Appetite 167 (2021) 105622

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Measuring consumers' knowledge of the environmental impact of foods

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ARTICLE INFO

Keywords:
Environmental impact
Food
Knowledge
Consumer
Test
Questionnaire

ABSTRACT

Our daily food choices have a huge impact on the environment. However, most consumers are not aware of the environmental impact of food production and consumption. Since there is no valid and reliable measure of knowledge regarding food's environmental impact, a 16-item multiple-choice knowledge questionnaire was developed. An example item reads: "*Which of the following meals is the most climate friendly?" – Organic beef burger, Organic salmon burger, Quinoa burger, Do not know.* The knowledge questionnaire was tested in a Swiss and German consumer sample (total N = 1810) and meets standard psychometric criteria. It showed good internal consistency across the adult samples. Validity was supported by small to medium-sized positive correlations with constructs of environmental (e.g., environmental apathy) and food (e.g., perceived environmentally friendly food purchasing behavior) attitudes. By using a food buffet made of replica food items, it was shown that consumers with higher knowledge scores are better able to compose lunch menus with a lower environmental footprint. The new scale will help to identify potential areas of misconceptions in people's understanding of the environmental friendliness of foods and in what respect a lack of knowledge poses a barrier to behavioral change. It also enables research into the efficacy of educational measures such as campaigns and decision aids for sustainable food consumption.

1. Introduction

With the advent globalization, the food knowledge that consumers need and from which they benefit has changed dramatically. Before globalization, farmers produced food for nearby cities. Food variety and access were limited. People needed a basic understanding of food preservation, preparation, and output maximization. The development of food economies has led to a shift from a supply-driven food system to a demand-driven one, and consumer preferences have become increasingly important in the process (Hueston & McLeod, 2012). The resulting globalized food system has replaced traditional, decentralized, small-scale food production. This development has its advantages but also comes with costs. With an ever-expanding variety of food products from all over the world in diverse sales locations, it becomes necessary and, at the same time, more difficult for consumers to evaluate products—for instance, in terms of healthiness, environmental friendliness, and social justice. Nevertheless, the ability to select foods with a high nutritional value and a small environmental footprint seems to be a desirable food skill nowadays (Willett et al., 2019).

However, surprisingly little is known about laypeople's level of knowledge of the environmental friendliness of foods. Using healthiness or dietary recommendations as decision aids for environmental friendliness assessments is not always sufficient. Studies have shown that simply following dietary recommendations does not automatically lead to a more environmentally friendly diet (Perignon, Vieux, Soler, Masset, & Darmon, 2017; van de Kamp et al., 2018). Thus, relevant knowledge is a prerequisite. When consumers are directly asked to evaluate the environmental friendliness of foods—for instance, in terms of energy consumption and greenhouse gas emissions—they often rely on factors such as organic labels as indicators (Camilleri, Larrick, Hossain, & Patino-Echeverri, 2019; Lazzarini, Zimmermann, Visschers, & Siegrist, 2016; Siegrist & Hartmann, 2019). Some consumers appear to question the environmental impact of meat production and are sceptical about the constantly changing scientific evidence (Macdiarmid, Douglas, & Campbell, 2016). However, consumers who have some relevant knowledge are more likely to make environmentally friendly choices (Peschel, Grebitus, Steiner, & Veeman, 2016). Nevertheless, in everyday life, food choices are often habitual and influenced by many interacting

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https://doi.org/10.1016/j.appet.2021.105622
Received 16 December 2020; Received in revised form 2 July 2021; Accepted 2 August 2021
Available online 4 August 2021

factors. Food-related knowledge is only one of these factors. However, a question that arises is whether people who are motivated to eat more environmentally friendly foods have sufficient knowledge to make appropriate choices or whether good intentions may result in bad decisions due to a lack of knowledge.

1.1. Environmental impact of food

It has been estimated that between 20% and 30% of humans' total environmental impact is related to food production (Tukker & Jansen, 2006). Particularly meat production is extremely resource-intensive in terms of land use and freshwater withdrawals, causing environmental problems such as terrestrial acidification and eutrophication (e.g. Gerber et al., 2013; Poore & Nemecek, 2018), and constitutes a major source of greenhouse gas emissions (e.g. CO2 and methane). For most food products, agricultural production accounts for most of the environmental impact, while other product stages, such as processing, packaging, or distribution, have a lesser impact (Nemecek, Jungbluth, Canals, & Schenck, 2016). Moreover, the environmental impact of a product does not change significantly depending on whether it is produced organically or conventionally (Nemecek et al., 2016), although this may be important in other aspects, such as animal welfare or agro-biodiversity (Mondelaers, Aertsens, & Van Huylenbroeck, 2009). More important in terms of environmental impact is whether meat originates from ruminants, such as cattle and sheep, or from non-ruminants, such as poultry and pigs. Ruminant meat production contributes considerably more heavily to greenhouse gas emissions and excessive land use (Stehfest et al., 2009). Moreover, the environmental footprint of products is multiplied when they are transported by air and has a much stronger impact than production system factors such as organic farming (Jungbluth, Tietje, & Scholz, 2000; Nemecek et al., 2016). Dairy production has a similarly large environmental footprint (Tukker & Jansen, 2006). Although there is high variability between producers and production systems (Poore & Nemecek, 2018), the environmental impact of meat is considerably greater than that of grains, vegetables, and other plant-based foods, regardless of how it is assessed (Poore & Nemecek, 2018). Based on a meta-analysis that included data from more than 38,700 farms in 119 countries, Poore and Nemecek (2018) concluded that processors, distributors, and retailers have enormous potential to reduce their impact—for instance, by reducing waste.

Today's food system needs to become much more sustainable (Willett et al., 2019). A complementary approach to changing the system is to increase consumers' awareness of sustainable food choices and enable informed decision-making with regard to dietary behaviour (Camilleri et al., 2019). Researchers have identified many reasons why consumers struggle with such behaviour (e.g., Bryła, 2016; Harguess, Crespo, & Hong, 2020; Hartmann & Siegrist, 2017). However, it appears that the reasons for the lack of public knowledge of the environmental impact of food production and consumption have not been systematically explored, as an appropriate assessment tool has been lacking.

1.2. Measuring knowledge of the environmental impact of food

In this study, we developed, validated, and tested a questionnaire for the assessment of knowledge of the environmental impact of food. The questionnaire was designed to test laypersons' factual knowledge of the environmental impact of certain food choices and food production activities.

We focused on the aspects of "environmentally friendly" and "climate friendly" food choices. We refer to the environmental impact of a food product through its life cycle, including production, transportation, and consumption, which can be estimated using life cycle assessments (LCAs) (Roy et al., 2009). However, the environmental impact of food production and consumption is only one aspect of the overly complex concept of food sustainability, which encompasses social, economic, and environmental aspects. While there are reliable methods for assessing environmental (e.g., LCA), economic (e.g., life cycle costing), and social (e.g., social life cycle assessment) impacts, research has focused mainly on the environmental impact. There has been no established method that systematically combines all aspects into a single overall sustainability score to enable comparisons between foods (Harangozó, Széchy, & Zilahy, 2016). Importantly, it is not always possible to evaluate the environmental friendliness of certain food products or food groups because of a lack of LCA data. Thus, we focused on aspects of food's environmental impact with the greatest practical relevance (e.g. plant-based versus meat-based) and aspects for which unambiguous statements can be made based on available scientific knowledge.

The new measurement tool was not designed to measure actual environmentally friendly behaviours or attitudes, even though such relationships can be expected. Likewise, the scale does not measure knowledge of healthy food choices, the calorie content of foods, or any other factors related to the evaluation of foods from a nutritional, physiological point of view, and does not represent a nutritional recommendation. The tool focuses on food items and groups typically consumed in Western and Westernized countries, although adaptation to a particular country's context and food system may be indicated. For instance, one knowledge question asks about fruits that can be harvested in the summer. Correct responses may differ between northern (e.g. Finland) and southern (e.g. Italy) countries; therefore, the responses need to be adapted to specific countries. Lastly, although the questions were designed to vary in difficulty levels, expert knowledge of LCAs or instruments for evaluating the environmental friendliness of foods is not necessary.

The scale was developed and tested in five steps and five study samples. In steps 1 to 3, the best-performing items were selected, and the resulting questionnaire was validated in two countries. In step 4, an experimental study examined whether persons achieving high scores on the questionnaire were better at composing environmentally friendly lunch menus. Finally, in step 5, the instrument's test-retest reliability was assessed. An overview of the steps is displayed in Fig. 1.

Fig. 1. Overview of the five steps in the development and validation process of the knowledge questionnaire.

2. Scale construction

Step 1 included the development of an initial item pool. The items were pretested, and the best performing items were selected.

2.1. Methods

2.1.1. Item generation

A working group consisting of a psychologist, an environmental scientist, and a nutritional scientist developed questions that aimed to measure people's knowledge about the environmental friendliness of food choices. An initial set of 40 questions was created that covered a diverse range of topics related to food production and transportation and sustainable food choices. Questions were developed in a multiple-choice format including a "don't know" answer option. The words used for the questions were kept as simple as possible, and technical terms were avoided. Correct answers are backed up by research and data (see Supplement B).

2.1.2. Participants

Pretesting was conducted through an online survey with 612 Swiss adults ranging in age from 20 to 70 years (M = 45.5 years, SD = 14.5). The study participants were recruited from an Internet panel from a commercial provider of sampling services (Respondi AG). Excluded were respondents who did not complete the survey (n = 27) and whose total survey duration was less than half of the median of the total survey duration (e.g., Hartmann, Keller, & Siegrist, 2016), which indicates that the respondent did not answer the questions seriously (n = 48). Quota samples were used with the quota variables of gender (50% men, 50% women) and age (equal number of participants in every age group). Table 1 shows the sociographic characteristics of the study sample.

2.1.3. Item analyses

Correct responses were scored as one point, while incorrect and "don't know" answers were scored zero. Since the option "forced response" (available for online surveys) was used, there were no cases of missing data.

In accordance with the procedure described by Parmenter and Wardle (1999), for the development of the general nutrition knowledge questionnaire, the performance of the individual items was evaluated for item discrimination and item difficulty. Thus, items with corrected item-total correlations lower than 0.2 were excluded in an iterative process. Moreover, percentages of correct answers were used as an indication of item difficulty. Items are not particularly useful when they are answered correctly by more than 80% or less than 20%. Thus, items that did not meet these criteria were excluded. Effort was also put forth to ensure that items were evenly varied on a spectrum from easy to difficult. Lastly, the reliability coefficient alpha was calculated for internal consistency of the scale. Items were excluded when the resulting Cronbach's alpha was higher or when the removal of an item did not affect reliability or when they were redundant with other higher-order items. When items were considered particularly important in terms of content validity, deviations from the criteria described above were accepted (Parmenter & Wardle, 1999).

All statistical analyses were performed using the SPSS Statistics software package version 26 (SPSS Inc., Chicago, IL).

2.2. Results and discussion

A set of 16 best-performing items was selected. All items had corrected item-total correlations between 0.23 and 0.45 except for Q16 (0.10), where it was below the threshold of 0.20. Q16 asks about the seasonality of commonly consumed fruits in Switzerland, and only 15% answered the question correctly. Thus, consumers seem to lack knowledge about local growing seasons, probably because of the availability of many fruits all year round in the supermarket (Wilkins, 2002). Two other questions were answered correctly by less than 20% (i.e., Q11, Q12). These two items capture very important knowledge areas when it comes to meat substitutes, the evaluation of different kinds of meat, and knowledge related to transportation. All three items were kept in the final set of items, because they capture relevant knowledge aspects that would otherwise not be assessed in the questionnaire.

Q15 was the only item above the threshold of 80% correct responses. More than 92% answered it correctly in this first study. However, because previous research has shown that bottled water and recycled water are prone to misconceptions (Etale & Siegrist, 2018; Rozin, Haddad, Nemeroff, & Slovic, 2015), the item was considered important for, for instance, cross-country research or subgroup analyses. Finally, Cronbach's alpha was α = .72, which is acceptable.

The final set of selected items was discussed with another group of experts in the field (i.e., environmental scientists, psychologists) regarding face and content validity as well as phrasing of the items. Some items were slightly revised to increase comprehensibility. The final knowledge questionnaire is depicted in Table 2 in English and in the Supplement A in German.

Table 1
Sociodemographic characteristics of the study samples.

	Step 1	Step 2	Step 3	Step 4	Step 5
	Scale development	Validation national (Switzerland)	Validation international (Germany)	Food choice experiment	Test-Retest
N	612	506	506	40	146
Men [%]	49.5	49.6	48.8	35	61.6
Age [Mean (sd)]	45.5 (14.5)	45.3 (14.3)	45.3 (14.6)	30.28 (13.6)	62.7 (12.1)
20–39 years [%]	37.3	37.2	37.2	82.5	5.5
40–64 years [%]	50.7	53.0	52.1	12.5	46.6
65–79 years [%]	12.1	9.9	10.7	5.0	42.5
80 + years [%]	/	/	/	/	5.5
Education [%]					
Primary, lower secondary school	5.9	4.2	8.1	17.5	3.4
Secondary school, vocational education, senior high school	50.2	53.9	40.3	42.5	30.1
Higher vocational education	18.3	18.8	13.4	5.0	28.8
College, university and above	25.7	22.6	36.0	32.5	37.7
Missing/no education	/	0.6	2.2	/	/

Table 2
Final 16-item food's environmental impact knowledge questionnaire (English translation for publication, German version Supplement A).

The next questions are about foods and their life cycle assessment, in particular, which negative effects their production, processing, distribution and storage have on the environment. Unless otherwise stated, the products concerned are conventionally produced (not organic products). Please indicate the answer that you think is correct. If you are unsure, please click on "don't know" instead of guessing. This increases the accuracy of the results.
Q1 The largest environmental impact in the food sectors has … ☑ Production ☐ Storage ☐ Packaging ☐ Transportation (Ship, truck) ☐ Do not know
Q2 Production of meat and milk products leads to higher CO2 emissions per kg than production of vegetables. ☑ Right ☐ Wrong ☐ Do not know
Q3 The production of 1kg of beef causes more greenhouse gases than the production of 1kg of wheat. ☑ Right ☐ Wrong ☐ Do not know
Q4 The negative effects of food consumption on the environment can be reduced by switching to a vegetarian diet (no meat consumption). ☑ Right ☐ Wrong ☐ Do not know
Q5 Which of the following foods is associated with the lowest climate impact (per 100g)? ☐ Potato chips ☑ Bread roll ☐ Salami stick ☐ Do not know
Q6 Which of the following foods is associated with the lowest climate impact (per 100g)? ☐ Milk chocolate ☐ White chocolate ☑ Dark chocolate ☐ Do not know
Q7 Which of the following meals is the most climate friendly? ☐ Pasta with beef bolognese ☑ Pasta with vegetable and tomato sauce ☐ Do not know
Q8 Which of the following meals is the most climate friendly? ☐ Organic beefburger ☐ Organic salmon burger ☑ Quinoaburger ☐ Do not know
Q9 Which of the following meals is the most environmentally friendly? ☐ Kebab with meat ☑ Kebab with falafel ☐ Do not know

Q10 Which of the following meals is the most environmentally friendly? ☐ Beef ragout, mashed potatoes and beans ☐ Poultry ragout, mashed potatoes and beans ☑ Mushroom ragout, mashed potatoes and beans ☐ Do not know
Q11 Which product is the most environmentally friendly? ☐ 100 g asparagus from overseas (air transport) ☐ 100 g Swiss chicken ☐ 100g Swiss beef ☑ 100 g tofu from overseas (ship transport) ☐ 100 g Swiss pork ☐ Do not know
Q12 You want to prepare a dinner that is as environmentally friendly as possible. Which ingredient do you choose for the main course? ☑ Tofu from overseas ☐ Swiss beef meat loaf ☐ Do not know
Q13 You want to prepare a dinner that is as environmentally friendly as possible. Which side dish do you choose? ☐ Asparagus (flight import) ☑ Beans (ship import) ☐ Do not know
Q14 Which beverage is more environmentally friendly? ☐ Coffee ☑ Black tea ☐ Do not know
Q15 Which beverage is more environmentally friendly? ☐ Mineral water ☑ Tap water ☐ Do not know
Q16 Which of the following fruits can be harvested outdoors in Switzerland throughout the summer (June to August)? (Several answers possible) ☑ Strawberries ☑ Cherries ☐ Pears ☐ Kiwi ☐ Banana ☐ Do not know

Note. People receive 1 point if they ticked the right answer. No point for "do not know" or wrong answer. The maximum number of points achievable is 16. No point should be allocated for multiple answers (except Q16). For Q16, only if both of the right answers are ticked, the point is allocated.

3. Scale validation Switzerland

The next step tested whether the item performances from the first study could be replicated in another sample of Swiss adults. Moreover, convergent and discriminant validation was performed in a national sample. The questionnaire was validated with constructs related to environmental attitudes and environmentally friendly food purchasing behavior.

A positive correlation was expected between knowledge scores and measures of environmental consciousness or concern. The established and validated "New Ecological Paradigm" scale (Dunlap, Van Liere, Mertig, & Jones, 2000; German translation by Schleyer-Lindenmann, Ittner, Dauvier, & Piolat, 2018) was used to measure pro-environmental value orientation and an "ecological worldview." Previous research showed that the scale differenciates between environmentalists and the general public or members of non-environmental interest groups (Dunlap et al., 2000). A relationship with general environmental knowledge was observed in several studies as well (e.g., Arcury,

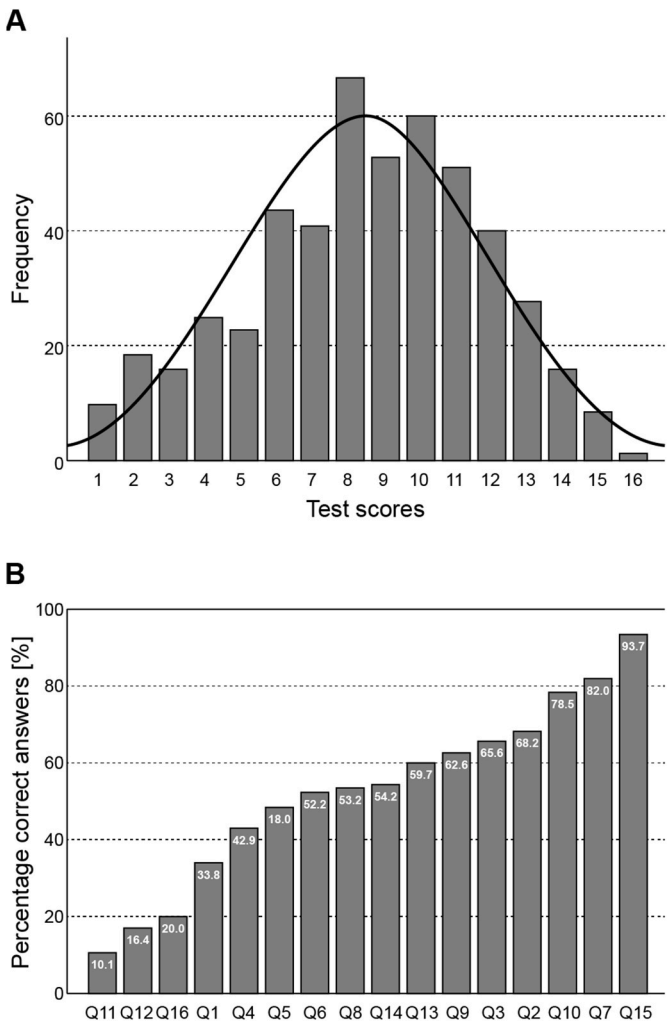

Fig. 2. (A) Distribution of the knowledge questionnaire variable. (B) Percentage correct answers per question. Data from Step 2, Switzerland (N = 506).

Johnson, & Scollay, 2010). Thus, a statistically significant correlation was expected. Additionally, climate change concern was measured (Tobler, Visschers, & Siegrist, 2012). In previous research, knowledge about climate change was the strongest predictor for climate change concern (Tobler et al., 2012). It was expected that persons with higher levels of climate change concern might also be more knowledgeable in the area of food's environmental impact. Two additional constructs were used for validity testing. These were environmentally friendly purchasing behavior when food shopping (Schlegelmilch, Bohlen, & Diamantopoulos, 1996) and diet-related health consciousness. The latter was used for testing discriminant validity, nevertheless, we expected a small-sized positive correlation because it is linked to the food domain.

Table 3
Mean values, range observed and Cronbach's alpha for the knowledge test on the environmental friendliness of foods in the three study samples as well as correlation coefficients between the test scores and validation constructs.

	Step 2 Validation Switzerland	Step 3 Validation Germany	Step 4 Food choice
Study type	Online survey	Online survey	Experiment
N	506[1]	506[1]	40
Knowledge food's env. Impact			
Mean (SD)	8.4 (3.4)	7.7 (3.3)	10.2 (2.4)
Range observed	0–16	0–15	3–15
Cronbach's alpha	.77	.77	.56
	Correlations with knowledge test scores		
Sociodemographic variables			
Age	ns	-.11*	ns
Education	.25***	.23***	ns
Environmental Attitudes			
New Ecological Paradigm Scale	-.11*	–	–
Climate Change Concerns	.16**	–	–
EAS –Anthropocentrism	–	ns	–
EAS –Environmental apathy	–	-.28***	–
EAS –Ecocentrism	–	.18***	–
Food attitudes			
(Perceived) Pro-environmental Purchase Behavior	.24***	.27***	–
Health Consciousness	.25***	.30***	–

Note. ***p < .001, **p < .01, *p < .05. EAS: Environmental attitude scale; ns: not statistically significant.
[1] Exact same number of participants is a coincidence.

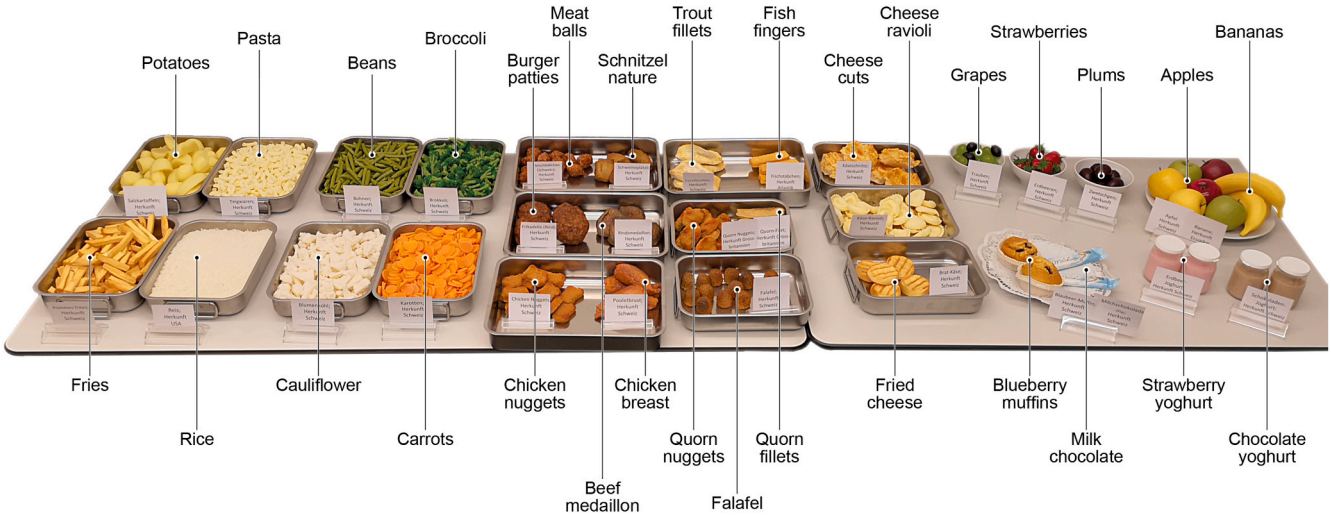

Fig. 3. The Fake Food Buffet including (from left to right) side dishes, vegetables, meat products, meat substitutes, cheese products and desserts.

3.1. Methods

3.1.1. Participants

An online survey was conducted in the German-speaking part of Switzerland. Study participants were recruited from an Internet panel from a commercial provider of sampling services (Respondi AG). Excluded were respondents who did not complete the survey and whose total survey duration was less than half of the median of the total survey duration (e.g., Hartmann et al., 2016), which indicates that the respondent did not answer the questions seriously (n = 55). Quota samples were used with the quota variables of gender (50% men and 50% women) and age (equal number of participants in every age group from 18 to 79 years). The final sample consisted of 506 persons (50% female) ranging in age from 18 to 79 years (M = 45 years, SD = 14). Participants reported their highest educational degree, and approximately 23% had a high educational level (Table 1). The study was approved by the Ethics Committee of ETH Zurich (EK 2019-N-05).

3.1.2. Validation constructs

Next to participants' sociodemographic information, the following constructs were assessed.

The translated and validated German version (Schleyer-Lindenmann et al., 2018) of the original New Ecological Paradigm scale (NEP scale) was used (Dunlap et al., 2000). Accordingly, participants' levels of environmental concern and attitudes were measured with 15 items. Two sample items read: "When humans interfere with nature, it often produces disastrous consequences" and "Humans were meant to rule over the rest of nature." Response options varied from "totally agree," (coded 1) "tend to agree," (2) "unsure," (3) "tend to not agree," (4) and "do not agree at all." (5). Cronbach's alpha was good (α = .80), and the observed mean value was M = 2.23 (SD = 0.53), with low values indicating higher levels of environmental concern.

Climate change concern was assessed with the following four items (Tobler et al., 2012): "We must protect the climate's delicate equilibrium"; "Climate protection is important for our future"; "I worry about the climate's state"; and "Climate change has severe consequences for humans and nature." People indicated their level of agreement on a six-point response scale ranging from "do not agree at all" (1) to "totally agree" (6). Only extreme categories were verbally labeled. Cronbach's alpha was good (α = .94), and the observed mean value was M = 4.95 (SD = 1.10).

Environmentally friendly food purchasing behavior was assessed with three items (adapted from Schlegelmilch et al., 1996). Participants were asked how often they do the following things when food shopping: "Choosing the environmentally friendly alternative if one of a similar price is available"; "Choosing the environmentally friendly alternative regardless of price"; and "Try to discover the environmental effects of products prior to purchase." Response options were "never" (coded 1), "seldom" (2), "sometimes" (3), "often" (4) and "always" (5). Cronbach's alpha was good (α = .75), and the observed mean value was M = 2.89 (SD = 0.86).

The following four items were used to assess diet-related health consciousness: "I think it is important to eat healthily"; "My health is dependent on how and what I eat"; "If one eats healthily, one gets ill less frequently"; and "I am prepared to leave a lot to eat as healthily as possible" (Dohle, Hartmann, & Keller, 2014; adapted from; Schifferstein & Ophuis, 1998). Response options ranged from 1 "not at all" to 7 "very much." Only the two extreme categories were labeled. Cronbach's alpha was good (α = .78), and the observed mean value was M = 5.10 (SD = 1.10).

3.1.3. Statistical analyses

The percentage of correct answers was analyzed. Internal reliability was assessed using Cronbach's alpha. Since the option "forced response" (available for online surveys) was used, there were no cases of missing data. Pearson's correlation coefficients were calculated for the scores achieved in the knowledge questionnaire and the validation constructs. All statistical analyses were performed using the SPSS Statistics software package version 26 (SPSS Inc., Chicago, IL).

3.2. Results

The internal reliability of the knowledge questionnaire was 0.77. The scores were normally distributed (Fig. 2A and 3). Percentages of correct answers for each question are displayed in Fig. 2B.

Correlations between knowledge questionnaire and validation constructs are displayed in Table 3. Scores achieved on the knowledge questionnaire did not correlate with age but were statistically significantly correlated with education ($r = .25$, $p < .001$). The knowledge scores correlated positively with climate change concern ($r = .16$, $p < .01$), environmentally friendly food purchasing behavior ($r = .24$, $p < .001$), and health consciousness ($r = .25$, $p < .001$). A negative correlation was observed with the NEP scale ($r = -0.11$, $p < .05$), which indicates that participants with lower NEP scores (i.e., higher levels of environmental concern and pro-environment attitudes) achieved higher knowledge scores.

3.3. Discussion

The results of the presented first validation study provide support for the convergent and discriminant validity of the knowledge questionnaire. As anticipated, participants with a higher educational level also had more correct answers in the knowledge test. Age, however, was not a significant correlate.

Furthermore, the results showed that persons with a pro-environmental orientation and who are more concerned about climate change also had more knowledge about the environmental impact of foods. Nevertheless, the effects were small. For a very long time, the food domain was neglected in the societal discussion about environmentally friendly behavior. Recently, with the EAT-Lancet report (Willett et al., 2019), the environmental footprint of foods has increasingly come to attention. But still, it seems imaginable that even those consumers who are more environmentally oriented lack corresponding knowledge when it comes to food.

A positive correlation between knowledge scores and pro-environmentally friendly food purchasing behavior was observed. In fact, the environmentally friendly food purchasing behavior scale measures whether people, if they have a choice, select the environmentally friendly alternative. However, the definition of "environmentally friendly alternative" is left up to the participants. From previous research, we know that people are not good at estimating the environmental impact of food production and consumption (Hartmann & Siegrist, 2017) and that they also tend to overestimate product attributes such as packaging (Lazzarini, Visschers, & Siegrist, 2017). Strategies that consumers use to evaluate the environmental friendliness of products, when they do not have the relevant knowledge, are heuristics, such as that organically grown is always better or that if the product is healthy, it must be better for the environment (Lazzarini et al., 2017). Thus, the observed medium-sized correlation seems to be caused by the fact that the scale used rather measures motivation to buy environmentally friendly and willingness to pay more for these products but not necessarily the ability to identify the environmentally friendly option. Another observation that supports these interpretations is that perceived environmentally friendly food purchasing behavior correlated rather high with climate change concern ($r = .54$, $p < .001$) and with the NEP scale ($r = -.30$, $p < .001$). Again, the two validation constructs also share variance because they both measure underlying attitudes and motivations and are thus strongly linked to environmentally friendly food purchasing behavior, but they do not measure the ability to behave

[1] Data can be made available on request.

accordingly.

Lastly, knowledge is not equal to behavior, and even though people might have a basic understanding of food's environmental impact, diverse motivational and practical barriers ranging from price, to negative taste expectations, to low availably might prevent consumers from buying the environmentally friendly option (Bryła, 2016; Moser, 2015; Tanner & Wölfing Kast, 2003).

Considering the positive correlation with health consciousness, it is possible that persons who are more health conscious when it comes to eating also have greater general knowledge about foods.

4. Scale validation Germany

Having provided initial support for the convergent and discriminant validity of the new knowledge questionnaire in Switzerland, a third step tested whether the knowledge scale works equally well in another country. Germany was the country of choice because of its language similarity with the German-speaking part of Switzerland. Of note is that the wording of three items needed to be adapted for the German context because they ask about country-specific meats and seasonal fruits. Again, variables related to environmental and food-related attitudes were used for validation.

4.1. Methods

Data collection took place in Germany by means of an online survey.

4.1.1. Participants

An internet panel from a commercial provider of sampling services (Respondi AG) was used for recruiting the study participants. Participants received a small financial reward for filling in the whole questionnaire. Excluded were respondents who did not complete the survey and whose total survey duration was less than half of the median of the total survey duration (e.g., Hartmann et al., 2016), which indicates that the respondent did not answer the questions seriously (n = 62). Quota samples were used with the quota variables of gender (50% men and 50% women) and age (equal number of participants in every age group from 18 to 80 years). The final sample consisted of 506 persons (48.8% men) ranging in age from 18 to 79 years (M = 45, SD = 15). The study was approved by the Ethics Committee of ETH Zurich (EK 2019-N-05).

4.1.2. Validation constructs

Environmental attitudes were assessed with the German version of the questionnaire by Thompson and Barton (1994) published by Siegrist (1996). Participants had to indicate their level of agreement in regard to 16 items measuring egocentrism (protecting nature because of its intrinsic values), anthropocentrism (protecting nature because of its benefits for humans), and apathy toward environmental issues. Example items are "Nature is valuable for its own sake" (ecocentrism, Cronbach's alpha = .87); "Continued land development is a good idea as long as a high quality of life can be preserved" (anthropocentrism, alpha = .70); and "Environmental threats such as deforestation and ozone depletion have been exaggerated" (environmental apathy, alpha = .86).

Additionally, two constructs included in the Swiss survey were also included here: environmentally friendly food purchasing behavior and health consciousness. In addition to the knowledge questionaire of the environmental impact of foods, sociodemographic variables were also assessed.

4.1.3. Statistical analysis

Internal reliabilities for all scales were assessed using Cronbach's alpha. Since the option "forced response" (available for online surveys) was used, there were no cases of missing data. Pearson's correlation coefficients were calculated for the knowledge scale and the validation constructs. Lastly, an independent samples *t*-test was conducted for knowledge scores, health consciousness, and environmentally friendly food purchasing behavior between Germany and Switzerland by including data from step 2. All statistical analyses were performed using the SPSS Statistics software package version 26 (SPSS Inc., Chicago, IL).

4.2. Results

The results are depicted in Table 3. A positive correlation between the knowledge scores and education, environmentally friendly food purchasing behavior ($r = .27$, $p < .001$), and health consciousness ($r = .30$, $p < .001$) as well as ecocentrism ($r = .18$, $p < .001$) was observed. Further analysis showed a negative correlation between environmental apathy and scores achieved on the knowledge questionnaire ($r = -0.28$, $p < .001$).

The scores observed in the German (M = 7.68, SD = 3.32) and the Swiss (M = 8.41, SD = 3.35) sample were statistically significantly different ($t(1010) = 3.48$, $p = .001$), but health consciousness and environmentally friendly food purchasing behavior did not statistically significantly differ between countries ($p > .05$).

4.3. Discussion

The results provide support for the applicability of the knowledge scale in another German-speaking country. In both countries – Germany and Switzerland – quota samples were used; thus the distribution of gender and age was similar. The German sample consisted of more highly educated participants, but still, on average, they scored lower on the knowledge questionnaire than did Swiss participants, and none of the participants in Germany received full points. These results indicate that knowledge about food's environmental impact in Germany is lower than in Switzerland.

The correlations between the validation constructs and the knowledge scale were as expected. Perceived environmentally friendly food purchasing behavior and health consciousness were positive correlates in size and direction, similar to the relationships observed in Switzerland. Environmental apathy was negatively correlated with the achieved knowledge test score. Participants with high scores on the subscale environmental apathy consider it unnecessary to protect the environment and think that threats to the environment have been exaggerated (Siegrist, 1996; Thompson & Barton, 1994). This attitude seems to come along with a lack of knowledge concerning the environmental friendliness of food choices.

We decided to include a "don't know" response option in the knowledge questionnaire and encouraged participants before the test to use this option instead of guessing. This is a widely used approach for knowledge scales (e.g., Mötteli, Barbey, Keller, Bucher, & Siegrist, 2016; Parmenter & Wardle, 1999). However, it might be that the results between countries and cultural regions differ because participants' propensity to guess might differ between countries and cultural regions. Additionally, uninformed participants who guess instead of using the "don't know" option will by chance achieve higher scores and thus knowledge level is slightly overestimated in these participants. However, we clearly recommend using a "don't know option" for the knowledge test.

5. Food choice experiment

In the fourth step, we investigated whether persons who achieved higher scores on the knowledge scale are better able to compose an environmentally friendly menu in a buffet situation. We hypothesized that persons who achieved higher knowledge scores have a more general understanding of food's environmental impact and will be better at composing environmentally friendly menus. Environmental friendliness for the composed menus was determined by the use of eco-points, which are the result of a specific life cycle assessment method, and which have been used in previous studies (Lazzarini et al., 2016). The buffet was compiled of replica food items (fake foods). The fake food buffet (FFB)

method is a validated research tool that enables the investigation of food selection behavior in a buffet setting in a standardized manner (Bucher, van der Horst, & Siegrist, 2011, 2012).

5.1. Methods

5.1.1. Participants

A convenience sample was recruited via Swiss websites during the months of August to October of 2018. Additionally, participants were recruited by inviting acquaintances or via the Internet panel of the Consumer Behavior group at ETH Zurich (persons who have agreed to take part in studies from time to time). Participants who took part in the study had to be at least 18 years old and fluent in German. Moreover, participants should not follow any special dietary regime (e.g., vegan, vegetarian) or suffer from food allergies or food intolerances. Lastly, participants were allowed to take part only if they were not trained in environmental science and related fields or if they had previously participated in other food studies. Overall, 40 participants between 18 and 74 years (M = 30, SD = 14) took part, of which 65% were female and 35% were male (Table 1). Before the experiment started, each participant was informed about the tasks and had to give their written consent. The study was part of a larger experiment about the effects of different types of food product information (e.g., conventional vs. organically produced) on food selection behavior. The whole experiment consisted of four experimental conditions, and participants were randomly assigned to one out of the four conditions. For the present study, only data from one group were analyzed. The study was approved by the Ethics Committee of ETH Zurich (EK 2018-N-62).

5.1.2. Study protocol

The study consisted of an interactive part with the fake food buffet (FFB) and an online questionnaire. Participants were tested individually. For the interactive part, the participants' task was to select for themselves an environmentally friendly lunch meal from the FFB. They were asked to imagine that the time of year is end of August/beginning of September. After introducing the FFB, the experimenter handed the participant a card with the written instructions. Participants were asked to serve themselves an environmentally friendly menu that they would eat. When the participant indicated that he/she had finished the task, he/she was asked to check the selected environmentally friendly lunch meal for completeness and whether the amounts served were reasonable. If needed, the participant had the opportunity to correct the selected meal. Lastly, the participant was asked to fill out the online questionnaire. Participants received 20 CHF ($20.61) in compensation, and the experimenter explained the aim of the study. Photos were taken of each composed meal, and food items were counted (e.g., meat products) or weighed (e.g., vegetables).

5.1.3. Fake food buffet

The food items were replica foods produced by the German company Döring GmbH in Munich (www.attrappe.de/). The FFB used in the present study was composed based on 31 food items. The buffet was supposed to reflect a typical buffet that can be found in a Swiss canteen. Thus, it contained four side dishes, four kinds of vegetables, six different kinds of meat products, five meat substitutes, three cheese products, and nine dessert options (Fig. 2). Alternative degrees of environmental friendliness of the food products were included, for instance, based on various food processing degrees (e.g., boiled potatoes vs. fries), meat and meat-free options, and regional (e.g., apples) and imported (e.g., banana) food products. Foods on the buffet were labeled with their respective names as well as Switzerland as the country of origin except for those few products that cannot be grown or produced in Switzerland (e.g., rice).

The theoretical energy contents of the replica food items (kJ per 100 g) were calculated. A conversion factor needs to be multiplied with the energy content of the corresponding real food. Further methodological details are described elsewhere (Bucher et al., 2011, 2012).

5.1.4. Life cycle assessment and eco-points (EP)

A life cycle assessment is an established tool used to assess environmental impacts induced by all stages of the life cycle of a product, process, or service. Different methods can be applied within this tool (Roy et al., 2009). We used the ecological scarcity method, which aggregates a broad range of environmental impacts into an easily comparable one-score impact value measured in EP per unit of quantity (Frischknecht & Büsser Knöpfel, 2013). The environmental impacts of pollutant emissions and resource extraction are taken into account and are evaluated in relation to politically defined environmental protection goals and aims. The more the pollutant emissions and resource extractions exceed environmental protection goals, the higher the EP. Thus, the higher the EP for a specific food, the more damaging it is assumed to be to the environment. The LCA for the products[1] used in the present study were conducted by the Swiss sustainability consulting company ESU Service Ltd. (http://esu-services.ch/).

The sustainability of the self-served lunch menu was expressed in eco-points (EP). EPs per self-served meal kilojoule ($EP_{per\ meal\ kJ}$) were calculated using the formula displayed below (Eq. 1). The calculation was based on the EP of the single foods ($EP_{food\ n}$) multiplied by its derived energy ($kJ_{food\ n}$) and divided by the total energy of the meal (kJ_{meal}).

Eco-points (EP) per self-served meal kJ:

$$EP_{per\ meal\ kJ} = \frac{\sum_{n=1}^{31}(EP_{food\ n} * kJ_{food\ n})}{kJ_{meal}}$$

5.1.5. Questionnaire

The questionnaire contained the knowledge scale and questions about sociodemographic factors. Additionally, participants had to indicate how hungry they felt when they arrived at the research facilities. Response options varied from "not at all" (1) to "very much" (6). Lastly, the authenticity of the fake food buffet was assessed (1 = "not realistic at all" to 6 = "very realistic").

5.1.6. Statistical analysis

Pearson correlation coefficients were calculated for the variable EP per served kJ (EP/kJ) and the variables hunger level, education, and scores achieved on the knowledge scale. For the latter relationship, a directed hypothesis was tested (i.e., the higher the knowledge scores, the lower the EP/kJ), and thus the significance value for a one-tailed test was used. Data were analyzed using the SPSS Statistics software package version 26 (SPSS Inc., Chicago, IL).

5.2. Results

Participants achieved on average 10.2 (SD = 2.4) points on the knowledge scale, and the observed range was 3–15 points (Cronbach's alpha = .56). The FFB was rated as authentic by the vast majority of participants (M = 4.5, SD = 1.30), which promotes natural behavior in an experimental setting. The majority of participants chose meat (55%). Half of the participants who did not choose meat chose fish. Thus, only 22% of the total sample chose neither fish nor meat. Out of all participants, 16 chose a meat substitute, of which 50% chose both a meat alternative and meat/fish.

The EP per self-served kJ was on average 1.5 (SD = 0.77). EP/kJ was neither correlated with hunger level nor with age. However, EP/kJ correlated statistically significantly with the scores achieved on the knowledge scale ($r = -0.28$, $p < .05$, one-tailed). These results indicate that participants who achieved higher scores on the knowledge scale also composed environmentally friendlier meals in the food experiment.

5.3. Discussion

The results showed that participants who achieved higher scores in the knowledge questionnaire composed more environmentally friendly menus than participants who achieved lower knowledge scores. To the best of our knowledge, consumers' ability to transfer knowledge into practice in this regard has not been experimentally investigated previously.

The FFB was composed in a way such that it offered variety and alternative food options. Participants were instructed to select for themselves an environmentally friendly menu. In doing so, diverse strategies could be applied to reduce the environmental impact of the chosen menu, such as choosing seasonal and regionally produced foods and substituting animal-based protein with plant-based protein. Participants might have been aware of some of these strategies or might have false beliefs and misconceptions considering the environmental impact of some food products. We did not assess which strategies and heuristics participants used to select the most environmentally friendly option. A think-aloud study could give further insights. But interestingly, the majority of the participants chose meat or fish products for their meals. Some participants might have replaced meat with fish in the belief that it improved the environmental friendliness of the menu. Even though participants were supposed to compose an environmentally friendly meal, only very few composed a menu with neither meat nor fish. The meat products on the menu were labeled as being of Swiss origin. Consumers tend to overestimate the impact of the origin of certain products for their environmental friendliness (Lazzarini et al., 2017). Thus, it may be that the regionality factor might have been more important for participants than avoiding animal products. Additionally, 20% of the participants chose both a meat alternative product (i.e., quorn-based or falafel) and meat or fish. This does not necessarily negatively influence the environmental friendliness of the menu because at least part of the meat is substituted by an alternative. However, depending on the amount and sort of meat alternative, it might increase the overall protein content of the lunch. This is relevant for overall protein intake. Thus, it is imaginable that some consumers do not substitute meat with a meat alternative product but rather eat it in addition. However, further research is needed to evaluate this hypothesis. Additionally, to have a scenario as close to real life as possible, we asked participants to select a menu that they would eat, offering a broad food variety and thus many possibilities to influence environmental friendliness. However, their food preferences still played a role. Thus, the observed correlation between the environmental friendliness of the menu and the knowledge scale scores may be higher if people select a menu disregarding their food preferences.

The FFB is a method for the investigation of food selection behavior but not food intake (Bucher, van der Horst, & Siegrist, 2012). Thus, we cannot rule out that participants would not have eaten all of their selected food items or would have eaten more than selected. Additionally, study participants were primarily younger persons, which limits the generalizability of the results. A larger sample also including elderly participants would be interesting for another study.

6. Test-retest reliability

Test-retest reliability is an important step in the psychometric testing of newly developed tests and questionnaires. The aim was to evaluate the short-term stability of the newly developed knowledge scale by examining the two-week test-retest reliability, which indicates whether the questionnaire produces the same results at two time points that are two weeks apart. Thus, the scores that participants achieved on the knowledge scale at time point 1 are expected to correlate highly with those achieved at time point 2.

6.1. Methods

6.1.1. Participants

Participants who took part in an experimental online study that is not presented here, were invited to fill in the knowledge scale a second time – two to three weeks after the first survey was launched. Only participants from the control group of the study were invited the second time. A self-generated ID enabled matching the individual answers from the first and second surveys. The self-generated ID does not allow conclusions to be drawn about personal details of the study participants. Overall, 146 persons filled in the questionnaire a second time. The characteristics of the study sample are depicted in Table 1.

6.2. Results and discussion

Cronbach's alpha was .73 at time point one and 0.78 at time point two. The test-retest correlation for the scale was $r = .77$, $p < .001$, which indicates good test-retest reliability. Thus, the scale consistently reflects knowledge about the environmental impact of foods over a period of two weeks.

7. General discussion

A working group of psychologists and environmental and nutritional scientists developed and validated a new tool for measuring laypeople's knowledge of the environmental friendliness of foods. The aim was to use a representative sample of easy-to-understand items related to the environmental impact of food without the use of technical terms. The questionnaire consisted of 16 items in a multiple-choice format with varying difficulty levels. The new tool was comprehensively validated in five steps and five study samples.

Psychometric property testing was conducted. In almost all study samples, Cronbach's alpha ranged between 0.72 and 0.77, indicating that the scale has good internal consistency. The slightly lower internal consistency observed in the fake food buffet experiment may be partly attributed to the small sample size and the lower variation in the obtained test scores. The test-retest reliability analysis results confirmed that the knowledge scale can be considered temporarily stable over two weeks. Higher knowledge scores were related to more positive environmental attitudes, environmentally friendly food purchasing behaviour, and diet-related health consciousness. Rather consistent positive correlations with educational level were observed, which is expected for knowledge questionnaires (Dickson-Spillmann, Siegrist, & Keller, 2011; Kliemann, Wardle, Johnson, & Croker, 2016; Mötteli, Barbey, Keller, Bucher, & Siegrist, 2017; Mötteli et al., 2016). The results confirmed the usefulness of the scale as a measure of knowledge and not as a measure of attitudes, even though a relationship between the two is plausible.

The correct item responses and eco-points used in the fake food experiment are backed up by the literature and LCA data. We deliberately avoided asking about the impact of food storage technologies, such as deep freezing, canning, or any other method of food processing, as such factors influence the LCA data, and their impact on the environmental friendliness of food is partially product-specific. The LCA method used in this study is one of many methods used to obtain information on the environmental impact of food products. These methods differ in their criteria, impact categories, and underlying assumptions (Cerutti, Bruun, Beccaro, & Bounous, 2011; Jungbluth, Büsser, Frischknecht, Flury, & Stucki, 2012). Some consider a very limited list of environmental problems and are insufficient to obtain a comprehensive picture (Jungbluth et al., 2012). The LCA data used in this study are based on the ecological scarcity method, which best reflects the environmental policy goals of Switzerland and countries with similar policies and can be used on a regional and national level for products sold in Switzerland (Jungbluth et al., 2012). In general, process chain analysis (i.e. LCA) is considered the most suitable and comprehensive approach to investigating the environmental impact of consumer goods (Jungbluth et al.,

2012) and identifying areas with the greatest environmental impacts (Roy et al., 2009).

Meat is a food group that has a significantly greater environmental impact than grains or vegetables (Poore & Nemecek, 2018). Of course, there are differences between production systems, and smaller integrated production systems may be more environmentally friendly than conventional large-scale systems. However, most of the beef consumed in industrialized countries is produced using mass production methods. Considering the significant global increase in meat demand due to population growth and increased economic welfare, it is rather unlikely that this will change in the future. If there were fundamental changes in production systems in the future, it is clear that the LCA data on some foods might change. Similarly, if consumers drastically reduced their meat consumption and beef were produced only on grasslands that are not otherwise useable, this would also change the environmental impact of meat production. However, considering the steady increase in meat consumption worldwide (Godfray et al., 2018), this remains a remote possibility.

Lastly, we did not include future foods (Parodi et al., 2018) because they are not yet part of typical Western diets. Moreover, since the questionnaire was developed in the Swiss context, it may be necessary to adapt some items (e.g. Q16, seasonality of fruits) to other countries' specific conditions and available LCA data on foods.

7.1. Implications for research and practice

Researchers and practitioners now have a suitable research tool for assessing laypeople's knowledge of the environmental impact of foods. Previously, a systematic assessment of what consumers know was lacking, and in some cases, it was implicitly assumed that consumers have relevant knowledge of the environmental impact of food (e.g., Schlegelmilch et al., 1996). The results of this study show that there are fundamental knowledge gaps—for example, regarding the environmental impact of meat production and consumption or the seasonality of fruits. Heuristics, such as "domestically produced food is always best," which people might use to evaluate products, are in no case justified. Of course, knowledge does not necessarily lead to favourable behaviour, and an interplay of many factors influences consistency or changes in habitual food behaviour, such as meat consumption (Harguess et al., 2020; Valli et al., 2019). However, without relevant knowledge, people cannot change even if they have the motivation to do so. Moreover, knowledge influences attitudes, behaviours, and intentions to change. A lack of such knowledge may be a barrier to changing consumption behaviour.

Policy measures aimed at increasing the sustainability of food choices are less effective when people do not have sufficient knowledge to understand them. The food industry is driven by many factors, and its environmental footprint has long been neglected. People have almost unlimited year-round access to a wide range of products from diverse production systems around the world. Consequently, calls to make more environmentally friendly purchase decisions seem inefficient if people lack relevant knowledge. There is a massive amount of information available in the media about the environmental impact of food production and consumption, and consumers have the opportunity to learn about it. Laying all responsibility for ethical, environmental, and social standards in food production on the industry alone by insisting that *it* must inform better and *it* must change the system is not a viable solution but rather a way to absolve consumers from their responsibility for their own food choices. It is important to involve consumers in the process of moving towards a more sustainable food system. To do so, it is crucial to assess consumers' knowledge at both the national and international levels.

In a further step, the developed knowledge scale should be validated in countries with other languages, such as England or France. Assessing the scale's applicability to low-literacy population segments and children could be another worthwhile endeavour. The efficacy of educational interventions, campaigns, and easy-to-apply decision aids (e.g. rules of thumb) could also be investigated. Lastly, the knowledge scale is well suited as a control variable in research on environmentally friendly food behaviour because it allows knowledge gaps to be ruled out as fundamental barriers.

8. Conclusion

A lack of knowledge related to the environmental impact of foods is the first hurdle in paving the way toward more environmentally friendly consumer behavior. Previously, it was unclear what people know about these aspects. By using the newly developed and psychometrically tested tool, we provide empirical evidence that knowledge levels seem generally to be low among consumers. Positive attitudes toward the environment and protection of the environment were positively correlated with higher knowledge scores. Those participants who achieved higher knowledge scores were more likely to be able to compose an environmentally friendly menu when asked to do so. The presented research not only shows the validity and applicability of the new tool but also indicates important knowledge gaps and potential barriers toward more sustainable diets as well as possibilities for further research activities.

Author's contribution

CH, GL and MS developed the questionnaire. CH designed the studies, collected the data, conducted data analyses and wrote the manuscript. MS was involved in all steps and gave feedback. AF was involved in designing the fake food experiment and data analysis. All authors gave feedback on the manuscript. All authors have approved the manuscript in it's present form.

Declaration of competing interest

The authors state no conflict of interest.

Acknowledgment

We would like to thank Bethan Turnbull and Chiara Semadeni for their support in conducting the food choice experiment and the reliability test.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2021.105622.

Funding sources

This research did not receive any financial support from external funding bodies.

Transparency declaration

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the studies being reported, that no important aspects of the studies have been omitted, and that any discrepancies from the studies as planned have been explained.

Ethical statement

Research involving human participants have been performed in accordance with the Declaration of Helsinki. The studies were approved by the Ethics Committee of ETH Zurich (EK 2019-N-05; EK 2018-N-62).

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