Beyond Neophobia: An Integrative Model of Psychological Factors Influencing 3DPF Acceptance

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Abstract

Despite rapid advances in food-printing technology, commercial uptake of 3D-printed food is still modest and extant research provides only piecemeal consumer-psychology perspectives. This study aims to develop and test an integrative model that jointly considers psychological barriers (perceived safety, food neophobia, perceived health risk), facilitators (perceived benefits, knowledge of the product, personal innovativeness) and the moderating roles of environmental consciousness and social desirability in shaping consumers' intention to consume 3D-printed food.

Primary data were collected through a structured questionnaire administered to 141 Italian consumers and analyzed with partial least squares structural-equation modelling. Results show that food neophobia is the unique barrier exerting a significant negative effect on intention, whereas perceived benefits, product knowledge and personal innovativeness all positively influence adoption. Environmental consciousness strengthens the impact of personal innovativeness, while other moderating paths and the direct effects of perceived safety and health risk are nonsignificant.

Theoretically, the study clarifies the relative salience of facilitators over risk-based deterrents and identifies an "eco-innovative" consumer segment in which sustainability values amplify innovativeness effects. Practically, marketers should foreground customizable nutritional and environmental benefits, provide experiential knowledge opportunities, and implement gradual exposure strategies to mitigate neophobia and accelerate mainstream acceptance of 3D-printed food products.

Keywords: 3D printed food (3DPF), Food Neophobia, Consumption Intention, Consumer Acceptance, Sustainability, Quantitative Research.

1. Introduction

Recent advancements in food technology are transforming the way individuals produce and consume food, with increasing emphasis on personalization, sustainability, and resource efficiency. Among these innovations, three-dimensional food printing has emerged as a promising solution that combines digital manufacturing techniques with culinary creativity. By layering edible materials through additive manufacturing techniques, three-dimensional food printing allows for the creation of customized shapes, textures, nutritional profiles, and even sustainability-enhanced meals (Varvara

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et al., 2021; Sun et al., 2015). These capabilities open new possibilities across sectors, from fine dining and healthcare to waste reduction and dietary personalization (Zhu et al., 2023). Despite these advantages, the commercial adoption of 3D-printed food (3DPF) remains limited.

Previous research has highlighted perceived benefits, such as nutritional optimization, environmental sustainability, and aesthetic appeal, as key factors in shaping positive consumer attitudes (Cunningham et al., 2025; Ng et al., 2022). Although enthusiasm for 3DPF is rising, research that explains the phenomenon from a consumer-psychology angle is still fragmented. Existing work has mostly concentrated on improving printing technologies and material attributes, while the psychological forces that drive, or deter, adoption receive far less attention (Zhu et al., 2023). Seo and Shigi (2024), for instance, emphasize positive expectations such as sustainability benefits, yet overlook potential inhibitors like food neophobia or perceived risk. Although Silva et al. (2024) include food neophobia, perceived benefits, and digital affinity when examining attitudes toward 3DPF, they do not attempt to integrate these elements into a single theoretical model.

To address this issue, the present study proposes an extended theoretical model that incorporates both psychological barriers, including perceived food safety, food neophobia, and perceived health risk, alongside major facilitators, such as perceived benefits, knowledge of the product, and personal innovativeness. In addition, the model introduces two moderating variables: environmental consciousness and social desirability, which have received limited attention in this context despite their relevance in sustainability and innovation literature (Kautish et al., 2021; De Jong et al., 2010).

Drawing on a nationally representative sample and validated scales analyzed through structural-equation modelling, the study delivers a more comprehensive, theoretically grounded picture of consumer responses to 3DPF.

This paper offers insights for both marketers and policy makers, including the need to turn knowledge into positive experiences through educational and tasting initiatives, and the importance of communicating clear environmental benefits to enhance consumer acceptance of 3DPF.

The remainder of the paper is structured as follows: Section 2 reviews the relevant literature and develops the research hypotheses. Section 3 presents the research methodology. Section 4 reports the empirical results, followed by Section 5, which discusses the main findings. Section 6, 7 present theoretical and managerial contributions while Section 8 concludes the study by outlining research limitations and future directions.

2. Theoretical Background

Three-dimensional food printing utilizes additive manufacturing techniques, digitally controlled processes that build objects layer by layer from a digital file, to create food products by depositing edible materials in successive layers (Varvara et al., 2021).

Currently, extrusion-based systems dominate the field due to their material flexibility and broad applicability, working by pushing paste-like materials such as doughs, purées, or plant proteins through nozzles (Baiano, 2022), while inkjet and binder-jet technologies offer finer structural detail by depositing liquid droplets or selectively

binding powdered ingredients, thus providing higher resolution in certain contexts (Shah et al., 2024). Selective laser sintering has also been adapted for materials like sugar and chocolate, using laser energy to fuse powder layers into delicate structures (Zhu et al., 2023).

The development of three-dimensional food printing gained early momentum with the 2005 launch of the open-source Fab@Home platform for multi-material printing, which by 2007 could print edible materials such as cookie dough and chocolate, and culminated in the early 2010s with the emergence of commercial devices like Natural Machines' Foodini printer for food pastes and purées, enabling shaped vegetable purées and pasta bases (Baiano, 2022).

Current applications of 3DPF span a wide range of contexts, from fine dining, where chefs use the technology to create geometric garnishes and bespoke chocolates (Baiano, 2022), to healthcare settings, where it supports personalized nutrition by printing vitamin-fortified bars and texture-modified purees for patients with dysphagia (Zhu et al., 2023). Organizations such as NASA are also investigating the use of three-dimensional food printing to produce on-demand meals in zero-gravity or remote environments, utilizing shelf-stable ingredient cartridges to ensure safety and efficiency (Baiano, 2022). Beyond institutional and professional use, hobbyists and home cooks have adopted consumer-grade printers to craft novelty items such as pancake art and customized cookies (Shah, 2024). One of the key advantages of three-dimensional food printing is its ability to produce customized meals by varying nutrient concentrations, introducing healthy ingredients such as vitamins and fibers, and adapting macronutrient and micronutrient profiles to meet individual dietary needs and preferences (Baiano, 2022). Another major benefit is sustainability: the technology minimizes ingredient waste and allows the repurposing of surplus produce and alternative proteins, thus enhancing supply-chain efficiency (Zhu et al., 2023). Finally, the technology improves accessibility in healthcare settings by enabling the production of nutritionally adequate meals with customized textures and shapes, particularly for patients with dysphagia, who require modified food consistencies for safe consumption (Baiano, 2022).

Perceived benefits, such as nutritional enhancement, convenience, and waste reduction, significantly drive consumer acceptance of 3DPF, notably increasing consumers' willingness to experiment when these clear advantages are evident (Cunningham et al., 2025). Supporting this, Ng et al. (2022) highlight that perceived benefits, particularly those related to health improvements, strongly shape positive consumer attitudes towards this technology. Additionally, emphasizing these nutritional and environmental benefits has proven effective in shifting consumer attitudes favorably towards 3DPF, as demonstrated by survey findings in South Africa and Malaysia (Cunningham et al., 2025; Ng et al., 2022). Furthermore, in emerging markets, emphasizing perceived product value, defined through quality and practical utility, can significantly enhance consumers' willingness to pay premium prices for printed foods (Yang et al., 2024).

2.1 Barriers and facilitators to adoption

The adoption of 3DPF faces different challenges. Recent research (Zhu et al., 2023) highlights consumers' lack of trust in 3DPF due to the unfamiliar and unclear process. The lack of standard regulations generates doubts about hygiene, safety, and naturalness (Hwang and Choe, 2020). The literature on the topic is still fragmented. No empirical study has identified a clear set of barriers or facilitators (Zhu et al., 2023). To address this gap, the present study introduces a theoretical model based on literature focusing on three potential psychological barriers and facilitators. Barriers may represent an obstacle to consumer adoption: *Perceived Safety* (SAF), *Food Neophobia* (FN), and *Perceived Health Risk* (PHR). Facilitators can increase consumption by reducing their reluctance: *Perceived Benefits* (PB), *Knowledge of the Product* (KN), and *Personal Innovativeness* (PI).

2.1.1 Food neophobia, perceived health risk and safety of 3DPF

SAF can be an obstacle to the adoption of 3DPF. There are no national or international laws that regulate the production process or define standards for food, which increases reluctance and reduces acceptance (Zhu et al., 2023). This absence of standardized guidelines restricts the potential consumption of 3DPF because no information scares consumers (Zhu et al., 2023). According to the findings of preceding studies, respondents have expressed a notable level of concern regarding the safety of 3DPF. Results found by Mansan and McSweeney (2020) that about half of the participants in their study were worried about the safety of 3DPF. A study by Lupton and Turner (2016), also highlighted that safety was a key concern among participants. Considering these insights, Hypothesis 1 is formulated as follows:

H1: SAF significantly and negatively affects the intention to consume 3DPF.

FN is the aversion to try novel or unfamiliar foods (Gustavsen et al., 2025). It is an adverse emotional reaction to new food, technologies, and sources. FN is a mental protective strategy used to avoid harmful substances or situations, often seen as a rejection of unfamiliar foods (Velasco Vizcaíno and Pohlmann, 2025). Nevertheless, it is influenced by demographic and socio-economic variables such as age, gender, education, and family background (Chang et al., 2024), which may sometimes reduce FN. For example, some studies have confirmed the value of minimizing FN in increasing consumer acceptance of insect consumption (Chang et al., 2024). Frequent exposure to new food reduces its perceived novelty and leads to acceptance among consumers (Gustavsen et al., 2025). Considering these insights, Hypothesis 2 was formulated.

H2: FN significantly and negatively affects the intention to consume 3DPF.

PHR influences consumer acceptance of innovative food products. The PHR is the consumer's belief that food may negatively impact health and rise when a product is novel and the information is limited (Chang et al., 2024). According to the World

Health Organization, foodborne illnesses related to food consumption represent one of the most frequent causes of mortality in the world (Chang et al., 2024). Food risk concerns increased during the COVID-19 pandemic due to the fears of indirect transmission through food or packaging (Hwang and Choe, 2020). Recent research on 3DPF highlights consumers' concerns about naturalness, potential harm, freshness, taste, and nutritional value (Chang et al., 2024). Considering these insights, Hypothesis 3 is formulated as follows:

H3: PHR significantly and negatively affects the intention to consume 3DPF.

2.1.2 Perceived benefit, knowledge, and personal innovativeness

The perception of benefits influences consumers' intention to consume and the acceptance of innovative foods. It is the subjective evaluation of the advantages of consuming 3DPF. PB are social and quality-related (Seo and Shigi, 2024). PB have a social advantage because they have a crucial role in reinforcing the sustainability of the production process, particularly for consumers who have green awareness. Moreover, taste, healthiness, convenience, and nutritional customization are essential to raising product acceptance (Seo and Shigi, 2024). Evaluating the benefit of adopting innovative food depends on the cost-benefit paradigm, which is often discussed in decision-making research (Kim et al., 2019). A strong perception of the social and health-related benefits of 3DPF positively influences consumers' intention to adopt innovative food (Seo and Shigi, 2024). Considering these insights, Hypothesis 4 is formulated as follows:

H4: PB has a significant positive impact on the intention to consume 3DPF.

Another key factor is PI which is the openness to new experiences or technologies (Agarwal and Prasad, 1998). It is considered a key dimension of consumers' personality, reducing reluctance and shaping adoption. With high PI, early adopters are consumers less constrained by traditional norms who show a higher propensity to try unfamiliar products (Agarwal and Prasad, 1998). Early adopters have high PI and, for this reason, are opinion leaders and can influence the diffusion of innovative technologies through social influence, particularly in food. Their openness to innovation may reduce psychological reluctance to 3DPF, which plays a decisive role in shaping public perception and normalizing the adoption of emerging food technologies (Wang et al.,2024). Considering these insights, Hypothesis 5 is formulated as follows:

H5: PI has a significant positive impact on the intention to consume 3DPF.

In addition, KN plays a significant role because it shapes consumers' attitudes toward innovative food. Previous research indicates that the level of knowledge impacts

consumers' choices and evaluation processes when there is an unfamiliar product (Kelting et al., 2017). For example, for insect-based foods (food with alternative proteins), good knowledge and more information are linked to higher product consumption. Previous experience and familiarity with products influence willingness to consume them (Piha et al., 2018). Better product knowledge reduces the perceived risk and raises trust in the production process. Knowledge leads consumers to a more deliberate decision-making process instead of an instinctive rejection of unfamiliar products (Piha et al., 2018). Considering these insights, Hypothesis 6 is proposed as follows:

H6: KN significantly and positively impacts the intention to consume 3DPF.

2.2 Moderating variables: environmental consciousness and social desirability

Based on existing literature, *Environmental Consciousness* (EC) and *Social Desirability* (SD) (Costa et al., 2021; Kautish et al., 2019) can play a fundamental role in shaping consumer intentions toward 3DPF. They can influence the relationship between barriers and facilitators to the intention to consume 3DPF. The acceleration of environmental concerns, sustainability challenges, and consumer awareness about environmental crises has positioned green consumption as socially relevant (Kautish et al., 2019).

According to Zelezny and Schultz (2000), EC is an individual's psychological propensity to engage in pro-environmental behavior. It is conceptualized as a multidimensional mental state that comprises value, emotional response, personality traits, and attitudinal orientations (Kautish et al., 2019; Kautish et al., 2021). EC is often reflected in attitudes and behaviors to minimize ecological harm. It is demonstrated that consumers with higher EC value green product attributes favorably and lead to eco-friendly decisions (Kilbourne et al., 2008). The value system is changing for all consumers toward more sustainable consumption, and incorporating sustainability attributes in products is a principal strategy of the company for raising consumption among eco-conscious individuals (Kautish et al., 2021). Pro-environmental values play a critical role in shaping consumer acceptance and always lead to the choice of a more sustainable product and green consumption (Pickett-Baker et al., 2008). Hypotheses of moderating effects of EC are shown in Table 5.

SD was originally conceptualized as a stable trait by Crowne and Marlowe, (1960), whose 33-item Marlowe-Crowne Social Desirability Scale (MC-SDS) remains the benchmark for assessing individual differences in this motive. Later work distinguished two underlying processes: self-deceptive enhancement and impression management, captured by the Balanced Inventory of Desirable Responding (Paulhus, 1991). From a theoretical standpoint, SD is rooted in social-norms theory, which posits that behavior is guided by injunctive and descriptive expectations (Cialdini and Goldstein, 2004), and in impression-management theory, which treats self-presentation as a strategic effort to claim socially valued identities.

Because the SD motive heightens concern with how one's choices will be judged, it can amplify the influence of factors that signal social approval (e.g., perceived environmental benefit) while muting factors rooted in private affect (e.g., food neophobia). A study by Fisher and Katz, (2000) confirmed that respondents high in SD inflate other-oriented values. Extending this evidence, De Jong et al., (2010) demonstrated that moving from conventional self-reports to indirect questioning eliminates SD-driven inflation of sensitive consumption desires, revealing stronger underlying relationships between genuine motives and intentions. Similar patterns appear in sustainable consumption: structural models of South-Australian organic purchasers indicate that impression-management SD suppresses the effect of personal ecological attitude on stated purchase frequency (Wheeler et al., 2019). Collectively, these studies justify modelling SD not merely as a statistical control but as a theoretically meaningful moderator of intention frameworks.

Within our conceptual framework, SD functions as a moderator overlaying both facilitators and barriers. When SD is high, the positive paths from PB, EC and PI to 3DPF intention should strengthen, because endorsing a cutting-edge, sustainable technology conveys a favorable social image. Conversely, the negative path from FN is expected to weaken: publicly admitting fear of novel foods is socially unattractive, so high-SD consumers may under-report neophobic tendencies, diluting their deterrent effect. By integrating SD, the model recognizes that stated intentions toward 3DFP reflect not only cognitive evaluations but also the social signaling value of embracing a futuristic diet. Hypotheses of moderating effects of SD are shown in Table 5.

The entire hypothesized model is visible in Figure 1.

Figure 1. Hypothesized conceptual model
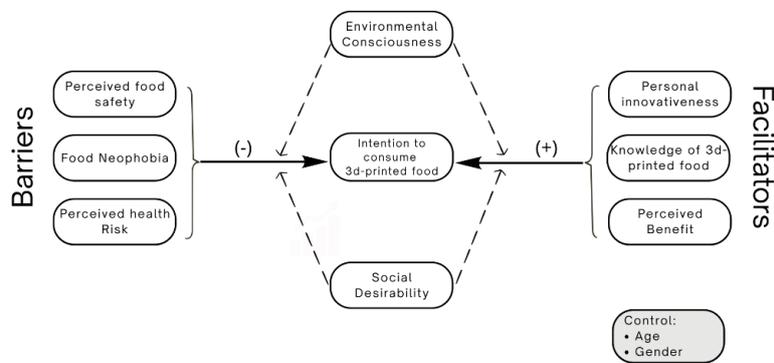
3. Materials and Method

This study adopts a quantitative research approach. Primary data were collected through a structured questionnaire administered to a convenience sample. The questionnaire consisted of two main sections. The first section began with a screening question assessing whether respondents were already familiar with 3DPF. It then included the

measurement items corresponding to the constructs tested in the theoretical model. The second section gathered socio-demographic information (e.g., gender, age, educational attainment, and income level). Table 1 reports the key demographic characteristics of the sample.

Table 1. Socio-demographic characteristics of the sample

Variable	Category	No.	Percentage (%)
Gender	Male	66	46.8%
	Female	75	53.2%
	Other/Choose not to say	0	0%
Educational level	Elementary school/Lower secondary school	4	2.8%
	Higher Secondary School	21	14.9%
	Bachelor's degree (3 years)	36	25.5%
	Degree (5 years or more)	68	48.2%
	Doctorate	12	8.5%
Monthly income range	<1,000 €	42	29.8%
	1,000 – 3,000 €	90	63.8%
	>3,000€	9	6.4%

Note: Sample size = 141 respondents
Source: Authors' elaboration

The sample's mean age was 29.8 years (SD=8.24; range 19–63) with a balanced gender distribution. The sample was characterized by a high level of educational attainment: cumulatively, nearly three-quarters of participants held a university degree (bachelor's or higher), with 48.2% holding a master's degree. Most participants (over 50%) reported a monthly income in the €1,000 to €3,000 range.

Out of a total of 270 responses, approximately 60% of participants (n = 162) answered "yes" to the initial screening question, indicating they had heard of 3DPF, even if only vaguely. To enhance data quality and reduce potential bias, 21 respondents were excluded due to invalid answers to the attention check question (Abbey and Meloy, 2017), for a total of 141 valid questionnaires.

3.1 Measures

The study employed nine latent constructs, which are detailed in Table 2. All constructs were rigorously validated in prior literature and carefully adapted to align with the specific objectives of this research.

The construct measuring *Knowledge of the Product* was adapted from Mitchell et al. (1996) and Kelting et al. (2017). The *Food Neophobia* scale draws from Pliner et al. (1992), Siegrist et al. (2013), Jaeger et al. (2017), and Lee et al. (2021). *Personal Innovativeness* was measured using the scale developed by Agarwal and Prasad (1998), while *Perceived Health Risk* was adapted from Hwang et al. (2020) and Tesikova et al. (2022). The construct *Perceived Benefit* follows Kim et al. (2019), *Social Desirability* is based on Ding et al. (2005), and *Perceived Safety* was derived from Lando and Carlton (2011) and Berry et al. (2015).

Environmental Consciousness was adapted from Kilbourne and Pickett (2008), and *Intention to Consume* was measured using items from Gao et al. (2017) and Alam et al. (2020).

The *Perceived Safety* construct was measured using a 7-point semantic differential scale, while all other constructs were assessed using 7-point Likert-type scales ranging from 1 ("strongly disagree") to 7 ("strongly agree").

Table 2. Overview of the measurements for reliability test

Dimension	Items	Factor Loadings	Cronbach's α	CR (ρc)	AVE
Knowledge of the Product	How familiar are you with 3D printed food?	0.878			
	How clear is your idea with respect to the characteristics of 3D printed food?	0.800			
	How much do you know about 3D printed food?	0.935	0.900	0.929	0.766
	How would you rate your knowledge of 3D printed food compared to the rest of the population? I think I am: one of the least informed/one of the most informed people	0.883			
Food Neophobia	In general. I don't trust innovative foods	0.829			
	In general. I don't try innovative foods	0.835			
	The unusual appearance of 3D printed food prevents me from eating it	0.843	0.895	0.922	0.703
	I have doubts about the hygiene and safety of 3D printed food	0.814			
	The ingredients of 3D printed food make me suspicious	0.871			
Personal Innovativeness	I like to explore new things	0.890			
	I am usually the first among my friends to try new foods	0.887			
	I openly accept new ways of thinking	0.658	0.917	0.938	0.755
	I like to try new things	0.938			
	I am interested in trying new foods	0.942			
Perceived Health Risk	I fear that 3D printed food is harmful to health	0.939			
	I fear that 3D printed food is unhealthy	0.952			
	I believe there is a risk of chemical contamination (e.g. heavy metals and pesticides) in 3D printed food	0.929	0.947	0.962	0.863
	I believe there is a risk of microbiological contamination (e.g. Escherichia coli and botulinum) in 3D printed food	0.893			

Perceived Benefit	Consuming 3D printed food is beneficial	0.883			
	Consuming 3D printed food has value to me	0.874	0.917	0.941	0.800
	I believe it is worthwhile to consume 3D printed food	0.939			
	Consuming 3D printed food is worthwhile to me	0.881			
Perceived Safety	I think consuming 3D printed food is: not at all safe/very safe	0.947	0.879	0.943	0.892
	I think the food safety level of 3D printed food is: very poor/very good	0.942			
Intention to Consume	I plan to consume 3D printed food	0.950			
	I will try to consume 3D printed food more often	0.926			
	I plan to consume 3D printed food	0.891	0.952	0.963	0.840
	I would be willing to consume 3D printed food	0.909			
	I plan to consume 3D printed food in the near future	0.905			
Social Desirability	I think it is socially desirable to eat 3D printed food	0.895			
	My friends and family would agree that it is socially desirable to consume 3D printed food	0.784	0.703	0.824	0.613
	There is a widespread perception that consuming 3D printed food is socially desirable	0.652			
Environmental Consciousness	I am very concerned about environmental issues	0.780			
	Human beings are severely abusing the environment	0.694	0.737	0.830	0.621
	I would be willing to reduce my consumption to help protect the environment	0.879			

Note: CR=Composite Reliability; AVE=Average Variance Extracted
Source: Authors' elaboration

3.2 Data Analysis

Data analysis was performed using SmartPLS version 4.1.0.6 to examine the relationships among the study constructs. The software implements structural equation modeling (SEM) techniques to explore linear relationships between variables and test the overall theoretical model, employing the Partial Least Squares (PLS) estimation method.

Partial least squares structural equation modeling (PLS-SEM) has gained increasing popularity across various fields, including strategic and international management as well as marketing, for testing theoretical frameworks and assessing hypothesized relationships within structural models (Channa et al., 2020). Furthermore, PLS-SEM focuses on estimating causal predictions in statistical models (Rigdon, 2014). The use

of this technique is particularly appropriate given its strong capability to handle complex structural models that include a large number of constructs, indicators, and paths (Hair et al., 2018).

The analysis was conducted in two main stages. First, the measurement model was assessed by examining the convergent validity and unidimensionality of the constructs. Second, the structural model was evaluated using a bootstrapping procedure based on 5,000 resamples, in order to test the statistical significance of the relationships between latent constructs and the individual path coefficients.

4. Results

4.1 Measurement Model

The measurement model comprises 35 items developed to capture the proposed theoretical framework, along with two control variables (age and gender). A Confirmatory Factor Analysis (CFA) was first conducted to assess the validity and reliability of the latent constructs, in accordance with the guidelines provided by Hair et al. (2022).

Convergent and discriminant validity were evaluated using a range of established metrics: Cronbach's alpha, factor loadings, composite reliability (CR), average variance extracted (AVE), and the Heterotrait-Monotrait Ratio of correlations (HTMT), following the recommendations of Hair et al. (2022) (see Table 2). All factor loadings meet or exceed the commonly accepted threshold of 0.70, indicating satisfactory item-construct relationships. Both Cronbach's alpha and CR values are above the recommended 0.70 cutoff, confirming strong internal consistency. Additionally, AVE values for all constructs exceed the 0.50 benchmark (Fornell and Larcker, 1981), thereby supporting convergent validity.

To assess discriminant validity, the HTMT criterion was applied, as it is considered the most rigorous approach in PLS-SEM analysis (Henseler et al., 2015). As reported in Table 3, all HTMT values fall below the conservative threshold of 0.85, providing robust evidence of discriminant validity among the latent constructs.

Collectively, these findings confirm the soundness of the measurement model in terms of both reliability and validity.

Table 3. Discriminant validity using HTMT

	AGE	EC	FN	GEN	ICONS	KN	PB	PHR	PI	SAF	SD
AGE											
EC	0.123										
FN	0.056	0.264									
GEN	0.219	0.198	0.115								
ICONS	0.035	0.296	0.655	0.037							
KN	0.054	0.182	0.155	0.210	0.384						
PB	0.034	0.243	0.432	0.043	0.755	0.277					
PHR	0.043	0.151	0.748	0.039	0.506	0.187	0.458				
PI	0.171	0.458	0.555	0.118	0.425	0.144	0.205	0.211			
SAF	0.058	0.236	0.557	0.077	0.586	0.184	0.563	0.711	0.215		

SD	0.053	0.225	0.267	0.065	0.585	0.308	0.761	0.318	0.135	0.506

Note: AGE = respondents' age; EC=Environmental Consciousness; FN=Food Neophobia; GEN=respondents' gender, ICONS=Intention to consume 3DPF; KN=Knowledge of the Product; PB=Perceived Benefit; PHR=Perceived Health Risk; PI=Personal Innovativeness; SAF=Perceived Safety; SD=Social Desirability

In order to guarantee the accuracy of the model, two indices were calculated: the coefficient of determination (R^2) and the standardized root mean square residuals (SRMR). The R^2 is a value ranging from 0 to 1, and it is employed to demonstrate the nomological validity and explanatory power of the model. The results of the analysis demonstrate a high explanatory power of the PLS-SEM model (adjusted = 0.707; SRMR = 0.075). The findings suggest that the variables considered as exogenous (the three facilitators and the three barriers) account for more than 70% of the variance of the construct. The SRMR indicates a satisfactory model fit, falling below the threshold recommended by Hu and Bentler (1999).

4.2 Structural Model

A two-tailed PLS bootstrapping test with 5,000 subsamples was conducted to estimate standard errors and t-values, which are essential for evaluating regression coefficients and significance of effects (Dijkstra and Henseler, 2015; Hair et al., 2022). The direct effects among the latent variables are presented below in Table 4 and in Figure 2.

Table 4. Direct effect hypotheses testing

Hypothesis	Path	Standardized effect (β)	T statistics	p-value
H1	SAF➔ICONS	0.112	1.550	0.121
H2	FN➔ICONS	-0.286**	3.365	0.001
H3	PHR➔ICONS	0.049	0.500	0.617
H4	PB➔ICONS	0.385***	4.971	0.000
H5	PI➔ICONS	0.197**	3.143	0.002
H6	KN➔ICONS	0.208***	3.585	0.000

Note: EC=Environmental Consciousness; FN=Food Neophobia; ICONS=Intention to consume 3DPF; KN=Knowledge of the Product; PB=Perceived Benefit; PHR=Perceived Health Risk; PI=Personal Innovativeness; SAF=Perceived Safety; SD=Social Desirability; ** p<0.05; *** p<0.001.

Figure 2. Structural model
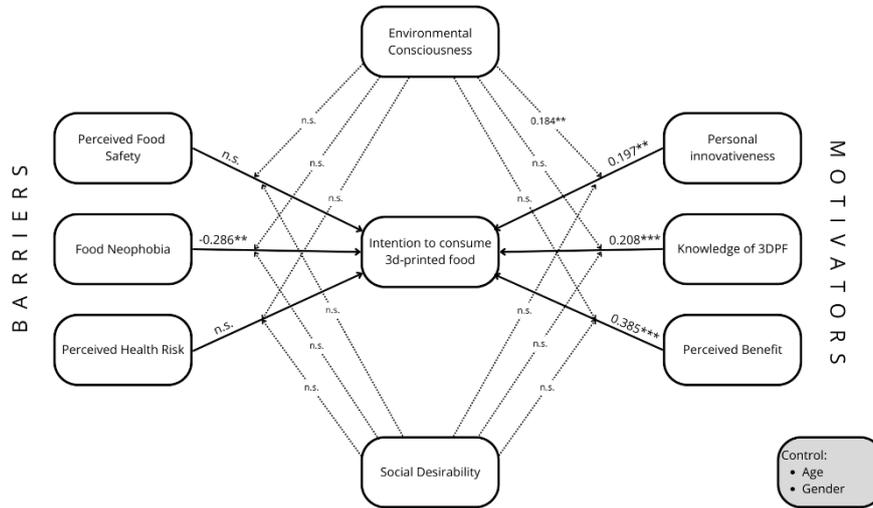
Note: ** p<0.05; *** p<0.001

The findings indicate that among the identified barriers, FN exerts a negative and significant influence (β = -0.286, t=3.365, p=0.001) on the intention to consume 3DPF, thereby substantiating hypothesis H2. Conversely, the findings demonstrate a positive and significant impact of all facilitators under investigation on intention to consume 3DPF, thereby supporting the hypothesized relationships (H4, H5, and H6). The findings indicate that PB exert a more substantial influence (β = 0.385, t=4.971, p<0.001) compared to KN (β = 0.208, t=3.585, p<0.001) and PI (β = 0.197, t=3.143, p=0.002). Therefore, the impact of facilitators on Intention to consume 3DPF is greater than that of barriers.

Table 5. Moderating effect hypotheses testing

Hypothesis	Path	Standardized effect (β)	T statistics	F²	p-value
H7a	EC*SAF→ICONS	0.036	0.475	0.002	0.634
H7b	EC* FN →ICONS	0.078	0.698	0.006	0.485
H7c	EC* PHR → ICONS	-0.062	0.635	0.004	0.526
H7d	EC* PB→ICONS	-0.042	0.575	0.004	0.566
H7e	EC* PI → ICONS	0.184**	2.024	0.068	0.043
H7f	EC* KN → ICONS	-0.009	0.152	0.000	0.880
H8a	SD*SAF → ICONS	0.028	0.241	0.038	0.810
H8b	SD* FN → ICONS	0.022	0.229	0.001	0.819

H8c	SD* PHR → ICONS	-0.168	1.667	0.001	0.095
H8d	SD* PB → ICONS	0.008	0.095	0.014	0.925
H8e	SD* PI → ICONS	0.082	1.196	0.000	0.232
H8f	SD* KN → ICONS	-0.006	0.103	0.000	0.918

Note: EC=Environmental Consciousness; FN=Food Neophobia; ICONS=Intention to consume 3DPF; KN=Knowledge of the Product; PB=Perceived Benefit; PHR=Perceived Health Risk; PI=Personal Innovativeness; SAF=Perceived Safety; SD=Social Desirability; ** $p<0.05$; *** $p<0.001$.

Among the hypotheses involving the moderating role of EC, only H7e showed a statistically significant effect ($\beta = 0.184$, $f^2 = 0.068$, $p = 0.043$), indicating that EC amplifies the positive relationship between PI and the Intention to consume 3DPF. This suggests that environmentally conscious individuals who are also open to innovation are more likely to adopt this type of food. For SD moderator, none of the interactions reached statistical significance at the $p < 0.05$ level. However, H8c showed marginal significance ($\beta = -0.168$, $p = 0.095$), suggesting a possible weakening effect of SD on the relationship between health risk perception and consumption intention. This might imply that when people are influenced by the desire to appear socially acceptable, the negative effect of PHR on intention to consume is weakened. However, these findings suggest that SD has limited influence on shaping consumers' intention to adopt 3DPF. A plausible explanation is that such food is not yet widely recognized or accepted as socially desirable, diminishing the impact of social pressure.

5. General Discussion

The results of the analysis demonstrate a high explanatory power of the PLS-SEM model. According to extant literature, three variables were identified in the hypothesized model that inhibit the intention to consume 3DPF. In particular, the effect of FN on the Intention to Consume 3DPF was found to be robustly negative. In the hypothesized model, the emotional response of disgust towards unusual foods continues to represent, as evidenced by other contributions in the literature, a barrier that limits their consumption (Velasco Vizcaíno and Pohlmann, 2025). The remaining two hypothesized barriers, SAF ($\beta = 0.112$) and PHR ($\beta = 0.049$), were not found to be significant. The absence of a direct effect indicates that, based on the characteristics of the sample under consideration, the benefits may potentially outweigh the risks, or that the latter variable may exert its influence through hitherto undetected indirect pathways. Consequently, based on the findings of this study, hypothesis H2 is endorsed, while hypotheses H1 and H3 are rejected.

However, three factors were theorized to motivate the Intention to Consume 3DPF. The most significant predictor is PB ($\beta = 0.385$, $p < 0.001$), confirming the assumption that perceived advantages prevail over fears when individuals evaluate emerging food technologies. This is followed by KN ($\beta = 0.208$, $p < 0.001$) and PI ($\beta = 0.197$, $p = 0.002$). Cognitive familiarity has been demonstrated to reduce information deficiency, while openness to innovation has been shown to act as a dispositional lever that brings consumers closer to food-tech solutions, thus confirming the literature to date (Agarwal

and Prasad, 1998; Wang et al., 2024). Therefore, all three facilitators included in the model act as enablers of the Intention to Consume 3DPF. In view of the above, hypotheses H4, H5 and H6 are verified and accepted simultaneously.

The model also hypothesized a dual moderating effect of the variables EC and SD on Intention to Consume 3DPF. A positive and significant interaction was identified between EC, PI and Intention to Consume 3DPF (β= 0.184; $p < 0.043$; $f^2 = 0.068$). This finding underscores the notion that open-mindedness, an inherent characteristic of consumers' psychological traits, is reinforced when individuals possess a pronounced environmental awareness. Consequently, consumers who prioritize environmental sustainability and are receptive to novel food products are more likely to experiment with 3DPF. These consumers appear to ascribe environmental and sustainable values (e.g. waste reduction or nutritional customization) to the consumption of those innovative foods. All other possible interactions of motivators and barriers with the EC variable did not show any significant effect on Intention to Consume. The findings of this study indicate that sensitivity to environmental issues does not exert a significant influence on the impact of SAF, FN, PHR, PB or KN on Intention to Consume 3DPF. Furthermore, efforts to incorporate the SD variable as a moderator yielded β values ranging from –0.168 to 0.082, with significance levels falling below the critical threshold (p values ranging from 0.095 to 0.93). The only significant value relates to the test of hypothesis H8c. Although it is not strictly supported, the observed coefficient is consistent with the hypothesized direction, and the marginal significance ($p = 0.095$) indicates a potential effect that could emerge with greater statistical power. In summary, it can be expected that SD could moderate by reducing the impact of PHR on the Intention to Consume 3DPF. However, the current sample size ($N = 141$) is inadequate for the reliable detection of an effect of probable small magnitude ($f^2 < 0.02$).

In conclusion, the assumption regarding the potential moderating effects of SD and EC was confirmed only for hypothesis H7e. The remaining statistical interactions did not demonstrate statistical significance and were thus rejected.

6. Theoretical contribution

The results reveal a markedly unbalanced picture in favor of facilitators: all the enabling drivers (PB, KN, and PI) exert a positive and significant impact on the Intention to Consume 3DPF. Among the barriers, only FN proves to be a real obstacle to the behavior under analysis. This suggests that, in the domain of 3DPF, when consumers perceive clear and tangible benefits, risk perception takes a back seat, and the only remaining resistance is emotional-dispositional in nature.

The lack of a significant moderating effect of SD adds an interesting insight: consuming 3DPF does not yet appear to be a "socially expected" or reputation-enhancing behavior. As long as the technology does not reach greater public visibility (e.g., through events, mainstream media, or endorsement by influential figures), peer approval will not serve as a relevant incentive, and choices will remain primarily driven by personal curiosity and utility evaluations.

In contrast, EC acts as a "multiplier" for PI. Among consumers already open to experimentation, the appeal of environmental sustainability serves as a value-based lever that further strengthens their Intention to Consume 3DPF. This finding highlights

the importance of alignment between personal values (green orientation) and dispositional traits (innovativeness) in shaping the adoption of emerging food-tech innovations.

Overall, the study advances theoretical understanding in three directions: (1) it confirms the predominance of facilitators over barriers in highly innovative contexts; (2) it emphasizes the still-incipient role of social norms in the adoption of 3DPF; and (3) it introduces the "eco-innovation" combination as a key segment, suggesting that traditional innovation diffusion models should be integrated with sustainability-related value variables.

7. Managerial Implication

At the managerial level, there is a clear need to transform knowledge into positive experience. In comparison to FN, information on motivating factors (i.e. nutritional personalization, creative design, waste reduction) has been shown to increase the intention to consume 3DPF (Jones et al., 2023). Therefore, it is recommended that companies invest in educational campaigns that combine informative content (e.g. videos, infographics, scientific Q&As) with hands-on tasting opportunities at points of sale and show cooking at culinary fairs, where participants can see and taste the product. A secondary approach involves the effective communication of the environmental dimension. The use of transparent data to illuminate the diminished utilization of raw materials, the feasibility of employing by-products or alternative ingredients, and the curtailment of waste throughout the supply chain serves to reinforce the perception of value among environmentally conscious consumers. This, in turn, serves to amplify the positive impact on those who already demonstrate a high propensity for innovation.

Finally, given that FN represents the only significant barrier to be addressed, it is recommended that companies adopt gradual exposure strategies, commencing with familiar foodstuffs, shapes, flavors and ingredients (e.g. snacks, biscuits or pasta) and subsequently introducing more daring foods. The reduction of the "psychological distance" between traditional and 3DPF could assist in the normalization of the technology and lead to an increase in actual consumption. To address FN, policymakers and institutions are advised to prioritize the promotion of traceability and food safety through the implementation of regulatory frameworks. Standard labeling for these products could represent an opportunity, a practice that is currently lacking.

8. Limitations and future research directions

In conclusion, consumer PB, as well as PI and KN about 3DPF are important facilitators of consumer intention. FN remains a barrier that inhibits individuals in their intention to try 3DPF. The study enriches the literature in the area of alternative foods and provides an inclusive picture of the factors that serve as both drivers and barriers toward the use of these new products. However, the research is not without limitations. First, the sample of respondents has not yet reached the ideal size in relation to the number of dimensions and effects investigated, as data collection is still ongoing. In addition, the study analyzes self-rated measures that are subject to encore and do not detect actual

behavior, but only a behavioral intention. Therefore, the next steps of analysis could be to expand the sample to strengthen the findings that emerged and to study the actual behavior through an experimental method.

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