



Consumers' evaluation of the environmental friendliness, healthiness and naturalness of meat, meat substitutes, and other protein-rich foods

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ABSTRACT

In an attempt to move consumers toward a more sustainable and healthy diet, meat substitute products have flooded the market. However, consumers tend to be conservative about new food products and technologies that are supposed to replace traditional ones. Thus, it is important to evaluate whether consumers see the benefits of consuming these new products compared to the traditional meat products they are intended to replace. This online study examined how study participants from the German-speaking region of Switzerland ($N = 534$) assessed the environmental friendliness, healthiness and naturalness of 20 protein-rich foods, including meat, fish, cheese and a diverse set of meat substitutes. The study also aimed to determine how well subjective consumer evaluations corresponded with objective evaluations based on life cycle assessments and nutrient profiling. Results show that most participants did not assume that meat substitutes are automatically healthier and more environmentally friendly just because they are meat-free. Participants did not evaluate meat substitute products as more environmentally friendly than meat or consider them a healthier option. Compared to traditional foods like meat, fish and cheese, meat substitutes were also evaluated as less natural. Furthermore, strong correlations were found between participants' perceptions of environmental friendliness, naturalness and healthiness, although objective evaluations of these attributes did not correlate. Consumers' generally negative impression of meat substitute products compared to meat remains a challenge for industry and public health as well as the establishment of more sustainable diets.

1. Introduction

There has been growing awareness among stakeholders and consumers of the major issues concerning highly industrialized and conventional meat production systems, which constitute most of the global meat production (Hartmann & Siegrist, 2020). Not only animal welfare and public health concerns (e.g., zoonotic diseases, cardiovascular diseases), but in particular, food security (e.g., high need for grains) and environmental concerns (e.g., depletion of natural resources, environmental pollution) are the focus of attention (Faucitano, Martelli, Nannoni, & Widowski, 2017; Kumar et al., 2017; Poore & Nemecek, 2018; Rohrmann et al., 2013). In order to provide the growing world population with protein sources and at the same time limit the burden caused by the mass production of animal protein (Jungbluth, Itten, & Schori, 2012; Poore & Nemecek, 2018), researchers are searching for alternative protein sources for human nutrition (He, Evans, Liu, & Shao, 2020). As alternatives to conventional meat products, meat substitutes and

alternative protein sources have been steadily growing in importance over the last few years.

Meat substitutes comprise many products, including the sub-categories tofu/seitan/tempeh, vegetable-based processed products like falafel, cultured meat and novel meat analogues that resemble meat as closely as possible in terms of texture, taste and appearance. Meat substitutes are not necessarily based only on plant material, and some of these products contain animal protein, such as milk, egg or insect components, in addition to plant-based components. However, the majority of products in Switzerland, where the present study was conducted, are plant-based or based on mycoprotein and fungi (Herrmann & Bolliger, 2021). There are other protein-rich plant- and animal-based foods that might be consumed as alternatives to meat (e.g., legumes, fish, egg and cheese), but following Hoek et al. (2011, p. 666), they are not considered meat substitutes in the present study.

Just as global meat consumption per capita is on the rise, meat alternatives across Europe are also increasing (Statista, 2020). In recent

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years, the variety of and access to meat substitutes have steadily increased. According to data from the market agency Nielsen, in 2020 alone, more than 150 new items were introduced in the Swiss market (+22.5%). However, the best-selling product subgroup in Switzerland is still tofu/tempeh/seitan followed by meat analogues steak/cutlet-like products and the fastest-growing product group, meat-like burgers (Herrmann & Bolliger, 2021). Although there has been rapid growth in the meat substitutes section, and consumers at least are becoming interested in these products, meat substitutes are still niche products with a market share of 2.3% in Switzerland (Herrmann & Bolliger, 2021). In fact, the vast majority of consumers never eat meat substitutes, and their expenditure for traditional meat products far outweighs that for meat substitutes not only in Switzerland but also across Europe (Michel, Knaapila, Hartmann, & Siegrist, 2021; Statista, 2020; Van Loo, Caputo, & Lusk, 2020).

The major target group for meat analogues is meat eaters who want to reduce or eliminate their meat intake. These products aim to provide a similar sensory and meal experience as meat, requiring less of a change of preference or eating habits (Siegrist & Hartmann, 2019). The hurdles for meat eaters to switch from traditional meat to the vegetarian alternative should actually be low. However, the majority of consumers, who are meat eaters, seem to have a negative view of meat substitutes. When asked to think about meat alternatives in a free association task, study participants came up with somewhat negative evaluations and associations, while associations with meat were mostly positive (Michel, Hartmann, & Siegrist, 2021). Only those who regularly consume meat alternatives seem to see additional benefits of these products, such as higher environmental friendliness and better nutritional value (Götze & Brunner, 2021; Hagmann, Siegrist, & Hartmann, 2019; Onwezen, Bouwman, Reinders, & Dagevos, 2021; Weinrich, 2018). The average consumer seems to question the environmental superiority and healthiness of meat alternatives (Graça, Calheiros, & Oliveira, 2015; Hoek et al., 2011; Michel, Hartmann, et al., 2021). Such negative attitudes prevent widespread acceptance of these products (He et al., 2020; Michel, Hartmann, et al., 2021; Michel, Knaapila, et al., 2021; Onwezen et al., 2021). Thus, understanding consumer perceptions of meat substitutes and meat regarding the central product attributes of healthiness and environmental friendliness is key to move consumers toward increased acceptance.

In the discourse about meat substitutes, it is not only environmental friendliness and health benefits that play a role. Because of the processing and technology involved, many meat substitutes are industrialized products, which might be considered as a disadvantage. Such industrial advances and novel foods and food technologies are needed not only to provide safe, edible and nutritious food but also to make sustainable developments in the food system (Sadler et al., 2021; Siegrist & Hartmann, 2020a). However, among consumers and some researchers, there seems to be the notion that food processing is always negative, and only minimally processed foods are “natural” and thus healthy foods (Monteiro et al., 2018; Sadler et al., 2021). Therefore, there seems to be a trade-off between sustainable developments and the absence of processing and human interference. Consequently, at this point, a better understanding of how consumers evaluate such substitute products compared to traditional ones regarding naturalness is key. Therefore, another focus of the present research was to assess the perceived naturalness of meat substitute products and compare it to other protein-rich products in order to explore whether a lack of perceived naturalness might be another barrier to wider acceptance of meat substitute products.

1.1. Perceived environmental friendliness of protein-rich products

Several studies have concluded that knowledge regarding environmentally friendly food consumption is low among the general population (Hartmann, Lazzarini, Funk, & Siegrist, 2021; Hartmann & Siegrist, 2017; Peschel, Grebitus, Steiner, & Veeman, 2016; Siegrist, Visschers, &

Hartmann, 2015). Compared to experts, consumers are more likely to underestimate the high environmental footprint of meat production and consumption (de Boer & Aiking, 2011; Hartmann & Siegrist, 2017). Although consumers' perceptions of the environmental impacts of certain foods have changed slightly in the past few years (Bryant & Sanctorem, 2021; Siegrist et al., 2015), most consumers are still not fully aware of the impact of meat consumption (Siegrist & Hartmann, 2019).

Regarding meat substitutes, several studies found that substitutes have a lower environmental impact than meat (Smetana, Mathys, Knoch, & Heinz, 2015; Van Huis et al., 2013), although there are differences between different types of products and factors; for example, the transportation system can increase environmental impact (Smetana et al., 2015). However, consumers seem to overestimate the environmental impact of meat substitutes, meaning that they may be perceived as less environmentally friendly than they are. In a Swiss panel study of the consumption of meat and meat substitutes, participants mistakenly believed that the environmental impact of soy-based meat substitutes was as high as that of conventionally produced meat (Siegrist & Hartmann, 2019). In a study by Michel, Hartmann, et al. (2021) with German consumers, higher environmental friendliness was attributed to tofu, vegetarian sausage and nuggets compared to steak and wiener sausages; however, the difference was very small and suggests that consumers are not fully aware of the substantial difference in environmental impact between these products. In contrast, in a (Lazzarini, Zimmermann, Visschers, & Siegrist, 2016) sorting-task study, Swiss consumers correctly evaluated minced meat substitutes as more environmentally friendly than many of the meat products evaluated in the study but incorrectly evaluated organic chicken breast and organic pork strips as more environmentally friendly than tofu or falafel.

These reviewed studies suggest that consumers seem to have misconceptions or are uncertain about the environmental friendliness of meat and meat substitutes. In most of these studies, consumers evaluated generic products that are not sold in the supermarket and were broadly described without pictures. Additionally, the range of alternative meat products tested in the previous studies was limited. Thus, in the present study, consumers' evaluation of the environmental friendliness of a diverse set of meat, meat substitute products and foods that might be eaten as alternatives to meat was investigated.

1.2. Perceived healthiness of protein-rich products

From a nutritional point of view, meat is a food source of high nutrient density; however, the average meat consumption in Switzerland is 52 kg per capita, which exceeds the official recommendations of two to three portions per week (Chatelan et al., 2017; Swiss Society for Nutrition, 2020). Even more meat is consumed in other European countries, such as Germany, Italy and Spain, and outside Europe in countries like the United States (OECD, 2021; Statista, 2021). High consumption of red meat and meat products is associated with an elevated risk of mortality, however (Godfray et al., 2018; Rohrmann et al., 2013). Meat substitutes are often marketed as healthy alternatives to meat. However, only a few researchers have addressed the question of how nutritionally valuable meat alternatives are (e.g. Bohrer, 2019; Petersen, Hartmann, & Hirsch, 2021). Bohrer (2019) concluded that the macronutrient composition of many meat substitute products is similar to that of the traditional meat products the substitutes simulate. Petersen et al. (2021) found, on average, higher “nutrients to limit” (salt, fat, sugar, sodium) in red meat products and poultry than in meat substitutes. Some substitute products are even fortified with vitamins (e.g., vitamin B12) or contain added fiber to improve their nutritional value (Zhang et al., 2021). The nutrient composition of meat substitute products can vary considerably (Bohrer, 2019), and researchers are concerned that consumption of processed plant-based foods high in fat, salt and sugar might shift dietary behavior in an unfavorable direction (Macdiarmid, 2021). For this reason, an objective measure was used in the present study to evaluate the nutrient profile of the tested products

(i.e., Ofcom/Food Standards Agency [FSA]) and compared to participants' perception of the healthiness of the products.

Regarding consumers' healthiness evaluation of meat and meat substitutes, previous research results are inconclusive. The most consistent finding is that consumers evaluate meat as an indispensable part of a healthy diet (Verbeke, Pérez-Cueto, Barcellos, Krystallis, & Grunert, 2010) and are convinced meat eaters consume more meat and are not willing to reduce their meat intake or substitute meat with alternatives (Hartmann & Siegrist, 2020; Piazza et al., 2015; Rothgerber, 2013). However, consumers seem to differentiate between different meat types in their evaluation. For example, in one study, participants considered beef healthful when unprocessed and lean (Van Wezemael, Verbeke, de Barcellos, Scholderer, & Perez-Cueto, 2010), and in another study, they evaluated chicken filet, lamb filet and beef entrecote as healthier than pork strips, ham and bacon cubes (Lazzarini et al., 2016). However, in the latter study, participants also considered some meats to be healthier than a minced meat substitute product, and only tofu received a somewhat positive evaluation. In contrast, researchers also showed that study participants evaluated a menu containing a vegetarian schnitzel (described in written form) as healthier than one containing a pork schnitzel (Hartmann, Ruby, Schmidt, & Siegrist, 2018). This leads to the question of how consumers evaluate different kinds of meat substitute products (e.g., vegetable-based processed products, meat analogues, tofu) compared to meat or dairy products like cheese. On one hand, this perception influences societal acceptance of these products and with it, their spread within the food and supply system. On the other hand, the perception has consequences for eating behavior at the individual level, mostly in the sense that a reduction in meat consumption cannot be achieved with these substitute products when consumers evaluate the products negatively. To the best of our knowledge, thus far, no study has investigated this aspect with a large range of diverse protein-rich food products based on a consumer survey and real food products available in the supermarket.

1.3. Perceived naturalness of protein-rich products

Consumers' desire for natural food products has emerged in recent decades and is accompanied by an increasing number of products carrying the claim "natural" on the package (Cao & Yan, 2016). However, there is no universal definition of food naturalness. A systematic review of consumers' conceptualization of food naturalness suggested that the following three aspects are relevant: 1) the way a food was grown (food origin), 2) how a food was produced (what technology and ingredients have been used) and 3) the properties of the final product (Román, Sánchez-Siles, & Siegrist, 2017). Accordingly, consumers associate with food naturalness that the product is minimally processed, does not contain artificial ingredients, was organically produced and is not based on a genetically modified organism (Román et al., 2017). Foods that are considered natural are perceived to be healthier, tastier and better for the environment (Román et al., 2017). In other words, naturalness evokes almost exclusively positive emotions in Western consumers and is a desired product attribute; perceived minimal degree of processing is key for perceived naturalness.

This "natural is better heuristic" or mental shortcut to evaluate foods is not necessarily based on rational arguments. Many foods produced with technology are considered natural by consumers (e.g., cheese), while others produced without technology are considered unnatural (e.g., misshapen carrots; (Hagen, 2021; Powell, Jones, & Consedine, 2019). Similarly, unnatural entities (e.g., medicine) can be good for human health and are considered progressive, while natural entities (e.g., toxic mushrooms) can be dangerous for humans. Technological processes like food processing, including chemical and physical changes, mixing entities and adding or removing something from the product, can have an impact on naturalness perception (Evans, de Challemaison, & Cox, 2010; Rozin, 2005). Except cultured meat (e.g. Bryant, Anderson, Asher, Green, & Gasteratos, 2019; Siegrist & Hartmann, 2020b; Siegrist,

Sütterlin, & Hartmann, 2018), the perceived naturalness of meat substitutes was rarely assessed in previous research. In one study, vegetarian sausage and nuggets were evaluated as somewhat artificial, while steak and wiener sausage were evaluated as natural products (Michel, Hartmann, et al., 2021). Moreover, steak was evaluated as much more natural than wiener sausage or chicken nuggets, which is probably due to the perceived degree of processing. Perceived unnaturalness might lead to product rejection, and consequently, the importance of naturalness has implications for product choice. Seemingly unnatural food products are less accepted by the public (Román et al., 2017), and unnaturalness might be regarded as a shortcoming of meat substitutes that leads to lower acceptance (Hartmann & Siegrist, 2017).

1.4. Study objectives

Previous studies have investigated the public's awareness of the impact of food on the environment (e.g. de Boer, Schösler, & Aiking, 2014; Lea & Worsley, 2008; Siegrist et al., 2015); however, they did not differentiate between different types of protein sources. The present study builds on a previous study in which environmental friendliness and healthiness were assessed, but the number of included meat substitute products was much smaller, and perceived naturalness was not assessed (Lazzarini et al., 2016). Following on from this previous study, the present study was designed to answer three complementary research questions.

First, the aim was to answer the question of how well consumers evaluate the environmental friendliness and healthiness of meat, meat substitutes and other protein-rich products. To determine this, participants' subjective perceptions were compared to objective measures of environmental friendliness (evaluated using the life cycle assessment) and healthiness (assessed using nutrient profiling).

Second, the aim was to determine how consumers perceived the naturalness of meat, meat substitutes and other protein-rich products. Perceived naturalness is an important driver for positive food product evaluations (Román et al., 2017), so participants were asked to evaluate the perceived naturalness of food products. Food naturalness is a consumer-driven attribute that cannot be objectively measured; therefore, no objective measures of naturalness were included.

Third, the aim was to answer the question of whether perceived naturalness, healthiness and environmental friendliness are intercorrelated. Previous studies have observed a relationship between environmental friendliness and naturalness perception (Verhoog, Matze, Van Bueren, & Baars, 2003) and sustainability and healthiness perception (Lazzarini et al., 2016). However, to the best of our knowledge, no study has explored the interplay between participants' perceptions of these three attributes for meat, meat substitutes and other protein-rich products. The present study fills this research gap.

2. Methods

Data collection took place via an online survey in April and May 2020 in the German-speaking region of Switzerland. Consumers' evaluations of the naturalness, environmental friendliness and healthiness of 20 high-protein food products were assessed. Sociodemographic variables (age, gender, education and region of residence), knowledge of the environmental friendliness of foods and frequency of consumption of meat and meat alternatives were also measured.

2.1. Participants

Study participants were recruited from the internet panel of a commercial provider of sampling services (Respondi AG) and received a small compensation for their participation. Respondents who did not complete the survey ($n = 21$), those who did not indicate their gender ($n = 3$) and those whose total survey duration was less than half of the median of the total survey duration, which indicated that they did not

answer the questions seriously ($n = 24$), were excluded from the study. Another respondent was excluded for giving identical answers to all food evaluation questions (straightlining). Quota samples were used, with the quota variables gender (50% men) and age (an equal number of participants per age group). The final sample consisted of 534 respondents. The mean age was 45.6 years ($SD = 14.5$, range 20–71 years) and 50.2% were female. Participants' education levels were categorized as follows: low, 3.9% (primary and lower secondary school); middle, 65.2% (secondary school, vocational education and senior high school) and high, 30.8% (higher vocational education, university and above). Of all participants, 30.5% lived in an urban area, 26.4% in suburbs and 43.2% in a rural area.

The frequency at which participants consumed food from five categories (meat, fish, cheese, legumes and meat alternatives) was assessed. Responses were given on a 6-point scale with the following options: "several times a day," "once a day," "several times a week," "several times a month," "several times a year" and "more rarely/never." Around 9% of the participants reported that they ate meat several times per year, less often or never. However, the majority (52%) reported that they ate meat several times per week, and 22% reported that they ate meat daily. With regard to the frequency of consumption of meat substitutes, 46% indicated that they never ate these products, while 14% reported that they ate them several times per week or more often.

Participants' knowledge of the environmental friendliness of foods was tested (Hartmann et al., 2021) to rule out that the present sample was particularly knowledgeable or uninformed in this domain. The observed mean value in the sample was 8.49 ($SD = 3.47$, range 0–16), which corresponds well to the observed mean value in a previous Swiss sample (Hartmann et al., 2021).

2.2. Product stimuli

The environmental friendliness of protein products varies greatly (Aiking, 2011), which makes them particularly interesting study objects. High-protein food products were used in the present study, including a broad range of plant-based meat substitutes, different types of meat and meat products in different shapes and textures, cheese, fish and tofu. The food products differed not only in product category but also in the presence or absence of an organic label and in their country of origin. These factors were varied because previous research revealed that they

were the main predictors of a product's perceived environmental friendliness (Lazzarini et al., 2016). To ensure that participants had some familiarity with the products, they were obtained from the two main grocery store chains in Switzerland. To minimize the effort study participants needed to make, we limited the number of different products to 20.

For each product evaluation, participants were shown a picture of the food product and information regarding ingredients, production method (organic or conventional) and country of origin (Fig. 1, or for a list of all products, please see the [Supplementary Material](#)). Participants were asked to indicate on a slider how environmentally friendly, natural and healthy they considered the products, from not at all (0) to totally (100). Only the extreme points of the slider were verbally anchored. The terms environmentally friendly, natural and healthy were not further specified, leaving the meaning open to interpretation by participants. The order of products was randomized between participants.

2.3. Life cycle assessment

The environmental friendliness of products was determined using life cycle assessment (LCA) data. The life cycle assessment is an established tool used to evaluate environmental impacts induced by all stages of the life cycle of a product, process or service. Different methods can be applied when using this tool (Roy et al., 2009). In the present study, the 2013 Swiss ecological scarcity method was used, which aggregates a broad range of environmental impacts (water resources, energy resources, mineral resources, land use, global warming, ozone layer depletion, main air pollutants and particulate matter, carcinogenic substances into air, heavy metals into air, water pollutants, persistent organic pollutants into water, heavy metals into water, pesticides into soil, heavy metals into soil, radioactive substances into air, radioactive substances into water, noise, non-radioactive waste to deposit and radioactive waste to deposit) into an easily comparable one-score impact value measured in Ecopoints (EPs) per unit of quantity (Frischknecht & Büsser Knöpfel, 2013; Jungbluth et al., 2020). 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 score. Thus, the higher the EP score for a specific food, the more damaging it is assumed to be to the



Ingredients: bacon**, beef**, water, rind**, nitrite curing salt, spices*, glucose syrup*, acerola powder*, antioxidant: sodium citrate, casing: beef intestine**;

** From Swiss organic production, * From foreign organic production

Origin: Switzerland

Production method: Organic

Fig. 1. Example of a presented product – Sausage (Cervelat). Information about ingredients, country of origin and production method was provided. Participants had to indicate how environmentally friendly, natural and healthy they considered the product. [Product information translated for publication]

environment. The LCAs for products used in the present study were conducted by the Swiss sustainability consulting company ESU Service Ltd (<http://esu-services.ch/>). Furthermore, estimations of EPs are usually based on the weight of food items (EPs per kilogram). This approach was applied in the present study during the main analysis. EP scores were further calculated per protein content, and as the results did not vary compared to EPs per kilogram, the scores per protein content were not included in the present manuscript.

2.4. Nutrient profiling

Nutrient profiling allows researchers to appraise and classify food products based on the healthiness of their nutritional composition (World Health Organization (WHO), 2020). Different nutrient profiling standards have been developed, such as the Ofcom/FSA nutrient profiling model (Food Standards Agency, 2011). This model has been well validated and has a good reputation (Rayner, 2017); thus, the model served as the objective measure of healthiness for the products in the present study. To objectively assess the healthiness of the 20 products, the Ofcom/FSA nutrient profile was calculated for each product based on its nutrient content per 100 g. The final nutrient profile value was composed of 0–10 A points, which were assigned for each unhealthy aspect (namely, for the amount of energy, saturated fatty acids, total sugar and sodium) and 0–5C points, which were assigned for each healthy aspect (i.e., for the content of fruits, vegetables and nuts, fiber and protein). This resulted in a maximum of 40 A points and 15C points. For the final calculation, the C points were subtracted from the A points, provided that fewer than 11 A points were scored. If this criterion was not met, then positive points for protein could not be subtracted from the A score. The possible final nutrient profiling scores ranged from – 15 to 40, with lower scores representing a greater level of healthiness. Foods scoring 4 points or more were considered less healthy (Food Standards Agency, 2011). The information needed for calculations was retrieved from product packages and the Swiss food composition database (Swiss Federal Food Safety and Veterinary Office, 2020).

2.5. Statistical analyses

Data can be analyzed using respondents as the unit of analysis or by using products as the unit of analysis (i.e., aggregated data). We present results from the latter analysis. Aggregated data with the products as the unit of analysis addressed the similarity of subjective and objective product evaluations. This was done by calculating the mean evaluation scores for each food product. Subsequently, products were ranked according to their mean values. This procedure was carried out for participants' evaluations of the environmental friendliness, naturalness and healthiness of products. Objectively determined environmental friendliness (based on LCA data) and healthiness (based on nutrient profiling) were also ranked. To determine whether a healthier product was automatically regarded as more natural and more environmentally friendly and vice versa, the relationship between participants' perceptions of environmental friendliness, naturalness and healthiness were displayed visually in scatterplots with corresponding product-moment correlation coefficients.

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

3. Results

3.1. Perceived environmental friendliness of the food products

The correlational analysis of the food products' mean subjective environmental friendliness scores (participants' self-reported evaluations) and objective environmental friendliness scores (LCA-based EP/kg) was not statistically significant ($r = -0.20$, $p = .405$). A visual inspection of the scatterplot in Fig. 2 suggests that participants generally seemed to underestimate the environmental impact of animal-based products and overestimate the environmental impact of meat substitutes. For instance, beef entrecote had the highest objective environmental impact (EP/kg) of all tested products; however, its environmental friendliness was greatly overestimated by consumers. A burger made from pea protein (Beyond Meat®) and a vegetarian sausage were mistakenly evaluated as less environmentally friendly than beef entrecote, although they received considerably fewer Ecopoints.

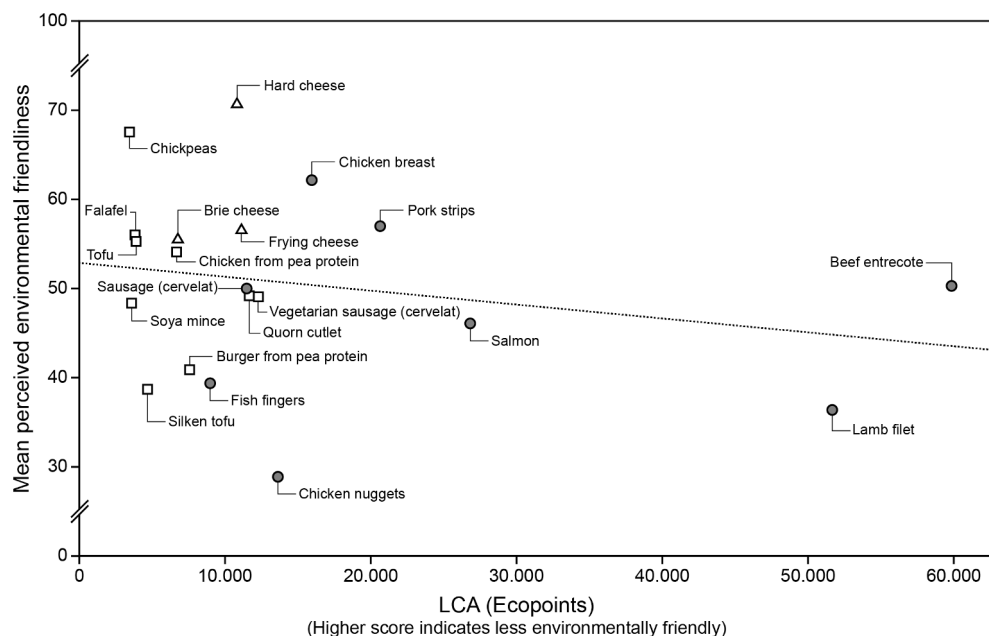


Fig. 2. Objective evaluation of the environmental friendliness of food products based on the LCA (Ecopoints) plotted against respondents' perception of the environmental friendliness of each product. No significant correlation was observed. Consumers seemed to underestimate the environmental impact of meat and meat products and overestimate the environmental impact of meat substitutes. Black dot: Meat and fish, triangle: cheese, square: meat substitutes.

Specifically, chicken breast ($M = 62.22$, $SD = 24.27$) was perceived, on average, as the most environmentally friendly meat type, followed by pork strips ($M = 56.95$, $SD = 25.56$). Chicken, pork, beef and meat sausage were also perceived as more environmentally friendly than most of the meat substitute products like Quorn cutlet, vegetarian sausage, soya mince and burger from pea protein. In fact, soya mince (ranked second), falafel (ranked third), tofu (ranked fourth), silken tofu (ranked fifth) and “chicken” made from pea protein (ranked sixth) were the most environmentally friendly options based on Ecopoints. However, consumers ranked these products much lower (14th, 6th, 8th, 18th and 9th, respectively) and thus, as having a higher environmental impact than meat. The largest discrepancy between the subjective and objective measures was 13 spots in the ranking, and this was observed for chicken breast, pork strips and silken tofu. Notably, based on LCA data, processed meat products (meat sausage, chicken nuggets) received the lowest number of Ecopoints out of all meat products, followed by chicken breast. However, compared to the meat-free alternatives, processed meat products have a much higher environmental impact, of course. Data for all products are summarized in Table 1.

3.2. Perceived healthiness of food products

No significant correlation ($r = -0.24$, $p = .299$) was observed between scores for perceived healthiness (participants' self-reported evaluations) and objective healthiness as measured by nutrient profiling (nutrient profile scores). An inspection of the scatterplot in Fig. 3 highlights a strong discrepancy between participants' evaluations and the objective evaluations. In fact, the nutrient profile scores were similar for most meat products and meat substitutes, such as tofu, falafel, “chicken” made from pea protein, soya mince and Quorn cutlet (Table 2). However, consumers evaluated all animal-based products (except for fish fingers and chicken nuggets) as healthier than meat substitutes. Chickpeas were correctly identified as the healthiest product, and meat-based and vegetarian sausages (cervelat) were also correctly identified as less healthy by participants.

3.3. Perceived naturalness of food products

Regarding participants' perceptions of the naturalness of meat and meat substitutes, similar patterns as for healthfulness and environmental friendliness were observed. Unprocessed meat products (ranked 3rd, 4th and 5th), hard cheese (ranked 1st) and chickpeas (ranked 2nd) were perceived as the most natural products, much more natural than meat analogues (ranked 13th, 14th, 16th, 18th and 19th), tofu (ranked 9th) and falafel (ranked 10th). Data for all foods are displayed in Table 3.

3.4. Intercorrelations among perceived environmental friendliness, naturalness and healthiness

The scatterplot matrix in Fig. 4 shows intercorrelations between the objective and subjective evaluations of the perceived environmental friendliness, healthiness and naturalness of food products. Clearly, perceived healthiness, perceived environmental friendliness and perceived naturalness were strongly intercorrelated ($r = 0.72$ – 0.91 , $p < .001$), while objective measures of these product attributes were not significantly statistically correlated. Some products (i.e., chicken breast, Gruyere cheese and chickpeas) were rated consistently positively for all three properties, while chicken nuggets were awarded low values for perceived environmental friendliness, naturalness and healthiness.

4. Discussion

An overarching goal of the present study was to find out how consumers evaluate vegetarian protein-rich products in relation to animal-based protein-rich products in three important product dimensions: environmental friendliness, healthiness and naturalness. Results showed that consumers evaluate traditional meat products more positively than their meat-free counterparts. These results held for all three assessed product dimensions. Furthermore, participants' evaluations of the perceived environmental friendliness and healthiness for most of the 20 food products differed substantially from the objective evaluations (LCA data and nutrient profiling). Accordingly, participants seemed to underestimate the negative environmental impact of meat products and overestimate the environmental impact of meat substitutes. Similarly,

Table 1
Food product characteristics and subjective and objective environmental friendliness of products.

| Product | Food group ^a | Country of origin | Organic | Environmental friendliness | | | Objective measure Rank ^d based on EPs/kg from LCA |
|-------------------------------|-------------------------|-------------------|---------|----------------------------|----------|-----------|---|
| | | | | Rank ^c | <i>M</i> | <i>SD</i> | |
| Gruyere cheese | D | CH | Yes | 1 | 70.73 | 21.37 | 10 |
| Chickpeas | S | IT | Yes | 2 | 67.49 | 21.87 | 1 |
| Chicken breast | M | CH | Yes | 3 | 62.22 | 24.27 | 16 |
| Pork strips | M | CH | Yes | 4 | 56.95 | 25.56 | 17 |
| Frying cheese | D | CH | No | 5 | 56.64 | 23.46 | 11 |
| Falafel | S | CH ^b | No | 6 | 55.91 | 22.54 | 3 |
| Brie | D | FR | No | 7 | 55.58 | 21.14 | 7 |
| Tofu | S | CH ^b | Yes | 8 | 55.16 | 25.27 | 4 |
| Chicken from pea protein | S | CH | No | 9 | 54.11 | 24.93 | 6 |
| Beef entrecote | M | CH | No | 10 | 50.34 | 26.95 | 20 |
| Sausage (cervelat) | M | CH | Yes | 11 | 49.86 | 23.41 | 12 |
| Quorn cutlet | S | GB | No | 12 | 49.11 | 24.46 | 13 |
| Vegetarian sausage (cervelat) | S | CH | No | 13 | 49.00 | 23.90 | 14 |
| Soya mince | S | CH ^b | No | 14 | 48.23 | 24.96 | 2 |
| Salmon | F | NO | No | 15 | 46.13 | 24.82 | 18 |
| Burger from pea protein | S | US | No | 16 | 40.89 | 26.77 | 8 |
| Fish fingers | F | PL | No | 17 | 39.26 | 22.37 | 9 |
| Silken tofu | S | US ^b | No | 18 | 38.59 | 25.83 | 5 |
| Lamb filet | M | NZ | No | 19 | 36.34 | 26.81 | 19 |
| Chicken nuggets | M | BR | No | 20 | 28.89 | 22.54 | 15 |

Note. Products are ordered according to subjective evaluation from best to worst. EPs: Ecopoints from the life cycle assessment (LCA)^aFood groups: M = Meat; F = Fish; D = Dairy; S = Substitute

^bOnly the country of processing is known.

^cRanking is based on mean perceptions.

^dRanking is based on LCA outcomes per kilogram.

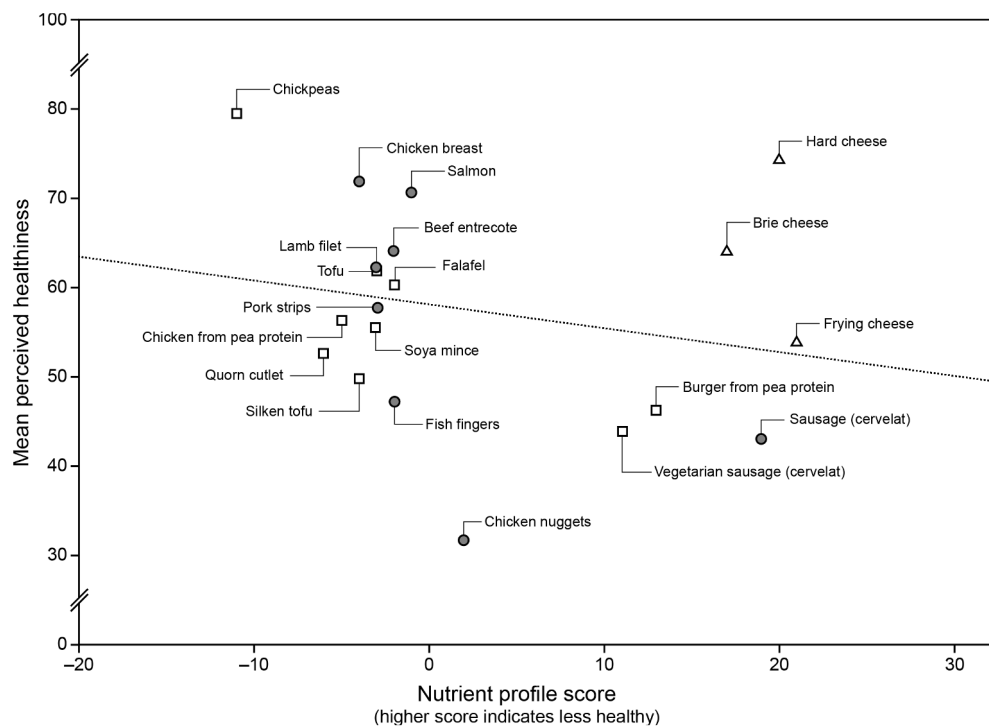


Fig. 3. Objective evaluation of the healthiness of food products based on nutrient profiling plotted against respondents' perception of the healthiness of each product. No significant correlation was observed. Consumers evaluated most meat products as healthier than the alternatives. Black dot: Meat and fish, triangle: cheese, square: meat alternatives.

Table 2

Subjective and objective healthiness evaluation of the tested food products.

| Product | Healthiness Consumer perception | | | Nutrient profiling (NP) | |
|-------------------------------|------------------------------------|-------|-------|----------------------------|----------|
| | Rank ^c | M | SD | Rank ^d | NP score |
| Chickpeas | 1 | 79.62 | 18.93 | 1 | -11 |
| Gruyere cheese | 2 | 74.37 | 20.07 | 19 | 20 |
| Chicken breast | 3 | 71.95 | 21.58 | 4.5 | -4 |
| Salmon | 4 | 70.76 | 22.44 | 13 | -1 |
| Beef entrecote | 5 | 64.17 | 23.19 | 11 | -2 |
| Brie | 6 | 64.06 | 20.54 | 18 | 19 |
| Lamb filet | 7 | 62.38 | 23.87 | 7.5 | -3 |
| Tofu | 8 | 61.94 | 24.35 | 7.5 | -3 |
| Falafel | 9 | 60.33 | 23.25 | 11 | -2 |
| Pork strips | 10 | 57.83 | 24.78 | 7.5 | -3 |
| Chicken from pea protein | 11 | 56.37 | 25.60 | 3 | -5 |
| Soya mince | 12 | 55.46 | 25.38 | 7.5 | -3 |
| Frying cheese | 13 | 53.91 | 23.41 | 20 | 21 |
| Quorn cutlet | 14 | 52.57 | 24.77 | 2 | -6 |
| Silken tofu | 15 | 49.75 | 25.03 | 4.5 | -4 |
| Fish fingers | 16 | 47.26 | 23.20 | 11 | -2 |
| Burger from pea protein | 17 | 46.37 | 25.54 | 16 | 13 |
| Vegetarian sausage (cervelat) | 18 | 44.02 | 25.00 | 15 | 11 |
| Sausage (cervelat) | 19 | 43.00 | 24.10 | 17 | 17 |
| Chicken nuggets | 20 | 31.78 | 22.33 | 14 | 2 |

Note. Products are ordered according to subjective evaluation from best to worst.

meat substitutes were evaluated as less healthy than meat products by participants, although from an objective point of view, differences between products were small. Strong correlations were observed between participants' product evaluations across the three dimensions of perceived healthiness, environmental friendliness, and naturalness, which indicated that in consumers' minds, these three factors are interrelated.

Table 3

Subjective naturalness perception of the tested food products.

| Product | NaturalnessConsumer perception | | |
|-------------------------------|--------------------------------|-------|-------|
| | Rank ^c | M | SD |
| Gruyere cheese | 1 | 80.88 | 17.65 |
| Chickpeas | 2 | 79.42 | 19.93 |
| Chicken breast | 3 | 74.07 | 22.52 |
| Pork strips | 4 | 71.14 | 23.69 |
| Beef entrecote | 5 | 70.41 | 23.99 |
| Brie | 6 | 69.94 | 20.48 |
| Salmon | 7 | 67.16 | 23.90 |
| Lamb filet | 8 | 66.81 | 25.29 |
| Tofu | 9 | 59.44 | 25.78 |
| Falafel | 10 | 56.75 | 23.58 |
| Frying cheese | 11 | 55.26 | 24.23 |
| Sausage (cervelat) | 12 | 51.29 | 24.94 |
| Soya mince | 13 | 49.83 | 27.16 |
| Chicken from pea protein | 14 | 48.47 | 27.88 |
| Fish fingers | 15 | 45.74 | 23.84 |
| Quorn cutlet | 16 | 45.70 | 26.04 |
| Silken tofu | 17 | 43.10 | 25.52 |
| Burger from pea protein | 18 | 37.88 | 26.66 |
| Vegetarian sausage (cervelat) | 19 | 36.82 | 26.09 |
| Chicken nuggets | 20 | 32.29 | 22.59 |

Note. Products are ordered according to subjective evaluation from best to worst.

4.1. Relationship among perceived environmental friendliness, healthfulness and naturalness

In accordance with previous research (Lazzarini et al., 2016), a positive correlation between perceived environmental friendliness and healthiness indicates that consumers relate the two dimensions to each other. A positive evaluation of meats' healthfulness could be the driver in the impression formation process for positive evaluations of environmental friendliness or vice versa. It might be that a halo effect misleads consumers to generalize from one perceived positive product attribute to another, unknown attribute. In reality, LCA-based

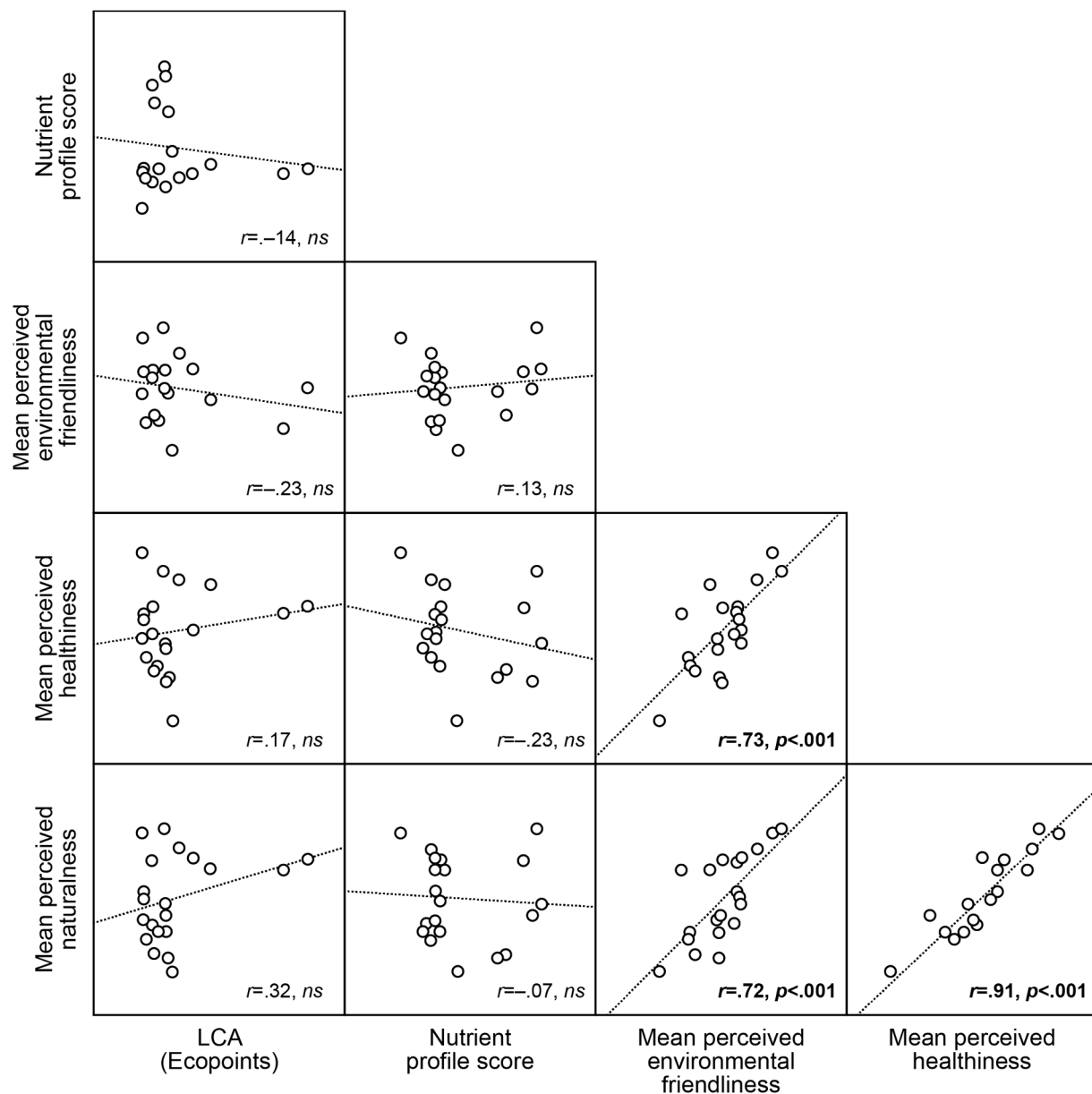


Fig. 4. Scatterplot matrix of objective and subjective evaluations of products' environmental friendliness, healthiness and naturalness.

evaluations and nutrient profiling were not correlated, which suggests that environmentally friendly products did not necessarily have a good nutrient profile, and healthy products were not necessarily environmentally friendly. Additionally, perceived naturalness is often correlated with positive evaluations of other product attributes. Products considered natural are often evaluated as being healthy and tasty (Román et al., 2017; Siipi, 2012). Results suggest that participants might have applied the same heuristic to the tested products.

4.2. Consumer perceptions of the environmental friendliness of food products

Consumer perception of the environmental friendliness of the products was not correlated with the objective evaluation based on LCA data (indicated by Ecopoints). Thus, many participants were unable to accurately assess the environmental friendliness of the presented products. The largest difference between participants' evaluations and Ecopoint values was observed for non-organic soy-based products (silken tofu and soya mince) and the meat types chicken breast, pork strips and

beef entrecote. Beef entrecote was the product with the highest Ecopoints by far, but participants evaluated alternative products such as vegetarian sausage, Quorn cutlet and beyond meat burger as less environmentally friendly than beef. Generally speaking, the environmental friendliness of the animal-based products was strongly overestimated, and the meat substitute products were perceived as much less environmentally friendly than they are. This finding supports previous findings that consumers are not good at evaluating products' environmental friendliness and not only consider meat as environmentally friendly as meat substitutes as in Siegrist and Hartmann's (2019) study, but even tend to consider meat to be superior to meat-free alternatives.

Participants seemed to have misconceptions about the importance of certain factors and lacked knowledge when evaluating the environmental friendliness of products. The LCA results show that ruminant meat production (beef entrecote and lamb filet) had the highest impact on the environment; the products' Ecopoints were three to four times higher than for non-ruminant meat (chicken breast and pork strips). The main factors that lead to the high impact of ruminant meat are high greenhouse gas emissions and excessive land use (Stehfest et al., 2009).

However, the huge differences in the environmental impacts between various animal species on meat production were not reflected in participants' evaluations. Thus, there seems to be little awareness of the difference between ruminants and other meats, and consumers likely do not consider animal species when evaluating the environmental impact of meat products. Consumers seem to rely on other factors, such as country of origin and organic label (Lazzarini et al., 2016). In fact, the lamb filet was imported from New Zealand, and the beef entrecote originated from Switzerland. These two products do not differ much in terms of environmental impact in relation to other meat products. However, the subjective evaluation of lamb filet was much more negative than that of beef. All products evaluated as less environmentally friendly by consumers were imported from another country (primarily overseas), but this has a much lower impact compared to the food product category (e.g., tofu versus beef; Nemecek, Jungbluth, i Canals, & Schenck, 2016). Thus, it is likely that for some products, participants put too much weight on the country of origin and rated Swiss products more positively than products from other countries. This "home country is best" effect has been shown in previous research with Swiss consumers but with other food products (Lazzarini, Visschers, & Siegrist, 2017).

Lastly, consumers often mistakenly use the organic label as a universal indicator of environmental friendliness (Camilleri, Larrick, Hosain, & Patino-Echeverri, 2019; Lazzarini et al., 2016). However, whether a product is produced organically or conventionally has only a marginal impact on the environment (Nemecek et al., 2016). For instance, transport via airplane multiplies the environmental footprint of meat products much more than production system factors (Jungbluth, Tietje, & Scholz, 2000; Nemecek et al., 2016). Products evaluated as the most environmentally friendly were all organically grown. Particularly striking is the difference between conventional silken tofu, which was rated environmentally unfriendly, and organic tofu, which was evaluated much more positively. Other factors such as animal species or meat-free are much more relevant but seem to be neglected by consumers.

4.3. Consumer perceptions of the healthiness of the food products

Meat substitute products were evaluated more negatively by participants than meat products. The substitutes were perceived as unhealthier than meat, although there was little difference between the meat and the meat substitutes based on nutrient profiling. In previous studies, correlations between perceived healthiness and nutrient profiling have been found (Bucher, Müller, & Siegrist, 2015; Lazzarini et al., 2016), but in the present study, participants' evaluation of products' healthiness was not correlated with the more objective nutrient profiling data. Different kinds of familiar foods, such as mayonnaise, chocolate and pasta (Bucher et al., 2015), and a range of protein-rich foods, such as different types of cheese and meat (Lazzarini et al., 2016), were included in previous research. Thus, it is possible that the range of products presented in this study posed additional challenges for participants with respect to their evaluations.

Based on nutrient profiling, there were no notably large differences between the meat products and the meat substitutes. Only two meat substitute products (burger from pea protein and vegetarian sausage) received a higher number of points during the nutrient profiling (more points were awarded for less healthy products), because they contained considerable saturated fat and salt. For these products, the objective and subjective evaluations matched very well.

When consumers evaluate the healthiness of a product, aspects such as packaging design, front-of-package labels, product ingredients, product category, origin of the product and sensory features are taken into account (Plasek, Lakner, & Temesi, 2020). Thus, many factors can be relevant for the somewhat negative healthiness image of meat substitutes. It is likely that the apparent degree of processing might be a crucial factor. In fact, almost all processed foods, vegetarian and non-vegetarian, were evaluated as unhealthier than the unprocessed foods. Consumers may believe that healthy foods must be natural and

unprocessed, which might have led to the described misconception. Consequently, unprocessed animal-based protein products were systematically evaluated as healthier than meat substitutes. Processed meat, namely, chicken nuggets and sausage (cervelat), however, also received a negative subjective evaluation.

4.4. The impact of the "natural is better heuristic"

Results suggest that, on average, meat substitutes are perceived as unnatural in comparison to other protein-rich products. Products like vegetarian sausage, a burger from pea protein, silken tofu and Quorn cutlet were evaluated as unnatural, while more traditional foods and meats like chicken breast, pork strips, beef entrecote, cheese and fish were perceived as more natural. It is likely that the lack of perceived naturalness is based on the perceived degree of processing. For instance, chicken breast and chicken nuggets were judged completely differently by participants. Chicken breast received the best evaluation out of all the meat products in all three dimensions, while chicken nuggets received the worst. However, the differences between the two products lay only in their country of origin and degree of processing. In fact, technological food processing and food additives have a negative image among many consumers (Bearth, Cousin, & Siegrist, 2014), and consumers link longer ingredients lists with less natural food products (Román et al., 2017). Despite a lack of perceived naturalness for meat substitutes considering the average, individual responses ranged from the minimum score of 0 to the maximum score of 100. Thus, they were not perceived as inevitably unnatural by all participants. Additionally, consumers differ in their preference for naturalness, and some might value other product characteristics (e.g., convenience) as more important. Nevertheless, meat substitutes might fall into the category of processed or highly processed foods for consumers. Thus, the alternatives might be considered unnatural and less desirable, tasty, healthy, and environmentally friendly. These findings pose a challenge to the promotion of meat substitute products, as the lack of perceived naturalness of meat substitutes likely lowers their acceptance (Román et al., 2017).

4.5. Limitations

The nutrient profiling method neglects some aspects of evaluating the healthiness of food products. For example, the healthiness of products is influenced by the amount consumed, the cooking method and the seasoning added (e.g., adding salt and oil to raw meat), but the nutrient profiling calculations were based only on the characteristics of the product when bought in an unprepared/raw state. Although some products like sausages, nuggets and falafel were already seasoned, others were not (e.g., meat and "chicken" made from pea protein). This may have impacted the nutrient profile scores. Preparing these products increases their fat and salt content, which would have a negative impact on nutrient profiling. Thus, the objective healthiness values of meat products could have been underestimated in this study. Finally, nutrient profiling should not be interpreted as dietary advice, because a healthy diet is influenced by many factors, including the combination of foods within a dish (Rayner, 2017).

It was not assessed whether study participants were willing to buy and eat the products tested in the study. For instance, chickpeas were evaluated as healthy, natural and environmentally friendly; however, chickpea consumption in Switzerland is low (Chatelan et al., 2017). Gruyere hard cheese was evaluated very positively in all three dimensions and is a strongly beloved traditional Swiss food. Chicken nuggets were rated negatively in all three dimensions, yet they still seem to be a popular product among consumers. Thus, positive, or negative evaluations of the three dimensions do not necessarily imply that consumers are (un)willing to frequently buy and consume the corresponding product. Other product attributes, most importantly taste and liking, were not assessed in the study.

Data collection took part during the first wave of the COVID-19

outbreak. Given the higher proportion of home consumption and panic buying during that time, food sales increased in the domestic sector. Peoples' consumption habits might have been affected by the situation. However, consumers attitudes towards food products do not fluctuate that much over shorter time periods and there is no reason to believe that consumers attitudes towards meat substitute products drastically changed in a negative direction in that time.

4.6. Implications and further directions

Consumers in different European countries tend to evaluate some meat substitute products similarly, but there are also differences in tastiness expectations (Michel, Knaapila, et al., 2021). Cultural differences, different consumption patterns and varying attitudes toward meat consumption are expected to lead to differing assessments in other parts of the world. It would be especially interesting to repeat this study in developing countries, where meat consumption is still strongly on the rise (Godfray et al., 2018). Additionally, we tested only 20 products to avoid placing a burden on the study participants, but many more products are available on the market: not only meat substitutes but also vegan alternatives to milk, cheese and other animal-based products such as fish. The findings of the present study suggested research opportunities for such product options.

The reduction of dairy product consumption is another effort in the attempt to move away from carbon-intensive diets that are high in animal protein, especially those associated with production of ruminant livestock (Climate Change Committee, 2020). However, some people might consume cheese and other dairy products instead of meat. Three cheese variations (hard cheese, brie cheese, frying cheese) were included in the present study. The results showed that Swiss consumers distinguish between these types of cheese when it comes to perceived healthiness, naturalness, and environmental friendliness. In line with previous findings, hard cheese was perceived as the most environmentally friendly, healthy and natural product (Lazzarini et al., 2016). These misconceptions might occur around dairy products in general, and in a future study, a broader dairy product range could be tested, and which product attributes consumers consider when evaluating dairy products could be investigated.

In the present study, the nutrient profiles of most of the tested meat substitute products were similar or better than those of meat. However, two alternatives from the subcategory meat analogues also performed worse. High consumption of such products seems to carry additional pitfalls. Even if it can be assumed that their production has a lower environmental impact, and animal welfare is not an issue, it seems counterproductive in the pursuit of a more sustainable and healthy diet. The risk of just having a new "vehicle for high fat, sugar and salt foods" may not be unfounded (Macdiarmid, 2021, p. 5). Healthy eating is often named as a motive for a shift to a meat-reduced or plant-based diet (Hagmann et al., 2019), which might not be achieved with certain types of alternative products. It is a task of the food industry to optimize the nutritional profiles of these products.

5. Conclusion

Thanks to new food technologies and resources, the possibilities for meeting humanity's protein requirements are constantly growing. However, consumers tend to be conservative about new food products and technologies that are supposed to replace traditional ones (Siegrist & Hartmann, 2020a). Thus, the consumer perspective is indispensable to achieve the goal of developing more sustainable food production systems and consumption patterns. It is essential to evaluate whether consumers see the benefits of buying and consuming technologically processed meat substitute products intended to replace traditional meat products. However, the present study showed that most consumers do not assume that meat substitutes are automatically healthier and more environmentally friendly just because they are meat-free. On average,

the environmental impact of meat substitute products was overestimated, and they were mainly perceived as less environmentally friendly than meat products. At the same time, meat substitute products were perceived as unhealthier and less natural than meat. The present results showed that in consumers' minds, naturalness goes hand in hand with environmental friendliness and healthiness, which is not necessarily the case based on objective assessment.

It does not seem justified to assume that meat substitute products are inherently healthier because they are plant-based and meat-free. The nutritional and sensory qualities of meat replacement products can vary considerably. However, consumers seem to have a somewhat negative impression of these products in general. Consumers not only might have negative attitudes toward these products (Michel, Hartmann, et al., 2021) but also seem to question their nutritional and environmental benefits and seemingly have no trust in these novel solutions to decrease the environmental impact of one's diet. This remains a challenge for industry and public health as well as the establishment of more sustainable food systems.

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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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodqual.2021.104486>.

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