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Short Communication

Carbon footprint labels involving traffic lights foster sustainable food choices

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ABSTRACT

One reason consumers buy unsustainable products is that judging the environmental impact of food choices is very difficult. This study examines whether using carbon footprint labels to convey relevant impact information increases the tendency to choose low-carbon food items. In a pre-registered online experiment, 1,126 participants chose between low-CO_2 and high-CO_2 products 14 times (e.g., chili sin carne versus chili con carne or margarine versus butter). The two alternatives were either presented without labels (*control*), with a label communicating the food alternative's relative sustainability within its food category (*traffic light*), with a label communicating the absolute carbon emissions in kg CO_2 (*absolute*), or with a label communicating both the relative sustainability and absolute carbon emissions (*combined*). The results show that the *traffic light* label and the *combined* label increased the chance of choosing a low-CO_2 (versus a high-CO_2) food item. There were no interactions between carbon footprint labels and environmental concern / cognitive reflection. Our research contributes to the discussion on the effectiveness and practical relevance of carbon footprint labels by testing a specific traffic light design and demonstrating the limited impact of communicating absolute carbon emissions.

1. Introduction

Our dietary habits are a major contributor to climate change, and without significant shifts in global dietary habits, it is unlikely the world will hit the necessary climate change targets. One reason consumers fail to shift their dietary habits may be that judging the environmental impact of food choices is very difficult (Camilleri et al., 2019; Shi et al., 2018). One way to overcome this difficulty is to make the relevant information available. For instance, carbon footprint labels visually represent the environmental impact of products and are thought to prompt more sustainable dietary decisions (Liu et al., 2016; Rondoni & Grasso, 2021).

Thus far, researchers have mostly focused on environmental labels that simply certify that a food product was produced sustainably, e.g., organic labels. Despite providing consumers with some orientation when deciding between a product that has a label and one that does not, such general environmental labels leave consumers uninformed when they are deciding between alternatives that are labelled as "sustainable". One labeling scheme that has been suggested to be particularly beneficial is to inform consumers about the impact a food item has on the environment. Specifically, the carbon footprint label displays the total greenhouse gas emissions that this product generates throughout its lifecycle. Thus, labels informing consumers about a food item's carbon footprint should help them identify sustainable food items (Thøgersen & Nielsen, 2016) and make more sustainable food decisions (e.g., Rondoni & Grasso, 2021). Based on this, we test the following hypothesis:

> H_{Label}: Consumers are more likely to choose a low-CO_2 (versus a high-CO_2) food item when food alternatives are presented with a carbon footprint label (versus no label).

A closer look at the literature reveals that there are different types of carbon footprint labels, which vary in terms of how they inform consumers about a food item's carbon footprint. For instance, some carbon footprint labels use *traffic light* colors and build on existing associations and heuristics (choose green, avoid red). These labels are easy to understand and seem particularly promising as a communication tool (Camilleri et al., 2019; Osman & Thornton, 2019; Thøgersen & Nielsen, 2016). Traffic light labels operate through improvements in knowledge and increase the ability to rank products based on carbon footprint (Panzone et al., 2020). A weakness of these labels is that the ratings are

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typically based on a selection of products within a specific food category, e.g., fruits or meat. In fact, the relative sustainability that the traffic light labels communicate is computed based on food items *within* (and not across) various food categories. As such, they only allow for fair comparisons between similar products, e.g., domestic apples versus imported apples, but lead to biased judgments and decisions when products belong to different categories, e.g., meat versus fruit (Waechter et al., 2015).

Carbon footprint labels communicating *absolute* carbon emissions have the advantage of stating an unambiguous number (kg CO_2), which enables consumers to directly compare any two products regardless of their categories (Thøgersen & Nielsen, 2016). However, this numerical information is difficult to interpret, for example, because it lacks context (Meyerding et al., 2019; Rondoni & Grasso, 2021).

In this study, we attempt to harness the benefits of the two label types by combining them into one: we test a new type of label that uses the traffic light as well as the absolute amount of CO_2. Based on the existing evidence, we did not feel confident enough to pre-register a clear hypothesis regarding the performance of the three label types. We therefore use an exploratory approach and formulate the following (not-preregistered) research question:

$Q_{\text{Relative effects of label type}}$: To what extent do the effects of the three labels differ?

In addition to the general effect of carbon footprint labels on diet decisions, the question arises as to whether individual consumer characteristics moderate this effect. Environmental concern, for instance, can be an important indirect determinant of specific behavior (Bamberg, 2003). The more people are concerned about the environment, the higher their preferences for sustainable products are, and the more likely they should be to choose products with an environmental label (Rondoni & Grasso, 2021). By contrast, people who are not concerned about the environment should not attach a great deal of importance to the information conveyed on an environmental label. We therefore hypothesize as follows:

$H_{\text{Environmental concern}}$: The more pronounced consumers' environmental concern is, the more likely it is that carbon footprint labels will promote sustainable food choices.

Variations in cognitive reflection could also moderate the effect of carbon labels. More specifically, the stronger people's tendency to invest cognitive effort when making decisions, the more should they reflect on the meaning of the information provided on the labels, i.e., colors and carbon emissions and the greater the impact of the labels should be (Frederick, 2005). Thus, we hypothesize as follows:

$H_{\text{Cognitive reflection}}$: The more pronounced consumers' tendency to engage in cognitive reflection is, the more likely it is that carbon footprint labels will promote sustainable food choices.

In the present study, we test our three hypotheses and examine our research question regarding the three label types. We conducted an online experiment in which participants had to make 14 dietary decisions, either with no carbon footprint label, a traffic light footprint label, a footprint label with only the absolute CO_2 information, or a label combining the traffic light and CO_2 information. All hypotheses and planned analyses were pre-registered before any of the data were cleaned or analyzed (https://osf.io/htuz3/?view_only=8895ec9d86ec460e97e2662ff4f34d8b).

2. Method

2.1. Participants

We recruited 1,126 citizens of Switzerland (69 % female, 30 % male, 1 % non-binary; $M_{Age} = 36.25$, $SD_{Age} = 28.61$) through diverse channels, e.g., blogs, social media, and a mailing list. As an incentive, participants were given the opportunity to participate in a raffle (10x ~$50 vouchers).

We obtained ethical approval for this experiment from the Ethics Committee of the Faculty of Business, Economics and Social Sciences of the University of Bern. This research complies with General Data Protection Regulation requirements. The data were collected and made publicly available (https://osf.io/e3prn/?view_only) without identifying information and with the informed consent of the respondents.

2.2. Design and procedure

We randomly assigned participants to one of four between-subjects conditions (carbon footprint label: *control* versus *traffic light* versus *absolute* versus *combined*). In the first part of the experiment, participants repeatedly chose between two food options (the within-subjects condition). They saw 14 food items — eight dish scenarios (e.g., chili sin carne versus chili con carne) and six product scenarios (e.g., margarine versus butter, see Online Appendix A for an overview of all dish and product scenarios) — together with the carbon footprint label (apart from the control condition, which did not include a label) and were asked to indicate which of the two products they are more likely to choose. In the second part of the experiment, participants responded to questions about environmental concern and completed a cognitive reflection task. Finally, participants answered some general food-related (e.g., whether they follow special diets or have food allergies) and sociodemographic questions and were debriefed.

2.3. Material

2.3.1. Carbon footprint label

In the *control* condition, no label was displayed. In the *traffic light* condition, a label was displayed that consisted of five feet — from a dark green (most sustainable) to a red foot (least sustainable) — with the appropriate foot being shown as larger depending on the food option's carbon emissions (see Fig. 1 for an example of each label). In the *absolute* condition, the CO_2 label consisted of a black foot displaying the food option's absolute carbon emissions in kg CO_2. In the *combined* condition, the design of the traffic light and absolute condition were combined; i.e., the label showed green to red feet (with the appropriate foot being shown as larger depending on the food option's carbon emissions) and the food option's absolute carbon emissions (written on the magnified foot).

To determine which foot to show as large in the conditions involving the traffic light, we first determined the carbon emissions for all food items (Online Appendix B). We then computed the ratio between the low-CO_2 and high-CO_2 alternatives for each of the 14 food item pairs (see Table 1). Next, we ordered the food item pairs according to these ratios, formed three groups, and used these groups to determine the distance between the two enlarged feet (large ratio: maximal distance of four feet; medium ratio: three feet apart; small ratio: two feet apart).

2.3.2. Food choice

We displayed a total of 14 food choice scenarios to the participants: eight scenarios involving dishes, e.g., lasagna, and six scenarios involving products, e.g., strawberries. In every scenario, there was a low CO_2-emission alternative (coded as 1) and a high CO_2-emission alternative (coded as 0). All options were presented with an image and information about their ingredients. An overview of the food choice scenarios can be found in Online Appendix A.

2.3.3. Environmental concern

To measure environmental concern, we used the New Ecological Paradigm (NEP) scale (Dunlap et al., 2000). Participants rated their agreement with 15 items (e.g., "Humans are severely abusing the environment") on a 5-point Likert scale (1 = *not agree*, 5 = *agree*), with an additional *don't know* option ($\alpha = 0.738$).

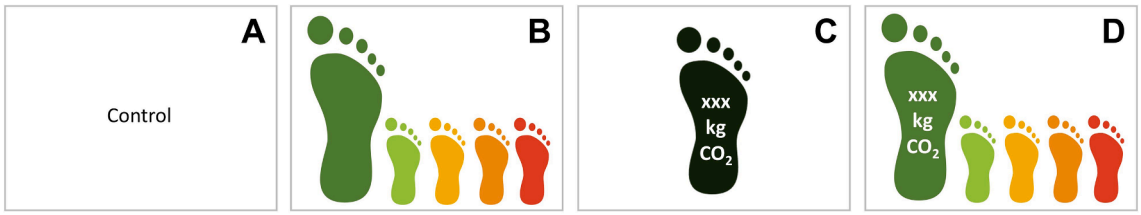

Fig. 1. *Note.* Carbon footprint label conditions: *control* (A) versus *traffic light* (B) versus *absolute* (C) versus *combined* (D).

Table 1
Overview calculation for traffic light labels.

Dish/ product	High-CO_2 alternative	Low-CO_2 alternative	Ratio (high: low)	Feet comparison
Wraps	2,289	1,983	1.15	1 vs 3
Peas	1,700	1,200	1.42	1 vs 3
Sushi	2,551	1,635	1.56	1 vs 3
Brownie	4,003	1,727	2.32	1 vs 3
Chili	12,974	4,355	2.98	3 vs 5
Lasagna	10,680	2,813	3.80	2 vs 5
Sandwich	8,600	2,125	4.05	2 vs 5
Cutlet	8,140	1,800	4.52	2 vs 5
Strawberries	3,400	700	4.86	1 vs 4
Milk	1,762	320	5.51	1 vs 4
Oil/fat	14,770	2,480	5.96	2 vs 5
Ramen	21,385	1,920	11.14	1 vs 5
Burger	26,678	2,268	11.76	1 vs 5
Pineapple	15,100	600	25.17	1 vs 5

Note. High-CO_2 and low-CO_2 alternatives are in gCO_2/kg.

2.3.4. Cognitive reflection

To measure cognitive reflection, we used the Cognitive Reflection Test (CRT) (Frederick, 2005). Participants were asked to solve three numerical tasks (e.g., "A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?") ($\alpha = 0.640$).

3. Results

3.1. The effect of carbon footprint labels on food choice

To test H_{Label}, we performed a mixed-effects logistic regression with food choice as the response variable (repeated measure), the carbon footprint label as a fixed factor, and several covariates (e.g., vegetarianism). We specified the random structure of the regression by entering a random intercept for participants and food choice scenarios. The random structure was included to adjust the intercepts for variance conditional to the participants and food choice scenarios. No random slopes were modelled.

We did not have strong expectations regarding varying effects on the part of the labels in terms of respondents and choice scenarios and, therefore, did not want to sacrifice model parsimony by adding random slopes. As hypothesized, Fig. 2 depicts that there was an effect on the

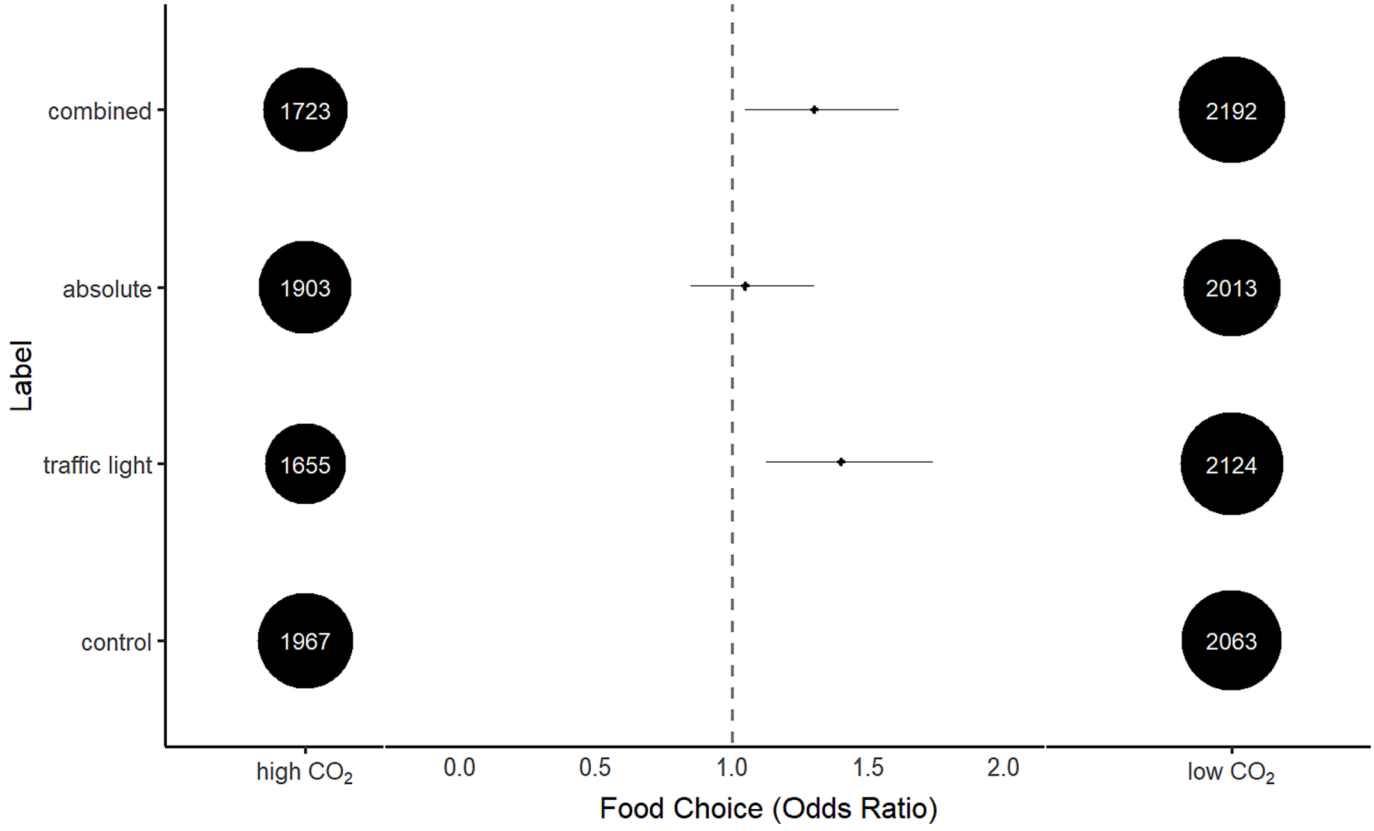

Fig. 2. *Note.* The sizes of the circles represent the counts for "high-CO_2" versus "low-CO_2" food choices. Furthermore, the plot depicts the ORs and their 95% CIs for the labels (reference category: control condition).

part of the traffic light and combined labels on food choice. When respondents saw the traffic light label (versus no label) along with the food options, the odds of choosing the low-CO_2 (versus the high-CO_2) food item grew about 1.45-fold, which corresponds to a small effect (Cohen's $d = 0.20$). Similarly, when compared to the no-label condition, the combined label increased the odds of choosing a low-CO_2 (versus a high-CO_2) food item by 1.35, which again represents a small effect (Cohen's $d = 0.17$). In contrast to our hypothesis, the absolute label did not have any effect on respondents' food choices (see Table 2).

With respect to our research question regarding the three label types, it was found that the labels only increased the number of low-CO_2 (versus high-CO_2) choices if they included the traffic light. Note that, when using the traffic light condition as a reference category (instead of the control condition), there was no difference between respondents in the traffic light and combined conditions (95 % CI [-0.30, 0.15]).

In addition to our pre-registered analyses, we computed an analysis of variance to separately test the effects of the two label elements, namely the *traffic light* and *absolute carbon emission* aspects. The results (SI Tab. 7) show that, while there is an effect on the part of the traffic light, there is no effect on the part of absolute carbon emissions.

3.2. No moderating role on the part of environmental concern and cognitive reflection

To test whether the positive effect of carbon footprint labels on sustainable food choice is contingent on environmental concern and cognitive reflection, we performed an additional mixed-effects logistic regression. We added the interactions of the carbon footprint label with environmental concern and cognitive reflection, as fixed factors, to the previously computed regression. As Table 2 reveals, there were no such interactions.

4. Discussion

The aim of this study was to test the effectiveness of carbon footprint labels as a tool with which to increase sustainable food consumption. Conducting an online experiment in which respondents chose between low-CO_2 versus high-CO_2 food items showed that the likelihood of choosing a low-CO_2 (versus a high-CO_2) food item increased with a label communicating the food alternative's relative "sustainability" (*traffic light*) and with a label communicating both the relative sustainability and absolute carbon emissions (*combined*). There were no interactions between carbon footprint labels and environmental concern / cognitive reflection when food choice was used as dependent variable.

Our findings are in line with previous research showing that carbon footprint labels have a positive but small effect on sustainable food choices (Brunner et al., 2018; Grunert et al., 2014). Moreover, the present research corroborates the notion that labels that inform consumers about the *relative* sustainability of a food alternative are particularly effective (Thøgersen & Nielsen, 2016). We also tested the notion that labels with information about absolute carbon emissions would be effective. However, our results do not support this idea, because such labels were only effective when combined with a traffic light element.

Thus far, we know relatively little about how traffic light carbon labels work. We find that neither environmental concern nor cognitive reflection affect how labels influence food choice. This means that the extent to which consumers are environmentally concerned does not explain whether traffic light carbon labels work. Similarly, the extent to which consumers can process numerical information does not explain whether traffic light carbon labels work.

These results suggest that future research need not necessarily study the effect of traffic light carbon labels via individual factors. Rather, the mechanism of information processing itself could be important.

Our research has limitations and suggests a call for further research. First, there are questions regarding the generalizability of the results. Women and young people were overrepresented in our sample. This

Table 2
Parameter estimates for mixed-effects logistic regressions.

H_{Label}: Effect of carbon footprint labels on food choice				
Fixed effects	***B***	***95 % CI***	***OR***	***95 % CI***
(Intercept)	−1.188**	−1.909, −0.466	0.305	0.148, 0.628
Traffic light label (versus control)	0.374**	0.147, 0.602	1.454	1.159, 1.825
Absolute label (versus control)	0.055	−0.170, 0.279	1.056	0.844, 1.322
Combined label (versus control)	0.299**	0.074, 0.524	1.348	1.077, 1.689
Vegetarianism	1.282***	0.652, 1.913	3.604	1.919, 6.774
Allergies	−0.064	−0.289, 0.161	0.938	0.749, 1.175
Age	−0.004**	−0.007, −0.001	0.996	0.993, 0.999
Gender	0.878***	0.705, 1.050	2.405	2.025, 2.857
Random effects	***SD***			
Participants (intercept)	1.160			
Food item (intercept)	1.113			
Observations	15,045			
Log likelihood	−8,316.411			
Deviance statistic	16,632.822			
AIC	16,652.822			
BIC	16,729.010			
$H_{Environmental\ concern}$ and $H_{Cognitive\ reflection}$: Moderating role of environmental concern and cognitive reflection				
Fixed effects	***B***	***95 % CI***	***OR***	***95 % CI***
(Intercept)	−4.631***	−6.062, −3.201	0.010	0.002, 0.041
Traffic light label × environmental concern	−0.264	−0.735, 0.206	0.768	0.480, 1.229
Absolute label × environmental concern	−0.336	−0.798, 0.126	0.715	0.450, 1.135
Combined label × environmental concern	0.117	−0.338, 0.572	1.124	0.713, 1.773
Traffic light label × cognitive reflection	−0.04	−0.247, 0.165	0.960	0.781, 1.179
Absolute label × cognitive reflection	0.098	−0.110, 0.306	1.103	0.896, 1.358
Combined label × cognitive reflection	0.104	−0.096, 0.304	1.109	0.908, 1.355
Traffic light label (versus control)	1.456	−0.409, 3.320	4.287	0.664, 27.672
Absolute label (versus control)	1.167	−0.690, 3.024	3.212	0.502, 20.570
Combined label (versus control)	−0.401	−2.222, 1.421	0.670	0.108, 4.141
Environmental concern	0.948***	0.631, 1.264	2.579	1.880, 3.538
Cognitive reflection	0.020	−0.127, 0.167	1.020	0.881, 1.182
Vegetarianism	1.295***	0.687, 1.903	3.651	1.987, 6.706
Allergies	−0.057	−0.273, 0.158	0.944	0.761, 1.171
Age	−0.005***	−0.008, −0.002	0.995	0.992, 0.998
Gender	0.726***	0.557, 0.895	2.066	1.745, 2.446
Random effects	***SD***			
Participants (intercept)	1.087			
Food item (intercept)	1.116			
Observations	15,031			
Log likelihood	−8,258.165			
Deviance statistic	16,516.331			
AIC	16,552.331			
BIC	16,689.453			

Note. Vegetarianism is coded from "not vegetarian" (0) to "vegetarian" (1). Allergies is coded from "no allergies" (0) to "allergies" (1). Significance coding = *** for $p < 0.001$, ** for $p < 0.05$, * for $p < 0.1$. Listwise deletion for missing data was performed. Because there were missing values for the covariates and moderators, the number of observations is smaller when including these variables. We provide alternative regression analyses for H_{Label} in Online Appendix

C, showing a significant effect on the part of labels (a) without entering any other covariates into the regression model (SI Table 3) and (b) after additionally entering environmental concern and cognitive reflection as covariates (SI Table 4). We provide alternative regression analyses for $H_{Environmental\ concern}$ and $H_{Cognitive\ reflection}$ in Online Appendix C, namely as pre-registered two separate regressions for $H_{Environmental\ concern}$ and $H_{Cognitive\ reflection}$. The results of the alternative analyses are essentially the same as in this table (see SI Table 5 and 6).

would be problematic if we wanted to make claims about the prevalence of certain views in the population. However, unrepresentative samples are typically unproblematic in terms of external validity when studying psychological processes (e.g., Druckman & Kam, 2011). Therefore, the limited representativeness of our sample is unlikely to represent a significant threat to our findings, but it should still be noted and considered a limitation. Second, hypothetical choice scenarios differ from real purchase situations. For example, real purchase situations involve many additional factors, such as price, packaging, and nutritional information, which can affect decisions. Even if these situational factors are held constant, there is often a discrepancy between consumers' hypothetical choices and actual purchase behavior (Ding et al., 2005). Thus, it remains unclear whether the labels we used would have the same influence in a real purchase situation. Based on previous research (e.g., Vanclay et al., 2011), we would expect that including realistic prices would attenuate the effect of the traffic light labels. Therefore, the next step would be to conduct field experiments, for example, in supermarkets or canteens (see, e.g., Brunner et al., 2018; Vanclay et al., 2011). Third, no information about or explanation of the labels was given to the participants. Therefore, it is not clear whether all participants fully understood the meaning of the label they saw. Providing additional information about the labels could increase the attention paid to the label when making decisions. Finally, the environmental impact of the products was determined in an ad-hoc manner based on the items used in this study. Future research could increase accuracy by using more products and more sophisticated estimation methods (e.g., lifecycle assessment (LCA)).

Author Note

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CRediT authorship contribution statement

Geraldine Holenweger: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Visualization, Project administration. **Sabrina Stöckli:** Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Visualization, Project administration. **Adrian Brügger:** Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Visualization.

Declaration of Competing Interest

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

Data availability

We share all our data and code via OSF.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2023.104813.

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