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Research article

Reimagining beef: Consumer attitudes and acceptance of upcycled animal feed

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Supplementary

S1. Full item list of the employed constructs in the consumer survey.

Each construct, contained the following variables:

- Food neophobia: the validated scale was composed by five neophilia and five neophobia items, retrieved from the Food Neophobia Scale developed by Pliner and Hobden (1992). The items were assessed through a 7-point Likert-type scale (from 1 = Strongly disagree to 7 = Strongly agree) [52].
- Weekly beef consumption frequency, rated on a 3-point scale (1 = 1 to 5 times per week; 2 = 6 to 10 times per week; 3 = more than 10 times per week).
- The Consumer green self-identity, measured by two queries ("I think of myself as an environmentally conscious consumer" and "I consider myself as someone who is very concerned about environmental issues"). The items were assessed through a 7-point Likert-type scale, ranging from 1 (= Strongly disagree) to 7 (= Strongly agree) [53]. Pearson correlation calculated to measure the scale internal consistency was equal to 0.89.
- Consumer self-perceived awareness and concern of food waste reduction: consumer self-perceived awareness was measured by four items ("I feel that I know a lot about food waste reduction", "Compared to my family, I know a lot about food waste reduction", "Compared to my friends, I know a lot about food waste reduction", "Compared to experts, I know a lot about food waste

reduction"). This scale measures the self-perceived level of knowledge about food waste reduction, both in absolute terms and relative to others (family, friends, experts).

- Consumer concerns were measured by three queries ("Food waste reduction is important to me", "I am concerned about food waste reduction" and "Food waste reduction is vital to me"). This scale assesses the personal importance and level of concern regarding food waste reduction. All items were assessed through a 7-point Likert-type scale, ranging from 1 (= Strongly disagree) to 7 (= Strongly agree). The Cronbach's Alpha calculated for the two scales was equal to 0.75 and 0.80, respectively.
- Consumer awareness and concern about animal feeding methods: consumer awareness was measured by four items ("I feel that I know a lot about animal feeding methods", "Compared to my family, I know a lot about animal feeding methods", "Compared to my friends, I know a lot about animal feeding methods", "Compared to experts, I know a lot about animal feeding methods"). Consumer concern was composed of three items ("What animals are fed is important to me", "I am concerned about what animals are fed" and "What animals are fed is very important to me"). All items were assessed through a 7-point Likert-type scale, ranging from 1 (= Strongly disagree) to 7 (= Strongly agree). The Cronbach's Alpha calculated for the two scales was equal to 0.81 and 0.82, respectively.
- Acceptability: this scale was composed by three queries ("I am interested in buying meat obtained from beef cattle fed hazelnut skins as part of the feed formula", "It is a good idea to buy meat from beef cattle fed hazelnut skin as part of the feed formula", "Buying meat from beef cattle fed hazelnut skin as part of the feed formula is important to me"). All queries were evaluated through a 7-point Likert-type scale, ranging from 1 (= Strongly disagree) to 7 (= Strongly agree) [54,55]. Cronbach's Alpha was equal to 0.83.
- Benefit and risks expectations of meat products obtained from beef cattle fed hazelnut skins as part of the feed formula. The perceptions were evaluated in terms of:

Organoleptic traits ("It is tasty", "It is attractive", "it is juicy", "It has a bad smell", "It tastes similar to products that I already know", "It is pleasant", "It looks good, smells good and has an adequate texture") [56]. Cronbach's Alpha was equal to 0.71.

Health ("It's nutritious", "It's healthy", "It has positive effects on my health", "It is more natural than meat products obtained from beef cattle fed with traditional feed", "It is more nutritious (more vitamins, fibres, etc.) than meat products obtained from beef cattle fed with traditional feed", "It is healthier than meat products obtained from beef cattle fed with traditional feed", "I'm concerned about the effects it could have on my health", "I feel a sense of concern", "It poses a risk to human health"), and risk perceptions ("It's safe", "It does not contain toxins, drug residues, antibiotics, etc") [57–60]. Cronbach's Alpha was equal to 0.83.

- Economic sustainability ("It's expensive", "It's cheaper than meat products obtained from beef cattle fed with traditional feed") [61]. Cronbach's Alpha was equal to 0.67.
- Environmental sustainability ("It has positive effects on the environment", "It helps reducing the environmental impact of beef production to some extent", "It helps reducing food waste) [62]. Cronbach's Alpha was equal to 0.71.
- Animal welfare ("It contributes to a high level of animal welfare", "It helps improving animal welfare", "I think it's dangerous for animal health") [63]. Cronbach's Alpha was equal to 0.77.

S2. Questionnaire.

Screening

Q1. Gender—Please choose ONE of the options below:
Woman
Man
Non-binary
Other
Prefer not to respond

Q2. How old are you? (open field)

Q3. Do you consume meat? ☐ Yes ☐ No

Q4. Do you consume beef? ☐ Yes ☐ No

Respondents selecting 'No' on Q3 or Q4 were screened out.

Section A—Food Neophobia Scale

Q5. To what extent do you agree with the following statements? Please respond quickly on the basis of your immediate impressions. No right or wrong answers exist — only your personal opinion counts.
7-point Likert scale: 1 = Strongly disagree → 7 = Strongly agree. Source: Pliner & Hobden (1992).
A1. I frequently try new and different foods
A2. I like foods originating from other countries
A3. When eating out, I will try new foods
A4. I will eat almost anything
A5. I like to try new ethnic restaurants
A6. I do not trust new foods
A7. If I do not know what is in a food, I will not try it
A8. I find unfamiliar foods too strange to eat
A9. I am afraid to eat things that I have never tried before
A10. I am very selective about what I will eat
Items A1–A5 = neophilia subscale; Items A6–A10 = neophobia subscale.

Section B—Beef Consumption Frequency

Q6. How many times per week do you usually eat beef?
1–5 times per week
6–10 times per week
More than 10 times per week

Section C—Consumer Green Self-Identity

Q7. How much do you agree with the following statements?
7-point Likert scale. Source: Altintzoglou et al. (2021).
C1. I think of myself as an environmentally conscious consumer
C2. I consider myself someone who is very concerned about environmental issues

Section D—Awareness and Concern about Food Waste Reduction

Q8. Please indicate your level of agreement with the following statements regarding food waste reduction.
7-point Likert scale. Source: Altintzoglou et al. (2021). D1–D4 = awareness subscale (α = 0.75); D5–D7 = concern subscale (α = 0.80).
D1. I feel that I know a lot about food waste reduction
D2. Compared to my family, I know a lot about food waste reduction
D3. Compared to my friends, I know a lot about food waste reduction
D4. Compared to experts, I know a lot about food waste reduction
D5. Food waste reduction is important to me
D6. I am concerned about food waste reduction
D7. Food waste reduction is very important to me

Section E—Awareness and Concern about Animal Feeding Methods

Q9–Q10. Please indicate your level of agreement with the following statements regarding animal feeding practices.
7-point Likert scale. Adapted from Altintzoglou et al. (2021). E1–E4 = awareness subscale (α = 0.81); E5–E7 = concern subscale (α = 0.82).
E1. I feel that I know a lot about animal feeding methods
E2. Compared to my family, I know a lot about animal feeding methods
E3. Compared to my friends, I know a lot about animal feeding methods
E4. Compared to experts, I know a lot about animal feeding methods
E5. What animals are fed is important to me
E6. I am concerned about what animals are fed
E7. What animals are fed is very important to me

Section F—Acceptability of HS-Fed Beef

Q11. How much do you agree with the following statements about buying beef from cattle fed hazelnut skins?
7-point Likert scale. Source: Escobedo del Bosque et al. (2021); Merlino et al. (2025). α = 0.83.
F1. I am interested in buying beef obtained from cattle fed hazelnut skins as part of the feed formula
F2. It is a good idea to buy beef from cattle fed hazelnut skins as part of the feed formula
F3. Buying beef from cattle fed hazelnut skins as part of the feed formula is important to me

Section G—Perceptions of HS-Fed Beef

Q12. Imagine that beef from cattle fed hazelnut skins is available in your local shop. To what extent do you agree with the following statements about this product?
7-point Likert scale: 1 = Strongly disagree → 7 = Strongly agree.

G1. Organoleptic traits (α = 0.71)
Source: Martins et al. (2022).
G1a. This beef is tasty
G1b. This beef is visually attractive
G1c. This beef is juicy
G1d. This beef has an unpleasant smell [reverse-scored]
G1e. This beef tastes similar to conventional beef I already know
G1f. This beef is pleasant overall
G1g. This beef looks good, smells good, and has an adequate texture

G2. Perceived health benefits (α = 0.83)
Source: Roininen et al. (1999); Verbeke et al. (2005).
G2a. This beef is nutritious
G2b. This beef is healthy
G2c. This beef has positive effects on my health
G2d. This beef is more natural than conventional beef
G2e. This beef is more nutritious (more vitamins, fibre, etc.) than conventional beef
G2f. This beef is healthier than conventional beef

G3. Perceived safety and health risks (α = 0.83)
Source: Verbeke et al. (2005); Antoniak et al. (2022). Note: Items G3a–G3c are risk items and should be reverse-scored in the composite health index.
G3a. Consuming this product makes me feel concerned about its safety [revised from original]
G3b. This beef poses a risk to human health [reverse-scored]
G3c. This beef is safe to eat
G3d. This beef does not contain harmful residues (toxins, drug residues, antibiotics, etc.)

G4. Economic sustainability (α = 0.67†)
Source: Lin-Schilstra & Fischer (2022). † See reliability note in Table M1.
G4a. This beef is expensive [reverse-scored]
G4b. This beef is cheaper than conventional beef

G5. Environmental sustainability (α = 0.71)
Source: Melios et al. (2025).
G5a. This beef has positive effects on the environment
G5b. This beef helps reduce the environmental impact of beef production
G5c. This beef helps reduce food waste

G6. Animal welfare perceptions (α = 0.77)
Source: Possidonio et al. (2021).
G6a. This beef contributes to a high level of animal welfare
G6b. Feeding hazelnut skins to cattle helps improve animal welfare
G6c. I think the use of hazelnut skins in feed is dangerous for animal health [reverse-scored]

Section H—Socio-demographic Characteristics

H1. Region of residence: ☐ North-East ☐ North-West ☐ Centre ☐ South and Islands

H2. Highest level of education: ☐ Primary ☐ Secondary ☐ Bachelor's ☐ Master's ☐ PhD ☐ None

H3. Employment status: ☐ Student ☐ Self-employed ☐ Private sector ☐ Public sector ☐ Retired ☐ Unemployed ☐ Other

H4. Marital status: ☐ Married ☐ Cohabiting ☐ Single ☐ Divorced ☐ Widowed

H5. Household size: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

H6. Number of children in household (0–16 years): ☐ None ☐ 1 ☐ 2 ☐ More than 2

H7. Monthly household income: ☐ < €1,000 ☐ €1,000–2,000 ☐ €2,001–4,000 ☐ €4,001–6,000 ☐ > €6,000 ☐ Prefer not to respond

Table S3. BIC values for automatic cluster number selection using the Two-step cluster analysis (SPSS v.29). The asterisk (*) indicates the number of clusters automatically selected by the algorithm based on the minimum BIC. The final solution adopted in the study (k = 5, highlighted in green) was selected based on BIC criterion combined with theoretical interpretability of the cluster profiles.

Number of Clusters (k)	BIC	BIC Change	Ratio of BIC Changes	Silhouette Measure of Cohesion and Separation
1	3184,686			
2	3228,229	43,543	1,000	1,276
3	3276,792	48,564	1,115	1,071
4	3308,595	31,803	,730	1,818
5	**3366,132**	**57,536**	**1,321**	**1,077**
6*	3424,330	58,198	1,337	1,219
7	3446,099	21,769	,500	1,207
8	3469,064	22,965	,527	1,215

* Number of clusters automatically suggested by SPSS Two-step algorithm based on minimum BIC. The k=5 solution (green) was adopted as the final solution based on theoretical interpretability. '—' = values to be filled in by authors from SPSS Two-step Model Viewer output. Note: AIC values are not produced by the SPSS Two-step algorithm and are therefore not reported.

S4. Socio-demographic characteristics of the five identified clusters.

	Cluster N.	% per cluster
Gender		
Women	1	37.36
	2	47.22
	3	53.13
	4	62.16
	5	50.00
Men	1	62.64
	2	52.78
	3	46.88
	4	37.84
	5	50.00
Age		
60–70	1	13.79
	2	21.3
	3	17.19

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	Cluster N.	% per cluster
	4	34.23
	5	11.25
45–59	1	30.46
	2	35.65
	3	36.72
	4	38.74
	5	34.38
31–44	1	29.31
	2	30.09
	3	31.25
	4	13.96
	5	21.88
18–30	1	26.44
	2	12.96
	3	14.84
	4	13.06
	5	32.5
Geographical area		
North-West	1	17.24
	2	20.83
	3	14.06
	4	16.22
	5	20.63
North-West	1	22.99
	2	29.17
	3	21.09
	4	27.93
	5	32.50
Centre	1	21.84
	2	23.61
	3	17.19
	4	16.22
	5	21.25
South and Islands	1	37.93
	2	26.39
	3	47.66
	4	39.64
	5	25.63