

Drivers and necessary conditions for the purchase intention of Genetically Modified Food among older consumers in Spain

Jorge de Andrés-Sánchez^a, María Puelles-Gallo^b, Mar Souto-Romero^c & Mario Arias-Oliva^b

ABSTRACT: This study analyses purchase intention toward genetically modified foods among older Spanish consumers (Generation X and Baby Boomers) using the TRA framework and a sample of 248 respondents. PLS-SEM results ($R^2 = 0.71$) show that subjective norms have the strongest positive effect, perceived usefulness also has a positive impact, and perceived risk has a negative effect. Perceived value influences intention indirectly through usefulness, while sociodemographic variables are not significant. NCA findings identify perceived usefulness and perceived value as necessary conditions for achieving high purchase intention.

Impulsores y condiciones necesarias de la intención de compra de Alimentos Modificados Genéticamente entre consumidores mayores en España

RESUMEN: El estudio analiza la intención de compra de alimentos modificados genéticamente en consumidores españoles mayores (Generación X y Baby Boomers) mediante el modelo TRA y una muestra de 248 personas. Con PLS-SEM ($R^2=0,71$) se observa que las normas subjetivas influyen positivamente con mayor fuerza, la utilidad percibida también impacta positivamente y el riesgo percibido lo hace negativamente. El valor percibido actúa de forma indirecta a través de la utilidad. Las variables sociodemográficas no resultan significativas. El NCA identifica la utilidad y el valor percibidos como condiciones necesarias para una alta intención de compra.

KEYWORDS / PALABRAS CLAVE: Genetically modified food, Partial least squares-structural equation modelling (PLS-SEM), Necessary Condition Analysis (NCA), Theory of Reasoned Action (TRA) / Alimentos modificados genéticamente, Partial least squares-structural equation modelling (PLS-SEM), Análisis de Condición Necesaria (NCA), Theory of Reasoned Action (TRA).

JEL Classification / Clasificación JEL: C12, M31, Q13, Q16.

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1. Introduction

The late-20th-century surge in food technology innovation gave rise to novel approaches to producing and processing food, including genetically modified organisms (GMOs), which enable the production of genetically modified foods (GMFs) (Inbar *et al.*, 2020). GMOs can be defined as living organisms whose genetic composition has been modified through techniques that would not naturally occur via reproduction or recombination (WHO, 2014). This study focuses exclusively on GMFs and does not examine gene-edited foods produced through techniques such as CRISPR. Although the current EU regulatory framework treats gene-edited foods in the same way as GMFs, their regulatory status remains under debate and may evolve in the future (Goodman, 2024).

GMFs offer numerous benefits such as enhancing the resistance of organisms to pests, diseases, and extreme weather conditions, which in turn increases the yield and productivity of agricultural enterprises (Bratlie *et al.*, 2019). Furthermore, GMFs can be engineered to improve their nutritional content by enhancing essential nutrients such as vitamins and proteins (Vega Rodríguez *et al.*, 2022). Genetic modification techniques also help to extend the shelf life of food products (Muringai *et al.*, 2020). Consequently, GMFs offer a reliable response to the pressing necessities of the 21st century by addressing food shortages through higher production efficiency, enhanced nutritional content, and more sustainable agricultural practices (Bongoni, 2016).

Despite these potential benefits of GMFs, negative perceptions from public organisations and citizens are widely observed worldwide (Goodman, 2024), and this hesitation is particularly strong in the European Union (Borrello *et al.*, 2021). Despite the fact that existing research has not identified negative repercussions on people's health, GMFs are still associated with potential dangers, including unforeseen genetic consequences, the creation of toxins, or heightened allergenic potential (Vega Rodríguez *et al.*, 2022). However, environmental concerns appear to be more justified, highlighting the impact on biodiversity, disruption of the food chain, and genetic contamination (Vega Rodríguez *et al.*, 2022). Also, ideological and religious reasons have been identified (Montesinos-López *et al.*, 2016), alongside broader consumer concerns such as distrust in institutions, perceived lack of naturalness, and limited familiarity with biotechnology (Kolkur *et al.*, 2024).

It is worth noting that intergenerational studies on food preferences often reveal substantial differences between older and younger generations in the factors that guide food-related decisions, a pattern that also extends to GMFs (Ramadan *et al.*, 2024). For instance, a study conducted in Poland found clear differences in attitudes toward food technologies between older and younger consumers (Makowska *et al.*, 2024). In Switzerland, Baby Boomers and Generation X show relatively homogeneous consumption patterns, with the strongest differences emerging only when compared with younger cohorts (Mann & Loginova, 2023). Similarly, research conducted in China by Chen *et al.* (2024) identified numerous commonalities in food

preferences among Generations Y and Z, suggesting a generational convergence among younger consumers. Ogundijo *et al.* (2022) noted that age is likely a more relevant sociodemographic variable in explaining the purchase intention of certain types of food than others, such as income or educational level. Furthermore, Makowska *et al.* (2024) found that, in the context of sustainable food choices, people belonging to X generation and older prefer food quality, whereas younger generations place greater emphasis on price.

Although older demographic groups are becoming increasingly prominent and economically influential, their potential remains underestimated in both marketing practice and academic research. As Bui (2022) notes, the growing number of ageing consumers and their rising engagement with digital platforms present a substantial opportunity for targeting the grey market, yet this segment continues to be undervalued by marketers and marketing scholars alike.

This study is motivated by the considerations outlined above. Accordingly, this research aims to analyse the determinants of purchase intention (PI) for genetically modified foods in a sample of 248 Spanish consumers aged 45 and older, belonging to Generation X and the Baby Boomer cohort. To achieve the aims of this study, we follow a twofold analytical strategy. First, we evaluate the explanatory power of a framework based on Theory of Reasoned Action (TRA) for purchase intention by identifying its principal antecedents using partial least squares structural equation modelling (PLS-SEM), adopting a net-effects perspective. Second, we assess whether shortfalls in specific predictors constitute bottlenecks that preclude the outcome regardless of other favourable drivers, applying Necessary Condition Analysis (NCA).

This paper contributes in three ways. First, although several studies –both earlier (Costa-Font *et al.*, 2008; Costa-Font & Gil, 2009) and more recent (Andrés-Sánchez *et al.*, 2025a)– have examined GMFs purchase intention in Spain, they refer to the general population. While some recent works focus on younger cohorts (Generations Y and Z) (Andrés-Sánchez *et al.*, 2025b), no Spain-specific evidence exists for older consumers (≥ 45 years). This gap is unsurprising, as research on older consumers tends to be more fragmented and less systematic, whereas the behaviour of younger consumers has been far more extensively investigated, particularly in marketing, innovation, and technology contexts where older groups remain underrepresented (Hettich *et al.*, 2018).

Although the primary aim of this study is to examine the determinants of purchase intention among older consumers in Spain, we additionally conduct an exploratory multigroup analysis (Baby Boomers vs. Generation X) to evaluate whether the proposed TRA-based model operates similarly across these two cohorts.

Likewise, drawing on TRA, we focus on attitudinal drivers and a normative driver as key antecedents of purchase intention. Methodologically, we combine PLS-SEM

with NCA to assess both net effects and necessary conditions for adoption. While regression-based approaches –typically structural equation models– are common in GMFs purchase intention research (Alalwan *et al.*, 2023; Andrés-Sánchez *et al.*, 2025a; Costa-Font & Gil, 2009; Marín-Díaz *et al.*, 2024; Safi-Sis *et al.*, 2022), the use of NCA remains, to our knowledge, non-existent, despite its potential to provide valuable complementary insights. Factors that are sufficient for adoption may not necessarily be necessary, and vice versa.

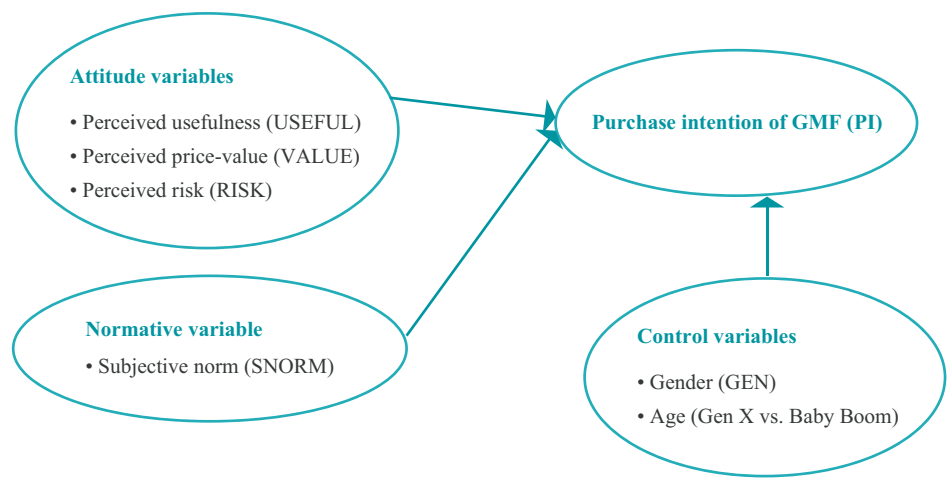
2. Theoretical framework

2.1. General overview of the theoretical ground

The approach presented in this study, illustrated in Figure 1, can be understood as a modified version of TRA. This theory is grounded in the seminal work of Fishbein (1967) and was explicitly formalized by Ajzen & Fishbein (1980), as later discussed by Ajzen (2012). Within this framework, PI is identified as the primary antecedent of actual behaviour. The theory emphasizes two key determinants of PI: attitude and subjective norm, both of which are based on belief structures–behavioural beliefs regarding the expected consequences of an action and normative beliefs concerning others’ expectations about performing that behaviour (Ajzen, 1991).

FIGURE 1

TRA-based explanatory ground of purchase intention of GMF



Source: Own elaboration.

Although genetically modified foods can be authorised for human consumption in the European Union –following a case-by-case safety assessment by EFSA and formal approval at EU level, with all authorised genetically modified products publicly listed and subject to mandatory labelling when the GM content exceeds 0.9 % per ingredient (Delgado-Zegarra *et al.*, 2022)– their actual market availability in the EU remains extremely limited. This restriction is largely driven by the disincentivising effect of the regulatory and commercial process, the perceived “negative image” associated with GMFs labelling among consumers, and the broader adverse market consequences this entails, such as reduced consumer acceptance and retailer reluctance to stock GM-labelled products (Goodman, 2024). Consequently, most European consumers, including those in Spain, are not regularly or directly exposed to GM foods in their daily food purchases. Instead, exposure occurs mainly indirectly, through the consumption of meat and dairy products derived from animals fed with genetically modified feed, or among individuals who actively seek specialised information or niche products. For this reason, focusing on purchase intention rather than observed behaviour is theoretically justified, as real-world opportunities to purchase GM foods in the EU context are scarce despite their legal authorisation.

Attitude ultimately reflects individuals’ perceptions of the positive and negative consequences associated with a specific action (Ajzen, 1991). Within TRA, it represents the aggregation of beliefs about the likely positive outcomes of the behaviour under consideration (Fishbein & Ajzen, 1975). These evaluations are formed by combining the perceived probability that each outcome will occur with the value assigned to that outcome; some studies suggest that, in certain cases, individuals rely on an average rather than a weighted sum when forming such judgments (Fishbein & Ajzen, 1975). In the context of biotechnology-derived foods, these behavioural evaluations frequently revolve around dimensions such as health, price, risk or sustainability (Jin *et al.*, 2022).

Attitude is often measured as a construct using simple evaluative items –e.g., bad idea/good idea, unpleasant/pleasant, regressive/progressive, or foolish/wise (e.g., Ajzen, 2006; Bhattacharjee & Premkumar, 2004). However, we understand that constructs that shape these underlying evaluations and that have been used in prior research may also be meaningfully incorporated within this attitudinal rubric, provided they are embedded in a structured behavioural theory. In our model, positive evaluations are mainly represented by perceived usefulness and perceived value, whereas negative evaluations are primarily reflected in perceived risk (Safi-Sis *et al.*, 2022; Marín-Díaz *et al.*, 2024). Thus, if GMFs are perceived as useful because they provide specific nutritional or functional benefits, their purchase may be evaluated as wise and good; conversely, if GMFs are perceived as risky, their consumption is judged as foolish and bad.

The subjective norm has been consistently shown to exert a decisive influence on food-related decision-making (Wolstenholme *et al.*, 2021). In the case of genetically modified foods (GMFs), factors shaping subjective norms include social beliefs –

whether supported by scientific evidence or not— concerning the safety, ethics, and desirability of GMFs (Kubisz *et al.*, 2021).

TRA later evolved into the Theory of Planned Behaviour (TPB) (Ajzen, 2012), which introduced the construct of perceived behavioural control. This variable refers to beliefs about resources and obstacles that can facilitate or interfere with the performance of a given behaviour (Ajzen, 1991). However, the present study does not include any construct related to this factor. This omission is justified by the fact that, in Spain, the limited availability of GMFs applies uniformly across the population, meaning that opportunities for purchasing or consuming such foods are equally restricted. Therefore, behavioural control is expected to be homogeneous among individuals and non-discriminant in explaining differences in PI. Furthermore, unless specifically sought out, GMFs are not different in appearance and flavour from their conventional counterparts (Boccia *et al.*, 2018). Likewise, the preparation and cooking processes required for GMFs do not differ from those used for conventional foods, implying that the effort, time, and skills involved in their consumption are essentially identical. In fact, for certain products –such as canola oil– genetic modification is designed to reduce negative outcomes associated with commonly used methods in conventional food preparation such as high-temperature cooking (Warda *et al.*, 2025). Consequently, no additional constraints or facilitators are expected to arise from the handling or preparation of GMFs that could influence consumers' perceived behavioural control.

2.2. Hypothesis development about attitude variables

Perceived usefulness

The perceived usefulness (USEFUL) of GMFs is one of the most frequently cited variables in the literature for explaining PI (Ramadan *et al.*, 2024). The development of GMOs reduces dependence on artificial pesticides, thus mitigating their corresponding environmental externalities. Additionally, GMOs can be produced under extreme conditions, both in low-quality soils and in the absence of water, enabling more sustainable production to adapt to climate change (Kubisz *et al.*, 2021).

A key factor to understand food consumption choices is that food products have good nutritional properties (Darian & Tucci, 2011). GMFs can be designed to enhance this aspect by developing varieties with added essential nutrients (e.g., vitamins). In this regard, “golden rice” is a clear example (Dubock, 2019).

Therefore, we propose:

Hypothesis 1 (H1). *A higher level of perceived usefulness leads to a higher level of purchase intention of GMFs.*

Perceived risk

Risk perception (RISK) is an essential factor in explaining consumer rejection of GMFs (Costa-Font *et al.*, 2008). Although no evidence has shown that GMFs have more negative effects than conventional foods (Vega Rodríguez *et al.*, 2022), there is widespread belief that their consumption may have adverse consequences for health and the environment (Montesinos-López *et al.*, 2016). A common belief in relation to GMFs consumption is that it may produce cancer (Kubisz *et al.*, 2021), and the perception of this risk is a fundamental criterion in food consumption decision-making (Darian & Tucci, 2011).

Some authors argue that the risk associated with GMFs consumption may be overestimated compared to other circumstances with objectively higher risks, such as food additives (Zhao *et al.*, 2023). Thus, we propose:

Hypothesis 2 (H2). *A higher level of perceived risk leads to a lower level of purchase intention of GMFs.*

Perceived value

The concept of perceived value (VALUE) of GMFs can be defined as the relationship between the utility or benefits that a customer perceives in a product and the money or other costs that must be paid to obtain it (Zeithaml, 1988). As long as consumers perceive that the use of GMFs offers more benefits and utility than the cost paid, they will perceive greater value, and consequently, will have a positive perception of GMFs (Alalwan *et al.*, 2023).

One of the main benefits of GMOs is increased productivity in their production, as they can be engineered to withstand pests, pathogens, and harsh environmental stresses, enabling farmers to obtain greater crop yields with reduced resource input. This, in turn, supports food security in areas facing agricultural constraints and helps make food more accessible and affordable (Kiran *et al.*, 2023).

Literature shows that higher perceived customer value, derived from functional benefits such as excellence and efficiency, enhances the perception of product usefulness by reinforcing the evaluation that the benefits obtained outweigh the sacrifices made (Blut *et al.*, 2024). Thus, a favourable price–value perception – meaning a lower price for GMFs compared to their conventional counterparts – can positively influence PI through a greater appreciation of their perceived benefits (Zheng *et al.*, 2023), as the properties of the conventional version of the food are enhanced by the favourable effect of a lower price.

In the case of Spanish households, food accounts for approximately 20 % of the family budget (INE, 2022). Therefore, a more favourable price–quality relationship implies either a reduction in the financial burden of food consumption for a given

quality level or, conversely, access to higher-quality food (e.g., organic or better-tasting products) within the same budget. In both cases, the perceived value of the product, following unidimensional conceptions of consumer value, entails that greater value leads to greater perceived usefulness, as value is directly associated with the functional and economic utility of the products (Sánchez-Fernández & Iniesta-Bonillo, 2007).

Therefore, we propose:

Hypothesis 3 (H3). *A higher level of perceived value leads to a higher level of perceived usefulness for GMFs.*

2.3. Hypothesis development about subjective norm

Subjective norm (SNORM) is the feeling about the existence of social pressure to perform a specific behaviour to be seen as desirable (Ajzen, 1991). Therefore, when individuals believe that their immediate social circles approve of or consume certain foods, they are more inclined to develop favourable attitudes toward those foods in order to conform to group behaviour (Wolstenholme *et al.*, 2021). This relevance of SNORM is more evident in GMFs, where customers are subject to a lack of knowledge of how they are produced and the non-existence of scientific reports about negative outcomes (Siegrist, 2008).

Moral, economic, and sustainability issues affect societies' beliefs about GMFs (Hingston & Noseworthy, 2018). Some individuals are concerned that genetically modified foods (GMFs) primarily advantage large agribusiness corporations by fostering seed monopolies and raising production costs for farmers (Lucht, 2015). Concerns have also been raised about the possible consequences for biodiversity, including the unintended transfer of genes to wild species or the emergence of pest and weed immunity (Vega Rodríguez *et al.*, 2022). Therefore, we propose:

Hypothesis 4a (H4a): *A higher level of favourable subjective norms toward GMFs leads to a higher level of purchase intention for GMFs.*

Likewise, people usually rely on social norms in their food decision making since they provide crucial information about suitability of a food or dietary practice (Günden *et al.*, 2024). In other words, the influence of SNORM on PI is partially mediated by the perception of usefulness and risk, shaping awareness of health and environmental concerns related to GMFs consumption (Hui *et al.*, 2024).

It is also relevant to mention that one variable contributing to SNORM formation is information from external sources, such as educational institutions, media, and government, which influences the perception of usefulness and risk (Zhou *et al.*, 2022). As users place greater trust in the institutions providing this information, their perception of GMFs' usefulness will increase, while their perception of risks decreases (Rodríguez-Entrena & Salazar-Ordoñez, 2013).

In the field of technology acceptance research, models such as the Technology Acceptance Model (TAM) (Davis, 1989) and its extension TAM2 (Venkatesh & Davis, 2000) explicitly propose that SNORM influences PI both directly and indirectly through perceived usefulness. A favourable social influence toward a technological innovation tends to foster a higher perception of its usefulness in the individual adopting it (Venkatesh & Davis, 2000).

Therefore, it can be deduced that social pressure highlighting the potential negative outcomes of a product is likely to increase the perception of risk associated with it. This argument can be supported by anthropological and sociological literature, which posits that risk perceptions are not merely individual judgments but are also socially constructed and institutionally reinforced. From this perspective, perceptions of risk arise through the interaction between social institutions, cultural values, and lifestyles (Wildavsky & Dake, 1990).

Therefore, we propose:

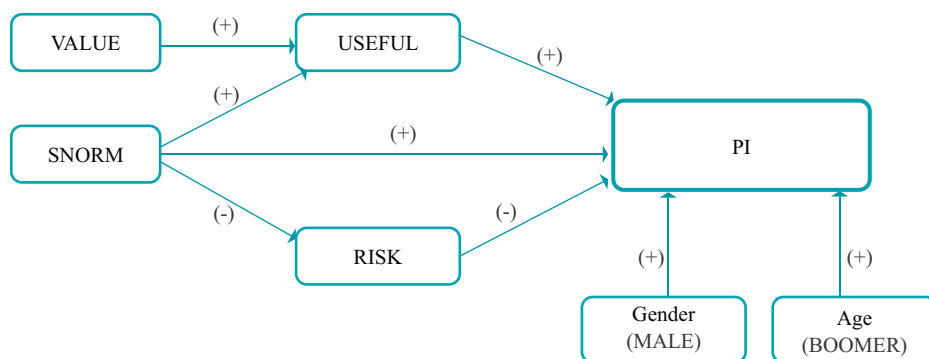
Hypothesis 4b (H4b). *A higher level of favourable subjective norms toward GMFs consumption leads to a higher perception of usefulness.*

Hypothesis 4c (H4c). *A higher level of favourable subjective norms toward GMFs consumption leads to a lower perception of risk in their use.*

So, the general framework presented in Figure 1, after the hypothesis development turns into the model displayed in Figure 2.

FIGURE 2

Relationships between the variables proposed in this study for the purchase intention to consume genetically modified foods (GMF)



Source: Own elaboration.

2.4. Sociodemographic variables: gender and age

In studies on purchase intention of novel foods, the inclusion of sociodemographic factors is common, with gender and age being the most relevant. Gender has been linked to food choices due to physiological differences in nutritional requirements between females and males, as well as cultural factors (Rodrigues *et al.*, 2020). It has been widely observed that males tend to accept GMFs more than females (Ramadan *et al.*, 2024).

A person's age can be a determining factor in their food preferences, even more so than other factors, such as income or education level (Ogundijo *et al.*, 2022). Ramadan *et al.* (2024) observe that, in general, there is a negative relationship between age and PI. Therefore, we propose:

Hypothesis 5 (H5). *Being male is positively related to a higher level of purchase intention of GMFs.*

Hypothesis 6 (H6). *Belonging to the Baby Boomer generation is negatively linked to the level of purchase intention of GMFs.*

So, the general framework presented in Figure 1, after the hypothesis development turns into the model displayed in Figure 2.

3. Materials and methods

3.1. Sampling and sample

This study relies on an online survey targeting individuals aged 45 years or older, conducted during the spring of 2023. The survey was distributed to food-opinion groups on social media using a non-probabilistic convenience sampling approach. Because participation was voluntary within these specialised online communities, the sample is inherently self-selected and should not be considered representative of the broader Spanish population. This strategy was chosen because, beyond differences in income or educational level, it is expected that members of such groups tend to be informed consumers –not necessarily with scientific expertise, but with a higher and relatively homogeneous level of knowledge about food-related issues, including GMFs, compared to the general population. Nevertheless, this implies a clear limitation: participants may be more engaged and hold stronger or more polarised attitudes toward food technologies than typical consumers, and thus the findings should be interpreted as reflecting the views of this highly involved subgroup rather than older Spanish consumers in general.

Only completed questionnaires that included responses to all items related to PI, USEFUL, RISK, SNORM, VALUE, as well as age and gender, were retained for analysis, resulting in a final sample of 248 valid responses.

Given that generational boundaries are inherently fluid rather than universally fixed (Dimock, 2019), rather than sharp demographic cut-offs, and that some market segmentation schemes place the start of Generation X in the mid-60s (Environics Analytics, 2023), we define two operational cohorts based on age at the time of data collection: Generation X (≤ 56 years) and Baby Boomers (≥ 57 years). This age-based operationalization acknowledges the inherent fuzziness of generational frontiers while producing adjacent cohorts of reasonably comparable size for multigroup analysis, while retaining the intended cohort meaning.

TABLE 1
Sociodemographic variable profile

	Overall sample (M=55.93, SD=6.06)		Generation X (M=51.84, SD=2.93)		Baby Boomers (M=62.22, SD=5.00)	
Variable	N	Rate (%)	N	Rate (%)	N	Rate (%)
Gender						
Male	95	38.31	45	34.09	50	43.10
Female	149	60.08	85	64.39	64	55.17
Other/prefer not to answer	4	1.61	2	1.52	2	1.72
Monthly income						
Less than €1,000	32	12.90	18	13.64	14	12.07
Between €1,000 and €1,749	70	28.23	42	31.82	28	24.14
Between €1,750 and €2,499	47	18.95	15	11.36	32	27.59
Between €2,500 and €3,000	43	17.34	25	18.94	18	15.52
More than €3,000	23	9.27	13	9.85	10	8.62
No response	33	13.31	19	14.39	14	12.07
Academic degree						
Less than secondary studies	20	8.06	8	6.06	12	10.34
Secondary	88	35.48	48	36.36	40	34.48
University	140	56.46	76	57.58	64	55.17
Age						
Age 56 years or younger	132	53.23	—	—	—	—
Age 57 years or older	116	46.77	—	—	—	—

Note: *M*=mean and *SD*=standard deviation.

Source: Own elaboration.

Table 1 presents the respondents' profiles for the overall sample. A total of 149 participants (60.08 %) identified as female. Regarding age, 53.23 % (132) of respondents were from Generation X, while 46.77 % (116) were from Baby Boomers. In terms of income, 28.23 % (70) of respondents reported earning €1,749 or less per month, 45.56 % (113) reported earnings above this threshold, and 13.31 % (33) preferred not to answer. Concerning educational level, 8.06 % (20) reported having primary education or lower, 35.48 % (88) had secondary education, and 56.45 % (140) held a university degree. Table 1 also provides a detailed breakdown of gender, income, and educational level by the two age groups.

Using G*Power 3.1 software (Faul *et al.*, 2009), we determined that the sample provides 80 % statistical power ($\alpha=0.05$) to detect small effect sizes ($f^2=0.05$) in the structural model. This corresponds to a minimum coefficient of determination (R^2) of 0.0476 for PI construct. At the level of individual paths, the same power is achieved for a two-tailed test ($\alpha=0.05$) with small effect sizes ($f^2=0.035$). Consistently, according to the gamma-exponential method proposed by Kock & Hadaya (2018), the sample size also ensures that path coefficients with an absolute value of at least 0.15 can be considered statistically reliable.

3.2. Materials and measurement of variables

The survey provided a short description of GMOs and GMFs. It also noted that although the commercialisation of GMFs is legally permitted in the European Union –subject to prior EFSA authorisation and mandatory labelling– the actual availability of such products on the Spanish market is extremely limited. In practice, consumers in Spain are exposed to GM-derived inputs mainly indirectly, through the consumption of animal products from livestock fed with authorised GM feed. Accordingly, the items in this study refer specifically to the evaluation of direct, intentional consumption of GMFs, which is the behavioural target that respondents meaningfully assess.

Subsequently participants answered items related to the explanatory framework in the second section, and the exact wording of these items is provided in Appendix A. The scales used to measure PI, SNORM, and VALUE were adapted from Venkatesh *et al.* (2012) and adjusted to the context of food adoption. The USEFUL scale was taken from Jin *et al.* (2022), who also analysed the purchase intention of GMFs, while the RISK items were derived from Faqih (2016) and adapted to the present context. All questions were answered using an 11-point Likert scale, ranging from 0 (“strongly disagree”) to 10 (“strongly agree”). In all cases, the constructs were modelled as reflective, as the items are understood to be manifestations of a single underlying factor, consistent with how these measurement scales are conceptualized in the literature.

Gender and age were modelled as dummy variables. In the case of gender, 1 represented male and 0 represented others; therefore, this variable is referred to as MALE. For age, 1 corresponded to members assimilated to the Baby Boomer generation (57 years or older) and 0 otherwise. Therefore, the age variable was named BOOMER.

3.3. Data analysis

The analysis was conducted using PLS-SEM, followed by NCA with the help of SmartPLS 4.1.1.5 software (Ringle *et al.*, 2024).

The model fit using PLS-SEM followed the protocol proposed by Hair *et al.* (2019), by assessing the validity and reliability of the measurement scales. These scales were modelled as reflective constructs; therefore, internal consistency was evaluated using Cronbach's alpha (CA) and composite reliability (CR), while convergent validity was assessed through the average variance extracted (AVE) and indicator loadings (Hair *et al.*, 2019). We also evaluated lateral and vertical collinearity by following the method proposed by Kock & Lynn (2012).

The model was then estimated through the application of partial least squares with percentile bootstrapping (10,000 resamples). This step enables the empirical examination of the hypotheses formulated earlier and the estimation of the effect size of the input factors' effect on consumers' intention to purchase GMFs. Additionally, we assessed the statistical robustness and validity of the proposed model and evaluated the mediation effects. With an exploratory purpose, we also implemented a Permutation Multigroup Analysis (5,000 permutations) and a Measurement Invariance of Composite Models (MICOM) assessment to assess potential differences in behaviour between two generational cohorts.

This study also conducted NCA following the steps outlined by Richter *et al.* (2020) and Dul *et al.* (2023), applied exclusively to latent variables (i.e., USEFUL, RISK, VALUE, and SNORM). The latent variable scores from the regressions performed using PLS-SEM were used for the values of these constructs. The analysis was carried out using the ceiling-envelopment fit of the free disposal hull. This free-disposal hull defines the region of the XY axis where realizations of the outcome variable are not possible, given the value of the input variable. If the relationship between input and outcome is positive, as in the case of USEFUL, free-disposal hull analysis will be conducted in the upper-left quadrant of the XY axis. By contrast, when the path is predictably negative (for example, with RISK), the analysis is conducted considering the upper-right quadrant.

The main measures of NCA are:

a) Necessity effect size (d): This can be classified as small ($0 < d < 0.1$), medium ($0.1 \leq d < 0.3$), large ($0.3 \leq d < 0.5$), or very large ($d \geq 0.5$), with statistically significant

differences. These effect sizes are practically relevant when $d > 0.1$, with a p -value < 0.05 (Dul *et al.*, 2023).

b) Bottleneck tables: These facilitate bottleneck analysis, which helps determine the necessity of the type “level Xa of input X is necessary to attain a level PIa of PI” (Dul *et al.*, 2023).

4. Results

4.1. Descriptive statistics, vertical and lateral collinearity assessment, and scale reliability analysis

Appendix A shows the basic statistics of the responses to the items. The results suggest that PI is closer to rejection than to acceptance. Similarly, the items of the factors that are supposed to positively influence PI also did not show an average evaluation higher than 5. This is particularly evident for SNORM, where the item ratings barely exceed 3. Additionally, the items related to risk score at least 5 on average.

Appendix B shows that all measurement scales demonstrated adequate internal validity. All latent variables presented CA and CR values greater than 0.70 and lower than 0.95, as well as AVE values above 0.50. Appendix A further indicates that virtually all indicator loadings exceeded the 0.70 threshold. As a robustness check to address potential heterogeneity in the risk construct, the uncertainty-related item (RISK2) was excluded from the final measurement model because it exhibited the weakest loading and a markedly different central tendency relative to the remaining risk indicators. All results reported hereafter are therefore based on this revised specification. This decision ensures a more homogeneous operationalization of perceived risk and avoids potential distortions in the necessity analysis arising from measurement heterogeneity. Notably, in the initial model including RISK2, the PLS-SEM structural path estimates remained substantively stable; however, the NCA results were less conservative and tended to support RISK as a necessary condition, indicating that necessity inferences were sensitive to the inclusion of the uncertainty indicator.

Lateral and vertical collinearity were assessed using the full collinearity variance inflation factor (VIF) approach at the construct level, which has been proposed as a variance-based SEM diagnostic that can also serve as an equivalent test for common method bias (Kock & Lynn, 2012). Appendix B reports the results of this assessment. All constructs exhibit VIF values below 3.3 (USEFUL = 2.758; RISK = 1.554; SNORM = 2.504; VALUE = 1.357), with the exception of PI (VIF = 3.444), which is only marginally above this conservative cutoff. Because problematic collinearity is typically expected to manifest across multiple constructs (often in pairs), this pattern suggests—at most—a limited/borderline degree of collinearity-driven inflation

rather than pervasive bias; nonetheless, a minor method-related component cannot be entirely ruled out (Kock & Lynn, 2012).

Appendix A also shows that indicator-level variance inflation factor (VIF) values ranged between 1.32 and 3.77, remaining below the critical threshold of 5 and indicating the absence of problematic collinearity among the items. Although some indicators of the SNORM construct exhibited VIF values slightly above the heuristic ideal 3.3 cut-off (e.g., SNORM1 and SNORM2), these values are still well within acceptable limits (5 cut-off), confirming that collinearity within the measurement model is not a concern.

Appendix B also demonstrates that the scales exhibit discriminant validity, as the Fornell-Larcker criterion is met and the heterotrait-monotrait (HTMT) ratios are under 0.85. Appendix C shows that all HTMT ratios were clearly below the conservative 0.85 threshold, and none of the 95 % confidence intervals approached 1.00, confirming strong discriminant validity among the latent constructs. Even the highest HTMT values (e.g., PI–USEFUL, PI–SNORM) remained well under 0.90.

It should be noted that, in the case of SNORM, some potential concern might arise regarding the overlap between its two items, given the high AVE. However, the wording of the items reflects conceptually distinct aspects. Specifically, SNORM1 refers to the influence of personally significant individuals (e.g., a close family member), whereas SNORM2 may capture the influence of socially relevant figures whose opinions about food are considered (e.g., chefs, influencers, nutritionists). These two dimensions, while related, do not necessarily coincide. Moreover, although the CA and CR values for SNORM are relatively high, they remain below the recommended upper threshold of 0.95, as suggested by Hair *et al.* (2019). Therefore, the decision was made to retain both items for the SNORM construct.

4.2. Structural model analysis

Table 2 presents the results obtained from estimating the model depicted in Figure 2, using percentile bootstrapping with 10,000 resamples. The outcome for PI was high, according to Hair *et al.* (2019) criteria, with $R^2=0.71$. In the case of USEFUL, R^2 decreases to 0.52, and for RISK, it is only 0.17. Nevertheless, all the coefficients of determination were above the 0.0476 threshold required for the power to be at least 80 % of the sample used. Likewise, this table shows that the Standardised Root Mean Square Residual of the model is 0.094, which, although not below the optimal threshold of 0.08, remains within the commonly accepted limit of 0.10 in the context of PLS-SEM analysis (Ringle *et al.*, 2024). Likewise, the model demonstrates predictive capacity across all constructs, since Stone-Geisser's Q^2 oscillates from 0.16 for RISK to 0.61 for PI, greater than 0. In the case of the main outcome variable, PI, the predictive power of the model can be considered high, according to the criterion proposed by Hair *et al.* (2019).

Table 2 also indicates that there are no collinearity concerns, as the explanatory factors present a $VIF < 3.3$. The variables related to attitudes significantly influenced PI. For USEFUL, the path coefficient (β) was 0.339 with a p-value (p) < 0.001 . For RISK, $\beta = -0.168$, $p < 0.001$. The variable relating to SNORM had the largest effect size on PI ($f^2 = 0.441$), and its positive impact was also significant ($\beta = 0.473$, $p < 0.001$). The relationship between the sociodemographic factors and PI has the expected sign, but its impact is not significant. These results suggest that two operational cohorts do not differ significantly in their intention to purchase GMFs since for BOOMER, $\beta = -0.108$, $p = 0.124$.

Regarding the adjustment for USEFUL, both the positive influences of SNORM ($\beta = 0.544$, $p < 0.001$) and VALUE ($\beta = 0.324$, $p < 0.001$) were significant, with SNORM showing the largest effect size ($f^2 = 0.546$). Finally, influence of SNORM on RISK was significantly negative ($\beta = -0.413$, $p < 0.001$).

In Table 3, we observe the total effect (TE) of all the latent variables on PI. For the USEFUL, RISK, and sociodemographic variables, this impact is simply the path coefficient obtained in Table 2. The total impact of VALUE, which is an indirect-only effect through USEFUL was also significant (TE = 0.110, $p < 0.001$). The total impact of SNORM is partially mediated by USEFUL and RISK, and it is the largest of all the variables (TE = 0.727, $p < 0.001$).

TABLE 2

Fitted path coefficients for the relations displayed in Figure 2

Relation	β	<i>t</i> -ratio	<i>p</i> -value	VIF	<i>f</i> ²	Decision on hypothesis
USEFUL -> PI	0.339	5.364	<0.001	2.083	0.189	H1(+): Acceptance
RISK -> PI	-0.168	3.587	<0.001	1.450	0.066	H2(-): Acceptance
VALUE -> USEFUL	0.324	7.764	<0.001	1.118	0.194	H3(+): Acceptance
SNORM -> PI	0.473	9.523	<0.001	1.742	0.441	H4a(+): Acceptance
SNORM -> USEFUL	0.544	6.718	<0.001	1.118	0.546	H4b(+): Acceptance
SNORM -> RISK	-0.413	5.582	<0.001	1.000	0.205	H4c(-): Acceptance
MALE -> PI	0.025	0.348	0.728	1.012	0.001	H5(+): Rejection
BOOMER -> PI	-0.108	1.538	0.124	1.011	0.01	H6(-): Rejection

Note: (a) The determination coefficient of the endogenous variables is 0.71 for PI, 0.52 for USEFUL, and 0.17 for RISK; and the Standardised Root Mean Square Residual is 0.094 (b) The Stone-Geisser’s Q2 is 0.61 for PI, 0.50 for USEFUL, and 0.16 for RISK (c) β represents the path coefficient, VIF is the variance inflation factor, and f^2 effect size factor.

Source: Own elaboration

TABLE 3
Total effects of explanatory variables

Path	TE	SD	t-ratio	p-value
USEFUL -> PI	0.339	0.063	5.364	<0.001
RISK -> PI	-0.168	0.047	3.587	<0.001
VALUE -> PI	0.110	0.029	3.853	<0.001
SNORM -> PI	0.727	0.034	21.314	<0.001
MALE -> PI	0.025	0.073	0.348	0.728
BOOMER -> PI	-0.108	0.07	1.538	0.124

Note: TE stands for the total effect and *SD* for the standard deviation.

Source: Own elaboration.

Table 4 shows that all mediated effects (ME) are statistically significant. The indirect effect of SNORM on PI via USEFUL is positive (ME = 0.184, $p < 0.001$), while the indirect effect of SNORM via RISK is also positive (ME = 0.069, $p = 0.003$). Additionally, VALUE influences PI positively through USEFUL (ME = 0.110, $p < 0.001$). The variance accounted for (VAF) values clarify the empirical relevance of the paths of SNORM: SNORM → USEFUL → PI shows a significant partial mediation (VAF = 0.253), and SNORM → RISK → PI exhibits a very low VAF (0.065), indicating mediation with negligible effects despite its statistical significance. This pattern confirms that for SNORM, indirect effects through USEFUL are substantively more important than those through RISK, and highlights that statistically detectable indirect paths may still lack practical or explanatory relevance when their mediated proportion is negligible.

Table 5 reports the permutation-based multigroup analysis (5,000 permutations). Overall, the structural path coefficients are similar across Baby Boomers and Generation X operational cohorts, and most permutation p-values indicate no statistically significant differences at the 5 % level. A marginal between-group difference is observed for the SNORM→USEFUL path ($p = 0.098$), suggesting that the normative climate may translate into perceived usefulness somewhat more strongly among Baby Boomers. By contrast, the remaining relations (USEFUL→PI, RISK→PI, SNORM→PI, SNORM→RISK, and VALUE→USEFUL) do not show meaningful heterogeneity across cohorts.

Appendix D shows that the MICOM procedure supports compositional invariance for all constructs, allowing meaningful comparisons of structural relations across cohorts. Concerning equality of composites, permutation tests indicate no statistically significant variance differences between groups at the 5 % level; however, the variance difference for USEFUL is marginal ($p = 0.066$), suggesting a small potential

dispersion difference that should be interpreted cautiously. Regarding composite means, PI, USEFUL, RISK, and SNORM do not differ significantly across cohorts, whereas VALUE exhibits a significant mean difference ($p = 0.043$), with Generation X reporting higher perceived value than Baby Boomers. Overall, these results provide partial measurement invariance and support the subsequent multigroup analysis, while noting minor residual differences in VALUE means and (marginally) USEFUL variance (Henseler *et al.*, 2016).

TABLE 4

Mediated effects due to relations stated in H3, H4b and H4c

Path	ME	SD	VAF	t-ratio	p-value
SNORM → USEFUL → PI	0.184	0.042	0.253	4.340	<0.001
SNORM → RISK → PI	0.069	0.023	0.065	2.959	0.003
VALUE → USEFUL → PI	0.110	0.029	n.a.	3.853	<0.001

Note: ME=mediated effect, SD=standard deviation and VAF=variance accounted for and n.a. (indirect only by design).

Source: Own elaboration.

TABLE 5

Permutation multigroup analysis for Baby Boomers vs Generation X

Path	β (Boomers)	β (Generation X)	Diff	p-value
USEFUL → PI	0.348	0.311	0.037	0.790
RISK → PI	-0.146	-0.195	0.049	0.608
SNORM → PI	0.501	0.46	0.041	0.783
SNORM → USEFUL	0.646	0.459	0.188	0.098
SNORM → RISK	-0.407	-0.419	0.012	0.927
VALUE → USEFUL	0.251	0.381	-0.13	0.273

Note: Diff stands for the difference between the path coefficients of the two generations.

Source: Own elaboration.

4.3. Necessary condition analysis

Table 6 reports the effect size (*d*) of each antecedent on PI, whereas Table 7 presents the bottleneck analysis. The effect sizes for USEFUL (*d* = 0.235) and VALUE (*d* = 0.166) can be classified as medium according to Dul (2016), and both are statistically significant (*p* < 0.001). In contrast, although SNORM is the strongest predictor of PI in the PLS-SEM estimation, it exhibits only a small effect size in the NCA (*d* = 0.068). Following Dul *et al.* (2023) guidelines, such a value has limited practical relevance, even though it remains statistically significant (*p* < 0.001). Finally, RISK does not emerge as a necessary condition for PI in the NCA, as its effect size is negligible and the bottleneck analysis does not indicate meaningful threshold requirements.

Table 7 presents the quantiles that must be reached for each variable to obtain a certain degree of PI. To reach the 50th percentile of PI (i.e., the median), the threshold effect was exerted by USEFUL (12.5th percentile) and VALUE (8.33rd percentile). Neither the perception of risk nor the subjective norm has a threshold effect at this level, as it is possible to reach PI at the 50th percentile, even with the maximum value of risk perception (100) or the minimum value of subjective norm (0th percentile).

From the 80th percentile onward, USEFUL, VALUE, and SNORM operate as bottlenecks, whereas RISK does not. Therefore, to reach the 90th percentile of PI, it is necessary to reach the 58th percentile of USEFUL, the 47.5th percentile of SNORM, and the 27th percentile of VALUE.

TABLE 6
Effect sizes of the explanatory variables on purchase intention

Variable	Effect size (<i>d</i>)	p-value
USEFUL	0.235	< 0.001
RISK	≈ 0.000	0.857
VALUE	0.166	< 0.001
SNORM	0.068	< 0.001

Source: Own elaboration.

TABLE 7

Bottleneck table of PI (expressed as quantiles)

Percentile (%)	PI Score	USEFUL (%)	RISK	VALUE (%)	SNORM
0.00	-1.457	NN	NN	0.000	NN
10.00	-1.138	NN	NN	0.000	NN
20.00	-0.820	NN	NN	0.000	NN
30.00	-0.501	12.50	NN	0.000	NN
40.00	-0.182	12.50	NN	6.670	NN
50.00	0.137	12.50	NN	8.330	NN
60.00	0.455	18.75	NN	8.330	NN
70.00	0.774	31.67	NN	15.000	NN
80.00	1.093	46.67	NN	18.330	47.50
90.00	1.411	58.33	NN	26.670	47.50
100.00	1.730	58.33	NN	26.670	47.50

Note: NN stands for non-necessary.

Source: Own elaboration.

5. Discussion

5.1. General overview

This study aims to understand the purchase intention (PI) of genetically modified food (GMF) among members of Generation X and the Baby Boomer generation in Spain. The analysis is based on a model derived from the Theory of Reasoned Action (TRA), where PI is explained by perceived usefulness (USEFUL), perceived risk (RISK), perceived value (VALUE), and subjective norms (SNORM). Gender and generational membership were included as additional variables. Although this model performs well with our data, the behaviour of these variables must be interpreted in light of the specific sociocultural and informational context associated with a convenience sample of Spanish consumers aged at least 45 years.

Our findings from a TRA-based model effectively explain PI and it is tested in older cohorts in Spain. SNORM emerges as the primary total driver of intention, suggesting that social information and normative cues dominate when objective

familiarity is limited. This dominance of SNORM is theoretically consistent with evidence showing that older consumers, especially in contexts of low familiarity, tend to rely more heavily on trusted reference groups. In the Spanish case, where direct exposure to GMFs is extremely limited, social norms often act as proxies for personal experience, amplifying their influence. Yet, NCA shifts the lens: USEFUL and VALUE set thresholds, without sufficient perceived benefits and perceived value, higher intentions do not materialize. The asymmetry between PLS-SEM and NCA is particularly important: while SNORM and RISK shape PI in PLS-SEM analysis, they are not necessary for reaching higher intention levels. This indicates that social approval and diminishing perception of risk can boost willingness to consume GMFs, but cannot compensate for insufficient perceptions of benefits, an insight that nuances the conventional view of normative influence in TRA. This dual evidence (net effects and necessary conditions) clarifies why persuasive messaging alone may fail unless it lifts perceived benefits/value over bottleneck levels.

Regarding the explanatory factors, the findings are in accordance with those in the literature on purchase intention for GMFs. The finding about the link between USEFUL and PI is aligned with reports in the context of genetically modified foods (Chen & Li, 2007; Costa-Font & Gil, 2009; McComas *et al.*, 2014) and foods produced using gene insertion techniques (Farid *et al.*, 2020; Jin *et al.*, 2022; Gao *et al.*, 2024; Marín-Díaz *et al.*, 2024; Ngo *et al.*, 2024). The negative and significant link between RISK and PI has been widely documented in the context of GMFs (Farid *et al.*, 2020; Yang & Hobbs, 2020; Alalwan *et al.*, 2023; Cabelkova *et al.*, 2024; Marín-Díaz *et al.*, 2024; Ogwu *et al.*, 2024). Notably, the greater influence of USEFUL is also reflected in the necessity analysis: USEFUL qualifies as a necessary condition to reach high PI, whereas this does not apply to RISK. This pattern suggests that, in our sample, perceived benefits carry more weight than abstract health or environmental concerns, possibly because evaluations are formed without direct personal experience with GMFs. In such cases, usefulness judgments are shaped by general beliefs about technological efficiency, nutritional enhancement or sustainability, which may feel more concrete than risk perceptions derived from media narratives.

The positive and significant indirect impact of VALUE on PI aligns with the findings of Alalwan *et al.* (2023) and Kiran *et al.* (2023), although the influence is not mediated in their studies. Additionally, in the NCA analysis, it was identified that VALUE had a medium effect size as a necessary condition for producing PI. These results suggest that reduced perceptions of naturalness or traditional character compared to conventional products might be compensated for by price. In this sense, findings indicate that there must be a price difference between conventional products and GMFs to induce PI (Montesinos-López *et al.*, 2016; Borrello *et al.*, 2021; Zheng *et al.*, 2023). This mediating mechanism suggests a tendency to adopt a pragmatic cost-benefit orientation when evaluating unfamiliar foods: if the product provides functional or economic advantages, reservations about naturalness may become less important. MICOM also indicates a significant mean difference for VALUE between operational cohorts, with Generation X reporting higher perceived value than Baby

Boomers. This suggests that younger older-adults may perceive a more favourable benefit–cost trade-off for GMFs, which could facilitate intention indirectly via perceived usefulness. However, because VALUE operates indirectly in the model, this mean difference should be interpreted as a contextual nuance rather than a structural change in the TRA mechanism.

From a statistical perspective, SNORM had the most significant influence on PI. This finding is understandable because the public is generally not very knowledgeable about the basics of genetic modification techniques (Gao *et al.*, 2024), and in the absence of knowledge, individuals often align their food choices with prevailing social norms (Günden *et al.*, 2024). Therefore, the results obtained in this study are consistent with those in the GMFs context by Prati *et al.* (2012), Borrello *et al.* (2021), and Safi-Sis *et al.* (2022). However, it is paradoxical that, although NCA reveals the status of SNORM as a significant necessary condition, its empirical relevance ($d < 0.1$) is considered limited according to the criteria by Dul (2016). This paradox reinforces the idea that SNORM functions as an accelerator, not a prerequisite: it strengthens intention when present, but its absence does not prevent consumers –particularly those in older cohorts– from reaching moderate intention if they perceive enough usefulness or value. Such asymmetry also reflects how societal narratives around GMFs in Spain, shaped by historical distrust and regulatory strictness, may encourage reliance on norms while simultaneously limiting their ability to independently generate intention.

We found that gender did not significantly influence PI. Although mainstream literature often suggests that females tend to show greater hesitation toward genetically modified foods, this study aligns with other research reporting no significant gender differences (Gao *et al.*, 2024; Hao *et al.*, 2024). A plausible interpretation is that, because our sample consists of relatively informed consumers already engaged in food-related discussions, gender-based gaps in risk sensitivity may be attenuated. Moreover, both generational groups examined here have been similarly exposed to public debates on biotechnology in Spain, which may contribute to more homogeneous attitudinal patterns across demographic subgroups.

Regarding age, the negative but non-significant coefficient of the BOOMER variable indicates that older respondents may be slightly less receptive to GMFs. This pattern would be consistent with Ramadan *et al.* (2024), who argue that higher age is generally associated with greater reluctance to adopt novel foods. However, the lack of statistical significance suggests that, in this sample, generational membership does not exhibit an additional net effect on PI once the TRA predictors are accounted for. This overall pattern is broadly consistent with the permutation-based multigroup analysis, which indicates stable estimates for most structural paths across the two cohorts. A single nuance emerges: the SNORM→USEFUL link is marginally stronger among Baby Boomers, suggesting that normative cues may translate into perceived usefulness somewhat more strongly for older consumers. Overall, cohort differences in the structural mechanism appear limited and should be interpreted

cautiously. Finally, our results remain consistent with studies reporting that age is not a significant predictor of purchase intention for GMFs (Bearth *et al.*, 2022; Cabelkova *et al.*, 2024).

5.2. Theoretical implications

This study demonstrates that a TRA-based groundwork provides a solid foundation for understanding purchase intention for GMFs. By integrating perceived usefulness, perceived value, perceived risk, and subjective norms, the model captures both cognitive and normative determinants of purchase intention. Moreover, the use of NCA extends traditional behavioural theory by identifying thresholds beyond which intention cannot increase. This approach advances the theoretical debate on bounded rationality and sufficiency/necessity in consumer behaviour (Richter *et al.*, 2020). To our knowledge, no previous study has applied this combined TRA-framework with NCA to the purchase intention of food elaborated with new technologies.

5.3. Methodological implications

The simultaneous use of PLS-SEM and NCA illustrates how complementary analytical perspectives can be employed to deepen model interpretation. PLS-SEM allows evaluation of explanatory and predictive power, while NCA identifies bottlenecks that constrain PI regardless of the model's fit or context. This dual approach is particularly relevant for studies that address technological adoption or risk-laden innovations, as it enables researchers to distinguish between drivers and necessary enablers of PI.

5.4. Practical implications

From a managerial perspective, this study highlights that fostering perceived usefulness and perceived value is essential for promoting purchase intention toward GMFs among older consumers. Both variables are necessary and sufficient conditions to induce PI.

Building on this central implication, the findings suggest that stakeholders – producers, marketers, and regulatory authorities – should focus on surpassing the thresholds of perceived value and usefulness. The literature shows that enhancing USEFUL may involve incorporating functional properties into GMFs that align with consumers' health or environmental concerns (Boccia & Punzo, 2021). Highlighting these benefits through clear communication cues (e.g., “produced with 50 % less water,” “contains 15 % more magnesium”) could help shift public perception from “potentially risky” to “clearly beneficial” (Hingston & Noseworthy, 2018).

Increasing VALUE can derive from improved crop productivity and cost efficiency, which is particularly relevant amid the food price inflation observed in the European

Union between 2022 and 2023 (European Central Bank, 2024). The availability of affordable yet high-quality GMFs would align with economic and nutritional policy goals.

The key role of SNORM, which influences PI both directly and indirectly through perceived usefulness and perceived risk, suggests that social awareness of the benefits of GMFs may be crucial for their successful adoption, especially in contexts where direct product availability is low. Public information campaigns emphasizing the usefulness and safety of GMFs, alongside communication by trusted institutions acknowledging that no scientific evidence has demonstrated higher risks compared to conventional foods, could play a decisive role in fostering PI. The literature has repeatedly highlighted the importance of effective communication about the absence of proven risks and the potential for GMFs to contribute to addressing major societal challenges, including food security, sustainability, and healthy diets (Hingston & Noseworthy, 2018; Goodman, 2024). Such efforts may help shift public perception from avoidance to informed and positive purchase intention.

The bottleneck analysis in NCA allows us to derive concrete managerial thresholds. For instance, among consumers aged 45+, PI cannot reach even moderate levels (50th percentile) unless USEFUL reaches at least the 12.5th percentile and VALUE at least the 8th percentile, irrespective of SNORM or RISK. For stronger intentions (70th percentile), USEFUL must rise to at least the 31.7th percentile and perceived value to the 15th percentile. These thresholds offer actionable targets: communication strategies should aim to move USEFUL beyond roughly the 30 % mark of its attainable range to meaningfully increase purchase intention among Baby Boomers and Generation X. SNORM does not operate as a necessary condition until the highest PI levels, whereas RISK –although it can reduce purchase intention in net-effect terms– does not constitute a binding bottleneck at any level. Accordingly, efforts to mitigate risk perceptions are unlikely to translate into higher PI unless the minimum thresholds of USEFUL and VALUE (and, at very high PI levels, SNORM) are simultaneously met.

Moreover, the non-significant BOOMER dummy indicates that generational membership does not add a net effect on PI once the TRA predictors are accounted for; however, multigroup analysis suggests a marginal cohort nuance, in that normative cues may translate into perceived usefulness somewhat more strongly among Baby Boomers. Accordingly, segmentation by cohort may be less critical than tailoring messages to reinforce perceived usefulness and value, while leveraging trusted normative sources when targeting older consumers.

The patterns identified in the sample should therefore be interpreted as evidence of attitudinal mechanisms within a highly informed and engaged segment, rather than population-wide estimates.

5.5. Policy implications

Although labelling was not examined in this study, prior work suggests that information cues and labelling practices can shape consumers' risk perceptions and broader social narratives around GMFs. In the European context, some authors argue that the mandatory "genetically modified" label –without differentiating between transgenic and gene-edited products– may contribute to negative affect and heightened concern among consumers (Goodman, 2024). Related research indicates that clearer distinctions between technological approaches (e.g., conventional transgenesis vs. CRISPR-based gene editing) could, in principle, improve perceived transparency and trust (Bratlie *et al.*, 2019; Bearth *et al.*, 2022). Accordingly, it is reasonable to expect that changes in consumer-facing labelling and information framing could influence both perceived risk and subjective norms regarding GMFs –an empirical channel that future research should test directly.

A policy-relevant avenue discussed in prior work is that educational campaigns delivered through trusted institutions and scientific agencies may help mitigate misinformation-driven fears by communicating evidence on safety, sustainability, and potential social benefits (Hingston & Noseworthy, 2018).

5.6. Ethical, social, and cultural implications

Beyond regulatory aspects, PI involves ethical and cultural dimensions (Warda *et al.*, 2025). Ethical communication should respect consumer autonomy and value pluralism, ensuring that promotional messages neither stigmatize caution nor trivialize legitimate concerns. Regarding information, linked to health, older cohorts –such as those studied here– may rely more on trust networks (family doctors, consumer associations, or public authorities) than on corporate or online communication (Ye, 2010). Therefore, inclusive and transparent dissemination of independent scientific evidence can enhance informed choice without coercion. Culturally, initiatives that link GMFs innovation to food security, environmental stewardship, and intergenerational responsibility could strengthen social legitimacy and public understanding (Warda *et al.*, 2025).

6. Conclusions

6.1. Principal takeaways

This study explored public perceptions in Spain with regard to the tendency to try GMFs. It tested a model that can be contextualized within TRA using PLS-SEM and complemented it with NCA to identify the key drivers and potential bottlenecks affecting GMFs purchase intention. By combining net-effects evidence (PLS-SEM) with necessity logic (NCA) and establishing measurement comparability across cohorts (MICOM) prior to group comparisons, the study provides a more actionable

interpretation of the determinants of PI. The framework was empirically tested on a sample of 248 Spanish consumers belonging to the Baby Boomer and Generation X cohorts.

Results from PLS-SEM confirmed that the model exhibited strong reliability and validity, ensuring confidence in the subsequent analyses. SNORM emerged as the most powerful driver of PI, underscoring the role of social influence in shaping consumers' intentions. Perceived usefulness also exerted a positive and statistically significant effect, whereas RISK showed a negative but comparatively weaker influence. The impact of VALUE was indirect, operating through perceived usefulness and reinforcing its mediating role. Generational membership does not exhibit an additional net effect on PI once the TRA predictors are accounted for. Permutation-based MGA further suggests that the structural relations are largely stable across cohorts, with only a marginal nuance for the SNORM→USEFUL path.

The NCA results complemented these findings by revealing that USEFUL and VALUE act as empirically significant necessary conditions for high levels of PI. In other words, achieving strong purchase intention of GMFs requires minimum thresholds of perceived benefits and value. By contrast, SNORM –and, to a lesser extent, RISK– although influential in the correlational analysis, did not emerge as binding constraints in the NCA, suggesting that social approval and lower risk perceptions may strengthen intention to purchase but cannot substitute for perceived product benefits. Together, these results indicate that perceived utility and value set the minimum conditions for high PI, whereas normative support and risk perceptions operate more as facilitating factors; accordingly, a lack of clear benefits can critically limit market expansion. From a practical perspective, this implies that communication strategies should prioritize strengthening perceived usefulness and value.

6.2. Limitations and further research

This study acknowledges several limitations, which should guide future research. First, the sample was obtained through convenience sampling in food-opinion social media groups, which entails a self-selection bias. Participants are likely to be more informed about food-related issues, more engaged with debates on food technologies, and potentially hold stronger or more polarised attitudes than the general population. Consequently, the findings cannot be directly generalised to all older Spanish consumers. It is plausible that, within their social environments, such individuals exert some influence due to their above-average knowledge and more elaborated opinions, and they may also show a greater predisposition to provide thoughtful survey responses compared to a randomly selected respondent. Nevertheless, this strength also embodies a limitation: the results ultimately reflect the perceptions of a specific, highly engaged subgroup rather than the broader population of older consumers.

Cultural and historical factors often play a key role in shaping the intention to purchase GMFs (Yang & Hobbs, 2020). These differences are evident across continents (Kiran *et al.*, 2023) and within the European Union itself (Wozniak-Gientka *et al.*, 2022). As a result, the conclusions extracted from this paper may be generalized to other geographical contexts with caution, even if they belong to the EU. In this regard, cross-cultural research could provide deeper insights into the most influential variables in explaining PI as well as identifying which factors act as significant bottlenecks depending on the cultural background of respondents.

Additionally, selecting an older consumer segment allows for a more precise understanding of this demographic, which typically has a greater purchasing power. However, these findings should be interpreted carefully when applied to younger generations of potential consumers.

Relatedly, the study focuses on purchase intention rather than observed purchasing behaviour, largely because the commercialisation and direct consumption of GMFs in Spain remain very limited. As GMFs become more widely available in the Spanish market, future research should assess whether the identified drivers and bottlenecks translate into actual choices under real-world constraints such as price, availability, and product labelling conditions. Likewise, because direct experience with GMFs is limited, responses may reflect hypothetical judgments. Future work should explicitly measure objective and subjective knowledge/familiarity and test their moderating role.

Although MICOM supported measurement comparability, multigroup inference may be underpowered to detect small cohort differences. Consistent with this, our permutation multigroup shows no differences at the 5% level, but one path (SNORM→USEFUL) is marginal, suggesting a possible cohort moderation in how subjective norms translate into perceived usefulness. Replication with larger, quota-balanced samples –and modelling age continuously rather than via cohort cutoffs– would strengthen conclusions about generational heterogeneity and clarify whether this borderline effect is robust.

Moreover, the broader applicability of this research in the medium and long term may be constrained by two key factors: the complex regulatory landscape surrounding GMFs (Goodman, 2024) and the rapid technological advancements in biotechnology (Bašinskienė & Šeinauskienė, 2021). Consequently, assessing public perceptions of GMFs requires longitudinal research and continuous monitoring of how both biotechnological innovations and regulatory frameworks evolve over time.

The need for longitudinal studies is further reinforced by the fact that in the European Union population, including Spain, the commercialisation and direct consumption of genetically modified products are very scarce. As a result, concepts such as perceived utility may be influenced by a limited level of information and familiarity. Although this limitation may have been partially mitigated by employing a non-probabilistic convenience sample, since the respondents are likely to possess above-average

knowledge about food-related issues, it should still be explicitly acknowledged. Future research should therefore conduct longitudinal assessments as GMFs become more commonly available and integrated into everyday consumption patterns, enabling a more accurate understanding of how attitudes and PI changes over time.

Authorship contribution

Jorge de Andrés-Sánchez: Software, Formal analysis, Writing – original draft, Visualization. **María Puellas-Gallo:** Conceptualization, Investigation, Resources, Data curation, Project administration. **Mar Souto-Romero:** Methodology, Validation, Writing – review & editing, Supervision. **Mario Arias-Oliva:** Conceptualization, Methodology, Investigation, Project administration, Funding acquisition.

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Declaration of conflict of interest

None.

Data availability

The raw data supporting the conclusions of this article will be made available by the authors on request.

References

- Ajzen, I. (1991). “The theory of planned behavior”. *Organizational Behavior and Human Decision Processes*, 50(2), 179-211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Ajzen, I. (2006). *Constructing a theory of planned behavior questionnaire*. Retrieved from: <https://people.umass.edu/ajzen/tpb.measurement.pdf>
- Ajzen, I. (2012). “Martin Fishbein’s Legacy: The reasoned action approach”. *The Annals of the American Academy of Political and Social Science*, 640(1), 11-27. <https://doi.org/10.1177/0002716211423363>
- Ajzen, I. & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood-Cliffs, NJ: Prentice-Hall.

- Alalwan, A.A., Abu-Romman, S., Al-Weshah, G., Dwivedi, Y.K. & Albanna, H. (2023). "Examining the key determinants of the Jordanian customer's adoption of genetically modified food". *Heliyon*, 9(6), e16920. <https://doi.org/10.1016/j.heliyon.2023.e16920>
- Andrés-Sánchez, J.d., Puelles-Gallo, M., Souto-Romero, M., & Arias-Oliva, M. (2025a). "Importance-Performance map analysis of the drivers for the acceptance of Genetically Modified Food with a Theory of Planned Behavior Groundwork". *Foods*, 14(6), 932. <https://doi.org/10.3390/foods14060932>
- Andrés-Sánchez, J.d., Puelles-Gallo, M., Souto-Romero, M., & Arias-Oliva, M. (2025b). "Drivers of genetically modified food acceptance in members of generations Z and Y: Insights from a theory of planned behavior framework". *Food and Humanity*, 5, 100703. <https://doi.org/10.1016/j.foohum.2025.100703>
- Bašinskienė, L. & Šeinauskienė, B. (2021). "Gene Editing versus Gene Modification: Awareness, attitudes and behavioural intentions of Lithuanian consumers, producers and farmers". *CET Journal-Chemical Engineering Transactions*, 87, 433-438. <https://doi.org/10.3303/CET2187073>
- Bearth, A., Kaptan, G. & Kessler, S.H. (2022). "Genome-edited versus genetically-modified tomatoes: An experiment on people's perceptions and acceptance of food biotechnology in the UK and Switzerland". *Agriculture and Human Values*, 39(3), 1117-1131. <https://doi.org/10.1007/s10460-022-10311-8>
- Bhattacharjee, A. & Premkumar, G. (2004). "Understanding changes in belief and attitude toward information technology usage: A theoretical model and longitudinal test". *MIS Quarterly*, 28(2), 229-254. <https://doi.org/10.2307/25148634>
- Blut, M., Chaney, D., Lunardo, R., Mencarelli, R. & Grewal, D. (2024). "Customer perceived value: A comprehensive meta-analysis". *Journal of Service Research*, 27(4), 501-524. <https://doi.org/10.1177/10946705231222295>
- Boccia, F., Covino, D. & Sarnacchiaro, P. (2018). "Genetically modified food versus knowledge and fear: A Noumenic approach for consumer behaviour". *Food Research International*, 111, 682-688. <https://doi.org/10.1016/j.foodres.2018.06.013>
- Boccia, F. & Punzo, G. (2021). "A choice experiment on consumer perceptions of three generations of genetically modified foods". *Appetite*, 161, 105158. <https://doi.org/10.1016/j.appet.2021.105158>
- Bongoni, R. (2016). "East versus West: Acceptance of GM foods by European and Asian consumers". *Nutrition & Food Science*, 46(5), 628-636. <https://doi.org/10.1108/NFS-10-2015-0121>

- Borrello, M., Cembalo, L. & Vecchio, R. (2021). "Role of information in consumers' preferences for eco-sustainable genetic improvements in plant breeding". *PLoS One*, 16(7), e0255130. <https://doi.org/10.1371/journal.pone.0255130>
- Bratlie, S., Halvorsen, K., Myskja, B.K., Mellegård, H., Bjorvatn, C., Frost, P. & Heiene, G., Hofmann, B., Holst-Jensen, A., Holst-Larsen, T., Malnes, R.S.E., Paus, B., Sandvig, B., Sjøli, S.I., Skarstein, B., Thorseth, M.B., Vagstad, N., Våge, D.I. & Borge, O.J. (2019). "A novel governance framework for GMO: A tiered, more flexible regulation for GMOs would help to stimulate innovation and public debate". *EMBO Reports*, 20(5), e47812. <https://doi.org/10.15252/embr.201947812>
- Bui, H.T. (2022). "Exploring and explaining older consumers' behaviour in the boom of social media". *International Journal of Consumer Studies*, 46(2), 601-620. <https://doi.org/10.1111/ijcs.12715>
- Cabelkova, I., Sanova, P., Hlavacek, M., Broz, D., Smutka, L. & Prochazka, P. (2024). "The moderating role of perceived health risks on the acceptance of genetically modified food". *Frontiers in Public Health*, 11, 1275287. <https://doi.org/10.3389/fpubh.2023.1275287>
- Chen, J., Xu, A., Tang, D. & Zheng, M. (2024). "Divergence and convergence: A cross-generational study on local food consumption". *Scientific Reports*, 14(1), 13463. <https://doi.org/10.1038/s41598-024-64284-1>
- Chen, M.F. & Li, H.L. (2007). "The consumer's attitude toward genetically modified foods in Taiwan". *Food Quality and Preference*, 18(4), 662-674. <https://doi.org/10.1016/j.foodqual.2006.10.002>
- Costa-Font, M. & Gil, J.M. (2009). "Structural equation modeling of consumer acceptance of genetically modified (GM) food in the Mediterranean Europe: A cross country study". *Food Quality and Preference*, 20(6), 399-409. <https://doi.org/10.1016/j.foodqual.2009.02.011>
- Costa-Font, M., Gil, J.M. & Traill, W.B. (2008). "Consumer acceptance, valuation of and attitudes towards genetically modified food: Review and implications for food policy". *Food Policy*, 33(2), 99-111. <https://doi.org/10.1016/j.foodpol.2007.07.002>
- Davis, F.D. (1989). "Perceived usefulness, perceived ease of use, and user acceptance of information technology". *MIS Quarterly*, 13(3), 319-340. <https://doi.org/10.2307/249008>
- Darian, J.C. & Tucci, L. (2011). "Perceived health benefits and food purchasing decisions". *Journal of Consumer Marketing*, 28(6), 421-428. <https://doi.org/10.1108/07363761111165930>

- Delgado-Zegarra, J., Alvarez-Risco, A., Cárdenas, C., Donoso, M., Moscoso, S., Rojas Román, B., Del-Aguila-Arcatales, S., Davies, N.M. & Yáñez, J.A. (2022). "Labeling of genetically modified (GM) foods in Peru: Current dogma and insights of the regulatory and legal statutes". *International Journal of Food Science*, 2022(1), 3489785. <https://doi.org/10.1155/2022/3489785>
- Dimock, M. (2019). Defining generations: Where Millennials end and Generation Z begins. Retrieved from: Pew Research Center. <https://www.pewresearch.org/social-trends/2019/01/17/where-millennials-end-and-generation-z-begins/>
- Dubock, A. (2019). "Golden Rice: To combat vitamin A deficiency for public health". In Queiroz Zepka, L., Vera de Rosso, V. & Jacob-Lopes, E. (Eds.): *Vitamin A*. London: IntechOpen. <https://doi.org/10.5772/intechopen.84445>
- Dul, J. (2016). "Necessary condition analysis (NCA) logic and methodology of "necessary but not sufficient" causality". *Organizational Research Methods*, 19(1), 10-52. <https://doi.org/10.1177/1094428115584005>
- Dul, J., Hauff, S. & Bouncken, R.B. (2023). "Necessary condition analysis (NCA): Review of research topics and guidelines for good practice". *Review of Managerial Science*, 17(2), 683-714. <https://doi.org/10.1007/s11846-023-00628-x>
- Environics Analytics. (2023). *Demographic cohort definitions: Generational segmentation*. Retrieved from: Environics Analytics. <https://environics.ca/expertise/solutions/segmentations/generational-segmentation/>
- European Central Bank. (2024). *Food inflation in the euro area: What are the driving forces behind the extraordinary surge in 2022-2023?*. Retrieved from: European Central Bank. https://ec.europa.eu/economy_finance/forecasts/2024/winter/04%20-%20Food%20inflation.pdf
- Faqih, K.M. (2016). "An empirical analysis of factors predicting the behavioral intention to adopt Internet shopping technology among non-shoppers in a developing country context: Does gender matter?" *Journal of Retailing Consumer Services*, 30, 140-164. <https://doi.org/10.1016/j.jretconser.2016.01.016>
- Farid, M., Cao, J., Lim, Y., Arato, T. & Kodama, K. (2020). "Exploring factors affecting the acceptance of genetically edited food among youth in Japan". *International Journal of Environmental Research and Public Health*, 17(8), 2935. <https://doi.org/10.3390/ijerph17082935>
- Faul, F., Erdfelder, E., Buchner, A. & Lang, A.-G. (2009). "Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses". *Behavior Research Methods*, 41, 1149-1160. <https://doi.org/10.3758/BRM.41.4.1149>

- Fishbein, M. (1967). "A behavior theory approach to the relations between beliefs about an object and the attitude toward the object". In M. Fishbein (Ed.), *Readings in Attitude Theory and Measurement* (pp. 389-400). New York: John Wiley & Sons.
- Fishbein, M. & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Menlo Park, California, United States of America: Addison-Wesley.
- Gao, S., Chen, J., Yang, Y. & Wang, G. (2024). "Understanding the factors driving consumers' willingness to pay for Gene-Edited Foods in China". *Foods*, 13(15), 2348. <https://doi.org/10.3390/foods13152348>
- Goodman, R.E. (2024). "Twenty-eight years of GM Food and feed without harm: Why not accept them?". *GM Crops & Food*, 15(1), 40-50. <https://doi.org/10.1080/21645698.2024.2305944>
- Günden, C., Atakan, P., Yercan, M., Mattas, K. & Knez, M. (2024). "Consumer response to novel foods: A review of behavioral barriers and drivers". *Foods*, 13(13), 2051. <https://doi.org/10.3390/foods13132051>
- Hair, J.F., Risher, J.J., Sarstedt, M. & Ringle, C.M. (2019). "When to use and how to report the results of PLS-SEM". *European Business Review*, 31(1), 2-24. <https://doi.org/10.1108/EBR-11-2018-0203>
- Hao, N. T., Ben Taieb, S., Moritaka, M. & Fukuda, S. (2024). "Consumer acceptance and valuation of quality-improved food products derived by genome editing technology. A case study of rice in Vietnam". *Agribusiness*, 42, 29-50. <https://doi.org/10.1002/agr.21929>
- Henseler, J., Ringle, C.M., & Sarstedt, M. (2016). "Testing measurement invariance of composites using partial least squares". *International Marketing Review*, 33(3), 405-431. <https://doi.org/10.1108/IMR-09-2014-0304>
- Hettich, D., Hattula, S. & Bornemann, T. (2018). "Consumer decision-making of older people: A 45-year review". *The Gerontologist*, 58(6), e349-e368. <https://doi.org/10.1093/geront/gnx007>
- Hingston, S.T. & Noseworthy, T.J. (2018). "Why consumers don't see the benefits of genetically modified foods, and what marketers can do about it". *Journal of Marketing*, 82(5), 125-140. <https://doi.org/10.1509/jm.17.0100>
- Hui, X., Amponsah, R.K., Antwi, S., Gbolonyo, P.K., Ameyaw, M.A., Bentum-Micah, G. & Adjei, E.O. (2024). "Understanding the societal dilemma of genetically modified food consumption: a stimulus-organism-response investigation". *Frontiers in Sustainable Food Systems*, 8, 1364052. <https://doi.org/10.3389/fsufs.2024.1364052>

- Inbar, Y., Phelps, J. & Rozin, P. (2020). "Recency negativity: Newer food crops are evaluated less favorably". *Appetite*, 154, 104754. <https://doi.org/10.1016/j.appet.2020.104754>
- INE. (2022). *Índice de precios de consumo. Base 2021*. Retrieved from: Instituto Nacional de Estadística. https://ine.es/prensa/ipc_base_2021.pdf
- Jin, S., Li, W., Dawson, I.G., Clark, B., Chen, S. & Frewer, L.J. (2022). "Consumer responses to genetically modified food in China: The influence of existing general attitudes, affect and perceptions of risks and benefits". *Food Quality and Preference*, 99, 104543. <https://doi.org/10.1016/j.foodqual.2022.104543>
- Kiran, F., Sultan, F. & Nawaz, M.A. (2023). "Acceptance of Genetically Modified Organism: A study based on consumption values, food attitude, and food technology neophobia". *Journal of Management Sciences*, 10(1), 57-75. <https://doi.org/10.20547/jms.2014.2310104>
- Kock, N. & Hadaya, P. (2018). "Minimum sample size estimation in PLS-SEM: The inverse square root and gamma-exponential methods". *Information Systems Journal*, 28(1), 227-261. <https://doi.org/10.1111/isj.12131>
- Kock, N. & Lynn, G.S. (2012). "Lateral collinearity and misleading results in variance-based SEM: An illustration and recommendations". *Journal of the Association for Information Systems*, 13(7), 546-580. <https://doi.org/10.17705/1jais.00302>
- Kolkur, S.U., Sharma, A., Gouda, M.N.R., Praveen, K.V. & Singh, A. (2024). "CRISPR in agriculture and its ethical implications: A bibliometric analysis". *Food and Humanity*, 3, 100322. <https://doi.org/10.1016/j.foohum.2024.100322>
- Kubisz, P., Dalton, G., Majewski, E. & Pogodzińska, K. (2021). "Facts and myths about GM food. The case of Poland". *Agriculture*, 11(8), 791. <https://doi.org/10.3390/agriculture11080791>
- Lucht, J.M. (2015). "Public acceptance of plant biotechnology and GM crops". *Viruses*, 7(8), 4254-4281. <https://doi.org/10.3390/v7082819>
- Makowska, M., Boguszewski, R. & Hrehorowicz, A. (2024). "Generational differences in food choices and consumer behaviors in the context of sustainable development". *Foods*, 13(4), 521. <https://doi.org/10.3390/foods13040521>
- Mann, S. & Loginova, D. (2023). "Distinguishing inter- and pangenerational food trends". *Agricultural and Food Economics*, 11(1), 10. <https://doi.org/10.1186/s40100-023-00252-z>

- Marín-Díaz, A., Alvarez-Risco, A., Del-Aguila-Arcntales, S., Rojas-Cangahuala, G. & Yáñez, J. A. (2024). "Evaluating the intention to purchase genetically modified food by consumers in Panama". *Journal of Agriculture and Food Research*, 16, 101194. <https://doi.org/10.1016/j.jafr.2024.101194>
- McComas, K.A., Besley, J.C. & Steinhardt, J. (2014). "Factors influencing US consumer support for genetic modification to prevent crop disease". *Appetite*, 78, 8-14. <https://doi.org/10.1016/j.appet.2014.02.006>
- Montesinos-López, O.A., Perez, E.F., Fuentes, E.E.S., Luna-Espinoza, I. & Cuevas, F.A. (2016). "Perceptions and attitudes of the Mexican urban population towards genetically modified organisms". *British Food Journal*, 118(12), 2873-2892. <https://doi.org/10.1108/BFJ-06-2016-0247>
- 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>
- Ngo, T.T.A., Phan, T.Y.N. & Le, T.N.T. (2024). "Impacts of knowledge and trust on consumer perceptions and purchase intentions towards genetically modified foods". *Plos One*, 19(10), e0311257. <https://doi.org/10.1371/journal.pone.0311257>
- Ogundijo, D.A., Tas, A.A. & Onarinde, B.A. (2022). "Age, an important sociodemographic determinant of factors influencing consumers' food choices and purchasing habits: An English university setting". *Frontiers in Nutrition*, 9, 858593. <https://doi.org/10.3389/fnut.2022.858593>
- Ogwu, M.C., Thompson, O.P., Kosoe, E.A., Mumuni, E., Akolgo-Azupogo, H., Obahiagbon, E.G., Izah, S.C. & Imarhiagbe, O. (2024). "Factors driving the acceptance of genetically modified food crops in Ghana". *Food Safety and Health*, 2(1), 158-168. <https://doi.org/10.1002/fsh3.12031>
- Prati, G., Pietrantoni, L. & Zani, B. (2012). "The prediction of intention to consume genetically modified food: Test of an integrated psychosocial model". *Food Quality and Preference*, 25(2), 163-170. <https://doi.org/10.1016/j.foodqual.2012.02.011>
- Ramadan, K., Neill, A., Garrod, G., Ojo, M. & Hubbard, C. (2024). "Societal perceptions and attitudes towards genetically modified (GM) crops, feed, and food products in the Middle East, North Africa, and Turkey (MENAT) region: A systematic literature review". *Food Quality and Preference*, 117, 105148. <https://doi.org/10.1016/j.foodqual.2024.105148>

- Richter, N.F., Schubring, S., Hauff, S., Ringle, C.M. & Sarstedt, M. (2020). "When predictors of outcomes are necessary: Guidelines for the combined use of PLS-SEM and NCA". *Industrial Management & Data Systems*, 120(12), 2243-2267. <https://doi.org/10.1108/IMDS-11-2019-0638>
- Ringle, C.M., Wende, S. & Becker, J.-M. (2024). *SmartPLS 4*. Bönningstedt: SmartPLS. Retrieved from: SmartPLS. <https://www.smartpls.com>
- Rodrigues, H., Gómez-Corona, C. & Valentin, D. (2020). "Femininities & masculinities: Sex, gender, and stereotypes in food studies". *Current Opinion in Food Science*, 33, 156-164. <https://doi.org/10.1016/j.cofs.2020.05.002>
- Rodríguez-Entrena, M. & Salazar-Ordóñez, M. (2013). "Influence of scientific-technical literacy on consumers' behavioural intentions regarding new food". *Appetite*, 60, 193-202. <https://doi.org/10.1016/j.appet.2012.09.028>
- Safi-Sis, Y., Rezaei, A., Karimi, H. & Ataei, P. (2022). "Modeling antecedent factors involved in behavioral intention towards technology application of genetically modified crops". *GM Crops & Food*, 13(1), 50-64. <https://doi.org/10.1080/21645698.2022.2057160>
- Sánchez-Fernández, R. & Iniesta-Bonillo, M.Á. (2007). "The concept of perceived value: A systematic review of the research". *Marketing Theory*, 7(4), 427-451. <https://doi.org/10.1177/1470593107083165>
- Siegrist, M. (2008). "Factors influencing public acceptance of innovative food technologies and products". *Trends in Food Science & Technology*, 19(11), 603-608. <https://doi.org/10.1016/j.tifs.2008.01.017>
- Vega Rodríguez, A., Rodríguez-Oramas, C., Sanjuán Velázquez, E., Hardisson de la Torre, A., Rubio Armendáriz, C. & Carrascosa Iruzubieta, C. (2022). "Myths and realities about genetically modified food: A risk-benefit analysis". *Applied Sciences*, 12(6), 2861. <https://doi.org/10.3390/app12062861>
- Venkatesh, V. & Davis, F.D. (2000). "A theoretical extension of the technology acceptance model: Four longitudinal field studies". *Management Science*, 46(2), 186-204. <https://doi.org/10.1287/mnsc.46.2.186.11926>
- Venkatesh, V., Thong, J.Y. & Xu, X. (2012). "Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology". *MIS Quarterly*, 36(1), 157-178. <https://doi.org/10.2307/41410412>
- Warda, M., Tekin, S., Khafaga, N., Sengul, E., Çelebi, F. & Laçin, B.B. (2025). "Comprehensive insights into Genetically Modified Foods: Technological Advances, nutritional benefits, therapeutic applications, and health implications". *Food Safety and Health*, 3(3), 334-355. <https://doi.org/10.1002/fsh3.70011>

- WHO. (2014). *Genetically modified food*. Retrieved from: World Health Organization. <https://www.who.int/news-room/questions-and-answers/item/food-genetically-modified>.
- Wildavsky, A. & Dake, K. (1990). "Theories of risk perception: Who fears what and why?" *Daedalus*, 119(4), 41-60. <http://www.jstor.org/stable/20025337>
- Wolstenholme, E., Carfora, V., Catellani, P., Poortinga, W. & Whitmarsh, L. (2021). "Explaining intention to reduce red and processed meat in the UK and Italy using the theory of planned behaviour, meat-eater identity, and the Transtheoretical model". *Appetite*, 166, 105467. <https://doi.org/10.1016/j.appet.2021.105467>
- Wozniak-Gientka, E., Agata, T., Milica, P., Anna, B., Dennis, E., Nick, V., Godelieve, G., Selim, C., Naghmeh, A. & Tomasz, T. (2022). "Public perception of plant gene technologies worldwide in the light of food security". *GM Crops & Food*, 13(1), 218. <https://doi.org/10.1080/21645698.2022.2111946>
- Yang, Y. & Hobbs, J.E. (2020). "Supporters or opponents: Will cultural values shape consumer acceptance of gene editing?" *Journal of Food Products Marketing*, 26(1), 17-37. <https://doi.org/10.1080/10454446.2020.1715316>
- Ye, Y. (2010). "Correlates of consumer trust in online health information: Findings from the health information national trends survey". *Journal of Health Communication*, 16(1), 34-49. <https://doi.org/10.1080/10810730.2010.529491>
- Zeithaml, V.A. (1988). "Consumer perceptions of price, quality, and value: A means-end model and synthesis of evidence". *Journal of Marketing*, 52(3), 2-22. <https://doi.org/10.1177/002224298805200>
- Zhao, L., Liu, S., Gu, H. & Ahlstrom, D. (2023). "Risk Amplification, risk preference and acceptance of transgenic technology". *Agriculture*, 13(10), 1871. <https://doi.org/10.3390/agriculture13101871>
- Zheng, Q., Nayga Jr, R.M., Yang, W. & Tokunaga, K. (2023). "Do US consumers value genetically modified farmed salmon?". *Food Quality and Preference*, 107, 104841. <https://doi.org/10.1016/j.foodqual.2023.104841>
- Zhou, Y., Chen, S., Wang, T. & Cui, Q. (2022). "Does education affect consumers' attitudes toward genetically modified foods? Evidence from China's two rounds of education reforms". *China Agricultural Economic Review*, 14(3), 631-645. <https://doi.org/10.1108/CAER-01-2021-0024>

APPENDIX A

Items, descriptive statistics and item loading

Item	Mean	Standard deviation	Factor loading	Variance Inflation Factor
Purchase intention (PI) of GMF				
PI1: I intend to eat genetically modified foods.	4.323	3.222	0.954	2.730
PI2: I predict that I will try genetically modified foods.	4.871	3.417	0.941	2.730
Perceived usefulness (USEFUL)				
USEFUL1: I consider it useful to cultivate and commercialise genetically modified foods.	4.819	3.043	0.924	1.730
USEFUL2: The production and consumption of genetically modified foods enable the achievement of important objectives more quickly.	4.835	2.843	0.905	1.320
USEFUL3: Producing and consuming genetically modified foods has many benefits.	4.234	2.859	0.924	1.930
Perceived Risk (RISK)				
RISK1: Trying genetically modified foods is risky.	5.000	2.993	0.920	1.710
RISK2: There is too much uncertainty in consuming genetically modified foods.	9.140	2.820	–	–
RISK3: In comparison with its alternatives, genetically modified foods have more risk.	5.468	2.928	0.900	1.710
Perceived Value (VALUE)				
VALUE1: Genetically modified foods have a reasonable price.	4.81	2.381	0.822	1.960
VALUE2: Genetically modified foods have good value for money.	4.722	2.355	0.909	2.450
VALUE3: The current price of genetically modified foods is good for what they offer.	4.488	2.263	0.892	2.020
Subjective Norm (SNORM)				
SNORM1: The people who are important to me think that I should eat genetically modified foods.	3.185	3.024	0.963	3.770
SNORM2: The people whose opinions I value would prefer that I eat genetically modified foods.	3.069	3.090	0.964	3.770

Source: Own elaboration.

APPENDIX B

Measures of the validity of the measurement model

	VIF ^a	CA ^b	CR ^b	AVE ^b	PI ^c	USEFUL ^c	RISK ^c	SNORM ^c	VALUE ^c	MALE ^c	BOOMER ^c
PI	3.444	0.886	0.896	0.897	0.947	0.822	0.657	0.839	0.471	0.047	0.071
USEFUL	2.758	0.906	0.911	0.842	0.741	0.918	0.650	0.708	0.553	0.052	0.033
RISK	1.554	0.784	0.791	0.822	-0.552	-0.552	0.907	0.484	0.289	0.043	0.022
SNORM	2.504	0.923	0.923	0.929	0.422	0.501	-0.413	0.875	0.347	0.032	0.008
VALUE	1.357	0.850	0.884	0.766	0.762	0.649	-0.246	0.324	0.964	0.046	0.130
MALE	–	–	–	–	0.045	0.049	-0.037	0.031	-0.018	1.000	0.093
BOOMER	–	–	–	–	-0.065	-0.031	0.019	0.003	-0.129	0.093	1.000

Note: (a) VIF=The variance inflation factor of constructs in lateral and vertical collinearity test (Kock & Lynn, 2012) (b) Measures of scale internal consistency and reliability: CA=Cronbach's α , CR=convergent reliability, AVE=average variance extracted. (c) Measures of scale discriminant validity: In the principal diagonal comes the squared root of AVE, below the principal diagonal comes the heterotrait-monotrait ratios, and above the principal diagonal, Pearson's correlations

Source: Own elaboration.

APPENDIX C

95 % bootstrap confidence intervals for HTMT ratios

Relation	HTMT (Original sample)	HTMT (Sample mean)	2.50 % - percentile	97.50 % - percentile
USEFUL <-> PI	0.822	0.820	0.731	0.895
RISK <-> PI	0.657	0.656	0.525	0.777
RISK <-> USEFUL	0.65	0.649	0.512	0.771
SNORM <-> PI	0.839	0.839	0.774	0.896
SNORM <-> USEFUL	0.708	0.706	0.596	0.796
SNORM <-> RISK	0.484	0.483	0.339	0.62
VALUE <-> PI	0.471	0.470	0.324	0.594
VALUE <-> USEFUL	0.553	0.554	0.401	0.685
VALUE <-> RISK	0.289	0.291	0.125	0.457
VALUE <-> SNORM	0.347	0.347	0.201	0.481
MALE <-> PI	0.047	0.069	0.009	0.186
MALE <-> USEFUL	0.052	0.073	0.015	0.185
MALE <-> RISK	0.043	0.076	0.013	0.183
MALE <-> SNORM	0.032	0.061	0.009	0.164
MALE <-> VALUE	0.046	0.077	0.025	0.159
BOOMER <-> PI	0.071	0.087	0.015	0.201
BOOMER <-> USEFUL	0.033	0.067	0.015	0.163
BOOMER <-> RISK	0.022	0.067	0.01	0.171
BOOMER <-> SNORM	0.008	0.056	0.007	0.149
BOOMER <-> VALUE	0.130	0.138	0.044	0.258
BOOMER <-> MALE	0.093	0.098	0.006	0.217

Note: HTMT=heterotrait monotrait.

Source: Own elaboration.

APPENDIX D

Measurement invariance of composite models (MICOM)

Construct	Compositional invariance			Equality of means			Equality of variances		
	OC	PM	p-value	OD	PM	p-value	OD	PM	p-value
PI	1.000	1.000	0.829	-0.13	0.003	0.300	0.006	-0.001	0.958
USEFUL	1.000	1.000	0.335	-0.061	0.003	0.624	0.265	-0.001	0.066
RISK	1.000	0.998	0.707	0.038	-0.005	0.764	0.139	0.001	0.365
SNORM	1.000	1.000	0.736	0.007	0.003	0.956	0.029	0.000	0.853
VALUE	0.992	0.997	0.075	-0.258	-0.001	0.043	0.194	-0.001	0.348

Note: OC stands for original correlation, OD, original difference (of means in the step of equality of means and of variances in the equality of variances) and PM permutation means in the three steps of MICOM

Source: Own elaboration.