on the transfer of genes among very distantly related, and sexually incompatible, organisms, GE mimics domestication and natural mutagenic events, speeding up traditional breeding processes (European Commission, 2017). According to some scholars, NBTs are not necessarily in contrast with agroecology: in fact, given their potential to produce vegetable varieties which demand less or no chemical, synthetic, and potentially harmful inputs, while reducing natural resource depletion, NBTs may directly promote and support sustainability in agriculture and food production (Ryffel, 2017).

A growing share of consumers appreciate sustainable production systems, and related "green" food products. The positive attitude towards agroecology is related to the growing demand for quality food and concerns over food safety, as well as limited trust in the agrifood industry, and ethical considerations on resource depletion and environmental impact of human activities (Vittersø, Tangeland, 2015). On the contrary, especially in Europe, biotechnologies are often conceived as risky and potentially harmful to both humans and nature (Lucht, 2015; Malyska *et al.*, 2106), even though public awareness and knowledge on these topics is limited, and often negatively biased (Bertuol-Garcia *et al.*, 2018; Helliwell *et al.*, 2017; McFadden and Lusk, 2016). Indeed, while differences and definitions are clear among practitioners and experts, non-technical communication and dissemination on biotech are generally simplistic and reductionist, and superficially present different techniques as part of a heterogeneous whole of complex, obscure and risky technologies. Ruling institutions as well are sometimes unable to identify complete definitions (Halford, 2019). As an example, in 2018 the Court of Justice of the European Union decided that organisms obtained by mutagenesis are Genetically Modified Organisms (GMOs) (Court of Justice of the European Union, 2018), and should therefore comply with the European GMO-Directive (2001/18/EC), imposing obstacles and limitations for the application of consolidated and efficient GE techniques (Wasmer, Robienski, 2018).

The literature demonstrates the ambiguous relationship between consumers and biotech food: while transgenic and cisgenic food products are often opposed *a priori*, the framing used to present different technologies may alter consumers' opinions and preferences (De Marchi *et al.*, 2018; Harvey, 2018; McFadden, Smith, 2019). The application of biotechnologies to food production is an example of "post-normal science", a scientific issue with prominent ethical, legal and social implications, whose risks and benefits demand to be assessed under different perspectives (Brossard *et al.*, 2019). The aim of this paper is to deepen knowledge of consumers' opinion on GE, and how clear communication on this topic may influence public acceptance of this technology. To this end, a Choice Experiment (CE) was undertaken with Italian consumers, who were asked to state their preferences for a novel bread product made with flour from GE wheat. In order to test for information effect, respondents were randomly assigned one of the two versions of the questionnaire, including either a neutral or a negatively biased definition of GE. The results demonstrate that the information effect is limited, if not irrelevant, which confirms that consumers are still struggling to effectively understand what NBTs and GE are.

In the next section, we briefly discuss the literature on GM and GE, and on consumers' preferences for biotechnologies. Section 3 describes the methodology and data used for the analysis. Results are presented in Section 4. Section 5 draws the conclusions and the limitations of the research.

2. BACKGROUND

Through domestication, humans started controlling the reproduction and dispersal of other species to better satisfy their needs (Purugganan, 2019). The selection process remained mainly intuitive and elementary up until the 19th century, with the publication of Mendel and Darwin's studies on trait inheritance and evolution of the species. During the following century, the evolution of the field of genetics confirmed these intuitions, with the decryption of the DNA, the discovery of the mechanisms through which genes are transmitted from parents to offspring, the effects of gene mutations and the development of genetic techniques to induce DNA alteration. The new discoveries were rapidly applied to crop science and, together with the introduction of machinery and synthetic fertilizers, strongly contributed to the improvements in agricultural productivity during the 20th century (Pellegrini, Fernández, 2018).

More recently, since the 1980s, transgenic techniques have been developed to precisely target specific genes, and directly alter DNA in order to obtain the desired modifications (Tagliabue, 2016). With the first generation of GM techniques, the DNA of crops and animals could be altered with the addition of specific genes, in order to produce individuals with specific characteristics (Bawa, Anilakumar, 2013; Krishna *et al.*, 2016).

Further evolution of biotechnologies led to the development of NBTs, through which it is now possible to transfer specific genes or DNA fragments between conspecific organisms or sexually compatible species, or precisely edit, crop or insert genetic material of plants, animals and humans (Hartung, Schiemann, 2014; Maaß *et al.*, 2019). Among the broad category of NBTs, GE refers to a set of molecular approaches, which allow scientists to deliver deletions or integrations of genetic material fragments, or entire genes, in specific DNA sites, thus inducing desirable mutations (Jouanin *et al.*, 2018; Lassoued *et al.*, 2019). Besides functional genomic research, GE can be used to improve yield, quality of crop varieties, and biotic and abiotic stress resistance (Bao *et al.*, 2019). GE-induced DNA mutations are technically analogous to spontaneous mutations, even though non-random and precisely aimed at producing the desired genetic traits. In other words, GE accurately and time-efficiently replicates natural evolution and selective crossbreeding, bypassing the need to grow several plant generations to obtain a specific genetic combination (Morgante, Di Gaspero, 2017; Ricroch, 2019).

Food, and its production methods, being one of the main pillars of human civilization, culture and identity, the introduction of disruptive innovations in these fields is not straightforward. In fact, the way we choose, produce and consume food contributes to defining our individual and communal identity. As values and technology proceed at different speed and on different paths, mismatch and contrasts may occur between culture and ethics on the one hand, and science on the other. Since the introduction and early diffusion of modern biotechnologies, scholars and practitioners have looked into consumers' acceptance of biotechnologies. American and Asian consumers seem to be more positive about GM and NBTs (Gatica-Arias *et al.*, 2019; Öz *et al.*, 2018; Lucht, 2015; Son, Lim, 2021). While several studies show that public opinion in the EU is averse to biotechnologies (Bredahl, 2001; Delwaide *et al.*, 2015; Special Eurobarometer 354, 2010), recent evidence from the literature suggests (Hess *et al.*, 2016; Wolfe *et al.*, 2018) that European consumers are not more reluctant to accept GMOs and biotech food; in line with these results, the latest Special Eurobarometer Survey on Food Safety in Europe (EB91.3, 2019) registered fewer negative views on GM food. According to Harvey (2018), the introduction of new technologies could create ethical unrest, as also described in Kato-Nitta *et al.* (2021), whose results highlight the emotional hurdle associated to the application of gene editing techniques to livestock. The differences in perceptions among the public reflect the complexity of the topic and the factionalism and partisanship it causes. Civil society organizations, NGOs and agricultural organizations have largely contributed to the polarization of public opinion through anti-GM food advocacy actions, propaganda and political pressure (Frewer, 2017; Oliveira *et al.*, 2006; Welsh, Wynne, 2013), and they have recently raised similar concerns for GE (Helliwell *et al.*, 2019); furthermore, science communication in the mass media is often centred on controversial reporting, politicized issues, and PR efforts (Schäfer, 2017). Moreover, the uncertainty of the legal framework, in the EU in particular, is slowing down the adoption of NBTs (Hundleby, Harwood, 2019). In addition to these elements, differences in perspectives and language between policymakers and scientists limit the possibility of current scientific literature to effectively and reliably support decision-making (Catacora-Vargas *et al.*, 2018).

As a result of a confusing public discourse, the relationship between information and consumers' acceptance of biotechnologies and GE is not yet clear. Indeed, while some studies demonstrate that positive communication on environmental and individual benefits may increase the acceptance of GM and GE foods (Beghin, Gustafson, 2021; Lusk *et al.*, 2004), according to Wuepper *et al.* (2018) the role of information is negligible. This ambiguity reflects the complexity of the relationship and interactions between information and consumer behaviour, which have been widely addressed in the literature. While the neoclassical assumptions of perfect information and rational agency of consumers are merely theoretical (Nelson, 1970; Welsch, Kühling, 2010), new institutional approaches recognize the existence of information asymmetry and stress the need to provide as much information as possible to support consumer choice (Kherallah, Kirsten, 2002). Behavioural economics approaches suggest that emotional and motivational factors may alter information perception, hence reduce rationality in consumer behaviour (Slovic *et al.*, 2002); furthermore, Grunert and Wills (2007) state that consumers' interest in information on food varies across situations and products. More recent evidence suggests that consumers often receive poor quality information, in terms of clarity and verifiability, and this, in turn, hampers its trustworthiness and usability (Oehler, Wendt, 2016). In view of all that has been mentioned so far, the analysis and correct use of information is a non-trivial problem, especially when introducing food technology innovations (Raley *et al.*, 2016).

3. MATERIALS AND METHODS

3.1. The Choice Experiment

To improve our knowledge about consumers' opinion on GE, and to identify the role of clear communication on public acceptance of gene-edited food, we conducted a survey including a Choice Experiment (CE). This method is based on the principle that goods differ in their characteristics, and each combination of characteristics yields a different good. CE mirrors real purchase decisions more closely than simple items in surveys, as respondents are asked to choose from an array of products, and select the one they prefer. CE combines insights from Lancaster's consumer theory (1966), the psychological processes of judgment and decision making (Hammond, 1955; Anderson, 1970), and McFadden's random utility model (1974). In detail, Lancaster's consumer theory states that consumers' utility derived from a good is the sum of the utilities derived from its characteristics; in mathematical terms this condition is formally expressed as:

$$U_{ni}=U(x_{ni},S_n)$$

where consumer *n*'s utility from good *i* depends on a vector of characteristics *x* of the good, and on the consumer's socio-economic characteristics *S*. Secondly, the psychology literature includes discussions about how consumers evaluate items, and use these evaluations in choosing among items. Finally, the random utility theory (McFadden, 1974) states that the utility function of each respondent is the sum of a deterministic part (i.e. a function of factors that influence the respondent's utility) and a stochastic random component, which is unobservable; while the researcher is not able to directly measure respondent utility, he can however observe consumers' choices.

According to this framework, consumers are assumed to maximize their expected utility when choosing among different alternatives that return distinct levels of benefit. In a CE, the alternatives are decomposed into their key attributes, then a range of levels are associated to each attribute. With the experimental design it is then possible to create different choice sets. The overall utility of an alternative can be decomposed into separate utilities for its attributes, and becomes a function of alternative characteristics. Such a design allows researchers to estimate the effect or value of each product characteristic on respondents' stated choices. CE was originally applied to marketing research and transport literature, but has recently been extended to food and agriculture research (Hauber *et al.*, 2016; Lancsar *et al.*, 2017; Louviere, Woodworth, 1983). A number of applications could also be found in the field of bread products.

Since consumers' interest towards food knowledge is basic, and information is essential to convey the existence of the characteristics desired by consumers (Akerlof, 1970), it is interesting to enhance the analysis of the effect produced by the provision of information when choosing products.

3.2. The survey

To analyze consumers' preferences towards GE techniques, and to verify the abovementioned role of information on consumers' choices of food produced using GE, we conducted a survey among Italian consumers. Data were collected from 2017 to 2018 through a face-to-face questionnaire with citizens in the Friuli Venezia Giulia Region, an area of North-Eastern Italy, bordering Austria and Slovenia to the north and east, the Veneto Region to the west, and Adriatic Sea to the south. As is usual in this kind of research, interviewees were contacted in the main lobby area of a number of supermarkets and groceries, in order to mirror at least partly the point-of-sale context. In detail, three trained interviewers randomly encountered consumers who stepped out. A number of studies aimed at exploring consumers' preferences and behaviour were conducted by using convenience samples (Garavaglia, Mariani, 2017; Nasir, Karakaya, 2014; Thach, Olsen, 2006). Only citizens over 17 years of age were contacted.

To be able to elicit WTP for GE products we performed an empirical analysis based on a CE. According to Valente and Chaves (2018) several studies involving GM food used the stated preferences methods, either contingent valuation or the CE methodology, to find a price premium, but only a few investigated willingness to pay (WTP) for GE food by using a CE (e.g. Edenbrandt *et al.*, 2018; Muringai *et al.*, 2020; Shew *et al.*, 2018).

In our experiment, bread was chosen as a product for which the notion of gene-edited food is meaningful.

We decided to use this specific food product, as several focus group discussions, conducted with ten researchers, operators, consumers and technicians, indicated it as the most suitable, reasonable although not neutral product when comparing the preferences of consumers towards new breeding techniques used to cultivate wheat. According to Aerni (2011), bread is a product which every consumer is familiar with, even though its personal, cultural and religious connotations may influence respondents. The literature provides several examples of investigations of consumers' preferences towards bread attributes with a CE (e.g. Edenbrandt *et al.*, 2018; Hu *et al.*, 2005; Wuepper *et al.*, 2018); however, to the best of our knowledge, no study has been conducted including both the GE attribute and controlling for information on this technique provided to respondents.

The experimental design process was based on focus groups and pilot testing to develop a questionnaire which included a definition of the GE technique. With the aim of analyzing the effect of question wording (Kolodinsky, DeSisto, 2004) when expressing preferences towards GE products, two treatment groups were used, which differed by the inclusion or omission of stakeholders' opinions (i.e. long/negative and short/neutral information treatment) on potentially consequences of GE. The formulations of the descriptions were discussed and pointed out during the abovementioned focus groups. Participants were randomly presented either the long or short information treatment according to a simple randomization method. The information effects for short and long information treatments were subsequently analyzed to understand the impact on consumers' preferences and valuation. More in detail, we decided to test whether the estimated information effects could provide a foundation for identifying different consumers' WTP. Both formats provided respondents with this definition (English translation, original in Italian):

> «Several studies show that genetic improvement already exists in nature and man has encouraged it for thousands of years with the selection and domesticating of plants up to current biotechnologies, which allow to more to be produced, consuming fewer resources and reducing pollution. Through the "targeted modification of the genetic heritage" (genome editing) any favourable mutation can be produced in a cultivated variety (e.g. wheat) without introducing new genes. The result is a wheat resistant to diseases and cultivable reducing the use of chemicals and water»;

while the following sentence was included exclusively in the long information treatment:

> «According to some farmers and environmentalists, the "targeted modification of genetic heritage" could cause many chain, unexpected and negative mutations with possible implications for the safety of food, feed and the environment. Furthermore, they highlight the ethical issues arising from improper or uncontrolled use of these techniques».

3.3. The questionnaire

The questionnaire was designed to familiarize respondents with different technologies used for wheat crop and breeding techniques, and then elicit preferences. In detail, the questionnaire consisted of two parts. The first part included questions on socio-demographic characteristics and generic food consumption preferences. With the aim of easing comparison with previous studies conducted to identify preferences towards these technologies, this first section of the questionnaire was based on the topics of the Special Eurobarometer 354 (2010). Because of the potential presence of opinion about this specific topic among respondents, a set of 4-point Likert scales (1 = "completely disagree", 4 = "completely agree") were used to measure opinions about different crop techniques (i.e. GM, GE, organic, traditional/conventional). A vast amount of study has been done on the impacts of including or not including a midpoint in the scale (e.g. Boone, Boone, 2012; Chyung *et al.*, 2017). given that respondents could either have already formed their opinion on the survey topic (Johns, 2005) or have little or no involvement in it (Weems, Onwuegbyzie, 2001), we decided to omit the midpoint and offer instead the "I do not know" option. Following Chyung *et al.* (2017) the "I do not know" option was not presented as a separate option off the scale in order to take into consideration the characteristics of collected data. The CE was included in the second section. CE attributes and their levels were identified through preliminary focus group discussions. A total of five attributes were set to examine the interactions between different characteristics of bread we presented in this experiment (Tab. 1).

The country of origin (COO) of wheat (*Triticum aestivum L.*) attribute was chosen as in focus groups it emerged as one of the defining elements of bread. Given that the literature demonstrates that consumers are willing to pay more for domestic food products, we included Friuli Venezia Giulia Region, other Italian Regions, and the rest of the world as possible alternatives. In addition, as regards breeding techniques, previous works on the interaction effect of GM and COO attributes on

Tab. 1. Attributes and levels in the choice experiment design.

Attributes	Levels
Country of origin of wheat	Friuli Venezia Giulia Region, Other Italian Regions, Other countries
Flour	"00", whole-wheat (or wholemeal)
Organic	Yes, No
Agricultural biotechnology	Genome editing, Genetic modification, Conventional breeding techniques
Price (€/kg)	2,00; 3,00; 4,00

Source: our elaboration.

consumer preference showed that respondents exhibited heterogeneous preference for the origin of GM products (Gao *et al.*, 2019). Furthermore, referring to bread, Kim *et al.* (2017) demonstrated that consumers are more willing to accord a premium for local wheat.

The second attribute we took into consideration was the flour type, either "00" or whole wheat. The name 00 (as in *zero zero*) refers to refined white flour, made using only the grain endosperm. The grading system, ranging from 2 to 00, indicates how finely ground the flour is and how much of the bran and germ has been removed. In detail, 00 is the most refined one, and presents the lowest level of bran content. This type of flour is used for both pasta and bread making, and is the most common commercial wheat flour. Whole-wheat (or wholemeal) flour is made milling all parts of the grain (i.e. bran, germ and endosperm). Because of this process, it has a brownish appearance, but its nutritional profile is superior to 00 flour.

Organic certification was also included as a variable attribute describing wheat production with two levels, i.e. present or absent. The inclusion of this attribute was decided as multiple studies (e.g. Bernard *et al.*, 2006) point out that simple GMO-free food is considered just as important to consumers as organic food. According to Christensen *et al.* (2020) consumers with positive preferences for organic products generally also tend to have healthy eating habits. Furthermore, Bartkowski *et al.* (2018) pointed out that different factors influence acceptance of genetic engineering (e.g. breeding techniques, breeding goals and cultivation methods, including organic).

Besides conventional breeding techniques to cultivate wheat, both GM and GE were taken into consideration since our objective was to compare different types of agricultural biotechnologies. According to Friedrichs *et al.* (2019) GE has already been successfully used with agricultural crops, improving the efficiency of plants and offering the possibility of new methods for the control of pests. However, the rapidly growing use of GE has policy implications and instigates human health and environmental safety considerations. Moreover, moral implications can be part of the debate (Harvey, 2018).

Three price levels were chosen, based on both retail prices and the Italian Institute for Monitoring Agro-Food price reports for bread (ISMEA, 2016).

By means of a fractional factorial orthogonal design, which was generated with the SPSS® software, 18 alternatives (i.e. profiles) were selected. These alternatives were randomly combined into six choice sets involving the comparison among different breads with varying levels of the attributes. An example choice set taken from the final questionnaire is provided in Table 2. Each choice task required respondents to choose among three hypothetical bread products defined according to the attributes, and the "opt-out" alternative, to give the respondents the freedom of choice they have in real market situations. The respondents were also informed that, except for these attributes, the three types of bread did not differ in any other aspect. They were then asked to consider the choice tasks as separate situations and answer each choice set. Moreover, bread attributes were described in the survey, so that interviewers could explain differences among levels. Furthermore, following good practice in conducting CE, the choice sets were shown in colour pictures to the survey participants. The dependent variable, i.e. what alternative respondents chose, takes on four values (three alternatives and "neither of these" alternative). Field testing with randomly selected respondents was conducted and 50 consumers filled in the pilot questionnaire providing feedback on survey comprehension, technical ease and length. This pre-test resulted in a number of minor changes in the formulation of questions.

Three trained interviewers collected the questionnaires through face-to-face interviews. As usual in this kind of study, respondents were contacted in the main lobby area of some supermarkets. Following Rossi *et al.* (2013), people were contacted every day of the week, at different times of the day. Every third person was approached (if unwilling, the following one was asked). Prior to the actual participation, interviewees had to confirm to be over 17 years old and have full or partial responsibility for food shopping in their households.

3.4. Model specification

Choice experiment data were analyzed with NLogit6®. The utility function we first considered is illustrated as follows:

Tab. 2. A choice set example (English translation, original in Italian).

SET 1				
Attribute	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Price/kg of bread	€ 2,00	€ 3,00	€ 4,00	None of these
Origin of wheat	Friuli Venezia Giulia Region	Other Italian Regions	Rest of the world	
Agricultural biotechnology	Genome editing	Conventional breeding	Genetic modification	
Organic wheat	No	Yes	No	
Flour type	"00"	"00"	Whole-wheat	
Which bread would you most likely buy?	○	○	○	○

Source: our elaboration.

$$U(x_i) = \text{OPT-OUT} + \beta_1 \cdot FVG_i + \beta_2 \cdot ITALY_i + \beta_3 \cdot TECCONV_i + \beta_4 \cdot TECGE_i + \beta_5 \cdot ORGANIC_i + \beta_6 \cdot 00FLOUR_i + \beta_{price} \cdot PRICE_i \quad (1)$$

where OPT-OUT is the dummy for the "none of these/ no choice" option, FVG is the dummy for wheat production in Friuli Venezia Giulia Region; ITALY is the dummy for wheat production in the remaining Italian Regions; TECCONV is the dummy for the use of conventional agricultural practices attribute; TECGE is the dummy for Genome editing practices attribute; ORGANIC is the dummy for organic wheat; 00FLOUR is the dummy variable for the 00 flour option; PRICE is the price of bread (€/kg). The β_x coefficients can be read as the marginal utilities of each attribute of the utility function.

An RPL model was estimated using a dummy variable to point out differences in respondents' preferences. This dummy variable interacted with all the bread attributes included in the questionnaire, giving us the opportunity to verify the effect of information on respondents' choices. In detail, the following function was used to estimate the model:

$$U(x_i) = \text{OPT-OUT} + \Sigma\beta_i \cdot A_i + \Sigma\beta_i \cdot A_i \cdot LongInfo + \beta_{price} \cdot PRICE_i \quad (2)$$

where A is a vector of all attribute levels apart from price, β_x is a vector of the n − 1 attribute levels coefficients, LongInfo is the interaction dummy for the presence of long information, and β_{price} is the price coefficient.

The variables taken into consideration were dummy coded, with the exception of price levels, and five parameters (conventional breeding technique, GE technique, "00" white-flour, organic wheat, FVG Region for wheat origin and rest of the world for wheat origin) brought heterogeneity in interviewees' preferences. In the model specification, we assume that all the parameters, apart from price, are random and have a normal distribution.

Secondly, a Latent Class (LC) analysis was conducted to classify respondents according to their evaluation of product attributes when buying bread. In fact, unlike conventional logit models, in which consumers' preferences are assumed to be homogeneous, both LC and RPL models relax the assumption of homogeneity of preference, hence allowing for heterogeneity. However, while heterogeneity is accommodated as a continuous function of the parameters (i.e. they are random underlying some ex-ante specified distribution) in an RPL model, the LC model can be considered as a semi-parametric version of the previous model. Indeed, LC derives heterogeneity from a number of different classes or groups which are hypothesized to differ significantly in preferences but have homogeneous within-class preferences. The LC model utility function we used was similar to Equation (1), with the inclusion of additional parameters to better describe the class membership.

Both abovementioned methods were used in this study, as we were not able to draw any *a priori* observation on heterogeneity nor to assume whether the differences in preferences were antipodal among the respondents' classes. Consequently, taking into consideration the objective of this study, and according to Sagebiel (2011), both RPL and LC models were estimated (Boeri *et al.*, 2020; Yang, Hobbs, 2020).

The presence of the monetary attribute enabled the premium price, or WTP, to be obtained for each attribute level. In detail, by means of the RPL it is possible to estimate the average marginal WTP and the distribution of frequency of the individual marginal WTP. As the price coefficient and the coefficients of the attributes are estimated separately, the marginal WTP can be calculated:

$$WTP = - \beta / \beta_{price} \quad (3)$$

where the marginal WTP is the marginal willingness to pay to move from the omitted dummy level to a level of an attribute; β is the marginal utility of a level of an attribute; β_{price} is the marginal utility of money that is measured by the coefficient of the price attribute.

According to Train and Weeks (2005), when dealing with random parameter models, two different approaches can be applied to compute marginal WTP. The first, defined as in "preference-space", identifies the distribution of the parameters in the utility function and derives the marginal WTP using Equation 3, while in the second approach, which is defined in "WTP-space", the researcher specifies the distribution of the marginal WTP for each of the parameters in the utility function and then derives the coefficients. One great advantage of this second approach is to allow a certain degree of heterogeneity to be supposed in the monetary parameter (Meijer, Rouwendal, 2006) that, on the contray, is usually kept fixed (non-random) in preference-space models (Hoyos, 2010). However, the fit of the model in WTP space could not be as good as that of the corresponding model in preference space (Scarpa *et al.*, 2008; Train, Weeks, 2005). Because of the exploratory aim of this study, and after comparing the results of both approaches, we applied the former. The average premium price was calculated, which is useful in particular in a management context.

Given the aim of the research, interaction terms were added to the base model to test the effects of information. The RPL model was estimated using dummy variables to highlight the differences in preferences among respondents receiving different information. In detail, a dummy variable referring to the respondents that received the long information treatment was interacted with the bread attributes under analysis in the utility function used to estimate the model.

Only significant interactions were considered in the final model. The RPL model was chosen taking into consideration both the McFadden pseudo-R^2 and Akaike's information criterion. To investigate the relationship between premium price and quantity sold we used the RPL model, which gives the opportunity to analyze respondents' heterogeneity and their WTP for each attribute included in the CE.

Finally, we estimated an LC model to test whether information similarly affected groups of respondents.

4. RESULTS

A sample of 389 consumers was collected (Tab. 3). The share of female respondents was 55.3%, which is adequately similar to the general regional population (51.34%) (ISTAT, 2020). The sample includes all the relevant age classes, even though most respondents (40.2%) fall in the 24-44 years old class, overrepresented with respect to the regional figure (25.53% of population aged 18 and over) (ISTAT, 2020). Almost half of the respondents had a secondary educational level, while the figure for the general population is 37.8% (ISTAT, 2021). Interviewees were mainly employed (66%). Data collected among respondents using different treatments do not differ significantly (Tab. 3).

The majority of the sample preferred to eat bread (84.1%), while 7.5% declared their preference for breadsticks. 41.6% of respondents declared they regularly eat bread at meals, while 28.3% only occasionally eat it. Most respondents (93.6%) affirmed to be familiar with organic food, and half of the sample sometimes consumed it. With respect to GMOs, respondents who received the short (neutral) information treatment on biotechnologies did not develop different views from those of who received the long, negatively biased, information treatment, as summarized in Table 4.

Similarly, Table 5 shows that the two subsamples did not statistically differ in the identification and ranking of the main attributes through which they define food quality.

Tab. 3. Socioeconomic characteristics of the sample (n=389).

		Total		Long Info Treatment	Short Info Treatment
		n.	%	%	%
Gender	Female	215	*55.3*	*55.0*	*55.6*
	Male	174	*44.7*	*45.0*	*44.4*
Age class (years)	18-24	55	*14.1*	*13.2*	*15.0*
	25-34	80	*20.6*	*22.0*	*19.3*
	35-44	76	*19.6*	*21.4*	*17.9*
	45-54	68	*17.5*	*19.8*	*15.5*
	55-64	55	*14.1*	*11.0*	*16.9*
	65-74	39	*10.0*	*9.3*	*10.6*
	Over 74	16	*4.1*	*3.3*	*4.8*
Education level	Primary and lower secondary	52	*13.4*	*13.7*	*13.0*
	Secondary	190	*48.8*	*48.4*	*49.3*
	Graduate	147	*37.8*	*37.9*	*37.7*
Employment status	Employed	256	*65.8*	*69.8*	*62.3*
	Non-employed or retired	133	*34.2*	*30.2*	*37.7*

Source: our elaboration.

Tab. 4. Opinions on GM food.

Statement	Short info treatment Mean* (SD)	Long info treatment Mean* (SD)
GM food is good for the Italian economy	2.77 (1.21)	2.71 (1.20)
GM food is not good for you and your family	3.40 (1.20)	3.66 (1.17)
GM food is safe for your health and your family's health	2.68 (1.19)	2.37 (1.12)
GM food helps people in developing countries	3.13 (1.30)	3.00 (1.31)
GM food is safe for future generations	2.62 (1.11)	2.43 (1.08)
GM food benefits some people but puts others at risk	3.54 (1.22)	3.68 (1.21)
The development of GM food should be encouraged	2.62 (1.38)	2.51 (1.42)

* Results referred to a 4-point Likert scales (1 = "completely disagree", 4 = "completely agree").
Source: our elaboration.

Tab. 5. Most relevant food quality attribute.

Attribute	Short info treatment	Long info treatment
Organic production method	135 (*65.22%*)	118 (*64.83%*)
Conventional production method	45 (*21.74%*)	44 (*24.18%*)
GE technology	22 (*10.63%*)	18 (*9.89%*)
GM technology	5 (*2.41%*)	2 (*1.10%*)
Total	207 (*100%*)	182 (*100%*)

Source: our elaboration.

RPL and LC models were estimated and results are reported in Table 6 and 7.

The RPL model was estimated using the simulated maximum likelihood method with 1,000 Halton draws with all attributes but price being randomly and normally distributed. The price coefficient was modelled as a fixed parameter (Lusk *et al.*, 2003). The RPL model has a reasonably good fit (McFadden Pseudo R-squared = 0.32). All the coefficients are statistically significant (p<0.05), indicating that the attributes were important in determining bread purchase intentions among respondents. As anticipated, the price coefficient is negative and all the other signs are as expected.

The different information treatment employed in our study (i.e. long and short information treatment, including or omitting opinions about potential negative consequences of the use of GE) does not seem to provide useful knowledge on how information may influence respondents' purchase behaviours. Table 6 presents firstly the RPL model and WTPs without considering the effect of different information treatment. On average, consumers showed the highest WTP for conventional breeding techniques (€ 7.76/kg), even though WTP for GE is positive as well (€ 6.39/kg), followed by the local origin (i.e. Friuli Venezia Giulia Region) (€ 2.85/kg), and organic production of flour (€ 2.72/kg). Considering the effect of the different information provided, none of the variables that interacted with "long information" (i.e.

Tab. 6. RPL model results.

	Coeff.	WTP (€/kg)	95% Confidence Interval	
Random parameters in utility function				
Opt out	-1.620***			
Conventional practices	2.890***	7.76	4.72	13.68
GE	2.379***	6.39	3.80	11.44
00 Flour	-0.308*	-0.83	-1.37	0.23
Organic flour	1.014***	2.72	1.16	5.76
Other countries	2.497***	-6.71	-6.47	-7.17
Friuli Venezia Giulia Region	1.061***	2.85	1.53	5.41
Nonrandom parameters in utility function				
Price	-0.372***			
Heterogeneity in mean parameter: Variable				
Opt out x long information	-0.291			
Conventional practices x long information	-0.285			
GE x long information	0.088			
00 Flour x long information	-0.123			
Organic flour x long information	-0.037			
Other countries x long information	-0.511			
Friuli Venezia Giulia Region x long information	-0.071			
Derived standard deviations of parameter distribution				
	Coeff.			
Opt out	4.636***			
Conventional practices	2.386***			
GE	2.024***			
00 Flour	0.695***			
Organic flour	0.860***			
Other countries	2.788***			
Friuli Venezia Giulia Region	1.264***			

*** significant at the 99% level; ** significant at the 95% level; * significant at the 90% level; N = 2334; R-squared = 0.315; Log likelihood = -2216.14; Halton draws = 1000; Coeff. = estimated coefficient; WTP = willingness to pay.
Source: our elaboration.

Tab. 7. Latent class model statistics.

	LCM-2	LCM-3	LCM-4	LCM-5
LL	-2420.66	-2259.35	-2246.83	-2207.74
AIC	2.090	1.962	1.960	1.936
BIC	2.137	2.036	2.061	2.065
HQIC	2.108	1.989	1.997	1.983
McFadden pseudo R^2	0.252	0.302	0.306	0.318

Source: our elaboration.

information treatment including opinions about potential negative consequences deriving from the use of GE) was significant, meaning that the WTP of interviewees who received this information treatment is not statistically different from that of respondents who did not.

A three-latent class model was chosen as the best compromise between interpretability and the evaluation of the decrease in the Bayesian information criterion (BIC) and the Akaike information criterion (AIC), which are commonly used to evaluate model fit in LC analysis (Train, 2009) (Tab. 7). In addition, according to Nylund-Gibson and Choi (2018) and Pastor and Gagnè (2013), we took into consideration that a larger number of variables are statistically significant in the three-class model than in the four-class one, indicating that the former outperforms the latter. Furthermore, in line with the literature, additional criteria to select the optimal number of classes included, in concordance with a number of past studies, the statistical significance of the parameter estimates in each class and the number of observations in each class (Greene & Hensher, 2003; Pacifico & Yoo, 2012). The results of the three-cluster solution and the parameters for each segment are shown in Table 8.

LC model results highlight a differentiated set of preferences among respondents. The three-latent class model shows that the sample had heterogeneous preferences and respondents could be divided into classes, representing 57%, 22% and 21% average class probability respectively. Each class is characterized by a different structure of preferences. In detail, members of class one were more interested in GE (WTP € 10/kg) and concerned about "rest of the world" origin of wheat (negative WTP € -9.93/kg), moreover they gave importance to the organic certification (WTP € 4.73/kg), the local origin of wheat (WTP € 4.53/kg), and the use of conventional agricultural techniques (WTP € 4.4/kg). These respondents could be considered "GE food consumers". Members of class two gave more importance to cultivation techniques adopted for wheat. They preferred conventional wheat production (WTP € 9.23/kg), however they seemed to be also attracted by GE breeding technique (WTP € 7.31/kg). Consequently, they could be defined as "suggestible consumers". Regarding the origin of wheat, they preferred wheat produced in Friuli Venezia Giulia Region (WTP € 1.23/kg). Furthermore, considering the organic production attribute, members of this class preferred organic wheat (WTP € 2.15/kg) while whole-wheat flour decreased their utility (negative WTP € -2.23/kg).

Looking at class three, it is interesting to notice how the price coefficient was not statistically significant ($p > 0.05$). Members of this class who chose the most preferred alternatives among the proposed bread products seemed indifferent to this attribute while sensitive to all the others. We will refer to members of the third class as "price-insensitive consumers" because of their indifference to the specified price levels (Lanz and Provins, 2013). However, this class strongly preferred bread produced with conventional techniques, while the foreign origin of wheat ("rest of the world") provided negative utility. It is interesting to observe how the coefficient of whole-wheat flour for this class is positive, meaning that respondents' purchase decisions were positively influenced by this characteristic. Moreover, they preferred organic production.

In the attempt to better explain class probability, socio-demographic and behavioural variables were included in the LC model; however, we found that these were not generally significant in explaining the probability of class membership. We retained the most significant socio-demographic variable, which is "female". In detail, this variable had a negative coefficient relative to the second class. This result means that female respondents were much more likely to fall into the first or third latent class.

With respect to the two information treatments, the long information did not have any significant impact, and it is not statistically significant in any latent class. Consequently, apart from confirming heterogeneity in respondents' preferences for the proposed bread, the LC model analysis did not allow us to identify at least one group of respondents for which the different information treatment could be considered a characteristic of the preference heterogeneity.

The ASC was significant ($P < 0.05$) for all classes, but negative for classes one and two. For class three, the ASC was positive, meaning that there was a propensity among respondents to choose the opt out option.

5. DISCUSSION AND CONCLUSIONS

In spite of their different characteristics, approaches and results, biotechnologies are often considered as a whole in the public discourse. Even though the results of

Tab. 8. Three-LC model results.

Variable	Class 1		Class 2		Class 3	
	Coeff. (S.E.)	WTP (€/kg)	Coeff. (S.E.)	WTP (€/kg)	Coeff. (S.E.)	WTP (€/kg)
Opt out	-1.91 (0.30)***	/	-1.06 (0.28)***	/	4.97 (0.44)***	/
Price	-0.15 (0.06)**	/	-0.26 (0.07)***	/	-0.19 (0.14)	/
Conventional	0.66 (0.15)***	4.4	2.40 (0.15)***	9.23	4.52 (0.34)***	/
GE	1.50 (0.14)***	10	1.90 (0.20)***	7.31	2.43 (0.38)***	/
00 Flour	-0.18 (0.14)	/	-0.58 (0.15)***	-2.23	0.37 (0.20)*	/
Organic flour	0.71 (0.17)***	4.73	0.56 (0.22)**	2.15	0.92 (0.29)***	/
Other countries	-1.49 (0.19)***	-9.93	0.27 (0.18)	/	-2.12 (0.29)***	/
Friuli VG R.	0.68 (0.08)***	4.53	0.32 (0.13)**	1.23	1.22 (0.20)***	/
Average probability	*0.57*		*0.22*		*0.21*	
Long info	0.03 (0.27)		-0.50 (0.34)		0.00 (fixed parameter)	
Female	-0.27 (0.28)		-0.90 (0.34)***		0.00 (fixed parameter)	

*** significant at the 99% level; ** significant at the 95% level; * significant at the 90% level.
Source: our elaboration.

species selection through GE are not technically different from conventional breeding or random mutagenesis, civil society organizations raise doubts and questions on the safety of biotech food and on the ethical and moral consequences, as already happened with GMOs (Ishii, Araki, 2016).

Both public and private actors have a role to play in improving knowledge among citizens (Kolodinsky, Lusk, 2018), and experts in life and social sciences agree that the development and diffusion of GE critically depends on public understanding of the differences between these biotechnologies and conventional GM (Lassoued *et al.*, 2019). In this study, we contribute to this debate by investigating consumer knowledge and preferences towards GE and gene-edited food.

In order to verify the effect of information on consumers' preferences for GE, a CE was designed to measure WTP for GE bread. Respondents randomly received two different treatments of the survey, which included either a balanced or positively biased description of the GE technique and its impact. The analysis shows that participants who initially read the technical and balanced statement did not answer differently from those who read the biased description. These results are coherent with the findings from Wuepper *et al.* (2018). In addition, it seems that our findings could be considered coherent with Kolodinsky and Lusk (2018), who stated that providing simple information with no bias in either direction can actually improve consumer attitudes. The rift between civil society and the scientific community, in fact, suggests that consumers are not fully aware of newer biotechnologies (Busch *et al.*, 2021) and may not have fully developed their opinion on GE yet.

In the light of these considerations, the scientific community should cooperate to develop better communication and dissemination strategies, in order to clearly and effectively inform consumers and policymakers on what GE is, how it works, and how it differs from conventional GM. The public debate on GE is at an early stage: it is therefore the responsibility of the scientists, as laymen, to share knowledge for the society to comprehensively understand biotechnologies and interact with institutions and policymakers, and support them in the definition of rational and informed regulation (Bartkowski, Baum, 2019; Bechtold *et al.*, 2018; DeLong, Grebitus, 2018). While science alone cannot answer all the political and social questions linked to the introduction of new technologies (Johnson *et al.*, 2007), effective and factual communication is fundamental to integrate scientific knowledge in decision making (Sundin *et* *al*., 2018); nevertheless, it is the responsibility of politics to bridge scientific knowledge, values and beliefs in informed decision making (Guo *et al*., 2020; von Winterfeldt, 2013).

On the theoretical side, our study contributes to the literature by informing it with a NBTs' consumer preference and WTP perspective and providing an illustration of the lack of precise knowledge of these techniques among citizens. The literature has had considerable developments when it comes to GMOs, while only a few studies analyzed consumer preferences and WTP towards gene-edited food products. Moreover, to the best of our knowledge no studies have used CE to compare GE with other breeding techniques using different information treatments and identifying respondents' WTP.

Following on from the results, we can draw some key implications for producers and marketers. Our study highlights heterogeneous consumers' preferences for GE. Findings point out that a group of respondents were willing to pay a premium price for the GE technique, while another class of participants seemed to be disoriented. This evidence implicates the importance of carefully selecting the characteristics of the information proposition that are devoted to the different public segments. The latent class analysis denotes the existence of an important group of consumers willing to pay a premium price for food from GE varieties: this confirms the rising openness of Italian, and European, consumers towards the adoption of biotechnologies and their application in food science. This emerging niche market partly overlaps with the sustainable and organic food consumer segment. Taken together, these results suggest that producers and marketers willing to adopt GE varieties should adequately frame communication, in order to enhance the technological content of gene-edited food as well as its benefits in terms of food system sustainability.

However, a number of limitations of our study merit emphasis. Firstly, it seems to be important to extend the research to real consumers' behaviour to better understand their preferences. Moreover, it may be useful to extend this research to other states or regions. Our findings are relative to the specific case study, bread considered and panel interviewed we analyzed. It is therefore recommended to further investigate bread consumer preferences for GE wheat in different geographical contexts. In addition, since our study captures the marginal effects of the two information treatments it seems to be useful to extend the survey having a control group to better estimate the effects of information.

Despite the limitations of our study, we believe the results may have significant impacts. Our results add useful data to currently available literature on consumers' preferences towards GE food. In addition, our findings should be useful for farmers in areas where the development of GE food as niche market product can be an important element for the improvement of costs and benefits of the agricultural sector and therefore for the increase of its revenues. However, effective adoption of GE will largely depend on the evolution of public and political discourse.

REFERENCES

Aerni P. (2011). Do political attitudes affect consumer choice? Evidence from a large-scale field study with genetically modified bread in Switzerland. *Sustainability,* 3(9): 1555-1572. https://doi.org/10.3390/su3091555

Akerlof G.A. (1970). The market for lemons: quality uncertainty and the market mechanism. *Quarterly Journal of Economics,* 84: 488-500. https://doi.org/10.1007/978-1-349-24002-9_9

Anderson N.H. (1970). Functional measurement and psychophysical judgment. *Psychological Review,* 77: 153-170. https://doi.org/10.1037/h0029064

Bao A., Burritt D.J., Chen H., Zhou X., Cao D., Tran L.S.P. (2019). The CRISPR/Cas9 system and its applications in crop genome editing. *Critical Reviews in Biotechnology,* 39(3): 321-336. https://doi.org/10.1080/07388551.2018.1554621

Bartkowski B., Baum C.M. (2019). Dealing with rejection: An application of the exit-voice framework to genome-edited food. *Frontiers in Bioengineering and Biotechnology,* 7: 57. https://doi.org/10.3389/fbioe.2019.00057

Bawa A.S., Anilakumar K.R. (2013). Genetically modified foods: safety, risks and public concerns-a review. *Journal of Food Science and Technology,* 50(6): 1035-1046. https://doi.org/10.1007/s13197-012-0899-1

Bechtold S.N., Schleissing S., Dürnberger C. (2018). The GMO debate reloaded-a survey on genome editing in agriculture. In Professionals in food chains (pp. 71-103). Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-869-8_53

Beghin J.C., Gustafson C.R. (2021). Consumer valuation of and attitudes towards novel foods produced with new plant engineering techniques: A review. *Sustainability,* 13(20): 11348. https://doi.org/10.3390/su132011348

Bernard J.C., Zhang C., Gifford K. (2006). An experimental investigation of consumer willingness to pay for non-GM foods when an organic option is present. *Agricultural and Resource Economics Review,* 35(2): 374-385. https://doi.org/10.1017/S1068280500006808

Bertuol-Garcia D., Morsello C., El-Hani C.N., Pardini R. (2018). A conceptual framework for understanding the perspectives on the causes of the science-practice gap in ecology and conservation. *Biological Reviews,* 93(2): 1032-1055. https://doi.org/10.1111/brv.12385

Boeri M., Saure D., Schacht A., Riedl E., Hauber B. (2020). Modeling heterogeneity in patients' preferences for psoriasis treatments in a multicountry study: a comparison between random-parameters logit and latent class approaches. *PharmacoEconomics,* 38(6): 593-606. https://doi.org/10.1007/s40273-020-00894-7

Boone H.N., Boone D.A. (2012). Analyzing likert data. *Journal of Extension,* 50(2): 1-5.

Bredahl L. (2001). Determinants of consumer attitudes and purchase intentions with regard to genetically modified foods – Results of a cross-national survey. *Journal of Consumer Policy,* 24(1): 23-61. https://doi.org/10.1023/a:1010950406128

Brossard D., Belluck P., Gould F., Wirz C.D. (2019). Promises and perils of gene drives: Navigating the communication of complex, post-normal science. *Proceedings of the National Academy of Sciences,* 116(16): 7692-7697. https://doi.org/10.1073/pnas.1805874115

Busch G., Ryan E., von Keyserlingk M.A., Weary D.M. (2021). Citizen views on genome editing: effects of species and purpose. *Agriculture and Human Values,* 1-14. https://doi.org/10.1007/s10460-021-10235-9

Catacora-Vargas G., Binimelis R., Myhr A.I., Wynne B. (2018). Socio-economic research on genetically modified crops: a study of the literature. *Agriculture and Human Values,* 35(2): 489-513. https://doi.org/10.1007/s10460-017-9842-4

Christensen T., Denver S., Bøye Olsen S. (2020). Consumer preferences for organic food and for the shares of meat and vegetables in an everyday meal. *Journal of International Food & Agribusiness Marketing,* 32(3): 234-246. https://doi.org/10.1080/08974438.2019.1599758

Chyung S.Y., Roberts K., Swanson I., Hankinson A. (2017). Evidence-based survey design: The use of a midpoint on the Likert scale. *Performance Improvement,* 56(10): 15-23. https://doi.org/10.1002/pfi.21727

Court of Justice of the European Union. (2018). Judgment of the Court (Grand Chamber) of 25 July 2018. Available at: http://curia.europa.eu/juris/liste.jsf?language=en&td=ALL&num=C-528/16 (accessed on 4th October 2021).

De Marchi E., Cavaliere A., Banterle A. (2018). Consumer choice behavior for cisgenic food: exploring attribute processing strategies and the role of time preference. In 2018 Conference, July 28-August 2, 2018, Vancouver, British Columbia (No. 277393). International Association of Agricultural Economists. https://doi.org/10.22004/ag.econ.277393

DeLong K.L., Grebitus C. (2018). Genetically modified labeling: The role of consumers' trust and personality. *Agribusiness,* 34(2): 266-282. https://doi.org/10.1002/agr.21521

Delwaide A.C., Nalley L.L., Dixon B.L., Danforth D.M., Nayga Jr R.M., Van Loo E.J., Verbeke W. (2015). Revisiting GMOs: are there differences in European consumers' acceptance and valuation for cisgenically vs transgenically bred rice?. *PLoS One,* 10(5): e0126060. https://doi.org/10.1371/journal.pone.0126060

Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC. Available at: http://eur-lex.europa.eu/eli/dir/2001/18/oj (accessed on 4th October 2021).

Edenbrandt A.K., Gamborg C., Thorsen B.J. (2018). Consumers' preferences for bread: Transgenic, cisgenic, organic or pesticide-free?. *Journal of Agricultural Economics,* 69(1): 121-141. https://doi.org/10.1111/1477-9552.12225

European Commission (2017). New Techniques in Agricultural Biotechnology, Scientific Advice Mechanism (SAM). Available at: https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/group-chief-scientific-advisors/new-techniques-agricultural-biotechnology_en (accessed on 4th October 2021)

Food and Agriculture Organization of the United Nations (FAO) (2016). Climate change and food security: risks and responses. FAO: Rome.

Food and Agriculture Organization of the United Nations (FAO) (2017). The future of food and agriculture - trends and challenges. FAO: Rome.

Frewer L.J. (2017). Consumer acceptance and rejection of emerging agrifood technologies and their applications. *European Review of Agricultural Economics,* 44(4): 683-704. https://doi.org/10.1093/erae/jbx007

Friedrichs S., Takasu Y., Kearns P., Dagallier B., Oshima R., Schofield J., Moreddu C. (2019). Meeting report of the OECD conference on "Genome Editing: Applications in Agriculture-Implications for Health, Environment and Regulation". *Transgenic Research, 28*(3-4): 419-463. https://doi.org/10.1007/s11248-019-00154-1

Gao Z., Yu X., Li C., McFadden B.R. (2019). The interaction between country of origin and genetically modified orange juice in urban China. *Food Quality and Preference,* 71: 475-484. https://doi.org/10.1016/j.foodqual.2018.03.016

Garavaglia C., Mariani P. (2017). How much do consumers value protected designation of origin certifications? Estimates of willingness to pay for PDO dry-cured ham in Italy. *Agribusiness,* 33(3): 403-423. https://doi.org/10.1002/agr.21494

Gatica-Arias A., Valdez-Melara M., Arrieta-Espinoza G., Albertazzi-Castro F.J., Madrigal-Pana J. (2019). Consumer attitudes toward food crops developed by CRISPR/Cas9 in Costa Rica. *Plant Cell, Tissue and Organ Culture, (PCTOC)* 139(2): 417-427. https://doi.org/10.1007/s11240-019-01647-x

Guo Q., Yao N., Zhu W. (2020). How consumers' perception and information processing affect their acceptance of genetically modified foods in China: A risk communication perspective. *Food Research International,* 137: 109518. https://doi.org/10.1016/j.foodres.2020.109518

Greene W.H., Hensher D.A. (2003). A Latent Class Model for Discrete Choice Analysis:

Contrasts with Mixed Logit. *Transportation Research Part B,* 37(8): 681-698. https://doi.org/10.1016/S0191-2615(02)00046-2

Grunert K.G., Wills J.M. (2007). A review of European research on consumer response to nutrition information on food labels. *Journal of Public Health,* 15(5): 385-399. https://doi.org/10.1007/s10389-007-0101-9

Johnson K.L., Raybould A.F., Hudson M.D., Poppy G.M. (2007). How does scientific risk assessment of GM crops fit within the wider risk analysis?. *Trends in Plant Science,* 12(1): 1-5. https://doi.org/10.1016/j.tplants.2006.11.004

Halford N.G. (2019). Legislation governing genetically modified and genome-edited crops in Europe: the need for change. *Journal of the Science of Food and Agriculture,* 99(1): 8-12. https://doi.org/10.1002/jsfa.9227

Hammond K.R. (1955). Probabilistic functioning and the clinical method. *Psychological Review,* 62(4): 255-262. https://doi.org/10.1037/h0046845

Hartung F., Schiemann J. (2014). Precise plant breeding using new genome editing techniques: opportunities, safety and regulation in the EU. *The Plant Journal,* 78(5): 742-752. https://doi.org/10.1111/tpj.12413

Harvey J. (2018). Ethical Tensions from New Technology: The Case of Agricultural Biotechnology, CABI: Wallingford, U.K.

Hauber A.B., González J.M., Groothuis-Oudshoorn C.G., Prior T., Marshall D.A., Cunningham C., IJzerman M.J., Bridges J.F. (2016). Statistical methods for the analysis of discrete choice experiments: a report of the ISPOR Conjoint Analysis Good Research Practices Task Force. *Value in Health,* 19(4): 300-315. https://doi.org/10.1016/j.jval.2016.04.004

Helliwell R., Hartley S., Pearce W., O'Neill L. (2017). Why are NGOs sceptical of genome editing?: NGOs' opposition to agricultural biotechnologies is rooted in scepticism about the framing of problems and solutions, rather than just emotion and dogma. *EMBO Reports,* 18: 2090-2093. https://doi.org/10.15252/embr.201744385

Helliwell R., Hartley S., Pearce W. (2019). NGO perspectives on the social and ethical dimensions of plant genome-editing. *Agriculture and Human Values,* 36(4): 779-791. https://doi.org/10.1007/s10460-019-09956-9

Hess S., Lagerkvist C.J., Redekop W., Pakseresht A. (2016). Consumers' evaluation of biotechnologically modified food products: new evidence from a meta-survey. *European Review of Agricultural Economics,* 43(5): 703-736. https://doi.org/10.1093/erae/jbw011

Hoyos D. (2010). The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics,* 69(8): 1595-1603. https://doi.org/10.1016/j.ecolecon.2010.04.011

Hu W., Veeman M.M., Adamowicz W.L. (2005). Labelling genetically modified food: Heterogeneous consumer preferences and the value of information. *Canadian Journal of Agricultural Economics/Revue Canadienne d'Agroeconomie,* 53(1): 83-102. https://doi.org/10.1111/j.1744-7976.2005.04004.x

Hundleby P.A., Harwood W.A. (2019). Impacts of the EU GMO regulatory framework for plant genome editing. *Food and Energy Security,* 8(2): e00161. https://doi.org/10.1002/fes3.161

Ishii T., Araki M. (2016). Consumer acceptance of food crops developed by genome editing. *Plant cell reports*, 35(7), 1507-1518. https://doi.org/10.1007/s00299-016-1974-2

ISMEA (2016). AgrOsserva, III Trimester 2016, Unioncamere, November 2016.

ISTAT (2020). Popolazione per sesso, fasce d'età quinquennali e provincia. Available at: https://www.regione.fvg.it/rafvg/cms/RAFVG/GEN/statistica/SCHEDA2/ (accessed on 16th November 2021).

ISTAT (2021). Popolazione 15 anni e oltre per titolo di studio. Available at: http://dati.istat.it/Index.aspx?QueryId=26176 (accessed on 16th November 2021).

Johns R. (2005) One size doesn't fit all: Selecting response scales for attitude items. *Journal of Elections, Public Opinion and Parties,* 15(2): 237-264, https://doi.org/10.1080/136898805001788

Jouanin A., Gilissen L.J., Boyd L.A., Cockram J., Leigh F.J., Wallington E.J., van den Broeck H.C., van der Meer I.M., Schaart J.G., Visser R.G.F., Smulders M.J. (2018). Food processing and breeding strategies for coeliac-safe and healthy wheat products. *Food Research International,* 110: 11-21. https://doi.org/10.1016/j.foodres.2017.04.025

Kato-Nitta N., Inagaki Y., Maeda T., Tachikawa M. (2021). Effects of information on consumer attitudes towards gene-edited foods: a comparison between livestock and vegetables. *CABI Agriculture and Bioscience,* 2(1): 1-12. https://doi.org/10.1186/s43170-021-00029-8

Kherallah M., Kirsten J.F. (2002). The New Institutional Economics: Applications for agricultural policy research in developing countries. *Agrekon,* 41(2): 110-133. https://doi.org/10.1080/03031853.2002.9523589

Kim M.J., Kwak H.S., Lee M.J., Kim O.W., Kim H., Kim S.S., Jung H.Y. (2017). Consumer perception of bread depending on wheat origin in relation to physicochemical characteristics of wheat flour. *Emirates Journal of Food and Agriculture,* 29(5): 351-358. https://doi.org/10.9755/ejfa.ejfa-2016-08-1131

Kolodinsky J., DeSisto T. (2004). Influences of question wording on levels of support for genetically modified organisms. *International Journal of Consumer Studies,* 28(2): 154-167.

Kolodinsky J., Lusk J.L. (2018). Mandatory labels can improve attitudes toward genetically engineered food. *Science Advances,* 4(6): eaaq1413. https://doi.org/10.1126/sciadv.aaq1413

Krishna V., Qaim M., Zilberman D. (2016). Transgenic https://doi.org/10.1111/j.1470-6431.2004.00348.x crops, production risk and agrobiodiversity. *European Review of Agricultural Economics,* 43(1): 137-164. https://doi.org/10.2139/ssrn.2405466

Lancaster K.J. (1966). A new approach to consumer theory. *The Journal of Political Economy,* 74(2): 132-157. https://doi.org/10.1086/259131

Lancsar E., Fiebig D.G., Hole A.R. (2017). Discrete choice experiments: a guide to model specification, estimation and software. *PharmacoEconomics,* 35(7): 697-716. https://doi.org/10.1007/s40273-017-0506-4

Lanz B., Provins A. (2013). Valuing local environmental amenity with discrete choice experiments: Spatial scope sensitivity and heterogeneous marginal utility of income. *Environmental and Resource Economics,* 56(1): 105-130. https://doi.org/10.1007/s10640-013-9648-9

Lassoued R., Macall D.M., Hesseln H., Phillips P.W., Smyth S.J. (2019). Benefits of genome-edited crops: expert opinion. *Transgenic Research,* 28(2): 247-256. https://doi.org/10.1007/s11248-019-00118-5

Louviere J.J., Woodworth G. (1983). Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregate data. Journal of *Marketing Research,* 20(4): 350-367. https://doi.org/10.2307/3151440

Lucht J.M. (2015). Public acceptance of plant biotechnology and GM crops. *Viruses,* 7(8): 4254-4281. https://doi.org/10.3390/v7082819

Lusk J.L., House L.O., Valli C., Jaeger S.R., Moore M., Morrow J.L., Traill W.B. (2004). Effect of information about benefits of biotechnology on consumer acceptance of genetically modified food: evidence from experimental auctions in the United States, England, and France. *European Review of Agricultural Economics,* 31(2): 179-204. https://doi.org/10.1093/erae/31.2.179

Lusk J.L., Roosen J., Fox J.A. (2003). Demand for beef from cattle administered growth hormones or fed genetically modified corn: A comparison of consumers in France, Germany, the United Kingdom, and the United States. *American Journal of Agricultural Economics,* 85(1): 16-29. https://dx.doi.org/10.1111/1467-8276.00100

Maaß O., Consmüller N., Kehlenbeck H. (2019). Socioeconomic impact of genome editing on agricultural value chains: the case of fungal-resistant and coeliac-safe wheat. *Sustainability,* 11(22): 6421. https://doi.org/10.3390/su11226421

Malyska A., Bolla R., Twardowski T. (2016). The role of public opinion in shaping trajectories of agricultural biotechnology. *Trends in Biotechnology,* 34(7): 530-534. https://doi.org/10.1016/j.tibtech.2016.03.005

McFadden B.R., Lusk J.L. (2016). What consumers don't know about genetically modified food, and how that affects beliefs. *The FASEB Journal,* 30(9): 3091-3096. https://doi.org/10.1096/fj.201600598

McFadden B.R., Smyth S.J. (2019). Perceptions of genetically engineered technology in developed areas. *Trends in Biotechnology,* 37(5): 447-451. https://doi.org/10.1016/j.tibtech.2018.10.006

McFadden D. (1974). Conditional logit analysis of qualitative choice behaviour. S. 105-142. In P. Zarembka (Ed.), Frontiers in econometrics. New York: Academic Press.

Meijer E., Rouwendal J. (2006). Measuring welfare effects in models with random coefficients. *Journal of Applied Economics,* 21(2): 227-244. https://doi.org/10.1002/jae.841

Morgante M., Di Gaspero G. (2017). Dalla trans-genesi alla cis-genesi e al genome editing. In Galbiati M., Gentile A., La Malfa S., Tonelli C. (2017). Biotecnologie Sostenibili-Scienza e innovazione in agricoltura per affrontare le sfide della sicurezza alimentare e della sostenibilità ambientale. Edagricole: Milano.

Muringai V., Fan X., Goddard E. (2020). Canadian consumer acceptance of gene-edited versus genetically modified potatoes: A choice experiment approach. *Canadian Journal of Agricultural Economics/Revue Canadienne d'Agroeconomie,* 68(1): 47-63. https://doi.org/10.1111/cjag.12221

Myers S.S., Smith M.R., Guth S., Golden C.D., Vaitla B., Mueller N.D., Dangour A.D., Huybers P. (2017). Climate change and global food systems: potential impacts on food security and undernutrition. *Annual Review of Public Health,* 38: 259-277. https://doi.org/10.1146/annurev-publhealth-031816-044356

Nasir V.A., Karakaya F. (2014). Underlying motivations of organic food purchase intentions. *Agribusiness,* 30(3): 290-308. https://doi.org/10.1002/agr.21363

Nelson P. (1970). Information and consumer behavior. *Journal of political economy*, 78(2): 311-329. https://doi.org/10.1086/259630

Nylund-Gibson, K., Choi, A.Y. (2018). Ten frequently asked questions about latent class analysis. *Translational Issues in Psychological Science,* 4(4): 440-461. https://psycnet.apa.org/doi/10.1037/tps0000176

Oehler A., Wendt S. (2017). Good consumer information: The Information Paradigm at its (dead) end? *Journal of Consumer Policy,* 40(2): 179-191. https://doi.org/10.1007/s10603-016-9337-5

Oliveira P.R.S., Silveira J.M.F.D., Bullock D.S. (2020). Innovation in GMOs, technological gap, demand lag, and trade. *Agribusiness,* 36(1): 37-58. https://doi.org/10.1002/agr.21622

Østerberg J.T., Xiang W., Olsen L.I., Edenbrandt A.K., Vedel S.E., Christiansen A., Landes X., Andersen M.M., Pagh P., Sandøe P., Nielsen J., Christensen S.B., Thorsen B., Kappel K., Gamborg C., Palmgren M. (2017). Accelerating the domestication of new crops: feasibility and approaches. *Trends in Plant Science,* 22(5): 373-384. https://doi.org/10.1016/j.tplants.2017.01.004

Öz B., Unsal F., Movassaghi H. (2018). Consumer attitudes toward genetically modified food in the United States: Are Millennials different?. *Journal of Transnational Management*, 23(1): 3-21. https://doi.org/10.1080/15475778.2017.1373316

Pacifico D., Yoo H.I. (2012). A Stata Module for Estimating Latent Class Conditional Logit Models via the Expectation Maximization Algorithm. Australian School of Business Research

Paper, 2012-ECON 49. University of New South Wales, Sydney.

Pastor D.A., Gagné P. (2013). Mean and Covariance Structure Mixture Models. In: G.R. Hancock, R.O. Mueller (Eds.), Structural Equation Modeling: A Second Course (Second edition, pp. 343-393). Greenwich, CT: Information Age Publishing.

Pecl G.T., Araújo M.B., Bell J.D., Blanchard J., Bonebrake T.C., Chen I.C., Clark T.D., Colwell R.K., Denielsen F., Evengard B., Falconi L., Ferrier S., Frusher S., Garcia R.A., Griffis R.B., Hobday A.J., Janion-Scheepers C., Jarzynna M.A., Jennings S., Lonoir J., Linnetved H.I., Martin V.Y., Mccormack P.C., Mcdonald J., Mitchell N.J., Mustonen T., Pandolfi J.M., Pettorelli N., Popova E., Robinson S.A., Sheffers B.R., Shawcascade J.D., Sorte J.B., Strugnell J.M., Wapstra E., Williams S.E. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science,* 355(6332): eaai9214. https://doi.org/10.1126/science.aai9214

Pellegrini P., Fernández R.J. (2018). Crop intensification, land use, and on-farm energy-use efficiency during the worldwide spread of the green revolution. *Proceedings of the National Academy of Sciences,* 115(10): 2335-2340. https://doi.org/10.1073/pnas.1717072115

Pigford A.A.E., Hickey G.M., Klerkx L. (2018). Beyond agricultural innovation systems? Exploring an agricultural innovation ecosystems approach for niche design and development in sustainability transitions. *Agricultural Systems,* 164: 116-121. https://doi.org/10.1016/j.agsy.2018.04.007

Purugganan, M.D. (2019). Evolutionary insights into the nature of plant domestication. *Current Biology,* 29(14): R705-R714. https://doi.org/10.1016/j.cub.2019.05.053

Raley M.E., Ragona M., Sijtsema S.J., Fischer A.R., Frewer L.J. (2016). Barriers to using consumer science information in food technology innovations: An exploratory study using Delphi methodology. *International Journal of Food Studies,* 5(1). https://doi.org/10.7455/ijfs/5.1.2016.a4

Ricroch A. (2019, August). Global developments of genome editing in agriculture. *Transgenic Research,* 28(2): 45-52. https://doi.org/10.1007/s11248-019-00133-6

Rossi P.H., Wright J.D., Anderson A.B. (Eds.). (2013). Handbook of Survey Research. Academic Press.

Ryffel G.U. (2017). I have a dream: organic movements include gene manipulation to improve sustainable farming. *Sustainability,* 9(3): 392. https://doi.org/10.3390/su9030392

Sagebiel J. (2011). Comparing the Latent Class Model with the Random Parameters Logit - A Choice Experiment analysis of highly heterogeneous electricity consumers in Hyderabad, India. Paper presented at the International Choice Modelling Conference 2011, July 04–06, 2011 in Leeds, UK.

Scarpa R., Thiene M., Train K. (2008). Utility in willingness to pay space: a tool to address confounding random scale effects in destination choice to the Alps. *American Journal of Agricultural Economics,* 90(4): 994-1010. https://doi.org/10.1111/j.1467-8276.2008.01155.x

Schäfer M.S. (2017). How changing media structures are affecting science news coverage. In Jamieson K.H., Kahan D., Scheufele D.A. (Eds.). The Oxford Handbook of the Science of Science Communication, Oxford: *Oxford University Press,* 51-57. https://doi.org/10.1093/oxfordhb/9780190497620.013.5

Shew A.M., Nalley L.L., Snell H.A., Nayga Jr R.M., Dixon B.L. (2018). CRISPR versus GMOs: Public acceptance and valuation. *Global Food Security,* 19: 71-80. https://doi.org/10.1016/j.gfs.2018.10.005

Slovic P., Finucane M., Peters E., MacGregor D.G. (2002). Rational actors or rational fools: Implications of the affect heuristic for behavioral economics. *The Journal of Socio-Economics,* 31(4): 329-342. https://doi.org/10.1016/s1053-5357(02)00174-9

Son E., Lim S.S. (2021). Consumer acceptance of gene-edited versus genetically modified foods in Korea. *International Journal of Environmental Research and Public Health,* 18(7): 3805. https://doi.org/10.3390/ijerph18073805

Sundin A., Andersson K., Watt R. (2018). Rethinking communication: integrating storytelling for increased stakeholder engagement in environmental evidence synthesis. *Environmental Evidence,* 7(1): 1-6. https://doi.org/10.1186/s13750-018-0116-4

Thach E.C., Olsen J.E. (2006). Market segment analysis to target young adult wine drinkers. *Agribusiness,* 22(3): 307-322. https://doi.org/10.1002/agr.20088

Tagliabue G. (2016). The necessary "GMO" denialism and scientific consensus. *Journal of Science Communication,* 15(4): Y01. https://doi.org/10.22323/2.15040401

Train K.E. (2009). Discrete Choice Methods with Simulation. Cambridge: Cambridge University Press.

Train K., Weeks M. (2005). Discrete Choice Models in Preference Space and Willingness-to-Pay Space. In Scarpa R., Alberini A. (Eds.). Applications of Simulation Methods in Environmental and Resource Economics. Springer Netherlands, 6: 1-16.

Valente M., Chaves C. (2018). Perceptions and valuation of GM food: A study on the impact and importance of information provision. *Journal of Cleaner Production,* 172: 4110-4118. https://doi.org/10.1016/j.jclepro.2017.02.042

Vittersø G., Tangeland T. (2015). The role of consumers in transitions towards sustainable food consumption. The case of organic food in Norway. *Journal of Cleaner Production,* 92: 91-99. https://doi.org/10.1016/j.jclepro.2014.12.055

Von Winterfeldt D. (2013). Bridging the gap between science and decision making. *Proceedings of the National Academy of Sciences,* 110(Supplement 3): 14055-14061. https://doi.org/10.1073/pnas.1213532110

Yang Y., Hobbs J.E. (2020). Food values and heterogeneous consumer responses to nanotechnology. *Canadian Journal of Agricultural Economics/Revue Canadienne d'Agroeconomie,* 68(3): 289-313. https://doi.org/10.1111/cjag.12225

Wasmer M., Robienski J. (2018). Which organisms and technologies fall under the mutagenesis exemption of the European GMO-Directive? *Journal of Consumer Protection and Food Safety,* 13(3): 323-327. https://doi.org/10.1007/s00003-018-1166-9

Weems G.H., Onwuegbyzie A.J. (2001). The impact of midpoint responses and reverse coding on survey data. *Measurement and Evaluation in Counseling and Development,* 34(3): 166-176. https://doi.org/10.1080/07481756.2002.12069033

Welsch H., Kühling J. (2010). Pro-environmental behavior and rational consumer choice: Evidence from surveys of life satisfaction. *Journal of Economic Psychology,* 31(3): 405-420. https://doi.org/10.1016/j.joep.2010.01.009

Welsh I., Wynne B. (2013). Science, scientism and imaginaries of publics in the UK: Passive objects, incipient threats. *Science as Culture,* 22(4): 540-566. https://doi.org/10.1080/14636778.2013.764072

Wolfe E., Popp M., Bazzani C., Nayga Jr R.M., Danforth D., Popp J., Chen P., Seo H.S. (2018). Consumers' willingness to pay for edamame with a genetically modified label. *Agribusiness,* 34(2): 283-299. https://doi.org/10.1002/agr.21505

Wuepper D., Wree P., Ardali G. (2018). Does information change German consumers' attitudes about genetically modified food? *European Review of Agricultural Economics,* 46(1): 53-78. https://doi.org/10.1093/erae/jby018