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Public acceptance of methane-reducing feed additives as a pathway to enhancing dairy farming sustainability

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ABSTRACT

This study aims to explore public acceptance of methane-reducing feed additives in the dairy sector and to examine how information influences public acceptance of these novel feeding strategies. The research focuses on European citizens' responses to 3 methane-mitigating feed additives: (1) algae or seaweed extracts, (2) plant-based oils or fats, and (3) a chemical feed additive, specifically the 3-nitrooxypropanol (3-NOP). A survey of 3,220 participants from 4 European Union member states (Finland, France, Poland, and Ireland) provides the data for this analysis. The results reveal significant differences in public acceptance, with natural additives receiving higher levels of support compared with chemical alternatives. Furthermore, the provision of additional information was found to negatively affect the acceptance of natural feed additives, whereas it improved support for the use of the chemical feed additive. Cluster analysis further revealed that these information effects were not uniform across the population. Negative reactions to additional information on algae or plant-based oils were concentrated among segments with strong animal-welfare concerns or high conscientious consumption preferences, whereas other groups showed little change. By contrast, for chemical additives, additional information increased acceptance across most attitudinal clusters. These findings suggest that public resistance to chemically derived additives such as 3-NOP may pose a barrier to their implementation. Information campaigns, if not carefully framed, could inadvertently reduce acceptance, highlighting the need for differentiated policy and communication strategies tailored both to the type of additive and to the specific consumer clusters most sensitive to information framing when promoting methane mitigation in the dairy sector.

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INTRODUCTION

Enteric fermentation in ruminants is a major contributor to GHG emissions from agriculture, particularly methane. Methane from dairy cattle accounts for around half of dairy-farm GHG emissions and corresponds to roughly 2% to 3% of total European Union (**EU**) GHG emissions (Ritchie, 2020; EEA, 2022). In the EU, agriculture accounts for about 11% of total GHG emissions; livestock-related sources (enteric fermentation and manure management) represent about two-thirds of agricultural emissions, implying that animal agriculture contributes roughly 7% of total EU GHG emissions (EEA, 2022).

Given the significant global demand for ruminant products such as meat and milk, reducing methane emissions is crucial. Various methods, such as adjusting ruminants' diets and feed production practices, breeding for low-emission animals, and the use of new feed additives, have been proposed to address the issue of methane emission reduction in dairy production (e.g., Hristov et al., 2022). For example, incorporating dietary fats, oils, or algae into dairy cows' rations has demonstrated effectiveness in reducing methane emissions in numerous studies (e.g., Kliem et al., 2019; De Bhowmick and Hayes, 2023). Furthermore, chemical additives such as 3-nitrooxypropanol (**3-NOP**), which was approved in the EU in 2022, offer additional options to curb methane release from dairy husbandry (e.g., Van Wesemael et al., 2019).

Agricultural innovations are critical for enhancing livestock productivity and environmental sustainability. Yet, their successful integration into practice is dependent on public support, driven by concerns over food safety, environmental impact, and animal welfare. Although bodies such as the European Food Safety Authority have established rigorous guidelines to assess the efficacy and safety of agricultural inputs such as feed additives (EFSA et al., 2018), research consistently underscores the neces-

The list of standard abbreviations for JDS is available at adsa.org/jds-abbreviations-26. Nonstandard abbreviations are available in the Notes.

sity of addressing public concerns and regulatory landscapes to leverage agricultural innovations effectively. The interplay between public perception and policy formulation is increasingly important in modern agriculture. Public opinions significantly influence policy direction, as seen in the evolution of the common agricultural policy (**CAP**) in the EU. The decline of public support for the CAP, noted in the Special Eurobarometer 440 (European Commission, 2016), indicates that misalignment with public expectations can erode trust and acceptance (Pe'er et al., 2017). Integrating public opinion into policymaking is crucial for ensuring relevant and effective policies.

At the same time, several countries have begun experimenting with policy approaches to reduce methane emissions from cattle. Within the EU, Denmark recently voted to introduce a carbon tax on agricultural production, including cattle, starting in 2030 (Wass, 2024), while simultaneously supporting producers through subsidies for a methane-reducing feed additive, 3-NOP (Carlsson, 2024). Other examples outside the EU include New Zealand's proposal to directly tax livestock emissions (Pannett, 2023) and Ireland's Department of Agriculture suggesting herd reduction measures to meet climate targets (Webber, 2023). These initiatives illustrate "stick" approaches relying on regulatory pressure, whereas other nations, such as Canada, have pursued "carrot" strategies by incentivizing emission reductions through carbon credit schemes (Government of Canada, 2023). Together, these developments reflect growing global momentum toward livestock methane mitigation and highlight the importance of social acceptance for the successful implementation of such measures.

Although consumers generally prefer food with natural additives, the acceptance of dairy products from cows fed with various methane-reducing additives remains unknown. However, recent public reactions to the introduction of methane-reducing feed additives in the United Kingdom have demonstrated a growing consumer interest in how livestock are fed and the environmental implications of these practices. Notably, controversy surrounding the rollout of such additives on UK dairy farms in 2025 (despite regulatory approval and scientific backing) revealed how quickly public concern can escalate and influence acceptance, or at least draw negative attention to the topic (Carrington, 2025). These developments highlight the growing visibility of feed innovations in public discourse and reinforce the need to better understand consumer attitudes toward various types of feed additives. Importantly, this public debate also underscores that the diffusion of "low-methane" innovations depends not only on consumer acceptance but also on farm-level uptake, which is shaped by how producers perceive these technologies.

Evidence from Finnish dairy farmers shows that although additives are generally considered safe, some farmers remain unconvinced of their effectiveness in reducing methane emissions, and their adoption is closely tied to profitability considerations (Sidhoum et al., 2025). This suggests that even when a technology is scientifically validated and approved, it may not be widely implemented unless it aligns with farmers' economic realities and is perceived as feasible in practice, conditions that ultimately determine whether consumers will encounter such products in the market. Even if farmers are willing to adopt such practices, their long-term viability will ultimately depend on acceptance at the consumer end of the supply chain. Public perception of methane-mitigating feed additives is expected to play a critical role in determining the adoption and long-term viability of these emerging technologies (Siegrist and Hartmann, 2020; Manning et al., 2025). As these innovations are relatively new, there remains a limited body of research examining consumer attitudes and preferences toward low-methane feed additives. To our knowledge, only 2 US-based studies have examined consumer preferences in this context. The first investigated willingness to pay for beef produced using 3 different methane-reducing additives (Davidson et al., 2025), and the second focused on public preferences and willingness to support policies aimed at reducing GHG emissions from beef production, particularly through strategies such as feed additives (e.g., seaweed; Luke and Tonsor, 2025). Though informative, these studies underscore the need for further research to better understand the social acceptability and potential market integration of such technologies. Although public awareness of climate change and livestock-related methane emissions is growing (Ilea, 2009), many citizens still lack a clear understanding of modern dairy farming practices, including emerging technologies such as low-methane feed additives (Boogaard et al., 2011). This knowledge gap presents a critical barrier to public acceptance of such innovations. Evidence suggests that information provision can play an important role in shaping consumer preferences, particularly when it enhances understanding or reframes the environmental and health-related implications (Caputo, 2020; Ploll et al., 2023). However, the effectiveness of such efforts depends heavily on how the message is framed and the audience's pre-existing beliefs (Ahn and Lusk, 2021). Against this background, the objective of our study is to contribute to the emerging literature in 2 ways: first, by examining European public perceptions of 3 low-methane feed additives—namely algae or seaweed extracts, plant-based oils or fats, and a chemical feed additive (3-NOP); and second, by analyzing the relationship between the provision of additional information and European citizens' willingness to accept methane-reducing feed additives for dairy cows.

MATERIALS AND METHODS

Survey Design and Data Collection Process

We conducted an online survey to collect data among citizens in 4 EU member states (Finland, France, Ireland, and Poland). Data collection took place in July 2023 by the market research company Taloustutkimus Ltd. through an online panel. The survey remained open until the pre-agreed target sample size was reached, and it lasted ~10 d. The provider operated under ICC/ESOMAR (2016) and ISO 20252 (ISO, 2019) standards and applied standard panel quality controls (e.g., restricting participation to registered panel members and preventing duplicate entries). The target population was adults aged 18 to 65 in each country. Quotas were applied to match the population distributions for gender, age, and region of residence. Recruitment relied on an opt-in online panel, so the sample is nonprobability, and representativeness was not enforced for other characteristics (e.g., education). The survey was available in French, Finnish, English, and Polish. A total of 3,220 respondents completed the survey. Before answering the survey, the respondents were required to provide an informed consent via an online form. In the survey invitation, the purpose of the survey and the data protection policy were clearly explained to the participants, and informed consent was required from each respondent before they began the survey. The full questionnaire is provided in the supplemental material, see Notes.

The survey was divided into 3 main parts. The first section aimed to evaluate the novel interventions, the second to assess associated attitudinal variables, and third to obtain basic socio-demographic information about the respondents. More specifically, in the first part, we asked participants to indicate their level of acceptance of 3 interventions using a 5-point Likert scale ranging from 1 to 5, with 1 indicating "strongly disagree" and 5 indicating "strongly agree." There was an option for respondents to answer "I do not know." All respondents were shown a brief description (2–3 sentences) of each intervention. All respondents evaluated all 3 interventions. To assess the relationship between providing additional information and public's perception, 50% of the sample in each country was randomly selected to receive additional information about the possible impact of the intervention on animals (animal health and welfare), products (the quality of milk and meat), and sustainability (environmental and economic effects). This additional information was provided as a single combined set (i.e., respondents received all 3 types of information, not only one). The remaining 50% received the baseline information only (control group). This 50/50 assignment was implemented independently of the 3 feed-additive interventions and was therefore balanced across them by design (~400/400 per country). The details of questions are presented in Figures 1–3.

In the second part of the survey, we asked participants questions regarding their perceptions and understanding of various aspects related to dairy production. This included their knowledge of farming systems, views on food safety, environmental considerations, animal welfare, cost considerations, and cultural views on dairy product consumption, among other general concerns associated with dairy production. These items were measured using 5-point scales: statements were rated on a 5-point agreement scale (strongly agree–strongly disagree), whereas concern items were rated on a 5-point concern scale (extremely concerned–not concerned at all). To summarize these attitudinal measures in a parsimonious way and to avoid including highly correlated statements in the subsequent analyses, we conducted a principal component analysis (**PCA**) on the 34 Likert scale attitudinal items. The PCA indicated 6 underlying dimensions: familiarity with farming practices, food safety, environmental awareness, animal welfare, cost-conscious preferences, and social norms. Following common practice, only items with factor loadings above 0.40 were retained for each dimension (refer to Supplemental Table S1 [see Notes]). Each dimension was then operationalized as a continuous index by summing the scores of the retained items, resulting in 6 aggregated attitudinal variables used in the regression models and the cluster analysis.

Finally, in the third part of the survey, we focused on participants' characteristics, such as gender, age, education, income levels, and consumption preferences.

Overall, the full questionnaire included 47 closed-ended items (1 consent item; 3 intervention acceptability items; 1 item rating the helpfulness of the information; 34 attitudinal items in Part B; and 8 socio-demographic items in Part C), plus optional open-ended follow-ups after each intervention. Based on pilot administration and the instrument length, the survey took ~10 to 12 min to complete on average. As an incentive for participation, respondents were not directly paid; instead, they received panel "points" for completing the survey, which could be redeemed (after accumulating enough points across surveys) for small vouchers or gift cards. The value of these rewards varied by country but was typically modest (generally less than €1 per completed survey). Data cleaning was minimal. All responses delivered by the provider were fully completed (n = 3,220), and we therefore retained the full sample for the analysis. No additional exclusions were applied beyond the provider's standard quality controls. The variables derived from these survey items and used in the empirical analysis are summarized in Table 1.

Group A

A1. After reading the information, to what extent do you agree that the following intervention is acceptable? Please select only one option.

Intervention 1	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	I don't know
Adding algae or seaweed extracts to the feed to reduce dairy cow methane emissions.						
Using Algae and seaweed extracts as feed additives to reduce dairy cow methane emissions can help to mitigate the environmental impact of dairy farming. By including certain feed additives to the cow's diet, it is possible to alter the microorganisms in the cow's gut and reduce the amount of methane produced.						

Group B

B2. After reading the information on impacts, to what extent do you agree that the following intervention is acceptable? Please select only one option.

Intervention 1	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	I don't know
Adding algae or seaweed extracts to the feed to reduce dairy cow methane emissions.						
Using Algae and seaweed extracts as feed additives to reduce dairy cow methane emissions can help to mitigate the environmental impact of dairy farming. By including certain feed additives to the cow's diet, it is possible to alter the microorganisms in the cow's gut and reduce the amount of methane produced.						

Criteria	Possible impacts
Animal health and welfare	No significant effect
The quality of milk and meat products	Residues in milk, but at minimal levels.
Environmental effect	Reduction of methane emissions by 30% to 50%
Effect on production	Feeding cost increase, No impact on labor costs. Difficult to impossible in pasture-based systems.
Cost of milk and dairy products for consumers	The rise in feed costs increases milk prices.

Figure 1. Comparison of information treatments provided to group A and group B in the survey for the algae/seaweed feed additive intervention.

Model Specification

The main goal of our analysis was to explore public acceptance of methane-reducing feed additives in the dairy sector and to examine how providing additional information to European citizens influences acceptance of these novel feeding strategies. Specifically, we focus on the following innovative feeding practices: (1) the use of natural feed additives (i.e., supplementing the feed with algae or seaweed extracts or plant-based oils or fats) to decrease methane emissions, and (2) the use of chemically synthesized feed additives (3-NOP) for the same purpose. The acceptance levels were evaluated in the survey through a 5-point Likert scale; we also report pairwise *t*-tests of mean differences in acceptance across additive types as descriptive evidence. Regression analysis was employed to control for covariates. The complete specification of estimated model is outlined below:

$$Y_i = \alpha_0 + \alpha_1 \mathrm{Info}_i + \beta \mathbf{X}_i + \varepsilon, \quad [1]$$

where Y_i denotes respondent i's acceptance of the feed-additive intervention. In our application, the intervention corresponds to one of the following additive types: (1) algae or seaweed extracts, (2) plant-based oils or fats, and (3) a chemical feed additive, specifically 3-NOP. Info_i is an indicator equal to 1 if the respondent received the additional information and 0 otherwise, and $\mathbf{X}_i$ is a vector of covariates. The main coefficient of interest is α_1, which captures the effect of receiving additional information on acceptance. The covariates comprised socio-demographic characteristics of the participants and their perceptions and preferences that might be associated with the decision to support the use of innovative feeding practices. These covariates were selected a priori to reflect key determinants of consumer acceptance and risk evaluation of novel agri-food technologies identified in the literature (Siegrist, 2008; Bearth and Siegrist, 2016; Laureati et al., 2024). In addition, we included country indicator variables to account for baseline differences across the 4 survey countries (Finland, Ireland, and Poland, with France as the reference category).

Group A

A2. After reading the information, to what extent do you agree that the following intervention is acceptable? Please select only one option.

Intervention 2	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	I don't know
Adding plant-based oils or fats to the feed to reduce dairy cow methane emissions						
Using plant-based oils and fats as feed additives to reduce dairy cow methane emissions can help to mitigate the environmental impact of dairy farming. By including certain feed additives to the cow's diet, it is possible to alter the microorganisms in the cow's gut and reduce the amount of methane produced.						

Group B

B2. After reading the information on impacts, to what extent do you agree that the following intervention is acceptable? Please select only one option.

Intervention 2	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	I don't know
Adding plant-based oils or fats to the feed to reduce dairy cow methane emissions						
Using plant-based oils and fats as feed additives to reduce dairy cow methane emissions can help to mitigate the environmental impact of dairy farming. By including certain feed additives to the cow's diet, it is possible to alter the microorganisms in the cow's gut and reduce the amount of methane produced.						
Criteria	**Possible impacts**					
Animal health and welfare	No known negative effects if fats and oils are less than 5% of cow's feed intake					
The quality of milk and meat products	May have small (positive) effects on human health					
Environmental effect	Reduction of methane emissions by 5% to 15%					
Effect on production	Feeding cost increase, May affect labor costs. Difficult to impossible in pasture-based systems.					
Cost of milk and dairy products for consumers	The rise in feed costs increases milk prices.					

Figure 2. Comparison of information treatments provided to group A and group B in the survey for plant-based oils/fats feed additive intervention.

We estimated the model in Equation [1] separately for each feed-additive type (algae/seaweed, plant-based oils/fats, and 3-NOP), using 2 specifications in each case: a baseline model without covariates and an adjusted model including the full set of covariates. This yields 6 regression models in total, reported in Table 2 (models 1–6).

Our primary findings were based on a linear probability model via ordinary least squares (**OLS**) regression. To ensure the robustness of our results, we further explored nonlinear probability models, including ordinal probit models. Following Angrist and Pischke (2009), the linear probability model was selected as our principal approach due to its advantages in the straightforward interpretation of the coefficients and the challenges presented by alternative models (see Breen et al., 2018). Additionally, we adjusted the SE to account for heteroscedasticity.

Robustness Checks for Validating Findings

A series of robustness checks to validate the stability of findings was conducted. We transformed the variables capturing the public's acceptance into binary variables to check for the robustness of our measurement approach. More specifically, we identified those individuals who had a highly positive view (rating 4 and 5 on a 5-point Likert scale) of the utilization of algae or seaweed extracts, plant-based oils or fats, or chemical feed additives in the diet of dairy cows. The binary variable is constructed as follows:

$$Y_i^* = \begin{cases} 1 \text{ if } Y_i \in \{4,5\} \\ 0 \ \text{ otherwise} \end{cases}. \quad [2]$$

This robustness check evaluates if the way we define our variables affects our main results while simultaneously simplifying their interpretation.

Second, to assess the robustness of our results to omitted variable bias, we applied the method proposed by Oster (2019), which quantifies the extent of selection on unobservables required to invalidate the observed effect of additional information on public acceptance. This approach examines how strongly unobservable factors would need to influence the outcome (relative to

Group A

A3. After reading the information, to what extent do you agree that the following intervention is acceptable? Please select only one option.

Intervention 3	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	I don't know
Adding chemical additives to reduce dairy cow methane emissions.						
Using chemical additives, such as 3-nitrooxypropanol, as feed additives to reduce dairy cow methane emissions can help to mitigate the environmental impact of dairy farming. By including certain feed additives to the cow's diet, it is possible to alter the microorganisms in the cow's gut and reduce the amount of methane produced.						

Group B

B3. After reading the information on impacts, to what extent do you agree that the following intervention is acceptable? Please select only one option.

Intervention 3	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	I don't know
Adding chemical additives to the feed to reduce dairy cow methane emissions.						
Using chemical additives, such as 3-nitrooxypropanol, as feed additives to reduce dairy cow methane emissions can help to mitigate the environmental impact of dairy farming. By including certain feed additives to the cow's diet, it is possible to alter the microorganisms in the cow's gut and reduce the amount of methane produced.						

Criteria	Possible impacts
Animal health and welfare	No impact known to date.
The quality of milk and meat products	No known risk. Research is currently being carried out to identify possible effects.
Environmental effect	Reduction of methane emissions by around 33%
Effect on production	Feeding cost increase. May affect labor costs. Difficult to impossible in grass-based systems.
Cost of milk and dairy products for consumers	The rise in feed costs increases milk prices.

Figure 3. Comparison of information treatments provided to group A and group B in the survey for plant-based oils/fats feed additive intervention.

observed covariates) to explain away our results. Specifically, we computed the bias-adjusted estimate using the following formula:

$$\hat{\delta} = \frac{\hat{\alpha}_1^{\text{full}} - \hat{\alpha}_1^{\text{restricted}}}{\mathrm{R}_{\max} - \mathrm{R}_{\text{full}}} \cdot \left(\mathrm{R}_{\text{full}} - \mathrm{R}_{\text{restricted}}\right), \qquad [3]$$

where $\hat{\alpha}_1^{\text{full}}$ and $\hat{\alpha}_1^{\text{restricted}}$ are the estimated coefficients from models with and without covariates, and R_{full}, $\mathrm{R}_{\text{restricted}}$, and $\mathrm{R}_{\max}$ are the respective R^2 values. We follow Oster's recommendation by setting $\mathrm{R}_{\max}$ to 1.3 times R_{full} (Oster, 2019). This 2-part procedure helped to evaluate both the relative strength of unobservables and the degree to which equal selection on observables and unobservables would alter our conclusions. A prepared explanation of the methodology is provided in Oster (2019), with practical implementation guidance available in Oster (2016).

Finally, to account for the ordinal nature of the dependent variable, we estimated an ordered probit model as a robustness check to complement the linear specification in Equation [1]. The model is defined as

$$P\left(Y_i = j\right) = \Phi\left(u_j - \mathbf{Z}_\mathbf{i}'\gamma\right) - \Phi\left(u_{j-1} - \mathbf{Z}_\mathbf{i}'\gamma\right), \qquad [4]$$

for j =1,2,3,4,5, where $\Phi(\cdot)$ is the standard normal cumulative distribution function, u_j are threshold parameters, $\mathbf{Z_i}$ is the covariate vector, and $\boldsymbol{\gamma}$ is the coefficient vector. We computed and report the corresponding marginal effects for comparison with the OLS estimates. The signs and significance levels were consistent across both approaches, confirming the robustness of our results.

Understanding heterogeneity in consumer acceptance is crucial for the industry, as uniform averages may obscure distinct subgroups with divergent attitudes and information responses. Segmentation approaches are well established in consumer research and provide a structured way to capture such preference heterogeneity, thereby offering insights relevant for targeted communication and

Table 1. Data overview and summary statistics of variables used in the analysis

Variable name	Unit	Description	Mean	SD
Acceptance of the use of algae or seaweed extracts	Scale 1–5	Stated acceptance of the utilization of the additive, rated from 1 (strongly disagree) to 5 (strongly agree).	3.10	1.57
Acceptance of the use of plant-based oils or fats	Scale 1–5	Stated acceptance of the utilization of the additive, rated from 1 (strongly disagree) to 5 (strongly agree).	2.98	1.56
Acceptance of the use of chemical feed additives	Scale 1–5	Stated acceptance of the utilization of the additive, rated from 1 (strongly disagree) to 5 (strongly agree).	2.18	1.41
Degree of information detail	Binary	Half of the participants were randomly selected to receive extra information on the intervention's potential impact on animals, product, and sustainability.	0.50	0.50
Age	Number of years	Participants' age in years.	41.65	13.08
Gender	Binary	The gender of each participant is coded as binary: 1 for male and 2 for female.	1.54	0.51
Education	Scale 1–5	Indicates the participant's level of education, ranging from 1 (less than primary education) to 5 (university education).	4.16	0.94
Income	Scale 1–8	Indicates the participant's annual income range, from 1 (€0–€10,000) to 8 (€150,001 or more).	3.54	1.71
Meat consumption	Binary	Indicates whether the participant consumes meat, with a dummy variable: 1 for yes and 0 for no.	0.89	0.31
Dairy consumption	Binary	Indicates whether the participant consumes dairy products, with a dummy variable: 1 for yes and 0 for no.	0.90	0.30
Residence area	Binary	Indicates the participant's living area with a binary variable: 1 for rural and 0 for urban.	0.25	0.43
Familiarity with farming	Aggregated score (3–15)[1]	Evaluates participants' knowledge and exposure to farming, understanding of microbiomes, and awareness of food production.	11.38	2.56
Food safety	Aggregated score (3–15)[1]	Measures participants' emphasis on food safety through label reading and expectations of producer responsibility.	12.55	1.93
Environmental awareness	Aggregated score (3–15)[1]	Assesses commitment to eco-friendly behaviors and sustainable practices.	15.17	3.04
Animal welfare	Aggregated score (3–15)[1]	Indicates concern for animal welfare, ethical purchasing, and support for animal rights organizations.	9.87	2.92
Conscientious consumption preferences	Aggregated score (4–20)[1]	Reflects a preference for ethical, organic, and high-quality food choices, even at higher costs.	13.81	3.63
Cultural view on dairy consumption	Aggregated score (3–15)[1]	Captures attitudes toward dairy's nutritional value, support for local dairy industries, and its cultural significance.	11.33	2.86

[1]Note: The attitudinal indices are summed scores of the retained Likert items (each item coded 1 = strongly disagree to 5 = strongly agree). The ranges shown in the Unit column are the theoretical minima and maxima of each summed index (minimum = number of items; maximum = 5 × number of items). Higher values indicate higher average responses on the 1–5 scale (i.e., lower agreement/stronger disagreement with the statements as coded).

market strategies (Wedel and Kamakura, 2000; Harwood and Drake, 2018).

To operationalize this, we applied k-means clustering on standardized attitudinal indicators (environmental awareness, animal welfare, familiarity with farming, food safety, conscientious consumption preferences, and cultural views on dairy consumption). K-means partitions individuals into clusters by minimizing the within-cluster sum of squared Euclidean distances and is particularly suitable for large survey datasets (Jain, 2010). The number of clusters was determined by examining the within-cluster sum of squares, which supported a 3-cluster solution as the most parsimonious and interpretable.

Cluster membership was then incorporated into regression models to test whether the effect of information differed across attitudinal groups. The empirical specification was

$$Y_i = \alpha_0 + \alpha_1 \mathrm{Info_i} + \sum_{c=2}^{C} \gamma_c D_{ic} + \sum_{c=2}^{C} \delta_c \left(\mathrm{Info_i} \times D_{ic}\right) + \varepsilon, [5]$$

where Y_i denotes acceptance of the feed additive for respondent i; $\mathrm{Info_i}$ indicates the information treatment; D_{ic} are cluster dummies (reference = cluster 1); α_1 is the baseline effect of information; γ_c captures mean differences across clusters; and δ_c measures whether information effects differ across clusters.

RESULTS

Public Acceptance of Feed Additives

Study participants were asked to assess the inclusion of 3 feed additives designed to reduce methane emissions, namely supplementing the feed with (1) algae or seaweed extracts; (2) plant-based oils or fats; or (3) chemical additives to reduce dairy cow methane emissions. Acceptance was measured on a 5-point scale (1 = strongly agree, 5 = strongly disagree), with an additional "I do not know" option. The responses of the whole sample to the different measures under study are presented in Figure 4. On average, the public's acceptance of incorporating algae or seaweed extracts (mean of index = 3.09, SD = 1.57) was significantly higher (*t*-test) than the acceptance of adding plant-based oils or fats (mean = 2.98, SD = 1.55). In addition, the value of the index measuring the public's acceptance of using chemical feed additives was significantly lower than that of both algae or seaweed extracts and plant-based oils or fats (mean = 2.17, SD = 1.41).

Impact of Information on Public Acceptance

Regression analysis was used to examine the relationship between providing additional information to European citizens and their willingness to accept novel livestock practices. Results are shown in Table 2. In models 1, 2, 4, and 5, which explored the public's acceptance of using algae or seaweed extracts and plant-based oils or fats in dairy cow feed, the degree of information detail was negatively and significantly associated with the acceptance. It appears from this that the public's acceptance of these innovative interventions tends to be more critical or circumspect the more detail there is available. However, when it comes to the use of chemically synthesized feed additives, Models 3 and 6 demonstrated a positive link between the level of information detail and public acceptance (coefficients: 0.139 and 0.125, significant at the 1% level). It is suggested that more specific information may help people acquire a more positive opinion of chemical feed additives. The consistency of the results between the models, with and without the covariates, emphasizes how robust the findings are. This consistency supports the study's findings, which show that the level of information detail has a considerable impact on public acceptance of interventions and is independent of other underlying factors.

The notion of exposing people to scientific information (e.g., novel feed additives or new technology) is associated with the accessibility of scientific knowledge on the topic and the comprehension of the individual (Allum et al., 2008). For example, research suggests that the reason people are reluctant to support sustainable and alternative practices is the lack of knowledge about the causes and effects of emissions (Drummond et al., 2018; Poortinga et al., 2019). Our results present a viewpoint challenging this hypothesis, indicating that the impact of information provision on public acceptance is influenced by the nature of the intervention, resulting in both negative and positive effects. It is worth noting that the manner in which information is presented, or "framed," can affect how individuals perceive it and their willingness to support new practices, programs, policies, or technologies (Dearing and Lapinski, 2020).

Table 2. Relationship between public's acceptance of innovative interventions to reduce methane emissions from dairy cow production and the provision of information[1]

Models for the public acceptance of use of additives in dairy cows' feed	Model 1 (the use of algae or seaweed extracts with no covariates)	Model 2 (the use of plant-based oils or fats with no covariates)	Model 3 (the use of chemical feed additives with no covariates)	Model 4 (the use of algae or seaweed extracts with covariates)	Model 5 (the use of plant-based oils or fats with covariates)	Model 6 (the use of chemical feed additives with covariates)
Degree of Information Detail (dummy) – effect of additional information	−0.320*** (0.043)	−0.240*** (0.044)	0.139*** (0.047)	−0.315*** (0.041)	−0.235*** (0.042)	0.125*** (0.045)
Covariates included in the model	Covariates are not included.	Covariates are not included.	Covariates are not included.	Covariates are included.	Covariates are included.	Covariates are included.
Number of observations	2,836	2,835	2,881	2,828	2,829	2,873

***Indicates statistical significance at the 1% level.

[1]Note: We present coefficient estimates (SE) from an OLS regression with heteroscedasticity robust SE.

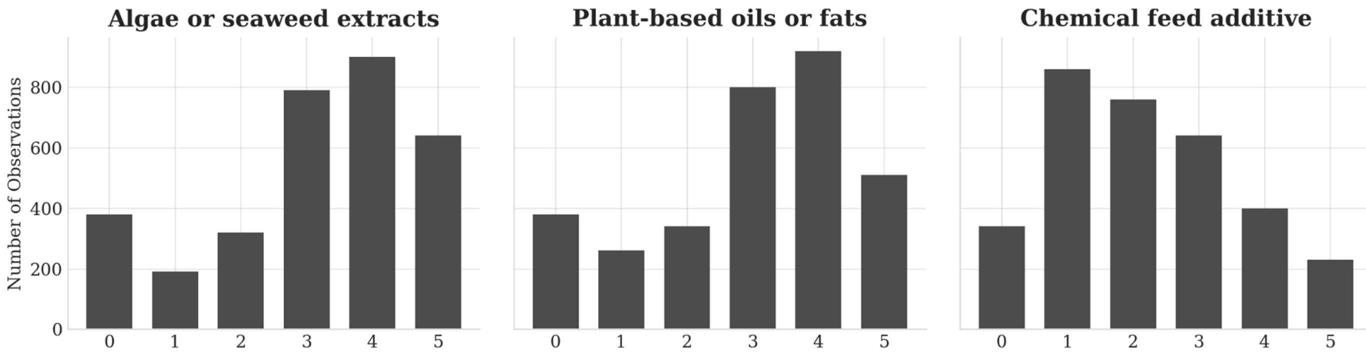

Figure 4. Public's acceptance of supplementing the feed with algae or seaweed extracts or plant-based oils or fats and chemical feed additives, measured using a 5-point Likert scale, ranging from 1 for strongly disagree to 5 for strongly agree, and 0 denoting "I do not know."

Additional Drivers of Public Acceptance

Turning now to the results of the association between the covariates that could potentially be correlated with the public acceptance (Table 3), our findings indicated that familiarity with the farming system positively influences the acceptance of all 3 interventions. Although concerns about food safety negatively influence the public's acceptance of all 3 interventions, the use of chemical feed additives is the most adversely affected. Unsurprisingly, environmental awareness positively affects the acceptance of algae/seaweed extracts and plant-based oils/fats. However, the association is not significant for chemical feed additives. One might speculate that using chemical feed additives may introduce complexity and uncertainty into respondents' decision-making. Chemical feed additives, even if intended to reduce methane emissions, could trigger concerns about potential risks to animal health, humans, and ecosystem integrity.

In our analysis, we also account for socio-demographic characteristics. We found that age and gender show a significant correlation with the public's acceptance (although the association with age is not significant for the algae/seaweed additive). Although previous studies suggested a positive association between females and support for environmentally friendly practices (Hunter et al., 2004; Glass et al., 2016), our results show that women generally have a more negative perception of these interventions. Additionally, older respondents, who may lean toward more traditional or conservative viewpoints, are linked with a negative perception of these environmental strategies. Country indicators suggest meaningful cross-country heterogeneity in acceptance, even after adjusting for covariates. Relative to France, acceptance is higher in Ireland and Poland across all 3 interventions, while Finland differs from France primarily for plant-based oils/fats and chemical additives, but not for algae/seaweed extracts (Table 3).

Robustness Checks

The estimated information effect differs in sign across feed additive types. We therefore conduct robustness checks to ensure that this pattern is not driven by modeling choices and that the main findings remain consistent across alternative model specifications and outcome definitions. Specifically, we perform a series of robustness checks to validate the reliability of our results. First, we transform variables related to the acceptance into binary form. We categorize individuals who rate the use of algae or seaweed extracts, plant-based oils or fats, and chemical feed additives in dairy cow diets as highly favorable (rating 4 or 5 on a 5-point scale). These groups represent 48%, 45%, and 19% of the total sample, respectively. Using these binary variables instead of the 5-point Likert scale responses does not alter our findings. Our results remain robust, meaning that the provision of additional information is strongly associated with a lower acceptance of the use of algae or seaweed extracts and plant-based oils or fats, while this extra information is positively linked to the public acceptance of chemical additives (see Table 4 for details).

Second, we examined the possibility of selection bias influencing our findings by evaluating the extent to which unobserved factors would need to alter our results (Oster, 2019). Our analysis indicates that the established relationships are robust. Specifically, for the relationships to be negated, unobserved variables not included in our comprehensive regression model would need to have a significantly greater impact than the observed variables we did include. To quantify this, we looked at how much more influential unobserved variables would need to be compared with observed ones to invalidate our primary findings (measured by the delta coefficient). Our findings suggest that unobserved factors would need to be disproportionately influential (by factors of 40.77, 55.37, and 30.68) to nullify the observed effects

Table 3. Results of regression analysis for the acceptance of the 3 interventions, including the covariates[1]

Item	The use of algae or seaweed extracts	The use of plant-based oils or fat	The use of chemical feed additives
Degree of information detail	−0.315***	−0.235***	0.125***
	(0.041)	(0.042)	(0.045)
Familiarity with farming	0.043***	0.023**	0.032***
	(0.011)	(0.011)	(0.011)
Food safety	−0.033**	−0.031**	−0.121***
	(0.015)	(0.015)	(0.015)
Environmental awareness	0.048***	0.059***	0.017
	(0.012)	(0.012)	(0.011)
Animal welfare	0.024*	0.011	0.058***
	(0.012)	(0.012)	(0.013)
Conscientious consumption preferences	0.027***	0.032***	0.012
	(0.010)	(0.010)	(0.010)
Cultural view on dairy consumption	−0.021**	0.002	0.002
	(0.009)	(0.009)	(0.010)
Age	−0.002	−0.006***	−0.013***
	(0.002)	(0.002)	(0.002)
Gender	−0.127***	−0.130***	−0.279***
	(0.042)	(0.043)	(0.046)
Education	0.006	−0.018	−0.009
	(0.023)	(0.023)	(0.026)
Income	0.007	0.009	−0.004
	(0.013)	(0.014)	(0.016)
Meat consumption	0.065	0.034	0.126
	(0.076)	(0.077)	(0.087)
Dairy consumption	−0.014	−0.114	−0.208**
	(0.079)	(0.079)	(0.089)
Residence area	−0.087*	0.024	−0.172***
	(0.047)	(0.048)	(0.052)
Finland	0.044	0.320***	0.163**
	(0.068)	(0.069)	(0.068)
Ireland	0.417***	0.434***	0.305***
	(0.060)	(0.063)	(0.066)
Poland	0.170***	0.325***	0.179***
	(0.059)	(0.061)	(0.064)
Intercept	2.409***	2.303***	3.214***
	(0.209)	(0.218)	(0.225)
Number of observations	2,828	2,829	2,873

[1]Note: We present coefficient estimates (SE) from an OLS regression with heteroscedasticity robust SE.

*, **, ***Indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

of public acceptance on the use of algae or seaweed extracts, plant-based oils or fats, and chemical additives, respectively (refer to Table 2). Additionally, we assessed how our main findings (outlined in Table 2) might shift if the influence of unobserved factors equaled that of observed ones (measured by the beta coefficient). This scenario indicated that even if unobserved factors were as influential as observed ones, the impact on our initial findings would be minimal, with a maximum change of only 0.004. For more detailed information, please refer to Table 5.

Finally, we opted for an ordinal probit model over a linear one to analyze the models presented in analysis. Results are shown in Table 6. We found that the direction and statistical significance of the results align perfectly with those from the OLS regression previously discussed. Moreover, the magnitude of the marginal effects derived from the probit model is very similar to those from the OLS regression.

Heterogeneity in Information Effects Across Consumer Clusters

To examine whether information shaped acceptance differently across attitudinal profiles, we incorporated cluster membership into the regression models. Figures 5, 6, and 7 illustrate the treatment effects by cluster across 6 attitudinal dimensions. For each attitudinal dimension, respondents were segmented into 3 groups using k-means clustering (k = 3) based on the corresponding standardized index. Cluster numbers (1–3) are labels only; clusters are interpreted using their mean index levels (e.g., low/intermediate/high), and we refer to them in the results using these descriptive terms.

Table 4. Robustness check 1: Transformation of the variables capturing public acceptance into binary variables[1]

Item	Model 1 (Acceptance of the use of algae or seaweed extracts in dairy cows' feed with no covariates)	Model 2 (Acceptance of the use of plant-based oils or fats in dairy cows with no covariates)	Model 3 (Acceptance of the use of chemical feed additives in dairy cows' feed with no covariates)	Model 4 (Acceptance of the use of algae or seaweed extracts in dairy cows' feed with covariates)	Model 5 (Acceptance of the use of plant-based oils or fats in dairy cows with covariates)	Model 6 (Acceptance of the use of chemical feed additives in dairy cows' feed with covariates)
Degree of information detail (dummy variable)	−0.141*** (0.018)	−0.113*** (0.020)	0.054*** (0.019)	−0.136*** (0.018)	−0.111*** (0.019)	0.047*** (0.018)
Covariates included in the model	Covariates are not included.	Covariates are not included.	Covariates are not included.	Covariates are included.	Covariates are included.	Covariates are included.
Number of observations	2,050	2,033	2,243	2,042	2,028	2,236

[1]Note: We present coefficient estimates (SE) from an OLS regression with heteroscedasticity robust SE. Variables capturing public acceptance were transformed into binary indicators, where a value of 1 denotes respondents with a highly positive view (ratings 4–5 on a 5-point Likert scale).

***Indicates statistical significance at the 1% level.

For algae or seaweed additives (Figure 5), information provision produced heterogeneous effects across clusters. Among respondents characterized by high concern for animal welfare (cluster 3), information significantly reduced acceptance (dashed lines). A similar negative effect of information was observed for cluster 2 respondents regarding the familiarity with farming dimension, as well as for cluster 2 in the cultural views on dairy consumption dimension. Moreover, the conscientious consumption preferences captured participants' willingness to prioritize ethical and high-quality food choices even at higher cost. For individuals with higher levels of this orientation (clusters 2 and 3), additional information significantly decreased the acceptance of using algae or seaweed. By contrast, for individuals with low levels of conscientious consumption (cluster 1), the provision of information significantly increased acceptance. This represents the only case in which information had a positive and significant effect on the acceptance of algae or seaweed additives. For the other dimensions, the effects of information were not significant.

For plant-based oils or fats (Figure 6), the patterns were quite similar to those observed for algae or seaweed additives. However, the effects of information provision were not significant across clusters, indicating that the acceptance of plant-based oils or fats is cluster-independent. The negative effect observed in the nonclustered model may therefore be a composition effect, where differences between the groups aggregate into a potentially misleading overall association (Vetőné Mózner, 2014).

For chemical feed additives (Figure 7), the provision of information significantly increased their acceptance across most attitudinal clusters. Respondents with higher environmental awareness, stronger animal-welfare concerns, greater familiarity with farming, and higher conscientious consumption preferences all showed significant positive acceptance for chemical feed additives when exposed to additional information. A similar positive effect was observed among individuals with stronger food-safety concerns, although this was not significant for clusters 2 and 3. For cultural views on dairy consumption, information also tended to increase acceptance, but the effect was not significant for cluster 3. In summary, unlike in the case of algae/seaweed or plant-based oils, the provision of more detailed information about chemical additives increased their acceptance, with only a few exceptions across specific clusters.

DISCUSSION

We studied the public's response to innovative feeding strategies aimed at lowering dairy cow methane emissions in 4 European countries. The results revealed a contrast in the acceptance levels between natural and

Table 5. Robustness check 2: Selection on observables and unobservables using Oster (2019)'s bounds[1]

Models for the acceptance of additives in dairy cows' feed	Algae or seaweed extracts		Plant-based oils or fats		Chemical feed additives	
	δ (β* = 0)	β* (δ = 1)	δ (β* = 0)	β* (δ = 1)	δ (β* = 0)	β* (δ = 1)
Beta	0	−0.311	0	−0.232	0	0.121
Delta	40.768	1	55.373	1	30.681	1
R^2 max	0.133	0.133	0.120	0.120	0.126	0.126

[1]Note: Following Oster (2019), we select the maximum R^2 (R^2 max) to be 1.3 times the R^2 value obtained from the regression that includes covariates.

chemical feed additives, with the public showing greater reluctance toward the latter. Furthermore, we found that offering more detailed information to participants during the evaluation of practices involving algae or seaweed extracts and plant-based oils or fats significantly reduced their acceptance. By contrast, when participants were provided with more details regarding the use of chemical feed additive that aims to lower enteric methane emissions, their acceptance of it increased. Cluster analysis confirmed these asymmetries: negative effects of additional information were concentrated among groups with strong animal-welfare concerns or high conscientious consumption preferences, although additional information generally boosted the acceptance of chemical additives across most attitudinal clusters.

The observed negative relationship between disseminating extra information and the public's view of utilizing algae or seaweed extracts and plant-based oils or fats in dairy cow diets appears to contradict the "information deficit approach." This approach suggests that enhancing public understanding of agricultural practices should lead to greater acceptance of innovative methods (Bidwell, 2016; Simis et al., 2016). Nevertheless, research on risk–benefit communication indicates that information effects depend strongly on the "nature and framing" of what is communicated (e.g., terminology, emphasis, order, and whether risks or uncertainties are made salient), and additional information can sometimes increase perceived risks or trigger new concerns rather than increase acceptance (Frewer et al., 2016; Fischer and Reinders, 2022). Although both interventions aim at reducing methane emissions and have potential benefits, the negative association with public perception might stem from concerns about product quality, safety (residues in milk), practicality and scalability of implementation (especially in pasture-based systems), increased production costs (feeding and possibly labor), and the direct impact on consumer prices. In other words, extra information may have shifted attention from the climate benefit toward trade-offs and implementation constraints, thereby increasing perceived risks and reducing perceived net benefits. These factors might outweigh the environmental benefits in the public's perception, leading to a less favorable view of these interventions. Our cluster analysis showed that this effect was not uniform: the negative response concentrated in segments with strong animal-welfare concerns and high conscientious consumption, whereas other segments changed little. For plant-based oils or fats, within-cluster effects tended to be marginal; the pooled negative association between acceptance and information likely reflects a composition effect, where group differences aggregate into a potentially misleading overall association.

Although some consumers express reservations about these interventions, their implementation at the farm level remains essential for reducing emissions. Therefore, policy mechanisms or market-based incentives could play a crucial role in promoting adoption despite limited public enthusiasm. Such incentives primarily address financial and risk-related barriers faced by farmers, rather than public perceptions directly. Some dairy companies have already introduced climate initiatives that offer point-based supplements to the milk price (Arla, 2023). These can help to mitigate the elevated expenses associated with feed additives, thereby enhancing the economic viability of the interventions. The EU has established rules for the authorization, marketing, and labeling of feed additives under Regulation 1831/2003 (European Union, 2003). Furthermore, scientific opinions on safety and efficiency, such as those for 3-nitrooxypropanol (EFSA et al., 2021), are issued before the authorization. Such measures will ensure that any residual substances in milk or meat products remain within safe thresholds, addressing public worries about the safety and quality of the products. Our results suggest that these mechanisms are particularly relevant for chemical additives, because additional information increased acceptance when safety and regulatory oversight were emphasized. In contrast, for algae and plant-based oils, where information tended to reduce acceptance, reassurance on product quality and price stability may be more effective than technical detail. This pattern indicates that standard information provision may not fully address, and may even activate, underlying consumer concerns. In such cases, complementary approaches such as qualitative research (e.g., focus groups) can help identify the specific sources of

Table 6. Robustness check 3: Probit estimates and marginal effects on association between public's acceptance of innovative interventions to reduce dairy cow methane emissions and the provision of information

Models for the acceptance of the use of additives in dairy cows' feed	Model 1 (algae or seaweed extracts with no covariates)	Model 2 (plant-based oils or fats with no covariates)	Model 3 (chemical feed additives with no covariates)	Model 4 (algae or seaweed extracts with covariates)	Model 5 (plant-based oils or fats with covariates)	Model 6 (chemical feed additive covariates)
Degree of information detail (dummy variable)	−0.293*** (0.040)	−0.211*** (0.039)	0.115*** (0.040)	−0.303*** (0.040)	−0.218*** (0.040)	0.107*** (0.040)
Covariates included in the model	Covariates are not included.	Covariates are not included.	Covariates are not included.	Covariates are included.	Covariates are included.	Covariates are included.
Number of observations	2,836	2,835	2,881	2,828	2,829	2,873

***Indicates statistical significance at the 1% level.

concern and uncertainty that shape public responses, thereby informing more targeted communication strategies. Building on these insights, communication efforts should explicitly acknowledge the concerns that the public has regarding the quality and price of dairy products. This can be accomplished by providing clear, factual information about the steps taken to address these problems, such as through quality assurance initiatives and subsidy programs.

Despite initial skepticism, public acceptance of chemically synthetized feed additives for reducing enteric methane emissions improved with the provision of additional, evidence-based information. As chemical substances can raise concerns, this result could be related to that respondents initially had negative perceptions about this intervention, and receiving more comprehensive information may have helped them to recognize the potential environmental benefits of reducing emissions, thus justifying the use of chemical feed additives. This emphasizes the importance of conveying messages to citizens in an understandable, consistent, and evidence-based manner. This finding holds significant implications for policy and industry sectors. Developing educational programs that present clear, precise, and extensive information about the advantages (notably the positive environmental impact of reducing methane emissions) and the safety of chemical feed additives is essential for positively shifting public perception. Additionally, proactively addressing and dispelling public doubts and misconceptions about chemical additives is fundamental in streamlining this process. At the same time, the cluster analysis shows that communication strategies cannot be designed as one-size-fits-all interventions. For natural additives such as algae and plant-based oils, negative reactions to additional information were concentrated in groups with strong ethical or welfare orientations, whereas other segments showed little change. This indicates that targeted framing (emphasizing naturalness, co-benefits for animal welfare, or cultural compatibility) may be more effective than technical explanations. For chemical additives, by contrast, the consistently positive impact of additional information across most clusters suggests that science-based communication is effective. Industry actors and policymakers should therefore consider differentiated outreach: technical assurance and regulatory transparency for chemical additives and communication strategies for natural additives that align with consumer values such as environmental stewardship and product naturalness.

A key limitation of this study is that participants' responses may be sensitive to how the informational materials are framed; therefore, future research should investigate the effectiveness of different communication strategies in enhancing public understanding and acceptance

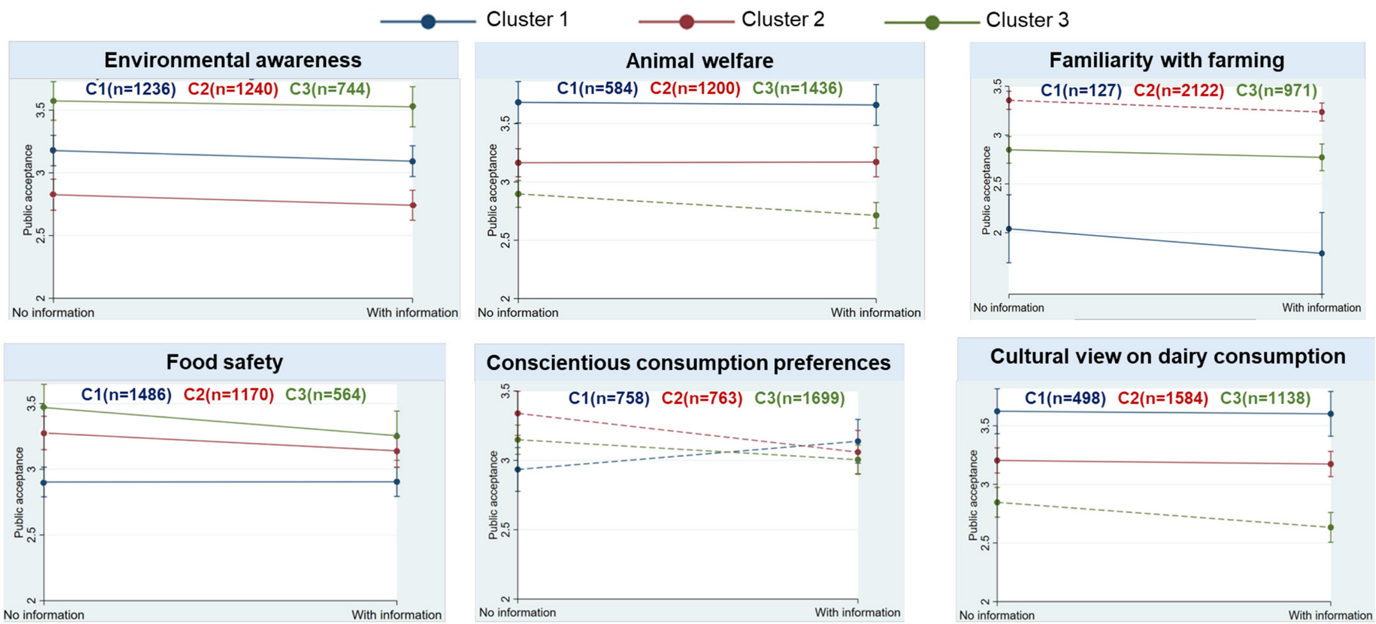

Figure 5. Effect of additional information on the acceptance of algae- or seaweed-based feed additives across attitude-based consumer clusters. Public acceptance is plotted by information treatment ("no information" vs. "with information") for 6 attitudinal dimensions examined in the study. Within each panel, clusters (C1–C3) represent groups with different levels of the corresponding attitudinal dimension (higher line = higher level of the attitudinal dimension). Dashed lines indicate a significant effect of information ($P < 0.10$), and solid lines indicate a nonsignificant effect. Error bars represent 95% CI.

of sustainable alternatives. This could involve comparing the impact of various formats (e.g., digital media, brochures, interactive sessions) and messaging approaches. In addition, it is important to examine how framing, such as emphasizing naturalness and provenance, regulatory assurance and safety, cobenefits (e.g., animal welfare and

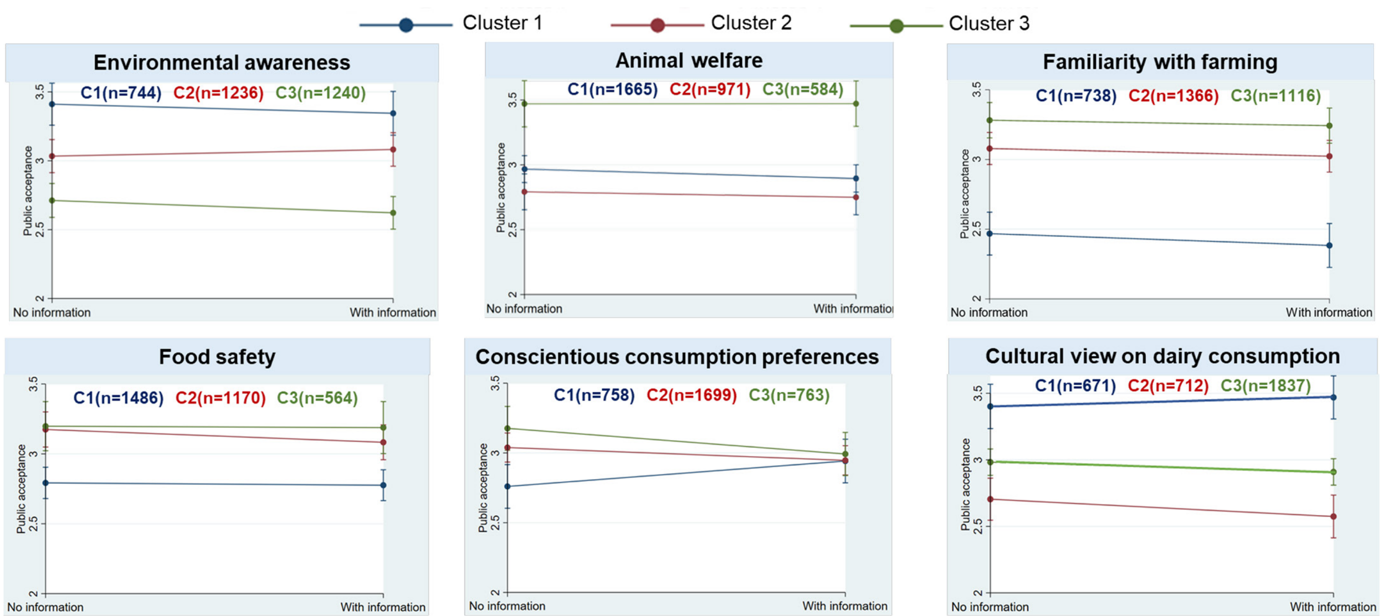

Figure 6. Effect of additional information on the acceptance of plant-based oils or fats feed additives across attitude-based consumer clusters. Public acceptance is plotted by information treatment ("no information" vs. "with information") for 6 attitudinal dimensions examined in the study. Within each panel, clusters (C1–C3) represent groups with different levels of the corresponding attitudinal dimension (higher line = higher level of the attitudinal dimension). Solid lines indicate a nonsignificant effect. Error bars represent 95% CI.

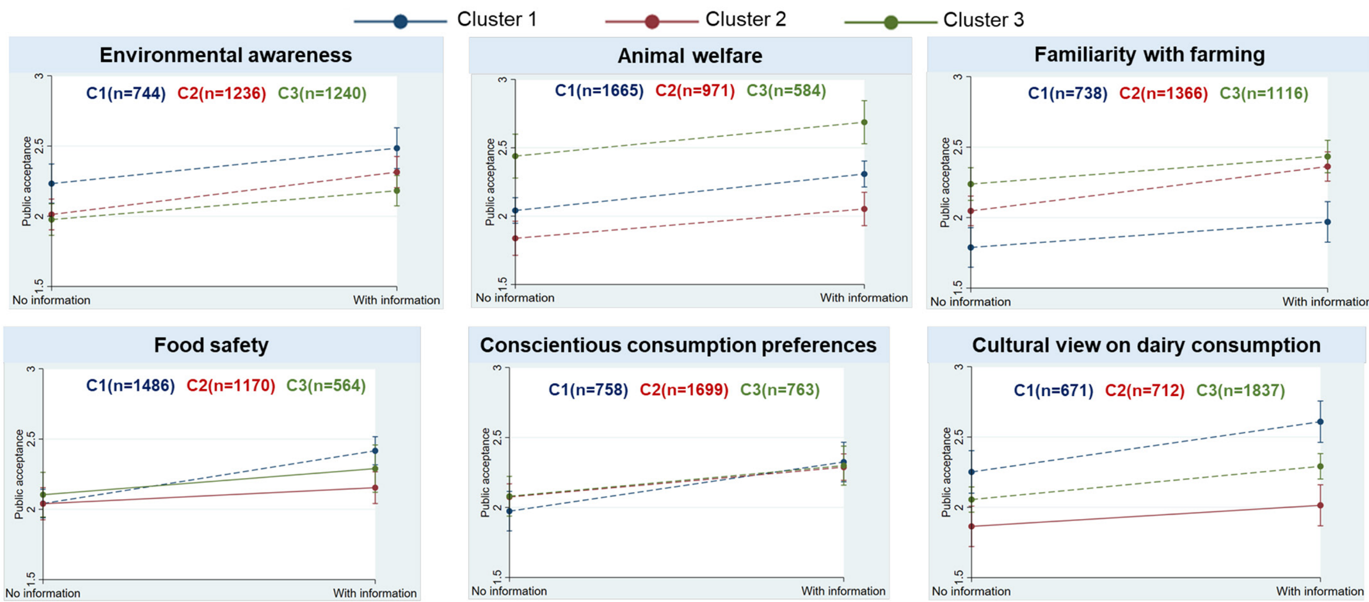

Figure 7. Effect of additional information on the acceptance of chemical feed additives across attitude-based consumer clusters. Public acceptance is plotted by information treatment ("no information" vs. "with information") for 6 attitudinal dimensions examined in the study. Within each panel, clusters (C1–C3) represent groups with different levels of the corresponding attitudinal dimension (higher line = higher level of the attitudinal dimension). Dashed lines indicate a significant effect of information ($P < 0.10$), and solid lines indicate a nonsignificant effect. Error bars represent 95% CI.

biodiversity), or economic practicality, affects acceptance across consumer groups. Because informational materials may inadvertently contain asymmetries in valence (for example, highlighting potential human health benefits while also emphasizing potential drawbacks such as higher milk prices due to feed costs), observed differences in acceptance may partly reflect reactions to wording and emphasis rather than underlying attitudes. Testing alternative frames can help to identify which narratives resonate with specific attitudinal clusters and which risk triggering resistance and to disentangle framing effects from "true" preference differences by systematically varying the balance, tone, and salience of risk–benefit information. Future work should also move beyond stated perceptions and acceptance to behavioral outcomes, for example, by using discrete choice experiments or willingness-to-pay studies for milk or meat produced using methane-reducing feed additives. Moreover, it may be necessary to extend the analysis presented here to include social-psychological factors that influence public acceptance of innovative agricultural practices. This could help in identifying underlying beliefs or misconceptions that influence acceptance levels and inform targeted educational interventions. Finally, further research could consider how information diffusion and amplification in online and social media environments may shape attitudes, including the potential for rapid spread of misleading or polarizing narratives around feed additives.

CONCLUSIONS

Public acceptance of methane-reducing feed additives depends on both the additive type and how information is presented. Additional information increased support for chemical additives such as 3-NOP but reduced acceptance of natural additives such as algae and plant-based oils, especially among consumers with strong ethical or welfare concerns. These results show that communication and policy strategies must be differentiated: transparent, science-based messages for chemical additives and reassurance about quality, price, and naturalness for natural additives. Tailoring these approaches can improve both public trust and the practical adoption of methane-mitigation measures in the dairy sector.

NOTES

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fully anonymized, and the research team had no access to any personal identifiers. According to the guidelines of the Finnish National Board on Research Integrity (TENK, 2019), ethical review by an ethics committee was not required for this study, as the research design did not involve elements necessitating such review (e.g., intervention in the physical integrity of participants, exposure to exceptional stimuli, or risk of harm). This assessment is consistent with the Ethics Committee for Human Sciences at the University of Turku (2023). The authors have not stated any conflicts of interest.

Nonstandard abbreviations used: 3-NOP = 3-nitrooxypropanol; CAP = common agricultural policy; EU = European Union; OLS = ordinary least squares; PCA = principal component analysis.

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