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# The Perceptions of Turkish Consumers Regarding In Vitro Meat and the Relationship Between These Perceptions and Willingness to Try and Consume In Vitro Meat

Ayse Gulin Eser[1] | P. Dilara Kecici[2] | Funda Yilmaz Eker[3] | Bulent Ekiz[2]

[1]Department of Food Technology, Biga Vocational School, Çanakkale Onsekiz Mart University, Biga, Çanakkale, Türkiye | [2]Department of Animal Breeding and Husbandry, Faculty of Veterinary Medicine, Istanbul University- Cerrahpaşa, Buyukcekmece Campus, Buyukcekmece, Istanbul, Türkiye | [3]Department of Food Hygiene and Technology, Faculty of Veterinary Medicine, Istanbul University-Cerrahpaşa, Avcilar, Istanbul, Türkiye

**Correspondence:** Ayse Gulin Eser (gsezen@comu.edu.tr)

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## ABSTRACT

This study aims to determine Turkish consumers' perceptions and attitudes toward in vitro meat and to investigate the relationship between their perceptions and their willingness to try and consume it. The questionnaire was distributed to potential participants via social media, and the responses of 989 participants were evaluated. The responses regarding the extent to which participants agreed with 32 opinions about in vitro meat were analysed using principal component analysis (PCA). As a result of PCA, four components were obtained explaining 63.3% of the total variance: i) benefits for the environment, and human and animal welfare; ii) safety and reliability; iii) social and ethical concerns; and iv) concerns about being unnatural. Regression equations developed with these components were able to moderately explain ($R^2$ ranged between 0.547 and 0.583) the variance observed in consumers' willingness to try, regularly consume, replace conventional meat with and try in vitro meat when recommended by a friend.

## 1 | Introduction

Despite the increasing concerns about the environmental and ethical issues associated with animal meat production (Scollan et al. 2011), the global demand for protein, particularly meat, continues to rise and is expected to reach 470 million tonnes by 2050 (É. Hocquette et al. 2022). Concerns regarding the impact of greenhouse gas emissions from livestock on climate change, the limited availability of natural resources, challenges in feed production, the restricted meat production capacity due to the growing global population, animal welfare and ethical considerations and the prevalence of zoonotic and foodborne diseases have driven the search for alternative sources of meat production. Meat derived from farm animal cells and produced in vitro in the laboratory is presented as one of the alternative methods that could potentially address the future protein source problem (Byrne and Murray 2021; Post 2012). In vitro meat is a biotechnological product obtained by culturing cells (embryonic stem cells or embryonic myoblasts) taken from a living animal via biopsy. These cells proliferate extensively and fuse to form clusters of muscle fibres (É. Hocquette et al. 2022; Mehta et al. 2019).

However, there is no consensus in the opinions of researchers regarding in vitro meat. Some researchers argue that in vitro meat is safer than traditionally produced meat, as it does not contain bacteria and viruses (Datar and Betti 2010). In addition, in vitro meat production is said to require less energy, emit fewer

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greenhouse gases and need less water and land, making it more environmentally friendly (Tuomisto and Teixeira de Mattos 2011; Tuomisto 2019). It also has several advantages, such as being free of antibiotics and hormones, containing zero cholesterol and having lower levels of saturated fat (Bryant 2022; Heller and Keoleian 2018). On the other hand, some researchers highlight concerns that the production stages of artificial meat are complex and carry a risk of accidental contamination (Bonny et al. 2015). They also point out that unknown harmful substances could emerge during the production process and that there is a lack of long-term scientific studies and data to prove the safety of in vitro meat (Chriki and Hocquette 2020; Petetin 2014). Furthermore, it is argued that in vitro meat production could consume more industrial energy, potentially negating its advantages in energy savings and environmental protection (Alexander et al. 2017; Min et al. 2024).

Public opinion on in vitro meat is also conflicted. Understanding consumer expectations regarding this issue is crucial. Therefore, various surveys have been conducted in different countries to investigate the attitudes of potential consumer groups and to assess their perceptions and acceptance of purchasing and consuming such a product (De Graag 2020; A. Hocquette et al. 2015; Mancini and Antonioli 2020; Weinrich et al. 2020; Wiks and Phillips 2017). These studies have found that while some individuals find in vitro meat repulsive, others consider it intriguing and novel. It has also been reported that most consumers lack knowledge about artificial meat. Although many consumers express a strong willingness to try in vitro meat at least once, they are not yet ready to consume it regularly (C. Bryant and Barnett 2020; É. Hocquette et al. 2022; Hwang et al. 2020; Wilks and Phillips 2017).

In Türkiye, there is currently no production or sale of in vitro meat. The primary aim of this study is to determine the perceptions and attitudes of Turkish consumers toward in vitro meat. In addition, the study examines the relationship between consumers' perceptions of in vitro meat and their willingness to try and consume it.

## 2 | Materials and Methods

The procedures of the study were approved by the Canakkale Onsekiz Mart University Graduate Education Institute Ethics Committee (Approval No: 2023-YÖNP-0498, Acceptance Date: 21/06/2023, Decision no: 08/07).

### 2.1 | Participants of the Questionnaire

The questionnaire was administered in Turkish and consists of four sections: i) socio-demographic information, ii) brief introduction to in vitro meat, iii) questions about the willingness to try, consume and purchase in vitro meat and iv) the extent to which respondents agree with various opinions presented about in vitro meat.

The first section of the questionnaire consists of participants' socio-demographic information. In this section, participants were asked about their age, gender, education level, city of residence, number of children, income level, meat consumption habits, frequency of meat consumption and whether they had previously heard of the concept of artificial meat.

Since in vitro meat is not available on the market in Türkiye and consumers may have limited knowledge about this product, the definition and visual representation of in vitro meat were included in the second section of the questionnaire. In this context, the following text was included in the survey.

'Artificial meat is a meat product produced in a laboratory using muscle stem cells that are never part of a living animal. This product is also called 'cultured meat, cell-based meat, in vitro meat, laboratory meat, clean meat, or synthetic meat.' Stem cells are taken without causing any discomfort to living animals and turned into tissue in a controlled laboratory environment. Artificial meat is bioidentical to meat tissue derived from animals. Artificial meat products are not yet available for retail sale in Türkiye'.

In addition, a security question (please mark 'yes' for this question so we can assess data security) was included in the second section to ensure data reliability. Participants who did not answer 'yes' were excluded from the evaluation.

The third section of the questionnaire consisted of two parts. In the first part, participants were asked about their willingness to try in vitro meat, whether they would consider consuming it regularly, and if they would be willing to try it if recommended. Participants were requested to respond using a 1–5 Likert scale (1: *absolutely no*, 2: *no*, 3: *not sure*, 4: *yes*, 5: *absolutely yes*). In the second part, participants were asked how much more or less they would be willing to pay for in vitro meat compared to meat obtained from traditional farming. Participants were instructed to select one of the following options: 1: *much less*, 2: *somewhat less*, 3: *similar*, 4: *somewhat more*, 5: *much more*.

In the fourth section of the questionnaire, participants were asked about their opinions regarding 32 different statements related to in vitro meat. These statements were compiled from previously published articles (C. J. Bryant and Barnett 2019; A. Hocquette et al. 2015; É. Hocquette et al. 2022; Pakseresht et al. 2022; Wilks and Phillips 2017). Participants were requested to indicate their agreement with each statement using a 1–5 Likert scale (1: *strongly disagree*, 2: *disagree*, 3: *neutral*, 4: *agree*, 5: *strongly agree*).

### 2.2 | Participants and Data Collection

This study was conducted from July to September 2023. The target group of the questionnaire comprised individuals over the age of 18 living in Türkiye. Before administering the questionnaire, a pilot survey was conducted online with 27 participants to assess the clarity, relevance and usability of the questions. Based on the feedback received, adjustments were made to the Turkish wording and to the fourth section of the questionnaire.

The sample size was determined based on a 95% confidence level and a 5% margin of error. The adult consumer population in Turkey is approximately 60 million, and the minimum required sample size for this population was calculated as 384. However,



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**TABLE 1** | Demographic characteristics of the respondents ($N = 989$).

| Factor | *n* | % |
|---|---|---|
| Gender | | |
| Female | 557 | 56.3 |
| Male | 419 | 42.4 |
| No wish to answer | 13 | 1.3 |
| Age (years) | | |
| 18–25 | 163 | 16.5 |
| 26–35 | 213 | 21.5 |
| 36–45 | 274 | 27.7 |
| 46–55 | 210 | 21.2 |
| >56 | 129 | 13.0 |
| **Total** | **989** | **100.0** |

considering the variability in response rates in online surveys, a larger sample size was targeted. In addition, since a stratified sampling method will be employed based on different age groups, education levels, occupational groups and income levels, the target sample size was set at approximately 1000 to ensure adequate representation from each stratum.

The questionnaire was prepared using Google Forms and distributed to potential participants via social media. Participants were presented with an 'informed consent' text to inform them about the study before they decided to participate. A total of 1009 individuals participated in the questionnaire. Among them, six individuals under the age of 18 were excluded from the analysis. In addition, nine participants clicked 'no' in response to the question 'I agree to participate in the research,' and five participants did not answer the security question. After data cleaning, the responses of 989 participants were evaluated. The distribution of these participants by age and gender is presented in Table 1.

## 2.3 | Statistical Analyses

The distribution of participants by gender and age groups, along with the distribution and descriptive statistics of responses to the 32 statements in the fourth section of the survey, were determined using the Jamovi 2.3 software (Jamovi 2022).

The principal component analysis (PCA) was applied to the responses of participants regarding 32 different statements related to in vitro meat. PCA aims to transform the observed data set into a lower-dimensional data set containing new uncorrelated variables called principal components (Jolliffe 2022). Firstly, the Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity were applied to evaluate the suitability of data for PCA. A KMO value greater than 0.7 and a $p$ value less than 0.05 for Bartlett's test were considered threshold levels.

Afterwards, a PCA with direct oblimin rotation was conducted to assess the dimensionality of the 32 Likert-type items. The number of components was determined based on criteria with eigenvalues greater than one. The initial PCA yielded four components. However, statements D9, D14 and D28 were excluded due to double loading. The remaining 29 items were subjected to reanalysis, resulting in the same four-factor structure obtained in the initial analysis; no further items were removed. The KMO value was 0.960, and Bartlett's test result was significant ($\chi^2 = 1948$, df = 460, $p < 0.001$), indicating that the data were suitable for the analysis.

To identify the predictive effects of participants' perceptions regarding in vitro meat on their willingness to try and consume in vitro meat, multiple linear regression analysis was conducted using the component scores determined with PCA.

## 3 | Results

The distribution of participants' responses regarding the extent to which they agree with various views related to in vitro meat is presented in Table 2. More than half of the participants agreed that consuming in vitro meat can be healthy (D1, 62.7%), in vitro meat is probably safe for human consumption (D5, 53.7%), in vitro meat is safe (D6, 59.8%), in vitro meat is an attractive product (D8, 68.9%), the development of in vitro meat is positive (D9, 53.2%), the idea of consuming in vitro meat is favourable (D11, 58. 6%), in vitro meat consumption poses a problem for their religious beliefs (D22, 53.4%), in vitro meat consumption is more ethical than consumption of meat obtained from farm animals (D24, 56.1%), in vitro meat production will reduce the number of happy animals in the world (D28, 55.6%) and not agree (strongly disagree + disagree) that in vitro meat can replace meat obtained from farm animals (D31, 54.5%).

On the other hand, 63.2% of the participants agreed (agree + strongly agree) that in vitro meat is unnatural (D7), 53.3% were concerned about in vitro meat consumption (D12), 79% could freely decide whether to consume in vitro meat (D14) and 67.9% agreed (agree + strongly agree) that in vitro meat production would have negative effects on traditional animal breeders and the meat industry (D17).

The extent to which respondents agreed with the 32 opinions on in vitro meat in section 'D' of the questionnaire was analysed by PCA. As a result of PCA, four components are obtained (Table 3). These components explain 63.3% of the total variance. PC1 includes 14 questions and explains 30.89% of the total variance. The Cronbach's alpha coefficient was 0.952. The factor loads of the questions in PC1 vary between 0.520 and 0.873. The three questions with the highest factor load in PC1 are D30 (*artificial meat is more humane because it is produced without slaughtering animals*), D26 (*artificial meat reduces the risk of disease transmission from animals to humans*) and D29 (*the widespread use of artificial meat diminishes the impact of livestock production on global warming*). It is seen that the questions in PC1 are generally related to the contributions of in vitro meat, such as animal welfare, the environment, the solution of the meat production deficit and hunger problem and reduction of zoonotic diseases. Therefore, PC1 is called 'benefits for environment, and human and animal welfare.'

Cronbach's alpha coefficient of PC2, which includes five questions, was found to be 0.897. PC2 explained 13.24% of the total



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**TABLE 2** | Responses regarding the perceptions of in vitro meat.

| Question | 1 (Strongly disagree) % | 2 (Disagree) % | 3 (Neutral) % | 4 (Agree) % | 5 (Strongly agree) % | Mean | SD |
|---|---|---|---|---|---|---|---|
| D1. Consuming artificial meat may be healthy. | 36.1 | 26.6 | 28.6 | 7.4 | 1.3 | 2.11 | 1.02 |
| D2. Artificial meat probably has a similar appearance, taste, odour and texture to meat from farm animals. | 19.9 | 19.2 | 28.2 | 28.8 | 3.8 | 2.77 | 1.18 |
| D3. I believe I can discern the difference between artificial meat and meat from farm animals. | 12.2 | 12.6 | 30.5 | 30.4 | 14.2 | 3.22 | 1.20 |
| D4. Artificial meat probably contains chemicals or components that may pose health risks. | 12.8 | 13.3 | 25.6 | 25.3 | 23.0 | 3.32 | 1.31 |
| D5. Artificial meat is probably safe for human consumption. | 33.9 | 19.8 | 30.8 | 12.8 | 2.6 | 2.31 | 1.14 |
| D6. I trust artificial meat. | 38.1 | 21.7 | 28.6 | 9.0 | 2.5 | 2.16 | 1.11 |
| D7. Artificial meat is unnatural. | 13.4 | 8.6 | 14.8 | 26.7 | 36.5 | 3.64 | 1.39 |
| D8. Artificial meat is an appealing product for me. | 46.1 | 22.8 | 22.1 | 5.3 | 3.7 | 1.98 | 1.11 |
| D9. I welcome the development of artificial meat. | 35.0 | 18.2 | 21.7 | 16.9 | 8.2 | 2.45 | 1.33 |
| D10. I find the idea of consuming artificial meat abhorrent. | 18.0 | 23.3 | 20.3 | 17.3 | 21.1 | 3.00 | 1.40 |
| D11. I am positively inclined towards the idea of consuming artificial meat. | 36.8 | 21.8 | 21.5 | 14.0 | 5.9 | 2.30 | 1.26 |
| D12. I am concerned about consuming artificial meat. | 9.4 | 14.4 | 22.5 | 27.4 | 26.3 | 3.47 | 1.28 |
| D13. Consuming artificial meat contradicts my values. | 16.4 | 19.8 | 21.6 | 18.8 | 23.4 | 3.13 | 1.40 |
| D14. I can freely decide whether or not to consume artificial meat. | 6.3 | 5.3 | 9.5 | 33.0 | 46.0 | 4.07 | 1.15 |
| D15. The production of artificial meat is a necessary scientific development. | 26.9 | 12.4 | 22.4 | 23.4 | 14.9 | 2.87 | 1.42 |
| D16. Other individuals will not approve of me consuming artificial meat. | 23.3 | 22.3 | 29.2 | 13.7 | 11.5 | 2.68 | 1.28 |
| D17. The production of artificial meat will have adverse effects on traditional animal breeders and the meat industry. | 7.5 | 12.8 | 11.8 | 34.7 | 33.2 | 3.73 | 1.25 |
| D18. The production of artificial meat is a wise step. | 29.7 | 17.0 | 25.1 | 20.2 | 8.0 | 2.60 | 1.31 |
| D19. The production of artificial meat is necessary. | 29.5 | 18.9 | 25.6 | 18.5 | 7.5 | 2.56 | 1.29 |
| D20. Artificial meat is environmentally friendly compared to meat from farm animals. | 28.2 | 18.2 | 28.9 | 16.7 | 8.0 | 2.58 | 1.27 |
| D21. The production of artificial meat poses a risk to society. | 11.1 | 18.0 | 31.5 | 18.0 | 21.3 | 3.20 | 1.27 |
| D22. The consumption of artificial meat poses a problem from the perspective of my religious beliefs. | 30.9 | 22.5 | 23.1 | 10.0 | 13.4 | 2.52 | 1.37 |
| D23. Artificial meat contributes to reduction of animal welfare issues. | 23.0 | 15.9 | 26.2 | 21.3 | 13.7 | 2.87 | 1.35 |
| D24. I consider the consumption of artificial meat more ethical than the consumption of meat from farm animals. | 33.7 | 22.4 | 23.4 | 11.2 | 9.3 | 2.40 | 1.30 |
| D25. Artificial meat may contribute to solving the issue of global hunger in the future. | 20.9 | 15.0 | 26.5 | 26.8 | 10.8 | 2.92 | 1.30 |
| D26. Artificial meat reduces the risk of disease transmission from animals to humans. | 18.2 | 14.6 | 26.1 | 29.6 | 11.5 | 3.02 | 1.28 |

(Continues)



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**TABLE 2** | (Continued)

| Question | 1 (Strongly disagree) % | 2 (Disagree) % | 3 (Neutral) % | 4 (Agree) % | 5 (Strongly agree) % | Mean | SD |
|---|---|---|---|---|---|---|---|
| D27. If it becomes widespread globally, artificial meat will be cheaper than meat from farm animals. | 13.8 | 12.0 | 25.7 | 34.0 | 14.6 | 3.24 | 1.24 |
| D28. The number of happy animals in the World will be reduced by artificial meat production. | 29.1 | 26.5 | 29.1 | 9.2 | 6.1 | 2.37 | 1.17 |
| D29. The widespread use of artificial meat diminishes the impact of livestock production on global warming. | 22.1 | 16.0 | 29.0 | 21.3 | 11.5 | 2.84 | 1.30 |
| D30. Artificial meat is more humane because it is produced without slaughtering animals. | 25.7 | 17.5 | 21.8 | 21.2 | 13.8 | 2.80 | 1.39 |
| D31. Artificial meat can replace meat from farm animal. | 35.4 | 19.1 | 25.8 | 12.1 | 7.6 | 2.37 | 1.28 |
| D32. I believe that artificial meat is feasible and realistic. | 28.4 | 16.3 | 28.4 | 18.7 | 8.2 | 2.62 | 1.29 |

variance. The questions in PC2 are related to the attractiveness, reliability, safety and healthiness of in vitro meat. Therefore, PC2 is called 'safety and reliability'.

PC3, which includes seven questions, explains 11.6% of the total variance, and Cronbach's alpha coefficient is 0.837. The question that has the highest factor load is '*other individuals will not approve of me consuming artificial meat* (D16). It is followed by D22 (*the consumption of artificial meat poses a problem from the perspective of my religious beliefs*) and D13 (*consuming artificial meat contradicts my values*). In general, the questions in PC3 consist of various concerns about in vitro meat, such as that other people may not view it favourably if in vitro meat is consumed or religious concerns. So that, PC3 is called 'Social and ethical concerns.'

PC4 consists of three questions, and it is about 7.53% of the total variance. The factor loads of these questions were found to be 0.700 and above. The question that has the highest factor load is '*I believe I can discern the difference between artificial meat and meat from farm animals* (D3).' It is followed by D7 (*artificial meat is unnatural*) and D4 (*artificial meat probably contains chemicals or components that may pose health risks*). So that, PC4 is called 'Concerns for being unnatural.'

The relationships between the PC scores obtained by PCA and consumers' willingness to try in vitro meat, consume it regularly, consume it instead of conventional meat, try it if recommended by a friend, and willingness to pay are presented in Tables 4–8.

When the relationships between PC scores and consumers' willingness to try in vitro meat were analysed (Table 4), it was seen that all four components were effective on willingness to try. The degree of determination of the regression model on willingness to try was found to be moderate (adjusted $R^2 = 0.565$). There is a positive correlation between consumers' opinions on 'benefits for environment, and human and animal welfare,' 'Safety and reliability,' and 'Concerns for being unnatural' of in vitro meat and their willingness to try ($p < 0.001$). On the other hand, the increase in the scores of PC3 (social and ethical concerns) negatively affects the willingness to try ($p < 0.001$).

In the study, there was a positive correlation between the increase in PC1 (benefits for environment, and human and animal welfare) and PC2 (safety and reliability) scores and the willingness to consume in vitro meat regularly ($p < 0.001$, Table 5). The increase in social and ethical concerns negatively affects the willingness to consume in vitro meat regularly ($p < 0.001$). On the other hand, the effect of concerns about the unnaturalness of in vitro meat on the willingness to consume in vitro meat regularly was found to be insignificant ($p > 0.05$).

PC1 and PC2 scores have a positive effect on the willingness to consume in vitro meat instead of conventional meat ($p < 0.001$), while PC3 ($p < 0.001$) and PC4 ($p < 0.05$) scores have a negative effect (Table 6). It is seen that if the participants think that in vitro meat can contribute positively to the environment, animal and human welfare, safety and reliability, they may prefer to consume in vitro meat instead of conventional meat. On the other hand, social and ethical concerns and other concerns about the unnaturalness of in vitro meat reduce the willingness to consume this product.

In the study, all four PCs were found to influence the willingness to try in vitro meat when recommended by a friend ($p < 0.001$). The degree of determination of the regression model was 0.570. Increasing PC1, PC2 and PC4 scores positively affected the willingness to try in vitro meat when recommended by a friend. On the other hand, if participants had social and ethical concerns, even the recommendation of a friend did not positively change their willingness to try in vitro meat.

The effect of the scores of the four PCs on the willingness to purchase in vitro meat instead of meat from farm animals was found to be significant. However, the degree of determination of the model was quite low (adjusted $R^2 = 0.160$). While the willingness to pay for in vitro meat increased with the increase in PC1 (benefits for environment, and human and animal welfare)



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**TABLE 3** | Dimensions (factor loadings) for various opinions on in vitro meat.

| Question | PC1- benefits for environment, and human and animal welfare | PC2 - safety and reliability | PC3- social and ethical concerns | PC4- concerns for being unnatural |
|---|---|---|---|---|
| D30 | **0.873** | | | |
| D26 | **0.857** | | | |
| D29 | **0.852** | | | |
| D23 | **0.780** | | | |
| D25 | **0.766** | | | |
| D27 | **0.762** | | | |
| D32 | **0.721** | | | |
| D20 | **0.715** | | | |
| D31 | **0.713** | | | |
| D24 | **0.706** | | | |
| D18 | **0.673** | | | |
| D19 | **0.641** | | | |
| D15 | **0.611** | | | |
| D2 | **0.520** | | | |
| D8 | | **0.723** | | |
| D6 | | **0.715** | | |
| D5 | | **0.645** | | |
| D11 | 0.342 | **0.580** | | |
| D1 | 0.332 | **0.566** | | |
| D16 | | | **0.779** | |
| D22 | | | **0.664** | |
| D13 | | | **0.650** | |
| D17 | | | **0.590** | |
| D21 | | | **0.579** | |
| D12 | | −0.341 | **0.551** | |
| D10 | | | **0.541** | |
| D3 | | | | **0.800** |
| D7 | | | | **0.701** |
| D4 | | | | **0.700** |
| Internal consistency | 0.952 | 0.897 | 0.837 | 0.670 |
| Eigenvalue | 12.473 | 3.363 | 1.335 | 1.173 |
| Total variance (%) | 30.89 | 13.24 | 11.60 | 7.53 |
| Cumulative variance (%) | 30.89 | 44.1 | 55.7 | 63.3 |

and PC2 (safety and reliability) scores, social and ethical concerns and views on unnaturalness decreased the willingness to pay.

## 4 | Discussion

In many studies, it has always been emphasised that consumer attitudes play an important role in the acceptance of new food technologies (Armitage and Conner 2001; Bekker, Fischer, et al. 2017; Frewer et al. 2014; Mancini and Antonioli 2019). Findings from many studies show that consumers are undecided about accepting in vitro meat (Bekker, Tobi, et al. 2017; Verbeke, Marcu, et al. 2015; Verbeke, Sans, et al. 2015; Wilks and Phillips 2017).

Flavour and taste characteristics of in vitro meat are one of the important criteria in consumer preferences. Gere et al. (2020) reported that consumers would prefer meat alternatives (including cultured meat) with similar sensory characteristics to



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**TABLE 4** | Multiple regression estimation for the relationships between PC scores and willing to try in vitro meat.

| Variable | *B* | SE | *ß* | *t* | *p* value | $R^2$ | Adjusted $R^2$ |
|---|---|---|---|---|---|---|---|
| Intercept | 2.442 | 0.027 | | 91.86 | < 0.001 | 0.567 | 0.565 |
| PC1 | 0.419 | 0.032 | 0.331 | 13.08 | < 0.001 | | |
| PC2 | 0.530 | 0.032 | 0.418 | 16.45 | < 0.001 | | |
| PC3 | −0.269 | 0.030 | −0.212 | −8.99 | < 0.001 | | |
| PC4 | 0.111 | 0.028 | 0.088 | 3.96 | < 0.001 | | |

*Note:* PC1: benefits for environment, and human and animal welfare; PC2: safety and reliability; PC3: social and ethical concerns; PC4: concerns for being unnatural.

**TABLE 5** | Multiple regression estimation for the relationships between PC scores and willing to consume in vitro meat regularly.

| Variable | *B* | SE | *ß* | *t* | *p* value | $R^2$ | Adjusted $R^2$ |
|---|---|---|---|---|---|---|---|
| Intercept | 1.959 | 0.020 | | 96.107 | < 0.001 | 0.547 | 0.545 |
| PC1 | 0.218 | 0.025 | 0.229 | 8.857 | < 0.001 | | |
| PC2 | 0.471 | 0.025 | 0.496 | 19.070 | < 0.001 | | |
| PC3 | −0.180 | 0.023 | −0.189 | −7.845 | < 0.001 | | |
| PC4 | −0.004 | 0.022 | −0.004 | −0.172 | 0.863 | | |

*Note:* PC1: benefits for environment, and human and animal welfare; PC2: safety and reliability; PC3: social and ethical concerns; PC4: concerns for being unnatural.

**TABLE 6** | Multiple regression estimation for the relationships between PC scores and willing to consume in vitro meat instead of conventional meats.

| Variable | *B* | SE | *ß* | *t* | *p* value | $R^2$ | Adjusted $R^2$ |
|---|---|---|---|---|---|---|---|
| Intercept | 2.031 | 0.022 | | 90.53 | < 0.001 | 0.583 | 0.581 |
| PC1 | 0.382 | 0.027 | 0.350 | 14.10 | < 0.001 | | |
| PC2 | 0.452 | 0.027 | 0.414 | 16.61 | < 0.001 | | |
| PC3 | −0.194 | 0.025 | −0.178 | −7.69 | < 0.001 | | |
| PC4 | −0.056 | 0.024 | −0.051 | −2.35 | 0.019 | | |

*Note:* PC1: benefits for environment, and human and animal welfare; PC2: safety and reliability; PC3: social and ethical concerns; PC4: concerns for being unnatural.

conventional meat. In this study, 32.6% of the participants agreed and 39.1% disagreed with the statement (D2) that in vitro meat probably has a similar appearance, taste, odour and texture to meat obtained from farm animals. In a previous Canadian study (Ruzgys and Pickering 2020), respondents were relatively evenly split between moderate or strong agreement (38%), moderate or strong disagreement (30%) and neither agreement nor disagreement (32%) that in vitro meat would not taste the same as farmed meat.

In the study, it was determined that only 38.3% of Turkish consumers adopted the opinion 'the production of artificial meat is a necessary scientific development (D15),' 28.2% adopted the opinion 'the production of artificial meat is a wise step,' 26%

**TABLE 7** | Multiple regression estimation for the relationships between PC scores and willing to try in vitro meat if it was recommended by friends.

| Variable | *B* | SE | *ß* | *t* | *p* value | $R^2$ | Adjusted $R^2$ |
|---|---|---|---|---|---|---|---|
| Intercept | 2.520 | 0.026 | | 95.75 | < 0.001 | 0.572 | 0.570 |
| PC1 | 0.428 | 0.032 | 0.339 | 13.48 | < 0.001 | | |
| PC2 | 0.505 | 0.032 | 0.400 | 15.84 | < 0.001 | | |
| PC3 | −0.293 | 0.030 | −0.232 | −9.90 | < 0.001 | | |
| PC4 | 0.126 | 0.028 | 0.100 | 4.55 | < 0.001 | | |

*Note:* PC1: benefits for environment, and human and animal welfare; PC2: safety and reliability; PC3: social and ethical concerns; PC4: concerns for being unnatural.



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**TABLE 8** | Multiple regression estimation for the relationships between PC scores and willing to pay for in vitro meat compared to meat from farmed animals.

| Variable | *B* | SE | *ß* | *t* | *p* value | $R^2$ | Adjusted $R^2$ |
|---|---|---|---|---|---|---|---|
| Intercept | 1.485 | 0.024 | | 62.51 | < 0.001 | 0.164 | 0.160 |
| PC1 | 0.173 | 0.029 | 0.212 | 6.02 | < 0.001 | | |
| PC2 | 0.133 | 0.029 | 0.163 | 4.63 | < 0.001 | | |
| PC3 | −0.098 | 0.027 | −0.121 | −3.68 | < 0.001 | | |
| PC4 | −0.052 | 0.025 | −0.064 | −2.08 | 0.038 | | |

*Note:* PC1: benefits for environment, and human and animal welfare; PC2: safety and reliability; PC3: social and ethical concerns; PC4: concerns for being unnatural.

adopted the opinion 'the production of artificial meat is necessary (D19)' and 26.9% adopted the opinion 'I believe that artificial meat is feasible and realistic (D32).' These results indicate that most Turkish consumers are not convinced about the benefits and necessity of in vitro meat. In another study conducted by Ede and Yalçın (2023) with Turkish consumers, it was found that only 15% of the respondents found in vitro meat realistic. On the contrary, in a study conducted in China (Liu et al. 2021), many respondents predicted that in vitro meat would become a realistic option in their daily lives in the short term (20.9% of respondents) and in the medium term (45.1%), while a smaller group (10.3%) disagreed with this view and believed that in vitro meat was not realistic. The difference in the perspectives of Chinese and Turkish consumers may be related to the distinctiveness of Chinese and Turkish cuisines and eating habits.

Many consumers are increasingly avoiding animal products, particularly beef, due to concerns about the significant contribution of methane emissions from livestock to climate change. This link between livestock production and global warming has sparked intense debate, leading to calls for major dietary changes and reductions in livestock production. (Scoones 2023). In this study, 24.7% and 32.8% of the respondents agreed with the views that in vitro meat is more environmentally friendly than meat produced from farm animals (D20) and that it can contribute to the reduction of global warming (D29), which is suggested to be associated with animal production, respectively. In other words, a small proportion of Turkish consumers agree that the widespread use of in vitro meat production can contribute to the reduction of environmental problems. Slade (2018) and Tucker (2014) found that participants thought that environmental and animal welfare concerns would not have an impact on consumers' willingness to consume in vitro meat. Circus and Robinson (2019) determined that consumers accept in vitro meat as an effective technology in finding solutions to global environmental problems. Many studies (C. Bryant et al. 2020; Dupont and Fiebelkorn 2020; Shaw and Mac Con Iomaire 2019; Valente et al. 2019; Weinrich et al. 2020) also concluded that consumers with animal welfare and ecological concerns find in vitro meat ethically acceptable. Sikora and Rzymski (2023) found that 67% of respondents in Poland believed that conventional meat production has negative impacts on global environmental problems. The results obtained in the current study indicate that Turkish consumers agree with the view that in vitro meat could be an environmentally friendly product compared to conventional meat to a lesser extent than consumers in other countries, as reported in previous studies.

In many countries, problems related to animal welfare are followed sensitively by large masses of people. In addition, a considerable number of people prefer not to consume animal products (Mancini and Antonioli 2019). In this study, 35% of participants agreed that 'in vitro meat can help reduce animal welfare problems' (D23). Only 20% of participants agreed with the statement 'I consider the consumption of artificial meat to be more ethical than the consumption of meat from farmed animals' (D24). Similarly, the proportion of people who agreed with the statement 'artificial meat is more humane because it is produced without slaughtering animals (D30)' was also low (35%). These results indicate that Turkish consumers do not view in vitro meat production as a solution to addressing animal welfare issues. Sikora and Rzymski (2023) found that 76% of respondents in Poland agreed that in vitro meat production can be an effective method to limit animal suffering. Mancini and Antonioli (2019) found that 26% of respondents in Italy tended to reduce meat consumption due to animal welfare issues, while consumers tended to adopt meat substitutes due to ethical concerns. Many studies (Dupont and Fiebelkorn 2020; Slade 2018; Valente et al. 2019) have also reported that animal welfare concerns play a role in consumers' reduction of meat consumption and acceptance of cultured meat. The global population is expected to exceed 9 billion by 2050. The Food and Agriculture Organisation (FAO) estimates that 70% more food will be needed in 2050 to meet the demand of the growing population (Chriki and Hocquette 2020; Steinfeld et al. 2006). In this study, 37.6% of Turkish consumers were found to believe that in vitro meat production could help solve future global hunger problems (D25). Some previous studies (C. Bryant and Barnett 2020; Laestadius 2015) reported that consumers perceived artificial meat as one of the ways to alleviate global hunger. On the other hand, 41.5% of participants supported the view that 'artificial meat reduces the risk of disease transmission from animals to humans (D26).' These results indicate that participants expect in vitro meat to contribute more significantly to the prevention of zoonotic diseases than to environmental issues, animal welfare and the reduction of global hunger. Zhang et al. (2022) claimed that cultured meat would 'reduce' the risk of zoonotic diseases. On the other hand, Giles (2023) reported that to date, no quantitative and measurable study has been conducted to prove that in vitro meat production reduces the spread of zoonotic diseases, and that the studies that have been conducted have been evaluated according to comments from consumer surveys.

Another interesting finding of the study was that 44.6% of respondents agreed that in vitro meat would be cheaper than farmed



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meat (D27) if it were to become widespread globally. On the other hand, 54.5% of respondents disagreed with the statement that in vitro meat could replace farmed meat (D31). These results suggest that respondents believe that biotechnological advances could make in vitro meat more readily available but are sceptical about the idea of in vitro meat replacing meat from farmed animals. Van Loo et al. (2020) found that even with significant price reductions (e.g., 50%) for in vitro meat, conventional beef remains the preferred option. In the case of Brazil, when comparing alternative proteins with conventional meat, it was reported that price alone was not important to participants, but that various factors (health, safety, nutritional content, flavour) were important in addition to low price (Gómez-Luciano et al. 2019). Wilks and Phillips (2017) found that, on average, their participants expected cultured meat to be cheaper than conventional meat.

In this study, 54% and 60% of respondents, respectively, disagreed with the statements 'Artificial meat is probably safe for human consumption (D5)' and 'Consuming artificial meat can be healthy (D1).' These results indicate that a significant proportion of Turkish consumers doubt that in vitro meat is a safe and healthy product. In addition, around 60% of respondents stated that they did not trust in vitro meat, and 69% stated that they did not find in vitro meat attractive. Previous studies conducted in Germany (Dupont and Fiebelkorn 2020), Brazil (Gómez-Luciano et al. 2019), Southwest Europe (Italy, Portugal and Spain) (Liu et al. 2023), Ireland (Shaw and Mac Con Iomaire 2019) and Australia (Bogueva and Marinova 2020) also concluded that a significant proportion of consumers are concerned about the health and safety of in vitro meat. On the other hand, a study conducted in China (C. Bryant et al. 2019) found that a higher proportion of consumers agreed that in vitro meat can be a healthy and safe product.

A total of 68% of respondents agreed that in vitro meat could have negative impacts on traditional animal breeders and the meat industry; 54% confirmed that they were concerned about consuming in vitro meat. Shaw and Mac Con Iomaire (2019) found that Irish survey participants expressed concern that in vitro meat production could negatively impact the beef industry and that purchasing such products could reduce their support for Irish farmers.

In the study, about half of the participants stated that in vitro meat contains chemicals or ingredients that could possibly pose a health risk (D4) and that they could distinguish between in vitro meat and meat from farmed animals (D3). In addition, around 63% said that in vitro meat was not natural. Verbeke, Marcu, et al. (2015) determined that consumers would reject in vitro meat if they perceived it to be over-processed, unnatural and lacking in sensory characteristics. Dupont and Fiebelkorn (2020), Wilks et al. (2021), Siegrist and Hartman (2020) and C. Bryant et al. (2020) reported in their studies that in vitro meat is perceived as unnatural, and this perception is effective in not accepting the food. The results of our study show that Turkish consumers have a generally negative attitude towards in vitro meat, and this negativity is even higher than that found in previous studies conducted in other countries.

In the study, it is seen that participants' views on 'benefits for the environment and human and animal welfare (PC1)' significantly determined their willingness to try cultured meat, consume it regularly, consume it instead of conventional meat and purchase it. Mancini and Antolioli (2019) also report that positive perceptions of animal welfare increase consumers' willingness to try cultured meat, and to pay a higher price for it. On the other hand, Slade (2018) and Tucker (2014) reported that environmental and animal welfare concerns would not affect consumers' willingness to consume in vitro meat. In another survey, French respondents reported that they were unwilling to try in vitro meat because in vitro meat is unnatural (72.6%), could have a negative impact on territories and rural life (65.0%) and local farmers (64.1%) and they have less trust in laboratories and 'in vitro meat' initiatives (59.2%). (É. Hocquette et al. 2022).

The willingness of Turkish consumers to try in vitro meat, to consume it regularly, to consume it instead of conventional meat and to buy it is significantly related to the safety and reliability of in vitro meat (PC2). PC2, together with PC1, was found to be the main determinant of consumer willingness to buy in vitro meat. Consumers with a positive perception of the safety and reliability of in vitro meat were more likely to try and consume in vitro meat. In the study conducted in Brazil, it was predicted that a one-unit increase in the perception of the health, safety and nutritional value of in vitro meat would increase the likelihood of purchase by 86.8% (Gómez-Luciano et al. 2019).

As consumers' social and ethical concerns about in vitro meat (PC3) increase, their willingness to try, regularly consume and purchase in vitro meat is negatively affected. In the previous study with Italian, Portuguese and Spanish participants (Liu et al. 2023), it was determined that the perception that current meat production causes ethical and environmental problems was found to be the main reason for the willingness to consume and pay for in vitro meat regularly.

The effect of consumers' perceptions of 'concern about unnaturalness (PC4)' on their willingness to try in vitro meat was found to be somewhat complex. As PC4 scores increased, willingness to try in vitro meat increased, while willingness to consume and purchase in vitro meat as a substitute for conventional meat decreased. This finding suggests that respondents' perception that in vitro meat is unnatural makes them reluctant to consume this product as a substitute for meat from farmed animals but does not completely inhibit their willingness to try in vitro meat. The association of PC4 with consumers' willingness to consume in vitro meat regularly was not significant. Liu et al. (2021) reported that because of their survey study in China, respondents did not perceive in vitro meat as a natural product; this perception may create a sense of mistrust or emotional resistance, and therefore they may reject this new product without the desire to consume it regularly.

The degree of determination of the regression equations established with the four components identified in this study was found to be low for willingness to pay for in vitro meat and moderate for the other attributes. The low $R^2$ for willingness to pay for in vitro meat indicates that 'some factors not addressed here (e.g., price, family income, etc.) may be much more influential in the purchase decision.

The present study was conducted using an online survey. Therefore, responses could only be collected from individuals with



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internet access via a computer or mobile device. This poses a limitation in terms of the representativeness of the sample. In vitro meat is not yet available on the market in Türkiye. Therefore, since participants' evaluations of a product that is not currently on the market may be influenced by contextual factors, this should be taken into account when interpreting the results.

## 5 | Conclusions

It has been determined that Turkish consumers are generally hesitant about in vitro meat. Their perceptions of in vitro meat can be categorised into four components: i) benefits for the environment, and human and animal welfare; ii) safety and reliability; iii) social and ethical concerns; and iv) concerns about being unnatural. Regression equations developed with these components were able to moderately explain the variance observed in consumers' willingness to try, regularly consume, replace conventional meat with, and try in vitro meat when recommended by a friend. However, these components failed to produce a satisfactory model for explaining consumers' willingness to pay for in vitro meat. Among these, the perceptions related to 'benefits for the environment, and human and animal welfare' and 'safety and reliability' were identified as the primary factors influencing the willingness to try and consume in vitro meat.

The results of the current study indicate that Turkish consumers have significant concerns about in vitro meat. If in vitro meat is to be introduced to the market as a product, the biases and concerns of Turkish consumers should first be addressed within a scientific framework. In this context, educational initiatives could be organised to inform consumers about the issue. In addition, further research on consumer perspectives could be considered even after in vitro meat becomes available on the market.

### Author Contributions

**Ayse Gulin Eser**: conceptualisation, methodology, project administration, investigation, writing – original draft. **Pembe Dilara Kecici**: investigation, formal analysis, writing – review and editing. **Funda Yilmaz Eker**: investigation, writing – review and editing. **Bulent Ekiz**: conceptualisation, data curation, methodology, project administration, formal analysis, supervision, writing – review and editing.

### Ethics Statement

The procedures of the study were submitted to Çanakkale Onsekiz Mart University Graduate Education Institute Ethics Committee, and the project was approved by the Scientific Research Ethics Committee (Approval No: 2023-YÖNP-0498, Acceptance date: 21/06/2023).

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

Data will be made available on request.

### Peer Review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/vms3.70314.

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