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European consumer acceptance of circular practices in chicken meat production: Exploring the impact of environmental attitudes and educational level

R. Nieto-Villegas [*], R. Bernabéu, A. Rabadán

Higher Technical School of Agronomic and Forestry Engineering and Biotechnology, University of Castilla-La Mancha, 02071, Albacete, Spain

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ABSTRACT

The food industry requires sustainable solutions to address environmental challenges and resource scarcity. This study examines acceptance of two circular economy practices in the poultry meat industry, analysing consumer attitudes towards sustainability: the use of agro-industrial by-products in animal feed and the development of biodegradable packaging from chicken feathers. This study uses Partial Least Squares Structural Equation Modelling (PLS-SEM) to evaluate data extracted from 1967 participants from four European countries (Spain, Denmark, UK and Poland). The results highlight the strong correlation between consumer awareness of circular economy concepts and support for the environmental attitudes considered (environmental threat, ecocentric concern and personal conservation behaviour). Consumer acceptance is significantly influenced by environmental attitudes ($p < 0.001$), openness to new sustainable food technologies ($p < 0.001$), food waste reduction behaviours ($p < 0.01$), and circular economy knowledge ($p < 0.05$). Cross-country differences show that in Denmark and the UK circular economy knowledge is more integrated into consumer acceptance, while the impact is lower in Spain and Poland, which requires adapted strategies. Education also plays a key role, with university-educated consumers showing greater openness to circular innovations. These findings underline the importance of adapting policies and educational efforts to local contexts, offering actionable insights for policymakers and the agro-food industry to promote sustainable food systems through resource-efficient and waste-reducing innovations.

1. Introduction

It is crucial to implement the circular economy into the food sector to realize its changes and ensuring environmental challenges take place for long-term sustainable development. According to Wongsaichia et al. (2024) and Rabbi and Amin (2024), this can change food supply and consumption systems by reducing waste while ensuring that resources and by-products are reused as well as possible to make them more efficient, resilient and environmentally friendly. Thus, Pearson et al. (2024) highlight that the transition to circular economy models in the food and agri-food sectors is a fundamental step towards combating environmental degradation, while updating the concept of sustainability and ensuring long-term economic and social well-being.

In this context, the meat sector emerges as a major contributor to environmental degradation and resource depletion, accounting for approximately 14.5 % of anthropogenic greenhouse gas emissions (Gerber et al., 2013). Although poultry production has a lower environmental footprint compared to beef or pork, it is among the fastest-growing meat sectors both in Europe and globally (Bist et al., 2024; Raihan, 2023). This growth, while favourable from an efficiency standpoint, intensifies pressures on feed resources, land use, energy demand, and waste management. Life cycle assessments have identified feed production, energy use and manure management as the main contributors to the environmental footprint of chicken meat (de Vries and de Boer, 2010; Guðjónsdóttir et al., 2025). In addition, it is estimated that 50–60 % of the live weight of livestock consists of by-products, offering significant potential for valorisation under circular economy frameworks (Mehmood et al., 2021). Chicken production is considered a strategic entry point for sustainability transitions due to its short production cycles, efficient feed conversion, and lower methane emissions compared to ruminants (Mottet et al., 2017). In parallel, recent research highlights that consumer acceptance, influenced by

* Corresponding author.
E-mail address: Roberto.Nieto@alu.uclm.es (R. Nieto-Villegas).

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cultural norms, education, and trust in innovation, plays a critical role in the adoption and scalability of circular strategies in the food sector, including poultry (Bist et al., 2024).

Food packaging and production systems are major contributors to waste, with global plastics production exceeding 400 million tonnes per year (Tsakona, 2021), and with low recycling levels adding to environmental pressures (Hahladakis and Iacovidou, 2018). Sustainable alternatives, such as bioplastics derived from renewable sources, exist. These offer long-term environmentally friendly substitutes for petroleum-based plastics, especially within the conceptual diameter of a circular economy that recycles by-products in its value chain (Karan et al., 2019; Rocchi et al., 2021). For example, in the poultry industry, circular economy principles can be embraced through agro-industrial by-products that are integrated into animal feed, along with the development of biodegradable packaging materials from chicken feathers, which are rich in keratin (Oluba et al., 2021; Vadillo et al., 2023) Recent innovations have shown that keratin can be hydrolysed and processed into biodegradable films by combining the extracted keratin with plasticisers or protein hydrolysates, resulting in active packaging materials that offer antioxidant properties, structural stability and reduced environmental impact, thus supporting circular economy strategies in the meat sector (Santos et al., 2024). This not only reduces waste, but also the use of artificial materials, which fits in with wider sustainability goals (Karan et al., 2019). These circular strategies can contribute to making the poultry sector and meat production more environmentally friendly (Zisis et al., 2023).

Beyond packaging, the reuse of food surpluses and by-products from food processing is another pillar of the circular bioeconomy (Toldrá et al., 2021). These practices not only improve resource efficiency and economic viability but also reduce the environmental impact of food systems (Georganas et al., 2023; Malenica et al., 2023). However, their success is reliant on consumer acceptance, which depends on their environmental attitudes, their familiarity with circular concepts and their openness to innovations in food technology (Li et al., 2023; Siegrist and Hartmann, 2020). Differences between countries in the acceptance of sustainable technologies and circular practices again highlight the mix of cultural and demographic factors in consumer preferences (Asioli et al., 2019; Rabadán et al., 2023). For example, according to Khanzada et al. (2023), even if bioplastics are made from chicken feathers and thus demonstrate the principles of circularity, consumer attitudes towards such products are actually varied, arguably reflecting very different cultural and social attitudes.

Consumer behaviour is important for reducing food waste and achieving a circular economy in the food sector. Tools such as the Food Waste Behaviour Questionnaire (FWBQ) assess behaviours related to food waste generation and prevention, providing practical information to align consumer practices with circular economy goals (Misiak et al., 2021). In addition, environmental attitudes (such as concern about environmental threats (ET), ecocentric concern (EC) and personal conservation behaviours (PCBs)) play a key role in the willingness to adopt sustainable practices (Bravo and Farjam, 2022). Following the study by Milfont and Duckitt (2010), environmental threat refers to the belief that the environment is fragile and easily damaged by human activity, which could have catastrophic consequences, while ecocentric concern is an emotional sense of loss from environmental damage. Meanwhile, personal conservation behaviour refers to everyday actions to conserve resources and protect the environment, as opposed to indifference to conservation. These factors are fundamental to understanding the relationship between attitudes and actual consumer behaviour towards sustainability. Such attitudes influence the uptake of more sustainable products and underline the need to address consumer awareness and perceptions.

Technological innovation for the circular economy in the food sector is also important. This can be assessed using a tool like the Openness to New Sustainable Food Technologies (OT_{food}) scale, which measures consumers' willingness to adopt innovations that optimise processes and reduce environmental impact (Berthold et al., 2022). Equally important is the knowledge and attitude that consumers have about innovations, as without consumer response, adoption and implementation, the circular economy cannot succeed.

The main objective of this study is to analyse how consumers' sustainability attitudes can help the promotion of circular economy implantation in the food sector through strategies such as the reuse of agro-industrial by-products and the use of biodegradable packaging made from recycled materials. We examine consumer acceptance of sustainable products and innovative circular economy technologies, such as feed made from agro-industrial waste. This article highlights the emerging role of consumer behaviour in driving a more widespread adoption of circular economy practices, indicating that a more sustainable food system goes beyond technological innovation towards a shift in consumer values and knowledge.

To assess these dynamics, the study used partial least squares structural equation modelling (PLS-SEM) based on data from four European countries. Established measurement scales were used to capture environmental attitudes, openness to sustainable food technologies, knowledge of the circular economy and food waste behaviours, allowing for a robust analysis of factors influencing consumer acceptance of circular innovations in chicken meat production.

2. Conceptual framework and hypotheses

This section addresses consumers' sustainability perceptions of the adoption of circular practices. The research hypotheses are detailed in the next section, which prepares the way for the conceptual model.

2.1. Environmental attitudes

Consumers' environmental attitudes significantly determine their food choices and behaviours (Roccatello et al., 2024). Perceived environmental threats are positively associated with pro-environmental actions, such as the adoption of sustainable practices. Research indicates that enhanced awareness of environmental challenges can increase consumers' receptiveness to sustainable food technologies (H1a) (Schnack et al., 2024) and foster motivation to reduce food waste (H2a) (Pandey et al., 2023). Similarly, ecocentrism, which emphasises the intrinsic value of nature, plays a nuanced role in shaping behaviour (Kortenkamp and Moore, 2001). While it often supports conservation behaviours, its effect on consumer choice is complex. Some works have shown that consumers perceive risk in food sustainable technologies (H1b) (Silva et al., 2024) but support established behaviour such as waste reduction (H2b) (Schrank et al., 2023). Personal conservation behaviour also predicts commitment to the environment. Therefore, individuals with a pro-environmental orientation are more likely to adopt sustainable food technologies (H1c) (Giacalone and Jaeger, 2023) and food waste reduction (H2c) (Gao et al., 2024) because these activities are in line with their orientation. All these results point to the interdependent relationship between attitudes and behaviours towards the environment and sustainable food practices, a reflection of how interventions need to be highly sensitive to the values consumers hold, but also to the actions they actually take. We thus propose the following hypotheses:

H1a. Environmental threat positively affects consumer openness to sustainable food technologies.

H2a. Environmental threat positively affects consumer food waste reduction.

H1b. Ecocentric concern negatively affects consumer openness to sustainable food technologies.

H2b. Ecocentric concern positively affects consumer food waste reduction.

H1c. Personal conservation behaviour positively affects consumer openness to sustainable food technologies.

H2c. Personal conservation behaviour positively affects consumer food waste reduction.

2.2. Openness to sustainable food technologies

Openness to sustainable food technologies (OT_{food}) significantly influences consumer acceptance of innovative products created to improve environmental sustainability. This tool measures the openness that allows individuals to adopt new methods and products that will help achieve ecological well-being. Consumers with a high level of OT_{food} are likely to exhibit such sustainable practices. For example, circular packaging made from chicken feathers is an example of resource efficiency and waste reduction (H3a) (Stoica et al., 2024; Tesfaye et al., 2017). This preference is decisive in explaining the environmental preference effect. Similarly, consumers with a greater openness to sustainable food technologies may positively accept poultry fed with food by-products, as this practice advances the principles of a circular economy and waste minimisation within the food system (H3b) (Rohm et al., 2017). Consumers with a strong environmental orientation tend to view these innovations as responsible and sustainable choices, thus strengthening their receptiveness to new technologies. These results point to the role of OT_{food} in driving the adoption of sustainable food innovations, linking it to much broader environmental attitudes and behaviours. Accordingly:

H3a. Openness to sustainable food technologies positively affects consumer acceptance of chicken breasts with circular packaging made from chicken feathers.

H3b. Openness to sustainable food technologies positively affects consumer acceptance of chickens fed with food by-products.

2.3. Food waste questionnaire behaviour

The degree of food waste, especially among environmentally conscious consumers, may moderate the likelihood of adoption of innovations aimed at sustainability. For this reason, the practice of waste reduction may act as a moderating variable in the adoption of innovative solutions designed to enhance sustainability, e.g. circular packaging made from chicken feathers (H4a) (Brennan et al., 2021; Tesfaye et al., 2017). Therefore, the demand for activities that reduce waste leads to the idea of chickens fed with food by-products, driving a circular food system (H4b) (Vlaicu et al., 2024). The relationship between waste reduction and the openness of sustainable food technologies highlights the need to promote circular food strategies and the driving role of environmentally conscious consumers in bringing about this transformation. Hence:

H4a. Food waste reduction positively affects consumer acceptance of chicken breasts with circular packaging made from chicken feathers.

H4b. Food waste reduction positively affects consumer acceptance of chickens fed with food by-products.

2.4. Circular economy knowledge

The circular economy is about minimising waste and maximising the reuse of resources, promoting sustainable practices in various sectors, of which one is the food industry (Pal et al., 2024). Knowledge of the circular economy significantly influences consumer acceptance of sustainable food innovations (Sousa et al., 2021). Consumers familiar with circular economy principles, which emphasise less waste and more reuse of available resources, would also support products such as chicken breasts packaged in circular materials made from chicken feathers (H5a) (Steenis et al., 2018) and poultry fed on food by-products (H5b) (Sousa et al., 2021). Understanding the environmental benefits of these practices is consistent with consumer values, which prioritise sustainability. We thus posit:

H5a. Circular economy knowledge positively affects consumer acceptance of chicken breasts with circular packaging made from chicken feathers.

H5b. Circular economy knowledge positively affects consumer acceptance of chickens fed with food by-products.

3. Methods

3.1. Database

This study investigated consumer preferences for fresh chicken breasts. The chicken sector was chosen because of its dynamic growth across Europe and its relevance for circular economy applications, as it generates significant amounts of agri-food waste and offers multiple opportunities for resource recovery. The data was collected through an online survey of consumers in Spain, the United Kingdom, Denmark, and Poland. The selection was made to ensure regional representation across Europe (South, West, North, and East, respectively) and to capture a variety of socio-environmental profiles. Denmark and the UK are among the most advanced in terms of environmental awareness and circular economy engagement, while Spain and Poland reflect more traditional consumption patterns and lower familiarity with circular economy practices. To participate in the survey, respondents needed to be 18 years of age or older and to be responsible for more than half of the food purchases in their household, purchasing fresh chicken breasts at least once a month. A total of 1967 surveys were conducted in Spain (506 consumers), the United Kingdom (505 consumers), Denmark (453 consumers), and Poland (503 consumers) in January 2024. Participants were recruited and the online survey administered by Qualtrics LLC Qualtrics LLC (Provo, USA). Consumers were randomly selected using a sampling quota based on age and gender. We obtained informed consent from all study participants and our study was approved by our institutional ethics committee.

We implemented two measures to ensure data quality. First, we included an "attention check" question, asking respondents whether they had "given [their] full attention to the study so far" and whether, in their honest opinion, their responses should be included in the study. According to Meade and Craig (2012), this type of question encourages respondents to focus more on subsequent questions rather than just identifying unreliable answers. To maximise its effectiveness, we strategically placed this question just before important sections. The data were filtered by retaining only responses from participants who spent at least one-third of the average time completing the questionnaire.

3.2. Procedure

We added questions to the survey in five sections designed to test our hypotheses about attitudinal factors. In the first section, we explained the definitions of the characteristics of chicken breast, such as packaging with chicken feathers and the feeding of food by-products. Respondents were presented with a detailed description of each of the attributes assessed. In the case of the “Packaging” attribute, it was explained that one of the options was packaging made from chicken feathers, using waste from meat production. It was indicated that the keratin present in the feathers allows for sustainable packaging that protects the product and reduces the environmental impact. This explanation was provided to ensure that participants understood the origin and purpose of the packaging material. Moreover, respondents were then asked if they would be willing to pay for chicken breasts from chickens fed with food by-products and with circular packaging made from chicken feathers. In the second section, we asked respondents how much they knew about circular economy before participating in the survey, on a scale from 1 (very little knowledge) to 7 (very high knowledge). In the third section, we asked respondents about their environmental attitudes (Bravo and Farjam, 2022). In this section, they answered three questions, each structured as a scale consisting of five items. The responding scales were environmental threat (ET), ecocentric concern (EC), and personal conservation behaviours (PCBs). In the fourth section, respondents were asked about their attitude towards openness to new sustainable food technologies (OT_{food}) (Berthold et al., 2022), with three items being used to measure it. In the fifth section, respondents were asked about their attitude towards food waste reduction (FWBQ) (Misiak et al., 2021), with this being measured through four items. For the five scales used, they were required to indicate their level of agreement with each statement on a 7-point Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree). The questionnaire was implemented in Spanish, English, Danish, and Polish.

3.3. Econometric analysis

This study employed Partial Least Squares Structural Equation Modelling (PLS-SEM) as the main statistical tool for data analysis. PLS was considered an appropriate method for testing the hypotheses derived from the conceptual framework (Fig. 1) supported by several justifications (Hair et al., 2019). As a widely used approach to analyse complex relationships between latent variables, PLS-SEM offers flexibility in model estimation where latent variables can act as independent and dependent variables depending on their role within the model (Hair et al., 2019). Although Covariance-Based Structural Equation Modelling (CB-SEM) is generally preferred for large sample sizes (Hair et al., 2011), PLS-SEM was selected for the present research due to its suitability for estimating highly complex models with numerous constructs or structural relationships, as well as its alignment with exploratory and predictive analysis goals (Hair et al., 2019; Hair and Sarstedt, 2019). SEM is widely used in behavioural science research and is particularly common in psychology studies (Ringle et al., 2012). Therefore, PLS-SEM was employed to examine structural relationships between constructs such as environmental attitudes (ET, EC and PCB), OT_{food}, FWBQ, knowledge of circular economy (KNOW) and behavioural intentions towards chicken breasts with circular packaging made from chicken feathers (PACK) and chickens fed with food by-products (BYPROD) (Fig. 1).

The analysis followed a two-step procedure (Hair et al., 2019; Hair and Sarstedt, 2019): (1) assessment of the validity and reliability of the measurement model, and (2) hypothesis testing by estimating the structural model. The validity and reliability of the measurement model were assessed through indicator loadings, construct reliability, convergent validity and discriminant validity. Once the measurement model was deemed satisfactory, the structural model was analysed by examining the significance and magnitude of path coefficients, effect sizes (f^2) and in-sample predictive power (R^2) (Hair et al., 2019; Hair and Sarstedt, 2019). A bootstrapping procedure with 5000 subsamples was used to determine the significance of the coefficients, both for the overall sample and for individual country samples (Hair et al., 2019). The use of 5000 bootstrap samples in PLS-SEM improves the precision and stability of parameter estimates and confidence intervals, thus supporting robust significance tests and ensuring the reliability of the results (Hair et al., 2021, 2022). Statistical significance was set at $p < 0.05$, and effect sizes were taken to be small, medium or large based on thresholds of 0.02, 0.15 and 0.35, respectively (Hair et al., 2019). The PLS-SEM analysis was conducted using SmartPLS 4 software.

4. Results and discussion

4.1. Measurement model

This study implemented a measurement model to ensure that all items and constructs used in the analysis were statistically reliable and valid. As shown in Table 1, the measurement model was assessed by calculating factor loadings, composite reliability scores, Cronbach's alpha and average variance extracted (AVE). To assess the reliability of individual items, their factor loadings were compared with the recommended threshold of 0.7 (Chin, 1998). According to this criterion, nineteen items were excluded from the analysis. The remaining items demonstrated loadings above 0.7, indicating sufficient internal reliability (Chin, 1998; Hair et al., 2017). Internal consistency, measured through composite reliability and Cronbach's alpha values, was above 0.7 for almost all latent variables, signifying strong internal consistency (Shrestha, 2021).

Convergent validity was assessed using the AVE. All factors exhibited AVE values above 0.5, indicating that the latent variables explained >50 % of the variance of their indicators. This level of validity meets the recommended threshold for AVE (Fornell and Larcker, 1981; Shrestha, 2021). The AVE was also used to assess discriminant validity, ensuring that each construct was distinct from the others. In line with Fornell and Larcker (1981) criteria, a construct should show stronger correlations with its associated indicators than with other constructs.

As shown in Table 2, diagonal items (square root of the AVE of each construct) outperformed non-diagonal items (correlations between constructs), supporting discriminant validity as recommended by Hair et al. (2014). Thus, discriminant validity was confirmed using Fornell and Larcker's criterion (Fornell and Larcker, 1981).

In addition, the heterotrait-monotrait ratio (HTMT) was applied to

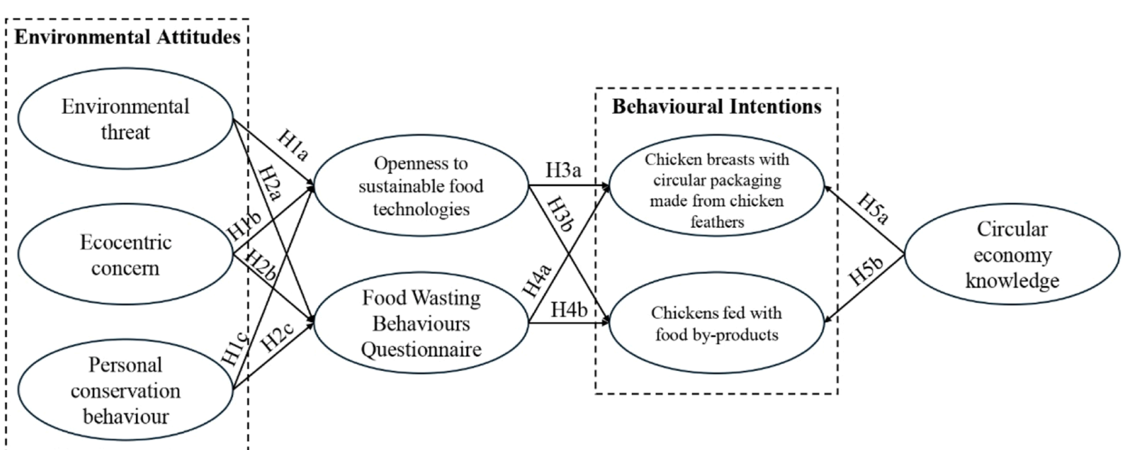

Fig. 1. Conceptual framework outlining the hypotheses.

Table 1
Measurement model.

Construct	Item code	Outer loading	Outer weights	Cronbach's Alpha	Composite reliability (rho_c)	AVE
Environmental threat (ET)				0.846	0.890	0.619
	ET1	0.718***	0.209***			
	ET2	0.778***	0.256***			
	ET3	0.833***	0.292***			
	ET4	0.806***	0.250***			
	ET5	0.794***	0.258***			
Ecocentric concern (EC)				0.873	0.908	0.664
	EC1	0.737***	0.240***			
	EC2	0.825***	0.223***			
	EC3	0.823***	0.253***			
	EC4	0.852***	0.267***			
	EC5	0.832***	0.244***			
Personal conservation behaviour (PCB)				0.834	0.883	0.599
	PCB1	0.723***	0.248***			
	PCB2	0.773***	0.249***			
	PCB3	0.755***	0.241***			
	PCB4	0.836***	0.275***			
	PCB5	0.788***	0.275***			
Openness to new sustainable food technologies (OTFOOD)				0.801	0.883	0.717
	OTFOOD1	0.788***	0.357***			
	OTFOOD2	0.881***	0.417***			
	OTFOOD3	0.868***	0.404***			
Food Wasting Behaviours Questionnaire (FWBQ)				0.805	0.873	0.632
	FWBQ1	0.810***	0.333***			
	FWBQ2	0.807***	0.314***			
	FWBQ3	0.733***	0.281***			
	FWBQ4	0.827***	0.328***			

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 2
Discriminant validity of the measurements (Fornell-Larcker criterion).

	ET	EC	PCB	OTFOOD	FWBQ	PACK	BYPROD	KNOW
ET	**0.787**							
EC	0.250	**0.815**						
PCB	0.510	0.353	**0.776**					
OTFOOD	0.260	−0.189	0.200	**0.847**				
FWBQ	0.339	0.243	0.443	0.076	**0.795**			
PACK	0.062	−0.137	0.019	0.224	0.019	**1.000**		
BYPROD	0.176	−0.208	0.111	0.514	0.239	0.160	**1.000**	
KNOW	0.161	−0.250	0.082	0.496	0.233	0.167	0.727	**1.000**

Note: Values on the diagonal (bold) are the square of the AVE while the off-diagonals are correlations.

further verify discriminant validity, addressing the specific limitations of Fornell and Larcker's method (Ramayah et al., 2018). Table 3 presents HTMT values below the threshold of 0.9, as suggested by (Henseler et al., 2015). Consequently, discriminant validity was also established using the HTMT approach.

4.2. Structural model

The analysis of the structural model began with an assessment of the variance inflation factor (VIF) to identify possible multicollinearity problems among the latent variables. VIF values below 5 are considered acceptable, allowing for the rejection of the multicollinearity hypothesis within the model's constructs (Hair et al., 2014). The results for the variables of "OT_{food}" and "FWBQ" were ET = 1.361; EC = 1.151 and PCB = 1.458. For the "PACK" and "BYPROD" variables, the values were OT_{food} = 1.059; FWBQ = 1.006 and KNOW = 1.053.

With all VIF values being below 5, the model was found to present no multicollinearity. A non-parametric bootstrapping method was then used to test the significance of the model. This method generates numerous subsamples from the original data to estimate bootstrap standard errors. For this analysis, 5000 subsamples were generated, which provided an approximation of t-values to assess the significance of the structural relationships, as shown in Table 4.

The structural model was also validated using Pearson's coefficient

Table 3
Heterotrait-monotrait ratio (HTMT) matrix.

	ET	EC	PCB	OTFOOD	FWBQ	PACK	BYPROD	KNOW
ET								
EC	0.285							
PCB	0.602	0.417						
OTFOOD	0.318	0.222	0.242					
FWBQ	0.404	0.286	0.538	0.094				
PACK	0.176	0.268	0.088	0.553	0.261			
BYPROD	0.192	0.222	0.120	0.574	0.268	0.727		
KNOW	0.068	0.146	0.051	0.252	0.037	0.167	0.160	

Table 4
Structural modelling analysis results.

Hypotheses	Path	Coefficient	Standard deviation	T statistics	P values	R^2	Decision
H1a	ET → OTFOOD	0.243	0.029	8.259	0.000***	0.160	Supported
H1b	EC → OTFOOD	−0.316	0.028	5.160	0.000***		Supported
H1c	PCB → OTFOOD	0.188	0.02	15.977	0.000***		Supported
H2a	ET → FWBQ	0.144	0.023	3.800	0.000***	0.220	Supported
H2b	EC → FWBQ	0.087	0.028	6.748	0.000***		Supported
H2c	PCB → FWBQ	0.339	0.028	12.031	0.000***		Supported
H3a	OTFOOD → PACK	0.223	0.008	27.020	0.000***	0.288	Supported
H4a	FWBQ → PACK	0.094	0.008	29.687	0.000***		Supported
H5a	KNOW → PACK	0.028	0.009	10.638	0.000***		Supported
H3b	OTFOOD → BYPROD	0.233	0.009	11.037	0.000***	0.307	Supported
H4b	FWBQ → BYPROD	0.096	0.01	2.880	0.002**		Supported
H5b	KNOW → BYPROD	0.022	0.01	2.293	0.011*		Supported

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

of determination (R^2), which assesses the model's explanatory power and effect sizes (f^2) (Hair et al., 2014). The model explained a considerable portion of the variance, with coefficients of determination (R^2) of 0.160 for "OT_{food}", 0.220 for "FWBQ", 0.288 for "PACK" and 0.307 for "BYPROD". According to Ozili (2022), even a low R^2 of at least 0.1 is acceptable if most of the predictors are statistically significant, which makes these values acceptable.

Effect size (f^2), measured using Cohen's indicator, assesses the influence of exogenous latent variables, with values of 0.02 (small effect), 0.15 (medium effect) and 0.35 (large effect), respectively (Hair et al., 2014). The f^2 results for the "OT_{food}" variable were ET = 0.052; EC = 0.103 and PCB = 0.029. The f^2 results for the variable "FWBQ" were ET = 0.020; EC = 0.008 and PCB = 0.101. The f^2 results for the variable "PACK" were OT_{food} = 0.291; FWBQ = 0.054 and KNOW = 0.004. The f^2 results for the variable "BYPROD" were OT_{food} = 0.325; FWBQ = 0.058 and KNOW = 0.003. Finally, the predictive accuracy of the model was assessed using the PLSpredict procedure (Shmueli et al., 2019) and the Cross-Validated Predictive Ability Test (CVPAT) (Sharma et al., 2022). The results indicated that the model possesses predictive validity, although without strong predictive power, which is acceptable given the exploratory nature of the study.

The results obtained indicate that environmental attitudes (ET, EC and PCB), OT_{food}, FWBQ and KNOW influence the adoption of sustainable food practices. Consumers with a higher perception of environmental threat have more positive attitudes towards sustainable food technologies and food waste reduction behaviours. In line with previous research by Roccatello et al. (2024), Schnack et al. (2024) and Pandey et al. (2023), higher awareness of environmental issues motivates individuals to adopt sustainable solutions and to be willing to pay for such innovations.

On the other hand, ecocentric concern acts in a twofold manner. It positively directs behaviours aimed at reducing food waste, in line with the work of Schrank et al. (2023), yet acts as a negative determinant of the factor that would increase openness to sustainable food technologies. Indeed, this contradiction supports the argument put forward by Silva et al. (2024) that a person with ecocentric concern values is likely to perceive new food technologies as risky or incompatible with the intrinsic value of nature. However, personal conservation behaviour was found to be a unifying factor that has a highly significant effect on both openness to sustainable food technologies and food waste reduction, confirming the findings of Giacalone and Jaeger (2023) and Gao et al. (2024).

It also indicates that the openness of sustainable food technology is decisive for sustainable innovations. More specifically, it positively influences circular packaging made from chicken feathers and poultry fed with food by-products. The results are in line with Stoica et al. (2024) and Rohm et al. (2017), as people with higher openness consider these innovations to be environmentally responsible and support their pro-environmental values. They are also willing to pay a higher price for environmentally sustainable packaging (Zhu et al., 2022). Bioplastics, in all their alternative forms, are among the packaging options that consumers perceive as most sustainable (Steenis et al., 2017), including chicken feather packaging.

Similarly, food waste reduction behaviour was found to be a significant predictor of the acceptance of circular solutions. It positively influences the acceptance of circular packaging, as found by Brennan et al. (2021) and Vlaicu et al. (2024). These results show that individuals who wish to minimise waste are more likely to engage in circular habits, thus once again confirming the importance of waste-conscious behaviours in sustainable innovation in food systems.

Finally, knowledge of the circular economy positively influences the acceptance of both circular packaging and poultry fed with food by-products. While the effect size is relatively small, the findings align with those of Sousa et al. (2021) and Steenis et al. (2018), who underline that knowledge improves consumer understanding of resource reuse and waste minimisation. However, the modest effect size suggests that awareness alone is insufficient; it must go hand in hand with practical demonstrations and targeted educational interventions to drive widespread adoption.

4.3. The moderating role of country

To investigate the moderating role of country, we conducted a multiple group structural analysis (Sarstedt et al., 2011), where the model was estimated simultaneously for each country. Table 5 shows significant variations between countries in consumer acceptance of chicken breasts with circular packaging made from chicken feathers, acceptance of chickens fed with food by-products and circular economy knowledge. The results underline the need to adapt circular economy strategies to the cultural and educational environments of each country to optimise the effectiveness of policies.

In all countries, ET and PCB have a significant positive impact on OT_{food} and FWBQ. These results correlate with the impact of similar attitudes towards environmental threats on the increased adoption of sustainable technologies, as people embrace the demand for pro-environmental actions (Gao et al., 2024; Schnack et al., 2024). Moreover, this finding highlights the importance of environmental perception, which is a key driver of innovation in the sustainable food sector (Giacalone and Jaeger, 2023).

Meanwhile, EC shows a twofold effect in all the countries studied. It tends to have a negative and significant impact on OT_{food}, which is consistent with studies that associate this stance with scepticism towards technologies perceived as risky (Silva et al., 2024). However, it has a positive influence on FWBQ, being significant only in Spain and the UK. This finding reflects its role as a facilitator of more established and less technological pro-environmental practices, such as conservation and proper resource management (Schrank et al., 2023).

OT_{food} also shows a positive influence on the uptake of innovations based on the circular economy, such as PACK and BYPROD. These results are in line with research highlighting how consumers with a greater

Table 5
Multiple group structural analysis for countries.

	Spain		UK		Denmark		Poland	
Path	Coefficient	R^2	Coefficient	R^2	Coefficient	R^2	Coefficient	R^2
ET → OTFOOD	0.351***	0.209	0.242***	0.206	0.145*	0.139	0.234***	0.116
EC → OTFOOD	−0.299***		−0.351***		−0.314***		−0.291***	
PCB → OTFOOD	0.171**		0.229***		0.210***		0.136*	
ET → FWBQ	0.146*	0.266	0.131**	0.193	0.115*	0.105	0.131**	0.305
EC → FWBQ	0.094*		0.040		0.037		0.144**	
PCB → FWBQ	0.375***		0.347***		0.240***		0.393***	
OTFOOD → PACK	0.263***	0.345	0.219***	0.299	0.188***	0.330	0.196***	0.269
FWBQ → PACK	0.068***		0.081***		0.148***		0.110***	
KNOW → PACK	−0.009		0.061**		0.088***		−0.013	
OTFOOD → BYPROD	0.259***	0.341	0.228***	0.298	0.210***	0.406	0.209***	0.263
FWBQ → BYPROD	0.082***		0.081***		0.157***		0.088***	
KNOW → BYPROD	−0.021		0.03		0.103***		−0.017	

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

disposition towards sustainable innovations perceive these technologies as responsible solutions aligned with their environmental values (Rohm et al., 2017; Stoica et al., 2024). Similarly, reducing food waste has a significant effect on the uptake of these innovations, underlining the connection between efficient resource management practices and support for circular food systems (Brennan et al., 2021; Vlaicu et al., 2024).

One of the most marked differences between countries is the role played by KNOW. In relation to the effect on PACK, KNOW has a positive and significant impact in Denmark and the UK. In fact, Denmark is the only country to show a positive and significant relationship between KNOW and BYPROD. These results fit with the idea that the circular economy is about minimising waste and reusing resources as much as possible, i.e. applying sustainable practices in different sectors, including the food sector (Pal et al., 2024). Therefore, consumers with high knowledge of circular economy may prefer chicken breasts with packaging made from chicken feathers (Steenis et al., 2018) and poultry fed with food by-products (Sousa et al., 2021).

In contrast, Spain, Poland and the UK report relatively lower levels of influence for KNOW. These countries do not associate KNOW with the adoption of sustainable technologies such as PACK or BYPROD. This divergence may be due to different cultural priorities or different levels of consumer familiarity with the environmental benefits of circular practices. As suggested by Parrott et al. (2002), northern European countries, such as Denmark, place a strong emphasis on industrial efficiency and technological innovation, while southern European nations, such as Spain, tend to prioritise tradition, territorial identity and artisanal production. This cultural divergence helps explain why Danish consumers are more receptive to technical know-how, while Spanish and Polish consumers are guided by the tangible benefits of sustainable practices. In Nordic countries, technology is generally considered a fundamental tool for achieving environmental goals (Khan et al., 2021), and environmental education and awareness are historically more valued (Cheah and Huang, 2019).

Overall, the findings reinforce that consumer responses to circular practices are shaped not only by individual factors, such as attitudes or environmental knowledge, but also by broader national contexts. In Denmark, the consistently positive role of knowledge in both PACK and BYPROD suggests a society with a high degree of environmental literacy, where the public is more likely to understand and support innovations around resource circularity. This has been a long, green, and institutional trust-based sustainable education emphasis in Denmark (Cheah and Huang, 2019).

In contrast, Spain and Poland are examples where knowledge does not significantly influence the acceptance of PACK or BYPROD. Consumers may support sustainability in practice; however, this does not necessarily translate into the theoretical understanding of circular concepts driving acceptance. Circular economy knowledge is what Sousa et al. (2021) sees as insufficient to drive acceptance unless accompanied by practical relevance, emotional resonance, or communicated benefits. In these countries, cultural preferences for traditional food production, as well as potential scepticism toward new technologies, could play a limiting role (Parrott et al., 2002).

The United Kingdom presents an intermediate case: KNOW influences PACK, but not BYPROD, possibly reflecting greater familiarity with sustainability in packaging innovations, which have received greater public exposure than feed-based strategies. This highlights the importance of prior consumer experience and the media presentation of circular solutions (Steenis et al., 2018).

These differences suggest that consumer acceptance of circular food innovations is not limited to personal values or beliefs but is also conditioned by how the innovations are communicated, contextualized, and culturally embedded. Consequently, one-size-fits-all approaches may fail to engage consumers across Europe. Instead, tailored communication strategies should be adopted, emphasizing technological efficiency and environmental benefits in countries like Denmark, while using family values, tangible examples, and food-related traditions to foster acceptance in more conservative or less technically oriented contexts, such as Spain and Poland.

4.4. The moderating role of education

Table 6 shows the effect of level of education on the consumer acceptance of chicken breasts with circular packaging made from chicken feathers, acceptance of chickens fed with food by-products and circular economy knowledge.

The results indicate that the level of education influences on how consumers perceive and adopt circular economy practices (Renfors, 2024). Circular innovations are more likely to be adopted by university-educated consumers due to their knowledge of circular economy principles (di Santo et al., 2024), while this factor is not

Table 6
Multiple group structural analysis for education.

Path	NO UNI Coefficient	R^2	UNI Coefficient	R^2
ET → OTFOOD	0.245***	0.146	0.234***	0.170
EC → OTFOOD	−0.297***		−0.325***	
PCB → OTFOOD	0.182***		0.200***	
ET → FWBQ	0.117**	0.239	0.183***	0.204
EC → FWBQ	0.101**		0.069*	
PCB → FWBQ	0.370***		0.299***	
OTFOOD → PACK	0.224***	0.295	0.218***	0.271
FWBQ → PACK	0.094***		0.093***	
KNOW → PACK	0.005		0.038**	
OTFOOD → BYPROD	0.224***	0.275	0.243***	0.350
FWBQ → BYPROD	0.089***		0.102***	
KNOW → BYPROD	−0.004		0.050***	

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

significant for consumers without higher education. For university-educated consumers, knowledge has a positive influence on the acceptance of circular packaging and by-products, highlighting how education promotes a deeper understanding of the environmental and systemic benefits of these practices (Serrano-Bedia and Perez-Perez, 2022). These results demonstrate that education not only speaks to understanding, but goes further to understand and emphasise actions towards sustainability.

5. Conclusions

The results of this study confirm that consumers' sustainability attitudes significantly explain acceptance of circular economy practices in the food sector. Circular strategies, such as reusing agro-industrial by-products and adopting biodegradable packaging made from recycled materials, are positively influenced by consumer knowledge and sustainable attitudes.

Our findings reveal significant differences in the perception towards circular economy practices relating to the use of packaging made from chicken feathers and the use of food by-products in animal feed. Danish consumers showed the most positive and strongest acceptance of adopting and paying for these innovations, reflecting a higher alignment with circular economy practices. In contrast, consumers in Spain and Poland showed limited support, while British consumers exhibited moderate openness, depending on the specific strategy. These variations underline the importance of cultural and educational factors in shaping consumers' acceptance of circular practices.

The role of education was particularly notable. University-educated consumers showed a greater acceptance of adopting circular practices compared to those without higher education qualifications. Therefore, educational campaigns tailored to these segments, showing the benefits and proven safety of circular innovations, could play a key role in converting general support for sustainability into active adoption of circular practices.

However, some challenges remain. These include consumer scepticism towards new technologies, low awareness in some countries and the need for tailor-made educational efforts. Addressing these obstacles is essential for the effective and equitable implementation of circular practices in the European food system.

This study is not without limitations. First, the study was conducted in only four countries, which limits the generalisability of the results. Future research should expand the geographical scope to include a wider range of EU Member States and possibly non-European countries in order to assess cross-cultural robustness and global trends. Secondly, the analysis focused exclusively on a single product category (chicken breast) which may limit the transferability of the results to other types of meat or food products. Future studies should explore consumer acceptance of circular practices in a wider range of food categories to better understand the general applicability of the model.

Based on the results obtained in this study, we recommend that educational campaigns about circular practices should be developed, more specifically for consumers with relatively low levels of formal education. In addition, co-creation strategies that involve consumers and pilot programs at retail establishments may increase trust and confidence in sustainable innovations related to meat production.

Ethical statement

The Research Ethics Committee of the University of Castilla-La Mancha granted full approval of this study under reference number CEIS-729623-P1T9. The participants provided informed consent to participate in the survey after reading important information in the introduction section, including details about privacy protection, their rights, and what they could do in the stress situation, during the survey. The research was conducted in accordance with the Declaration of Helsinki.

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CRediT authorship contribution statement

R. Nieto-Villegas: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **R. Bernabéu:** Investigation, Formal analysis, Resources, Writing – review & editing, Supervision. **A. Rabadán:** Conceptualization, Methodology, Investigation, Resources, Formal analysis, Writing – original draft, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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