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Perceived naturalness predicts public support for sustainable protein technology

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Abstract
The widespread demand for animal-sourced foods poses challenges in addressing climate change due to their significant greenhouse gas emissions. Alternative proteins like cultured meat show promise with lower greenhouse gas emissions, but have faced public resistance, posing substantial barriers to their broad development and adoption. This paper reports a survey that examined the perceived naturalness of protein sources as an important factor that predicts perceived risks, benefits, and support for consumption. A diverse sample from the United States considered six different protein technologies, including three newer alternative proteins such as cultured meat and three more conventional proteins. Newer alternative proteins were perceived as less natural and were less supported than conventional proteins. Additionally, the more participants perceived protein sources as natural, the less risky and more beneficial they perceived them to be, contributing to their support. These results suggest that perceived naturalness, and associated risks and benefits, could be an important factor in shaping public support for or opposition to new proteins. These findings have theoretical and broader implications for the development and adoption of sustainability technologies.

Keywords Alternative proteins · Climate change solutions · Naturalness · Risk perception · Sustainability technology

1 Introduction

Current and changing patterns of food consumption pose major sustainability challenges. Recent dietary trends towards processed and animal-sourced foods reflect improved standards of living, but also lead to environmental degradation and diet-related diseases (Ambikapathi et al. 2022; Clark et al. 2018; Clark et al. 2022; Maxwell et al. 2016; Tubiello et al.

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2022; Whitton et al. 2021). Ensuring healthy and sustainable diets for a growing population requires technological development, public support, and consumer behavior change (Myers et al. 2017; Willett et al. 2019). Widespread transition away from traditional meat-based diets could mitigate the negative environmental impacts of current food production practices (Searchinger et al. 2019; Willett et al. 2019; WWF 2020). There are, however, major barriers to such a transition: Animal-sourced foods are nutritionally rich, economically important, and culturally significant (Agarwal et al. 2015; Banda and Tanganyika 2021; Chiles and Fitzgerald 2018; Dabasso et al. 2022; Sievert et al. 2021). Consumers may lack motivation to change consumption behavior, and may have limited awareness of the environmental impacts of animal-sourced foods (Kwasny et al. 2022; Happer and Wellesley 2019; Perez-Cueto et al. 2022). Enacting policies that effectively promote sustainability is unlikely without broad public support as part of a broader social-economic-political system and associated climate policies (Burgess et al. 2024; Sherman and Van Boven 2023).

Alternative protein products ("alt-proteins") present market-driven alternatives to reduce consumption of animal-sourced foods (Green et al. 2022). Alt-proteins are substitutes that mimic the taste and texture of animal products, often with reduced environmental impacts (Poore and Nemecek 2018), especially compared with traditional beef products (Hadi and Brightwell 2021; Poore and Nemecek 2018; Santo et al. 2020). Beyond ® and Impossible ® burgers, for example, might appeal to people interested in reducing the consumption of animal-sourced foods with similar sensory experiences as conventional meat products. Alt-proteins are thus an important sustainability technology to reduce environmental impact of animal-based foods, yet alt-proteins are unlikely to be widely adopted at scale to without broad public support.

This study examines the psychological factors that predict public support for or opposition to a broad range of protein technologies. These include conventional plant-based veggie burgers, grain-fed, and grass-fed beef burgers, as well as newer, less familiar alt-protein technologies of plant-based protein burgers, plant-based burgers that contain proteins produced through fermentation of genetically engineered yeast, and cultured beef burgers produced through animal cell culture techniques. We hypothesize that newer alt-protein technologies will enjoy relatively low public support, in large part because people perceive them as less natural and therefore riskier and less beneficial. We tested these hypotheses in a survey with a broad sample of respondents in the United States (US).

1.1 Naturalness, familiarity, and support

The psychological construct of naturalness reflects people's construal of objects as close to their originally occurring form (Rozin 2004; Rozin 2005; Rozin et al. 2012; Scott et al. 2018; Scott and Rozin 2020). Natural objects are seen to exist independent of human intervention or influence (Rozin 2005). Mountains, rivers, and trees are natural, for example, because they exist without human intervention. Landscapes predominated by plants, water, and rocks are construed as more natural than landscapes predominated by concrete, glass, and metal. For food products, the absence of additives and extensive processing is a key attribute of naturalness (Brunner et al. 2010; Hemmerling et al. 2016; Pula et al. 2014). People perceive foods as more natural when they are free from preservatives (Tobler et al. 2011), additives (Brunner et al. 2010), absent of artificial ingredients (Hemmerling et al. 2016; Lockie et al. 2002; Pula et al. 2014), grown locally (Hemmerling et al. 2016), or grown organically (Roininen and Tuorila 1999).

Naturalness is culturally constructed (Rozin et al. 2012; Nawaz and Satterfield 2022; Siipi 2008). Familiarity may be an important factor that defines naturalness. The philosopher Siipi (2008) writes, "People tend to consider those entities to which they are accustomed to be natural, with which they are familiar, and which occur relatively frequently. On the other hand, 'unnatural' often means 'uncustomary,' 'odd,' and that the entity is not what we are accustomed to" (Siipi 2008, p. 93). The familiarity component may explain why people perceive that extensive human intervention undermines naturalness. For example, chemical reactions in the atmosphere that produce a novel type of natural gas were seen as more natural when the reaction was attributed to a change in the sun's activity, compared to when it was due to the development of a new cordless transmission procedure to produce more TV channels for human consumption (Böhm and Pfister 2000; 2005). We therefore hypothesized that people would perceive newer, less familiar proteins as less natural compared with more conventional, familiar proteins.

People generally regard natural objects as benevolent, desirable, and even morally good, displaying a "naturalness bias" (Corner and Pidgeon 2015; Klebl et al. 2022; Lacroix et al. 2021; Li and Cao 2022a, b; Meier et al. 2019; Rozin et al. 2004; Scott and Rozin 2020). People perceive natural foods as healthy (Honkanen and Olsen 2009), fresh and tasty (Hemmerling et al. 2016), environmentally friendly (Olbrich et al. 2015), and beneficial (Li and Chapman 2012). People perceive genetically modified foods, in contrast, as unnatural and less beneficial, and people support them less than non-modified foods (Scott et al. 2018). Perceived naturalness significantly influences food purchasing and consumption (Román et al. 2017).

People may thus be less inclined to support alt-proteins they construe as unnatural compared with those they construe as natural (Onwezen et al. 2021; Román et al. 2017). Public support for plant-based alt-proteins is greater than products created using cell culture (Onwezen et al. 2021; Siegrist et al. 2018). Alt-proteins framed as natural are likely to enjoy public acceptance compared with proteins framed as unnatural (Etale and Siegrist 2021; Siegrist and Hartmann 2020a, b). For example, more technical cultured meat product descriptions have been found to decrease consumer acceptance compared with other types of product framing (Bryant and Dillard 2019; Siegrist et al. 2018). We therefore hypothesized that people would support proteins more when they construed them as relatively more natural.

1.2 Risk, benefit, and familiarity

One reason people may support proteins they construe as natural is that more natural proteins are perceived as safer and more beneficial. Public support for technologies is diminished when people perceive them as risky, non-beneficial, and unfamiliar (Fischhoff et al. 1978; Rudski et al. 2011; Slovic 1987; Westerman et al. 2015). In one study, participants preferred so-called natural risks (e.g., lightning) than unnatural risks that were objectively more threatening (e.g., downed power line; Rudski et al. 2011). In another study, people perceived methane gas products as safter when framed as "natural gas" (Lacroix et al. 2021).

People perceive natural products as safer and more beneficial partly because they are more familiar (Rudski et al. 2011). A hallmark of intuitive risk perceptions is that unfamiliar and poorly understood threats are dreaded and deemed dangerous (Slovic 1987). In comparing perceptions of novel technologies (e.g., nuclear power) with older technologies (e.g., x-rays, electricity), newer technologies are regarded as less known, controllable, and

more likely to have catastrophic consequences (Fischhoff et al. 1978; Song and Schwarz 2009). Familiarity may also directly increase liking (de Zilva et al. 2016; Mrkva and Van Boven 2020). Familiar objects are more fluent, or easily cognitively processed, and people like fluent objects more than disfluent objects (Alter and Oppenheimer 2008; Olds and Westerman 2012; Schwarz et al. 2021; Westerman et al. 2015).

We hypothesized that proteins construed as natural would be seen as safer as more beneficial, contributing to public support. We also hypothesized that proteins construed as newer and unfamiliar would not only be judged as less natural, but also as risker and less beneficial.

1.3 Aversion to tampering with nature, ideology, and climate change belief

The ideas summarized above emphasize general associations between naturalness, risks, benefits, familiarity, and support. Several individual differences might moderate these associations. Of particular interest is that people vary in the degree to which they are averse to tampering with nature (Raimi et al. 2020; Wolske et al. 2019). People who are more averse to tampering with nature have lower trust in technology and support for geoengineering; they exhibit stronger naturalness bias and environmental beliefs and values. We therefore expect that aversion to tampering with nature would moderate the association between naturalness and support. That is, independent of the degree to which people construe proteins as natural, perceived naturalness should more strongly predict support among people who are more averse to tampering with nature.

We explored whether political ideology and climate change belief would moderate the hypothesized relationships. To the extent that alt-protein technologies are developed to address climate change by reducing consumption of animal-sourced foods, people may support those technologies less if they are skeptical of climate change, and conservatives are more skeptical of climate change than liberals. People may be unlikely to support unfamiliar technologies to solve a problem (climate change) about which they are unconcerned.

1.4 Overview of hypotheses

We hypothesize that construing proteins as more natural predicts lower risk perceptions, greater perceived benefit, and stronger support (Fig. 1). That is, the association between naturalness and support is partly explained by the associations between naturalness and perceived risks and benefits. We also hypothesized that familiarity and understanding of protein technologies predicts naturalness, beyond any direct association between familiarity, risk, benefit, and support. As described above, previous research provides support for

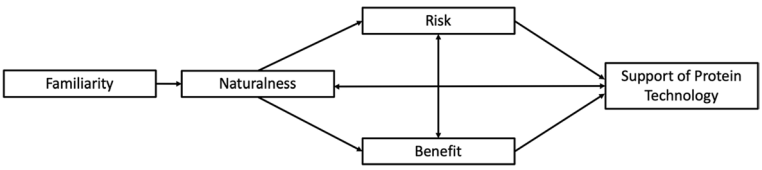

Fig. 1 A conceptual model of public support for protein technologies predicted by perceived naturalness, risks, benefits, familiarity and understanding

various components of the framework. A major contribution of the present research is that it affords a simultaneous test of multiple associations across a broader range of proteins.

We conducted a survey with a diverse sample of US respondents to examine public support for six protein technologies and their perceived naturalness, risk, benefit, and familiarity. This approach included a wider range of measures and proteins that varied more broadly in naturalness than in previous research. We pre-registered our study design and several of our primary hypotheses [bit.ly/osfproteins]. We minorly revised the procedure and analyses after pre-registration upon further discussion among collaborators. Changes were made to the number of proteins that participants rated and the comparisons we made between burger types [bit.ly/osfproteins].

Participants considered three of six different types of burgers currently on the market or in development (Good Food Institute 2023). We used burgers to maintain appearance and consumption modality. Three burgers were newer alt-protein technologies: "plant-based" burgers manufactured with processing techniques to modify plant-sourced ingredients (e.g., Beyond Burger); "plant-based fermentation" burgers containing plant-sourced ingredients and a protein produced through the fermentation of a genetically engineered yeast strain (e.g., the Impossible Burger); and "cultured beef" (also referred to as "cultivated beef") burgers manufactured with animal cell culture techniques. The three other burgers were more "conventional", produced from grass-fed pasture-raised cattle, cattle finished on a grain-fed diet in a feedlot, and "veggie" burgers produced from minimally processed plant-sourced ingredients.

We constructed a set of orthogonal contrasts, detailed below, to test whether people would support relatively new alt-protein burgers (cultured beef, plant-based, and plant-based fermentation) less than conventional burgers (grass-fed beef, grain-fed beef, veggie), and whether people would judge newer burgers are risker, less beneficial, less familiar, and less natural. The contrasts included focused comparisons of cultured beef with the two other newer alt-protein technologies. Cultured beef has been prominent in public discourse, highlighting concerns about unnaturalness and risk (Pakseresht et al. 2022). We also examined whether these associations varied across individual differences in aversion to tampering with nature and in political orientation.

2 Method

2.1 Participants

We set a target sample size of 1000 U.S. residents from CloudResearch, obtaining 1005 complete responses in March 2022 (see Supplementary Information, Table 5). We calculated our sample size to achieve 80% power to detect a Cohen's *d* effect size of 0.2 at an alpha of 0.05 and sufficiently power interactions. Respondents were paid $6. Survey completion time was approximately 15 min.

2.2 Stimuli

Participants read a mock newspaper article describing burgers titled, "What's the deal with all of these new burgers? A brief guide to how modern burgers are made" (see Supplementary Information). The six burgers in the article were: *cultured beef*, with cells extracted from cattle then fed sugars and nutrients in a biotechnological manufacturing facility;

plant-based fermentation burger, made from ingredients extracted from vegetables, then altered and combined to mimic a beef burger, with an additional ingredient derived from soy plants produced in a fermentation process by a genetically modified microorganism; *plant-based protein burgers*, made from plant ingredients including fat and oils extracted from vegetables then altered and combined to mimic the taste and texture of beef; *veggie burgers* which are distinctly different from beef burgers, made entirely from minimally processed plant ingredients that look, feel, and taste like vegetables; *grain-finished feedlot beef*, the standard beef burger with cattle that spend most of their lives grazing on grass and hay before being moved to a small "feedlot" for several months where they are fed a diet of grain to promote weight gain; and *grass-fed pasture raised beef burger*, a standard beef burger that is slightly leaner than a grain-finished burger, spending their entire lives grazing on grass and hay. We used Linguistic Inquiry and Word Count (LIWC-22) analyses (Boyd et al. 2022) to standardize tone valence between 0 and 1.53 and set reading at a ninth-grade level. Descriptions were between 65–75 words.

2.3 Measures of burgers

Participants evaluated three burgers, randomly selected from the six (see Supplementary Information for the full set of items). This design kept survey completion time manageable. The description was provided at the top of the screen. For each burger, participants reported agreement (0 = *Strongly Disagree*, 100 = *Strongly Agree*) with various statements. Participants responded to all statements for a burger type before moving onto the next burger type. We counterbalanced the order of constructs, with statements randomly ordered within each set. We averaged ratings of agreement into an index for each construct. We calculated Cronbach alphas within each burger type, then averaged across types (cf. Circus and Robison 2018).

2.3.1 Support

Four statements indicated support, including "I support this" and "Society should support this" ($a = 0.9$).

2.3.2 Naturalness

Four statements based on previous research (Rozin 2005; Inbar et al. 2020; Scott et al. 2018) indicated naturalness, including "This is natural", "This is artificial" (reversed), "This involves humans altering naturally occurring processes" (reversed), and "This relies on science-based technology" (reversed) ($a = 0.7$).

2.3.3 Benefit

Four statements indicated perceived benefit, including "This is beneficial to society" and "This is beneficial to the environment" ($a = 0.8$).

2.3.4 Risk perception

Four statements indicated perceived risk, including "Producing this is risky for society" and "This is risky to eat" ($a = 0.9$).

2.3.5 Familiarity and understanding

We averaged participants' agreement with the statements "This is familiar" and "I understand how this works" into an index ($r = 0.52$).[1]

2.4 Individual difference measures

After participants evaluated the burgers, they reported agreement with statements to assess individual differences. Statements were randomly ordered within each individual difference measure, which were counterbalanced.

2.4.1 Aversion to tampering with nature (Raimi et al. 2020)

This measure comprised six statements including, "Human beings have no right to meddle with the natural environment" and "People who push for technological fixes to environmental problems are underestimating the risks" ($a = 0.6$).

2.4.2 Climate change belief (Van Boven et al. 2018)

This measure comprised five statements such as, "Climate change poses a risk to human health, safety, and prosperity" and "Human activity is largely responsible for recent climate change" ($a = 0.9$).

2.4.3 Political ideology

We used 7-point scales to measure political ideology (-3 = very liberal, + 3 = very conservative) and partisan identification (-3 = strong Democrat, + 3 = strong Republican), which we averaged into an index of political orientation ($r = 0.45$).

2.4.4 Demographics and additional measures

Participants reported their age, ethnicity, highest education completed, and socioeconomic status using standard demographic questions. We included several exploratory measures of individual differences, including extensive demographics, that are beyond the scope of the present investigation and not reported here: disgust sensitivity ($a = 0.27$; Haidt et al. 1994; modified by Olatunji et al. 2007); concern for animal welfare ($a = 0.80$; adapted from Steptoe et al. 1995); connectedness to nature ($a = 0.78$; Mayer and Frantz 2004), collectivism ($a = 0.76$) and individualism ($a = 0.80$; Kim et al. 2016; Leong et al. 2022). We also measured average weekly beef and non-beef meat consumption (e.g., chicken, pork).

[1] We also analyzed familiarity and understanding separately, with the same pattern of results.

3 Results

3.1 Data analysis

We analyzed data using R (version 2023.03.0 + 386) with linear mixed-effect models with random intercept for participants (Westfall et al. 2014). We mean-centered continuous predictors. We used five orthogonal contrast codes to make categorical comparisons between burger types (Table 1). One key contrast (C1) compared newer alt-protein burgers (cultured beef, plant-based, and plant-based fermentation) with conventional burgers (grass-fed beef, grain-fed beef, veggie). The second (C2) compared cultured beef with plant-based and plant-based fermentation burgers. Three additional contrasts (C3, C4, and C5) were included for completeness and not directly related to hypotheses.

3.2 Comparing burgers

We regressed each measure on the contrast codes described above (Table 2). In the analyses of perceived risk and benefit, we included the other outcome as a control given the negative correlation between risk and benefit (r = -0.26, $p < 0.001$).

As predicted, participants supported newer alt-protein burgers (M = 53.19, SD = 30.72) less than conventional burgers (M = 59.46, SD = 28.65, C1: b = -6.49, 95% CI = [-8.07, -4.92], $p < 0.001$), and they supported cultured beef burgers (M = 49.36, SD = 31.76) less than plant-based and plant-based fermentation burgers (M = 55.11, SD = 30.20, C2: b = -6.20, 95% CI = [-8.61, -3.79], $p < 0.001$). Participants also perceived newer alt-protein burgers as less natural (M = 38.45, SD = 20.84) than conventional burgers (M = 54.46, SD = 22.52, C1: b = -8.15, 95% CI = [-9.67, -6.62], $p < 0.001$), and they perceived cultured beef burgers (M = 34.30, SD = 21.68) as less natural than plant-based and plant-based fermentation burgers (M = 40.52, SD = 20.42, C2: b = -17.99, 95% CI = [-20.26, -15.73], $p < 0.001$).

Participants perceived newer alt-protein burgers as riskier (M = 47.41, SD = 28.23) than conventional burgers (M = 41.33, SD = 27.44, C1: b = 3.96, 95% CI = [2.47, 5.45], $p < 0.001$). They also perceived cultured beef burgers as riskier (M = 54.20, SD = 28.05) than plant-based and plant-based fermentation burgers (M = 44.20, SD = 28.33, C2: b = 4.97, 95% CI = [2.78, 7.17], $p < 0.001$). Participants perceived newer alt-protein burgers as less beneficial (M = 57.05, SD = 27.64) than conventional burgers (M = 63.76, SD = 27.44, C1: b = -4.04 95% CI = [-5.50, -2.58], $p < 0.001$). They also perceived cultured beef burgers as less beneficial (M = 52.55, SD = 28.38) than plant-based and plant-based fermentation burgers (M = 59.31, SD = 27.27, C2: b = -4.17, 95% CI = [-6.32, -2.02], $p < 0.001$).

Participants were less familiar and less understanding of newer alt-protein burgers (M = 54.64, SD = 28.23) compared with conventional burgers (M = 68.19, SD = 24.11, C1: b = -13.76, 95% CI = [-15.34, -12.17], $p < 0.001$). They were less familiar with and less understanding of cultured beef burgers (M = 52.09, SD = 28.20) compared with plant-based and plant-based fermentation burgers (M = 55.91, SD = 26.18, C2: b = -3.58, 95% CI = [-5.92, -1.24], p = 0.003). These differences in familiarity and understanding are consistent with our selection of alt-protein at new and unfamiliar, as operationalized in the contrast codes.

Table 1 Orthogonal contrast codes used to compare alt-protein burgers and conventional burgers in multilevel models

	Cultured Beef Burger	Plant-based Fermentation Burger	Plant-based Protein Burger	Veggie Burger	Grain-fed Feedlot Burger	100% Grass-fed Pasture-raised Burger
New vs. Conventional (C1)	1	1	1	-1	-1	-1
Cultured vs. Plant Fermentation & Plant-based (C2)	2	-1	-1	0	0	0
Veggie vs. Conventional Beef (C3)	0	0	0	2	-1	-1
Grain vs. Grass-fed (C4)	0	0	0	0	1	-1
Plant Fermentation vs. Plant-based (C5)	0	1	-1	0	0	0

Table 2 Means, standard deviations, and contrast codes used to compare differences among alt-protein and conventional burgers. We controlled for risks and benefits together, given the negative correlation (approximate $r = 0.26$, $p < 0.001$) between the measures

Burger Mean Ratings	Support	Naturalness	Risk	Benefit	Familiarity & Understanding
Cultured Beef	49.36 (31.76)	34.32 (21.71)	54.20 (28.05)	52.55 (28.38)	52.09 (28.20)
Plant-based Fermentation	52.69 (31.03)	38.66 (20.69)	45.56 (29.46)	57.15 (28.37)	52.95 (28.00)
Plant-based Protein	57.53 (29.36)	42.37 (20.17)	42.48 (27.19)	61.46 (26.16)	58.87 (24.35)
Veggie	62.93 (27.38)	51.39 (22.39)	36.41 (26.57)	67.74 (24.60)	65.33 (23.84)
Grain-fed Feedlot	57.91 (29.22)	49.53 (21.27)	48.87 (27.89)	56.20 (27.07)	66.18 (24.80)
100% Grass-fed Pasture-raised	57.53 (29.36)	62.46 (23.86)	38.72 (27.87)	67.33 (24.01)	73.05 (23.68)
Contrasts					
New vs. Conventional (C1)	-6.49*** (0.80)	-8.15*** (0.78)	3.96*** (0.76)	-4.04*** (0.74)	-13.76*** (0.81)
Cultured vs. Plant Fermentation & Plant-based (C2)	-6.20*** (1.23)	-17.99*** (1.16)	4.97*** (1.12)	-4.17*** (1.10)	-3.58** (1.19)
Veggie vs. Conventional Beef (C3)	5.18*** (1.28)	-4.62*** (1.19)	-4.91*** (1.15)	3.56** (1.13)	-3.70** (1.23)
Grain vs. Grass-fed (C4)	0.29 (1.42)	-12.95*** (1.34)	3.46** (1.30)	-7.19*** (1.27)	-7.18*** (1.39)
Plant Fermentation vs. Plant-based (C5)	-5.10*** (1.44)	19.90*** (1.35)	3.47** (1.30)	-2.96* (1.27)	-6.87*** (1.39)

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Note: Standard deviations in parentheses for burgers. Standard errors in parentheses for contrasts

These results provide support for our hypothesized pattern of support and perceived naturalness, risk, and benefit of differences between alt-protein burgers. People perceived newer alt-protein burgers, especially cultured beef burgers, as less familiar, less beneficial, riskier, and less natural than conventional burgers.

3.3 Predicting support from naturalness, risk, and benefit

We conducted a series of regression analyses to test how much perceptions of naturalness, risk, and benefit predicted support for alt-protein technologies (Table 3, Model 1). We first regressed support on the five contrasts, as reported above (see also Table 2). We added perceived naturalness as a predictor in Model 2. As expected, naturalness strongly predicted support ($b = 0.39$, 95% CI = [0.35, 0.43], $p < 0.001$). The contrast comparing newer alt-protein burgers with conventional burgers was reduced but still significant (C1: $b = -3.21$, 95% CI = [-5.00, -1.42], $p < 0.001$). The contrast comparing cultured beef with plant-based burgers and plant-based fermented burgers was reduced to non-significance (C2: $b = 0.67$, 95% CI = [-1.81, 3.15], $p = 0.530$).

We next added perceived risk and benefit as predictors (Table 3, Model 3). Support was negatively predicted by perceived risk ($b = -0.05$, 95% CI = [-0.08, -0.02], $p < 0.001$), and positively predicted by perceived benefit ($b = 0.81$, 95% CI = [0.78, 0.84], $p < 0.001$). The effect of naturalness predicting support was smaller, although still significant ($b = 0.09$, 95% CI = [0.06, 0.13], $p < 0.001$), compared with Model 2. The contrast comparing newer alt-protein burgers with conventional burgers became non-significant (C1: $b = -0.27$, 95% CI = [-1.60, 1.07], $p = 0.692$), and the contrast comparing cultured beef with plant-based burgers and plant-based fermented burgers was marginally significant (C2: $b = 1.78$, 95% CI = [-0.06, 3.61], $p = 0.058$). These findings are consistent with the hypothesis that differences in support for newer alt-protein burgers with conventional burgers are partly due to perceived naturalness, risk, and benefit.

In additional analyses including the five contrast codes, naturalness was a significant negative predictor of perceived risk ($b = -0.31$, 95% CI = [-0.35, 0.28], $p < 0.001$), controlling for perceived benefit. And naturalness was a significant positive predictor of perceived benefit ($b = 0.21$, 95% CI = [0.17, 0.25], $p < 0.001$), controlling for perceived risk.

Finally, perceptions of familiarity and understanding predicted naturalness ($b = 0.21$, 95% CI = [0.18, 0.24], $p < 0.001$). The contrast comparing the naturalness newer alt-protein burgers with conventional burgers was smaller, though still significant, than it was in the model without familiarity and understanding (C1: $b = -5.26$, 95% CI = [-6.78, -3.73], $p < 0.001$). The contrast comparing cultured beef with plant-based burgers and plant-based fermented burgers was also smaller but still significant (C2: $b = -17.00$, 95% CI = [-19.19, -14.82], $p < 0.001$).

These results are consistent with the hypothesis that the effect of naturalness on support is partly attributable to the effect of naturalness on perceived risks and benefits, and that differences between burgers in perceived naturalness is at least partly attributable to differences in perceived familiarity and understanding.

3.4 Individual difference moderators

We next examined moderation by individual diference measures. We first added (mean-centered) aversion to tampering with nature (mean-centered) to Model 2, interacting with naturalness and the five orthogonal contrasts. Aversion to tampering with nature did not

Table 3 Regression models with unstandardized coefficients predicting support by naturalness, risk, benefit, and orthogonal protein technology contrasts

	Model 1				Model 2				Model 3			
	b	*SE*	95% CI	*t*	*b*	*SE*	95% CI	*t*	*b*	*SE*	95% CI	*t*
Intercept	56.48	0.81	[54.97, 58.00]	72.91***	54.87	0.76	[54.84, 57.83]	71.42***	56.56	0.43	[55.72, 57.40]	129.36***
Naturalness					0.39	0.02	[0.35, 0.43]	18.02***	0.09	0.02	[0.06, 0.13]	5.53***
Risk									-0.05	0.01	[-0.08, -0.02]	-3.57***
Benefit									0.81	0.01	[0.78, 0.84]	56.20***
Burger Contrasts												
New vs. Conventional (C1)	-6.49	0.77	[-8.07, -4.92]	-8.07***	-3.21	0.91	[-5.00, -1.42]	-3.52***	-0.27	0.68	[-1.60, 1.06]	-0.40
Cultured vs. Plant Fermentation & Plant-based (C2)	-6.20	0.80	[-8.61, -3.79]	-5.04***	0.67	1.27	[-1.81, 3.15]	0.53	1.78	0.94	[-0.06, 3.61]	1.89
Veggie vs. Conventional Beef (C3)	5.18	1.23	[2.67, 7.69]	4.05***	7.17	1.41	[4.40, 9.93]	5.08***	-0.33	1.05	[-2.38, 1.72]	-0.31
Grain vs. Grass-fed (C4)	0.29	1.42	[-2.48, 3.07]	0.21	5.43	1.92	[1.67, 9.18]	2.83**	9.1	1.40	[6.36, 11.85]	6.49***
Plant Fermentation vs. Plant-based (C5)	-5.10	1.44	[-7.92, -2.28]	-3.55***	-12.72	1.47	[-15.62, -9.84]	-8.64***	-2.74	1.11	[-4.92, -0.56]	-2.46*

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

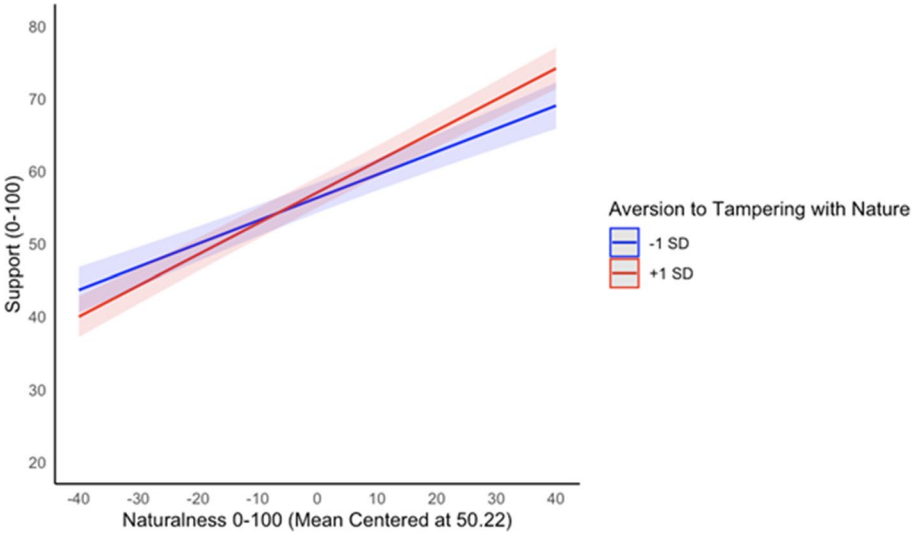

Fig. 2 The interaction of technology naturalness perception scores (mean-centered) and aversion to tampering with nature scores (mean-centered; modeled at ± 1 standard deviation) predicting willingness to support protein technology. The re-centered scale, originally ranging from 0–100, now runs from approximately –45 to + 45

directly predict support ($b = 0.02$, 95% CI = [-0.06, 0.11], $p = 0.603$). Importantly, aversion to tampering with nature and naturalness interactively predicted support ($b = 0.003$, $CI = [0.001, 0.005]$, $p = 0.002$, Fig. 2). Among participants who were relatively more averse to tampering with nature (+ 1 SD, the red line in Fig. 2), naturalness was a stronger predictor of support ($b = 0.43$, 95% CI = [0.38, 0.47], $p < .001$) than it was among participants who were less (-1 SD, the blue line in Fig. 2) averse to tampering with nature ($b = 0.32$, 95% CI = [0.26, 0.38], $p < 0.001$). The more people reported discomfort with human interference with nature, the less that they supported alt-proteins they perceived as unnatural, and the more they supported proteins they perceived as natural. This moderation effect provides convergent evidence that naturalness, and not some confounded construct, predicts support for the proteins.

We next conducted an analogous analysis with political ideology as a moderator. Ideology negatively predicted support such that more conservative participants were less supportive of protein technologies overall ($b = -1.90$, CI = [-3.39, -0.52], $p = 0.007$). However, ideology did not significantly interact with naturalness ($b = 0.02$, CI = [0.00, 0.04], $p = 0.096$). This suggests that the relations between naturalness and support do not vary by political ideology, attesting to the generality of the above findings.

4 Discussion

We found that respondents in a broad US sample were less supportive of newer alt-protein technologies (plant-based protein burgers, plant-based fermentation burgers, and cultured beef burgers) and considered them to be less natural, riskier, less beneficial, and less familiar compared with conventional protein technologies (veggie burgers, grain-fed burgers, and grass-fed burgers). People were especially unsupportive of

cultured beef, which was regarded as particularly unnatural. Regression analyses were consistent with the hypothesis that perceiving protein technologies as natural predicted their support partly by increasing perceived benefits and reducing perceived risks. Individuals who were more averse to tampering with nature were even less inclined to support alt-protein technologies to the extent that they perceived them as unnatural.

Our findings conceptually replicate and extend previous research (Bearth et al. 2014; Etale and Siegrist 2021; Siegrist and Hartmann 2020a, b) in at least two important ways. First, we broadened the scope of stimuli by including a diverse set of burgers that varied in human intervention and familiarity. These six burger stimulus types enabled us to examine perceived naturalness on a wider spectrum of proteins (e.g., cultured beef tended to be perceived as less natural, and grass-fed beef tended to be perceived as more natural), compared to previous studies that looked at perceptions of fewer proteins. Second, we included a broader range of measures in our analyses along with individual differences. Using a larger set of measure and broader range of stimuli that spanned a spectrum of naturalness allowed us to examine associations robustly and comprehensively between support, benefit, risk, familiarity, understanding, and naturalness. These findings substantially expand the scope of previous research.

4.1 Theoretical and broader implications

The present findings have broader implications for theories of public acceptance of sustainability technology. The findings suggest that people's construal of naturalness plays an important role in shaping public acceptance of sustainability technologies. Our findings also suggest that perceived familiarity and understanding may contribute to people's construal of technologies as natural (Siipi 2008). Mere familiarity may lead people to perceive objects as natural, which would broaden understanding of the naturalness construct beyond considerations of being free from additives and science-based human processing (Rozin 2004; Rozin 2005; Rozin et al. 2012; Scott et al. 2018; Scott and Rozin 2020).

Our findings also suggest that people vary in their reactions to naturalness. Those who have a stronger aversion to tampering with nature (Raimi et al. 2020) are more likely to support alt-proteins they construe as natural—and to oppose proteins they perceive as unnatural. We did not find that ideology moderated reactions to naturalness. The relationship between naturalness and support is one on which liberals and conservatives agree. This highlights the generalizability of the associations between naturalness and support.

Our findings also have broad implications for understanding practices that might facilitate public acceptance of sustainability technologies. If construal of technologies as natural increases support, those concerned with increasing public support should highlight the natural aspects of new technologies. Encouraging support for alt-protein technologies and other novel sustainability technologies in the food sector could be facilitated by highlighting similarities between alt-protein technologies and conventional food processing techniques (Inbar et al. 2020). Although sustainability technologies are being rapidly developed, it remains unclear which options will gain public acceptance. Further research could provide insights on effective communication about new technologies across contexts, populations, and technology types.

4.2 Future directions and open questions

Further research might also address open questions about the present findings. First, while our study found a positive correlation between naturalness and support, correlational findings do not imply causation. An important task will be to experimentally manipulate the construal of naturalness within the same type of protein to measure its impact on support. One approach could be to use terminology associated with naturalness (such as "local" or "organic") to frame technologies and measure the resulting support.

Second, future work could examine whether mere familiarity with technologies increases perceptions of naturalness. Our design compared perceived naturalness, risk, benefit, and support for conventional, familiar proteins with newer, less familiar technologies. Such broad manipulations, while ecologically valid, might have included confounding attributes unrelated to the technologies themselves. More precise manipulations of familiarity and naturalness are needed in future work. Without changing the descriptions of technologies, simply becoming more familiar with them may make them seem more natural. Third, future research could examine the relationships across a wider variety of proteins, including other types of meat, fish, and non-animal products. Fourth, an open question remains regarding the cultural generalizability of our findings, which was conducted in the United States. It is unclear whether perceptions of naturalness and support for alt-protein technologies may differ across cultures.

Finally, it will be important to examine whether self-reported support for alternative protein technology translates to behavior. When new technologies arrive on the market, they are more expensive than conventional technologies for a host of reasons such as economies of scale. Currently, for example, one pound of *Beyond Beef*, akin to the plant-based protein burger described in our study, costs $7 in the US while the same amount of conventional beef costs $5 (U.S. Bureau of Labor Statistics 2023). Would self-reported consumer support translate to willingness to pay 40% more for an alternative protein product? Or, if climate policies increase the cost of conventionally produced beef—for example, by imposing a tax on greenhouse gas emissions associated with production—would consumers who view alternative protein technologies as unnatural incur financial costs to avoid consuming them? Research to translate support to economic preferences will be an important avenue to guide policy regarding sustainability technologies because it could inform constraints on consumer elasticity.

4.3 Conclusion

In the early days of any new technology, public acceptance is key to successful diffusion and adoption. This is especially true for alt-protein technologies, which are often perceived as risky and unfamiliar. Our study shows that the more natural a technology is perceived to be, the more people support it. Naturalness is associated with lower perceptions of risk, higher perceptions of benefit, and greater general understanding and familiarity of the technology. By understanding how to communicate the naturalness of alt-protein technologies, we can better understand what facilitates or impedes public acceptance. Further research on factors that influence public acceptance of sustainability technologies is critical to facilitating the adoption of technologies capable of helping to address climate change and other sustainability concerns.

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Data availability The datasets, materials, and analysis scripts generated during and/or analyzed during the current study are available in the Open Science Framework (OSF) repository, bit.ly/osfproteins.

Declarations

Ethics approval and consent to participate We conducted the research in adherence to APA ethical standards. All procedures were approved by the Institutional Review Boards at the University of Colorado Boulder.

Consent for publication NA.

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References

Agarwal S, Fulgoni VL 3rd, Berg EP (2015) Association of lunch meat consumption with nutrient intake, diet quality and health risk factors in U.S. children and adults: NHANES 2007–2010. Nutr J 14:128. https://doi.org/10.1186/s12937-015-0118-9

Alter AL, Oppenheimer DM (2008) Easy on the mind, easy on the wallet: The roles of familiarity and processing fluency in valuation judgments. Psychon Bull Rev 15(5):985–990. https://doi.org/10.3758/PBR.15.5.985

Ambikapathi R, Schneider KR, Davis B, Herrero M, Winters P, Fanzo JC (2022) Global food systems transitions have enabled affordable diets but had less favourable outcomes for nutrition, environmental health, inclusion and equity. Nature Food 3:764–779. https://doi.org/10.1038/s43016-022-00588-7

Banda LJ, Tanganyika J (2021) Livestock provide more than food in smallholder production systems of developing countries. Anim Front 11(2):7–14. https://doi.org/10.1093/af/vfab001

Bearth A, Cousin ME, Siegrist M (2014) The consumer's perception of artificial food additives: Influences on acceptance, risk and benefit perceptions. Food Qual Prefer 38:14–23. https://doi.org/10.1016/j.foodqual.2014.05.008

Böhm G, Pfister HR (2000) Action tendencies and characteristics of environmental risks. Acta Physiol (oxf) 104(3):317–337. https://doi.org/10.1016/S0001-6918(00)00035-4

Böhm GB, Pfister HR (2005) Consequences, morality, and time in environmental risk evaluation. J Risk Res 8(6):461–479. https://doi.org/10.1080/13669870500064143

Boyd RL, Ashokkumar A, Seraj S, Pennebaker JW (2022) The development and psychometric properties of LIWC-22. Austin, TX: University of Texas at Austin. https://www.liwc.app. Accessed 1 Apr 2023

Brunner TA, Van der Horst K, Siegrist M (2010) Convenience food products Drivers for Consumption. Appetite 55:498–506. https://doi.org/10.1016/j.appet.2010.08.017

Bryant C, Dillard C (2019) The impact of framing on acceptance of cultured meat. Front Nutr 6. https://doi.org/10.3389/fnut.2019.00103

Burgess M, Van Boven L, Wagner G, Wong-Parodi G, Baker K, Boykoff M, Converse BA, Dilling L, Gilligan JM, Inbar Y, Markowitz E, Moyer JD, Newton P, Raimi K, Shrum T, Vandenbergh M (2024) Supply, demand, and polarization challenges facing U.S. climate policies. Nat Clim Change. https://doi.org/10.1038/s41558-023-01906-y

Chiles RM, Fitzgerald AJ (2018) Why is meat so important in Western history and culture? A genealogical critique of biophysical and political-economic explanations. Agric Hum Values 35:1–17. https://doi.org/10.1007/s10460-017-9787-7
Circus VE, Robison R (2018) Exploring perceptions of sustainable proteins and meat attachment. British Food J 121(2):533–545. https://doi.org/10.1108/BFJ-01-2018-0025
Clark M, Tilman D, Hill J (2018) The diet, health, and environment trilemma. Annu Rev Environ Resour 43:109–134. https://doi.org/10.1146/annurev-environ-102017-025957
Clark M, Springmann M, Rayner M, Scarborough P, Hill J, Tilman D, Macdiarmid JI, Fanzo J, Bandy L, Harrington RA (2022) Estimating the environmental impacts of 57,000 food products. Proc Natl Acad Sci USA 119(33):e2120584119. https://doi.org/10.1073/pnas.2120584119
Corner A, Pidgeon N (2015) Like artificial trees? The effect of framing by natural analogy on public perceptions of geoengineering. Clim Change 130:425–438. https://doi.org/10.1007/s10584-014-1148-6
Dabasso BG, Makokha AO, Onyango AN, Mathara J (2022) Beyond nutrition: social cultural values of meat and meat products among the Borana people of Northern Kenya. J Ethnic Foods 9(46). https://doi.org/10.1186/s42779-022-00160-5
de Zilva D, Newell BR, Mitchell CJ (2016) Multiple context mere exposure: Examining the limits of liking. Q J Exp Psychol 69(3):521–534. https://doi.org/10.1080/17470218.2015.1057188
Etale A, Siegrist M (2021) Food processing and perceived naturalness: Is it more natural or just more traditional? Food Qual Prefer 94(104323):0950–3293. https://doi.org/10.1016/j.foodqual.2021.104323
Fischhoff B, Slovic P, Lichtenstein S, Read S, Combs B (1978) How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. Policy Sci 9(2):127–152. https://doi.org/10.1007/BF00143739
Good Food Institute (2023) Defining Alternative Proteins. Retrieved April 14, 2023 from. https://gfi.org/defining-alternative-protein/. Accessed 1 Apr 2023
Green A, Blattmann C, Chen C, Mathys A (2022) The role of alternative proteins and future foods in sustainable and contextually-adapted flexitarian diets. Trends Food Sci Technol 124:250–258. https://doi.org/10.1016/j.tifs.2022.03.026
Hadi J, Brightwell G (2021) Safety of alternative proteins: Technological, environmental and regulatory aspects of cultured meat, plant-based meat, insect protein and single-cell protein. Foods 10(6):1226. https://doi.org/10.3390/foods10061226
Haidt J, McCauley C, Rozin P (1994) Individual differences in sensitivity to disgust: A scale sampling seven domains of disgust elicitors. Person Individ Differ 16:701–713. https://doi.org/10.1016/0191-8869(94)90212-7
Happer C, Wellesley L (2019) Meat consumption, behaviour and the media environment: A focus group analysis across four countries. Food Secur 11(1):123–139. https://doi.org/10.1007/s12571-018-0877-1
Hemmerling S, Canavari M, Spiller A (2016) Preference for naturalness of European organic consumers: First evidence of an attitude-liking-gap. British Food J 118:2287–2307. https://doi.org/10.1108/BFJ-11-2015-0457
Honkanen P, Olsen SO (2009) Environmental and animal welfare issues in food choice: The case of farmed fish. British Food J 111(3):293–309. https://doi.org/10.1108/00070700910941480
Inbar Y, Phelps J, Rozin P (2020) Recency negativity: Newer food crops are evaluated less favorably. Appetite 154. https://doi.org/10.1016/j.appet.2020.104754
Kim HS, Sherman DK, Updegraff JA (2016) Fear of ebola: The influence of collectivism on xenophobic threat responses. Psychol Sci 27(7):935–944. https://doi.org/10.1177/09567976166425
Klebl C, Luo Y, Bastian B (2022) Beyond aesthetic judgment: Beauty increases moral standing through perceptions of purity. Pers Soc Psychol Bull 48(6):954–967. https://doi.org/10.1177/0146167221102364
Kwasny T, Dobernig K, Riefler P (2022) Towards reduced meat consumption: A systematic literature review of intervention effectiveness, 2001–2019. Appetite 168:105739. https://doi.org/10.1016/j.appet.2021.105739
Lacroix K, Goldberg MH, Gustafson A, Rosenthal SA, Leiserowitz A (2021) Different names for "natural gas" influence public perception of it. J Environ Psychol 77. https://doi.org/10.1016/j.jenvp.2021.101671
Leong S, Eom K, Ishii K, Aichberger MC, Fetz K, Müller TS, Kim HS, Sherman DK (2022) Individual costs and community benefits: Collectivism and individuals' compliance with public health interventions. PLoS ONE 17(11):e0275388. https://doi.org/10.1371/journal.pone.0275388
Li H, Cao Y (2022) Exposure to nature leads to a stronger natural-is-better bias in Chinese people. J Environ Psychol 101752–101752. https://doi.org/10.1016/j.jenvp.2021.101752

Li M, Chapman GB (2012) Why do people like natural? Instrumental and ideational bases for the naturalness preference. J Appl Soc Psychol 42(12):2859–2878. Wiley Periodicals. https://doi.org/10.1111/j.1559-1816.2012.00964.x
Li H, Cao Y (2022b) Exposure to nature leads to a stronger natural-is-better bias in Chinese people. J Environ Psychol 79:101752. https://doi.org/10.1016/j.jenvp.2021.101752
Lockie S, Lyons K, Lawrence G, Mummery K (2002) Eating "Green": Motivations behind organic food consumption in Australia. Sociol Rural 42:23–40. https://doi.org/10.1111/1467-9523.00200
Maxwell S, Fuller R, Brooks T, Watson J (2016) Biodiversity: The ravages of guns, nets and bulldozers. Nature 536:143–145. https://doi.org/10.1038/536143a
Mayer FS, Frantz CM (2004) The connectedness to nature scale: A measure of individuals' feeling in community with nature. J Environ Psychol 24(4):503–515. https://doi.org/10.1016/j.jenvp.2004.10.001
Meier BP, Dillard AJ, Lappas CM (2019) Naturally better? A review of the natural-is-better nias. Soc Pers Psychol Compass 13(8):1–9. https://doi.org/10.1111/spc3.12494
Mrkva K, Van Boven L (2020) Salience theory of mere exposure: Relative exposure increases liking, extremity, and emotional intensity. J Pers Soc Psychol 118(6):1118–1145. https://doi.org/10.1037/pspa0000184
Myers S, Smith MR, Guth S, Golden CD, Vaitla B, Mueller ND, Dangour AD, Huybers P (2017) Climate change and global food systems: Potential impacts on food security and undernutrition. Annu Rev Public Health 38(1):259–277. https://doi.org/10.1146/annurev-publhealth-031816-044356
Nawaz S, Satterfield T (2022) On the nature of naturalness? Theorizing 'nature'for the study of public perceptions of novel genomic technologies in agriculture and conservation. Environ Sci Policy 136:291–303. https://doi.org/10.1016/j.envsci.2022.06.008
Olatunji BO, Williams NL, Tolin DF, Abramowitz JS, Sawchuk CN, Lohr JM, Elwood LS (2007) The Disgust Scale: Item analysis, factor structure, and suggestions for refinement. Psychol Assess 19(3):281–297. https://doi.org/10.1037/1040-3590.19.3.281
Olbrich R, Hundt M, Grewe G (2015) Willingness to pay in food retailing—An empirical study of consumer behaviour in the context of the proliferation of organic products. In: Foscht T, Morschett D, Rudolph T, Schnedlitz P, Schramm-Klein H, Swoboda B (eds) European Retail Research. European Retail Research. Springer Gabler, Wiesbaden. https://doi.org/10.1007/978-3-658-09603-8_4
Olds JM, Westerman DL (2012) Can fluency be interpreted as novelty? Retraining the interpretation of fluency in recognition memory. J Exp Psychol Learn Mem Cogn 38(3):653–664. https://doi.org/10.1037/a0026784
Onwezen MC, Bouwman EP, Reinders MJ, Dagevos H (2021) A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. Appetite 159:105058. https://doi.org/10.1016/j.appet.2020.105058
Pakseresht A, Ahmadi Kaliji S, Canavari M (2022) Review of factors affecting consumer acceptance of cultured meat. Appetite 170:105829. https://doi.org/10.1016/j.appet.2021.105829
Perez-Cueto FJA, Rini L, Faber I, Rasmussen MA, Bechtold K-B, Schouteten JJ, De Steur H (2022) How barriers towards plant-based food consumption differ according to dietary lifestyle: Findings from a consumer survey in 10 EU countries. Int J Gastronomy Food Sci 29:100587. https://doi.org/10.1016/j.ijgfs.2022.100587
Poore J, Nemecek T (2018) Reducing food's environmental impacts through producers and consumers. Science (New York, N.Y.) 360(6392):987–992. https://doi.org/10.1126/science.aaq0216
Pula K, Parks CD, Ross CF (2014) Regulatory focus and food choice motives. Prevention orientation associated with mood, convenience, and familiarity. Appetite 78:15–22. https://doi.org/10.1016/j.appet.2014.02.015
Raimi KT, Wolske KS, Hart PS, Campbell-Arvai V (2020) The Aversion to Tampering with Nature (ATN) Scale: Individual differences in (dis)comfort with altering the natural world. Risk Anal 40(3):638–656. https://doi.org/10.1111/risa.13414
Roininen K, Tuorila H (1999) Health and taste attitudes in the prediction of use frequency and choice between less healthy and more healthy snacks. Food Qual Prefer 10:357–365. https://doi.org/10.1016/S0950-3293(98)00057-3
Román S, Sánchez-Siles L, Siegrist M (2017) The importance of food naturalness for consumers: Results of a systematic review. Trends Food Sci Technol 67:44–57. https://doi.org/10.1016/j.tifs.2017.06.010
Rozin P, Spranca M, Krieger Z, Neuhaus R, Surillo D, Swerdlin A, Wood K, Wood KC (2004) Preference for natural: Instrumental and ideational/moral motivations, and thecontrast between foods and medicines. Appetite 43(2):147–154. https://doi.org/10.1016/j.appet.2004.03.005

Rozin P (2005) The meaning of "natural": Process more important than content. Psychol Sci 16(8):652–658. https://doi.org/10.1111/j.1467-9280.2005.01589.x
Rozin P, Spranca M, Krieger Z, Neuhaus R, Surillo D, Swerdlin A, Wood K, Wood KC (2004) Preference for natural: Instrumental and ideational/moral motivations, and the contrast between foods and medicines. Appetite 43(2):147–154. https://doi.org/10.1016/j.appet.2004.03.005
Rozin P, Fischler C, Shields-Argel`es C (2012) European and American perspectives on the meaning of natural. Appetite 59(2):448–455. https://doi.org/10.1016/j.appet.2012.06.001
Rudski JM, Osei W, Jacobson AR, Lynch CR (2011) Would you rather be injured by lightning or a downed power line? Preference for natural hazards. Judgm Decis Mak 6(4):314–322. https://doi.org/10.1017/S1930297500001923
Santo RE, Kim BF, Goldman SE, Dutkiewicz J, Biehl EMB, Bloem MW, Neff RA, Nachman KE (2020) Considering plant-based meat substitutes and cell-based meats: A public health and food systems perspective. Front Sustain Food Syst 4:134. https://doi.org/10.3389/fsufs.2020.00134
Schwarz N, Jalbert M, Noah T, Zhang L (2021) Metacognitive experiences as information: Processing fluency in consumer judgment and decision making. Consum Psychol Rev 4(1):4–25. https://doi.org/10.1002/arcp.1067
Scott SE, Inbar Y, Wirz CD, Brossard D, Rozin P (2018) An overview of attitudes toward genetically engineered food. Annu Rev Nutr 38:459–479. https://doi.org/10.1146/annurev-nutr-071715-051223
Scott SE, Rozin P (2020) Actually, natural is neutral. Nat Hum Behav 4(10):989–990. https://doi.org/10.1038/s41562-020-0891-0
Searchinger T, Hanson C, Ranganathan J, Lipinski B, Waite R, Winterbottom R, Dinshaw A, Heimlich R (2019) Creating a sustainable food future: Interim findings. A menu of solutions to sustainably feed more than 9 billion people by 2050. World Resources Institute. https://research.wri.org/sites/default/files/2019-07/WRR_Food_Full_Report_0.pdf
Sherman DK, Van Boven L (2023) The connections—and misconnections—between the public and politicians over climate policy: A social psychological perspective. Soc Issues Pol Rev 1–28. https://doi.org/10.1111/sipr.12104
Siegrist M, Hartmann C (2020a) Perceived naturalness, disgust, trust and food neophobia as predictors of cultured meat acceptance in ten countries. Appetite 155:104814. https://doi.org/10.1016/j.appet.2020.104814
Siegrist M, Hartmann C (2020b) Consumer acceptance of novel food technologies. Nature Food 1(6):343–350. https://doi.org/10.1038/s43016-020-0094-x
Siegrist M, Sütterlin B, Hartmann C (2018) Perceived naturalness and evoked disgust influence acceptance of cultured meat. Meat Sci 139:213–219. https://doi.org/10.1016/j.meatsci.2018.02.007
Sievert K, Lawrence M, Parker C, Baker P (2021) Understanding the political challenge of red and processed meat reduction for healthy and sustainable food systems: A narrative review of the literature. Int J Health Pol Manage 10(Special Issue on Political Economy of Food Systems):793–808. https://doi.org/10.34172/ijhpm.2020.238
Siipi H (2008) Dimensions of naturalness. Ethics Environ 71–103. http://www.jstor.org/stable/40339149
Slovic P (1987) Perception of risk. Science 236(4799):280–285. https://doi.org/10.1126/science.3563507
Song H, Schwarz N (2009) If it's difficult to pronounce, it must be risky: Fluency, familiarity, and risk perception. Psychol Sci 20(2):135–138. https://doi.org/10.1111/j.1467-9280.2009.02267.x
Steptoe A, Pollard TM, Wardle J (1995) Development of the motives underlying the selection of food: The food choice questionnaire. Appetite 25:267–284. https://doi.org/10.1006/appe.1995.0061
Tobler C, Visschers VHM, Siegrist M (2011) Eating green. Consumers' willingness to adopt ecological food consumption behaviors. Appetite 57:674–682. https://doi.org/10.1016/j.appet.2011.08.010
Tubiello F, Karl K, Flammini A, Gütschow J, Obli-Laryea G, Conchedda G, Pan X, Yue Qi S, Halldórudóttir Heiðarsdóttir H, Wanner N, Quadrelli R, Rocha Souza L, Benoit P, Hayek M, Sandlow D, Mencos Contreras E, Rosenzweig C, Rosero Moncayo J, Conforti P, Torero M (2022) Pre- and post-production processes increasingly dominate greenhouse gas emissions from agri-food systems. Earth Syst Sci Data 14(4):1795–1809. https://doi.org/10.5194/essd-14-1795-2022
U.S. Bureau of Labor and Statistics (2023) Average retail food and energy prices, U.S. and Midwest Region. Bureau of Labor Statistics.https://www.bls.gov/regions/mid-atlantic/data/averageretailfoodandenergyprices_usandmidwest_table.htm. Accessed 1 Apr 2023
Van Boven L, Ehret PJ, Sherman DK (2018) Psychological barriers to bipartisan public support for climate policy. Perspect Psychol Sci 13(4):492–507. https://doi.org/10.1177/1745691617748964
Westerman DL, Lanska M, Olds JM (2015) The effect of processing fluency on impressions of familiarity and liking. J Exp Psychol Learn Mem Cogn 41(2):426. https://doi.org/10.1037/a0038356

Westfall J, Kenny DA, Judd CM (2014) Statistical power and optimal design in experiments in which samples of participants respond to samples of stimuli. J Exp Psychol Gen 143(5):2020–2045. https://doi.org/10.1037/xge0000014

Whitton C, Bogueva D, Marinova D, Phillips CJC (2021) Are we approaching peak meat consumption? Analysis of meat consumption from 2000 to 2019 in 35 countries and its relationship to gross domestic product. Animals 11(12):3466. https://doi.org/10.3390/ani11123466

Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, Garnett T, Tilman D, DeClerck F, Wood A, Jonell M, Clark M, Gordon LJ, Fanzo J, Hawkes C, Zurayk R, Rivera JA, De Vries W, Majele Sibanda L, Afshin A, … Murray CJL (2019) Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lancet (London, England) 393(10170):447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

Wolske KS, Raimi KT, Campbell-Arvai V, Hart PS (2019) Public support for carbon dioxide removal strategies: the role of tampering with nature perceptions. Clim Change 152:345–361. https://doi.org/10.1007/s10584-019-02375-z

WWF (2020) Bending the curve: The restorative power of planet-based diets. Loken, B. et al.WWF, Gland, Switzerland. https://files.worldwildlife.org/wwfcmsprod/files/Publication/file/7b5iok5vqz_Bending_the_Curve__The_Restorative_Power_of_Planet_Based_Diets_FULL_REPORT_FINAL.pdf.pdf?_ga=2.71316371.1054766392.1682390652-119340544.1682390651. Accessed 1 Apr 2023