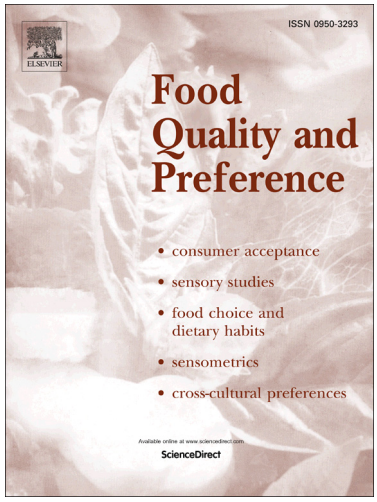


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# Duckweed as human food. The influence of meal context and information on duckweed acceptability of Dutch consumers.

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# Abstract

Duckweed is considered a promising source of protein for human food products due to its high protein content and environmentally friendly production properties. In order to achieve successful inclusion in the diet, duckweed should be presented to consumers in an acceptable way. This paper explores Western consumers' perceptions towards duckweed as human food and investigates in what contexts duckweed could be acceptable to consumers who are not used to eating it. In a first interview study (N=10), consumers generally responded positively towards duckweed as human food, although associations with turbid ponds also did come up. According to the respondents, duckweed belonged to the food category vegetables. So, duckweed was considered to fit best in meals where vegetables and greens are expected. In a larger online survey (N=669), it was confirmed that consumers had a more positive deliberate evaluation of duckweed and were more likely to accept a meal with duckweed if duckweed was applied in a fitting meal. It was also shown that providing information about nutritional and sustainability benefits increased deliberate evaluation and acceptability for fitting meals, but decreased it for non-fitting meals. Automatic evaluations positively influenced deliberate evaluation and acceptability, supporting the 'yuck' effect, but they did not differ between the meal applications. The current paper shows that if applied in a meal context that fits with consumer expectations, under the assumption that sensory properties like taste are satisfactory, there appear no major objections from consumers against the introduction of duckweed as human food at a larger scale.

**Keywords**: duckweed, consumer attitude, meal, fit, information, protein.

# Highlights

- Consumers were generally positive towards duckweed as human food.
- Duckweed was considered a vegetable and is seen as fitting in meals where consumers expect vegetables and other greens.
- Acceptability of duckweed was higher in fitting meals.
- Positive nutritional and environmental information increased duckweed acceptability of fitting meals, but decreased acceptability of non-fitting meals.

**Abbreviations**: AMP – Affect Misattribution Procedure; FNS – Food Neophobia Scale, EMS – Environmental Motives Scale, FCQ – Food Choice Questionnaire.

# 1 Introduction

Sufficient intake of protein (amino acids) is required for optimal growth, development, performance and health of individual humans (Boland et al., 2013). The growth of the world population (United Nations, 2015) in numbers and in standards of living results in an increased demand for animal-derived protein (Boland et al., 2013; Gilland, 2002). Animal-derived proteins (e.g. meat, fish, dairy and eggs) currently account for about 45% of human's total protein consumption (Pasiakos, Agarwal, Lieberman, & Fulgoni, 2015). Until now, production has been able to keep up with the population growth by intensifying animal production (Aiking, 2011), but it is expected that production will not increase sufficiently to keep up with the population growth (Gilland, 2002). In addition, environmental and social impacts of animal-derived proteins are high, and this forms also a barrier for a further increase of animal protein production (Aiking, 2011; Bruinsma et al., 2006; Van der Peet & Kamp, 2011).

It seems therefore inevitable to explore alternative sources of protein. Plant protein is an obvious alternative source as the conversion of plant into animal protein leads to substantial inefficiency (De Boer & Aiking, 2011). Promoting plant proteins over animal proteins can also bring human health benefits, for instance in preventing type 2 diabetes, which may be due to increased fibre intake, the polyphenols in plant protein or an effect of plant protein on glucose metabolism (Virtanen et al., 2017). Thus, there are several reasons to increase the usage of plant protein. To facilitate this, new plant proteins sources such as seaweeds, rapeseed, and duckweed, are expected to enter the European feed and food market (Van der Peet & Kamp, 2011; van der Spiegel, Noordam, & van der Fels-Klerx, 2013).

Duckweed has attracted attention because it (1) contains high amounts of high quality protein when grown under optimal conditions, ranging from 35 to 43% in dry matter (considering a water content of 92 to 94% in fresh duckweed) (Appenroth et al., 2017; Leng, Stambolie, & Bell, 1995); (2) contains protein with a better composition of essential amino acids, thus covering nutritional requirements to a larger extent than many other plant proteins (Iqbal, 1999; Leng et al., 1995); (3) has a high growth rate and can tolerate extreme circumstances (Goopy & Murray, 2003; Hassan & Edwards, 1992; Iqbal, 1999; Leng et al., 1995); (4) can be cultivated in a basin

on non-arable land, thereby avoiding the use of farming land (Ziegler, Adelmann, Zimmer, Schmidt, & Appenroth, 2015).

Human consumption of duckweed is common in some parts of Southeast Asia, including Laos, Thailand and Myanmar, as a vegetable named 'Khai-Nam' (Bhanthumnavin & McGarry, 1971). Wolffia arrhiza and Wolffia globosa are the dominating species used for human consumption (Appenroth et al., 2017; ISCDRA, 2016). Despite the great potential of duckweed as a source of plant protein in human nutrition (Appenroth et al., 2017), it is not part of the diet in Western countries. It is unclear how Western consumers perceive duckweed as food and in which foods they would accept duckweed and its derived products. The current paper aims to shed light on this in order to provide suggestions for acceptable introduction of duckweed as human food in Western societies by investigating which duckweed applications are acceptable to consumers and why.

Changing consumer's dietary patterns is challenging, because food acceptability and food choices are influenced by many factors and sensory preferences play an important role. Traditionally, changing acceptability of new food product alternatives (e.g. insects as protein sources) among Western consumer has focused on providing information in order to persuade consumers of the value of the alternative (Verneau et al., 2016). It is assumed that communication about the functional properties of a product will lead to a better evaluation of, or attitude towards, the product defined in terms of good, positive, approachable (De Vries, Modde, & Stoeller, 2009). However, this may not be sufficient because attitudes are based on a combination of cognitive and emotional elements (Ajzen, 1991) and are likely to include both conscious and unconscious evaluations (Gawronski & Bodenhausen, 2006). These emotional and unconscious evaluations may not be influenced by first encountered communication of functional benefits (De Vries et al., 2009).

Furthermore, personal factors play in role in the acceptability of new foods. Research on insects has shown that environmental motives are likely to support their adoption when insects are promoted as a sustainable alternative (Schultz, 2001). Also neophobia, the fear of eating new or unfamiliar foods, may hinder the consumption of unconventional sources of protein like duckweed. As such, it has been shown that children with high levels of neophobia are less willing to eat unfamiliar vegetables (Zeinstra, Vrijhof, & Kremer, 2018). This neophobia is a

personal trait that tends to differ between individuals and is particularly common in young children and generally decreases with age (Birch, McPhee, Shoba, Pirok, & Steinberg, 1987; Cooke, Carnell, & Wardle, 2006).

In order to change behaviour effectively, attention needs to be paid to the cognitive processes as well as the emotional processes of an individual. To understand the distinction between emotional, and more functional, cognition-based arguments, two types of consumer evaluation of foods are distinguished: automatic and deliberate evaluation. Automatic evaluations are assumed to be immediate, unintentional, implicit, stimulus based, and directly linked to approach and avoidance motives (Duckworth, Bargh, Garcia, & Chaiken, 2002). This involves emotional judgments based on quick intuitions (i.e. 'gut feelings'), including food relevant emotion disgust ('yuck' and 'disgust') responses (Haidt, 2001). People use these responses to quickly evaluate both novel and known stimuli as either good or bad, without much cognitive effort (de Vries et al., 2009; Duckworth et al., 2002). Such initial responses may influence immediate evaluation, while a more deliberate evaluation of information about the food product may raise other thoughts which can overrule the initial automatic response. Thus, both automatic and deliberate evaluations of food products are considered predictors of willingness to try new products (Gawronski & Bodenhausen, 2006).

*Hypothesis 1:* the more positive both automatic and deliberate evaluations of consumers towards duckweed as food are, the more willing consumers are to try or buy duckweed for human consumption.

While a given food product may trigger parallel activation of automatic and deliberate evaluation, automatic evaluations are faster and can influence the slower deliberate evaluations (Gawronski & Bodenhausen, 2006).

*Hypothesis 2:* the more positive the automatic evaluation of duckweed as human food, the more positive the deliberate evaluation will be.

Consumers are predominantly positive about sustainability (Bekker, Fischer, Tobi, & van Trijp, 2017; Schäufele & Hamm, 2018). Providing people with positive and/or sustainability information about new products increases their self-reported positive attitude towards these products (Bekker et al., 2017). Processing sustainability information was shown to influence

deliberate but not automatic evaluations (Bekker et al., 2017), which suggests processing sustainability information is a predominantly deliberate process. Similarly, (European) consumers are mostly positive about healthy food (Roininen et al., 2001) with effective health information being processed in a deliberate way (Grunert, Wills, & Fernández-Celemín, 2010).

*Hypothesis 3:* People who are provided with information about nutritional and sustainability benefits of duckweed as human food are more likely to have a positive deliberate evaluation of duckweed as human food compared to people who are not provided with any positive information.

Evaluation of food products does however, not only depend on health and sustainability perception but also on expectations of taste and appropriateness (Cardello, Schutz, Snow, & Lesher, 2000). Before actual consumption, evaluation of food products is limited to the mere sight of food, which already can facilitate the subjective desire to eat it (Hill, Magson, & Blundell, 1984; Marcelino, Adam, Couronne, Köster, & Sieffermann, 2001) and can activate brain areas and neural pathways associated with reward (Beaver et al., 2006). Thus, even before food is consumed, its appearance provides expectations about the taste, flavour, and palatability (Hurling & Shepherd, 2003). These consumer expectations play a significant role in the determination of food acceptability (Cardello, 1994). Exposure to a visually similar and familiar food prior to a new food, reduces the uncertainty about the taste of a new food and therefore generate a greater willingness to try (Dovey et al., 2012). As such, consumer expectations based on visual stimuli may be an important determinant in food acceptability when food products are not yet available for tasting.

Visual perception of a new product can instigate categorisation to a product category with which it shares physical or conceptual characteristics (Craig, 1986; Mandler, 1982) either by automatic categorisation (i.e. driven by unconscious cognitive processes) or by motivated categorisation (i.e. driven by individual needs and desires) (Elsbach & Breitsohl, 2016; Smith & DeCoster, 2000). Once a product has been categorised, expectations and inferences about its physical and sensory properties can be made, which influences product evaluations (Kardes, Posavac, & Cronley, 2004) and subsequent acceptability. When confronted with a new product, the product is likely to be categorised into the first plausible category (Moreau, Markman, & Lehmann, 2001). Inferences on a new product can also be based on analogies, which − in contrast to

categorisation − requires only partial resemblance of objects to make a mental connection (Gentner & Forbus, 2011). To assimilate a new product into a relevant category or to provide relevant analogies, the combination of product properties should show a consistent fit to be assimilated into the intended category. Misfit between elements of the new product can result in ambivalence towards the product, leading to a negative evaluation of that product (Gibbert & Mazursky, 2009). In addition, the degree of perceived fit and subsequent categorisation depends on the goal of the product in a given situation (Ratneshwar, Barsalou, Pechmann, & Moore, 2001), and this has been shown to influence how acceptable and fitting food-ingredient combinations are perceived to be (Tan, Fischer, van Trijp, & Stieger, 2016). The more fitting a product is in a particular situation, the more the product will be liked in general (Schutz, 1988, 1995). In summary, it is likely that the success of a new food product like duckweed depends on the extent to which the product attributes of duckweed can be associated with existing attributes of food consumed in a similar context.

*Hypothesis 4:* people who are exposed to an image of duckweed in a fitting context are more likely to have positive deliberate and automatic evaluations of duckweed as human food than people who are exposed to an image of duckweed in a non-fitting context.

Two studies were conducted to investigate the four hypotheses, which are summarised in figure 1. The aim of study 1 was to gain insight into consumers' perceptions about duckweed as human food and to establish more and less fitting meal contexts for duckweed. These findings provided input for study 2. In this study, the effect of fit (fitting versus non-fitting) and of information (presence or absence of information) was tested using different duckweed applications (meals).

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FIGURE 1 ABOUT HERE

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# 2 Study 1: explorative interviews

The aim of study 1 was to get an impression of people's ideas and opinions about duckweed as human food. A secondary aim was to investigate which meal applications are perceived as a fitting context for duckweed and which ones as a non-fitting context, where a fitting context represents a way (meal) in which duckweed may be processed or presented before people consider this food as acceptable.

## 2.1 Method

To obtain a broad range of individual opinions without, possibly normative, peer influence, one-to-one explorative semi-structured interviews were executed to explore acceptability of duckweed as human food, by inducing participants to express their views in their own terms (Cohen & Crabtree, 2006). Because duckweed is not yet available on the Western market for human consumption, participants could not taste duckweed. An interview protocol was developed based on Harrell & Bradley (2009), which presented concrete topics and questions in order to retrieve reliable and comparable qualitative data (Cohen & Crabtree, 2006). Questions were phrased in an open and neutral way to avoid leading questions and socially desirable answering. Verbal (e.g. 'can you tell more about this') and non-verbal (e.g. nodding) probes were used to get more clarity and/or in-depth information (Harrell & Bradley, 2009). After some first open questions, a photograph of duckweed was shown to make sure all participants referred to the same product. The following topics were addressed:

1) prior knowledge about duckweed and its benefits;
2) attitude towards duckweed as human food;
3) analogies and categories regarding duckweed as human food;
4) attitude towards new food products in general;
5) ideas about possible applications of duckweed in meals.

Ten Dutch subjects between 18 and 39 years of age were recruited by convenience sampling via a message on Facebook asking for 'people willing to give their opinion on a possible new food product'. People with food allergies or intolerances were excluded, because this could limit the range of categories and analogies. Demographic information on gender, age and study or work

domain of all ten participants was collected. Six males and four females participated in the semi-structured interviews. All interviews were executed by the first author in a one-on-one interview setting at Wageningen University. At the end of each interview, there was room for remarks and questions and to freely discuss ideas emerging from a duckweed recipe book (Gauw & Derksen, 2015). Each interview session took approximately 20 minutes and all participants received a small present after completion.

## 2.2 Data analysis

The recorded interviews were transcribed verbatim. The interviewer checked the transcripts with the recordings, in order to align transcripts with notes on non-verbal responses. A coding framework was developed based on the interview objectives and the interview guide. The qualitative data analysis package NVivo (QRS International, 2015) was used to code and organise the data systematically. Relevant statements were coded with a label and corresponding statements received the same label. Key concepts and categories were identified. Results were discussed among the authors to reach consensus.

## 2.3 Results

### 2.3.1 Prior knowledge about duckweed and its benefits

Six participants were immediately familiar with the term ‘duckweed’ and could explain what it was; all other four participants recognized it after seeing photographs. Participants mentioned protein and fibre as potential nutritional benefits of duckweed. Frequently mentioned environmental benefits included easy growing, reduced meat consumption, and the possibility to recycle waste waters. Toxicity and capacity to absorb heavy metals were raised as possible negative points. Although approximately half of the participants expressed interest in duckweed because of its sustainable qualities, they could not explicitly describe the specific environmental benefits of duckweed.

### 2.3.2 Attitude towards duckweed as human food

Participants’ attitude towards duckweed as human food was predominantly positive; as long as it was safe for consumption, no participant objected. At first glance, duckweed did not seem tasty to the participants because of its association with its natural environment (ponds), which were

described as ‘dirty’, ‘filthy’, or ‘turbid’. However, when presented in a supermarket, showing only the edible parts, participants thought that duckweed would look more attractive as a food product. Participants who mentioned duckweed as ‘interesting’, as a ‘new possibility for variation in the diet’, or as ‘beneficial for the environment’ showed a special interest in trying it.

While their attitude towards duckweed as human food was predominantly positive, all participants expected that the general population might not be as open towards human consumption of duckweed. The main reason for this was the association of duckweed with dirty/turbid ponds, which contrasts with ‘healthy’, ‘safe’, ‘attractive’, and ‘appetizing’ foods. Unfamiliarity with duckweed was mentioned as a second reason for reluctance to try/eat it. Nevertheless, duckweed was considered more easily accepted than other suggested new foods, such as insects or algae, because it is a plant and ‘does not move like insects’. Especially ‘green’ and ‘fresh’ were considered appealing characteristics. An attractive presentation in the supermarket and a ‘nice’ and ‘hip’ story around duckweed were suggested to increase acceptability. To elicit positive associations, it was suggested to add terms like ‘fresh’ and ‘healthy’ on the package, as well as differentiating duckweed growing in ponds from duckweed growing in a controlled environment.

### 2.3.3 Analogies and categories regarding duckweed as human food

When asked about analogies when considering duckweed, most frequently mentioned were: ‘salad’, ‘ponds’, ‘green’, ‘food’, ‘plants’, ‘watercress’, ‘algae’, ‘herbs’, ‘ducks’, ‘dirty’, and ‘insects’.

When asked about suitable food categories for duckweed, ‘vegetables’ came up as most prominent; followed by ‘salad’ and ‘herbs’; and ‘leafy vegetables’, ‘plants’, and ‘superfoods’. Duckweed was mostly categorized as a vegetable that would fit in the vegetable section (the salad and cress section in particular) or the herbs section of any supermarket. Participants also imagined duckweed as a refrigerated food product, a food fitting the organic section, or food situated somewhere near the vegetarian burgers. Some participants doubted whether consumers would recognize duckweed as the plant that grows in ponds when presented in a supermarket-context.

Overall, participants negatively associated the word 'duckweed' with 'dirty ponds', and 'weed' was negatively associated with undesirable plants or drugs (cannabis). In addition, the reference to 'duck' in the name appeared confusing to some participants, because duckweed is not an animal product. Alternative names were suggested: (water)cress, Lemna minor, Minilemna, duck salad, 'three-pointed leaf'. In contrast, several participants supported use of the word 'duckweed' because 'it is what it is' and it makes the food product 'interesting', 'funny' and 'transparent', especially if it becomes a hype.

### 2.3.4 Attitude towards new food products in general

Participants had a predominantly positive attitude towards new food products in general; terms like 'nice', 'special', 'interesting', 'chance' and 'positive' were used. However, they indicated that they would not accept 'too weird' or 'extreme' products. They also mentioned that for duckweed to become a successful food product, it needs to be introduced in supermarkets. By ensuring large scale sustainable production and broad availability of duckweed in the Netherlands, a large part of the Dutch population can consume it, which is deemed necessary for success. In contrast, a few participants articulated the advantages of limited availability, as scarcity could increase the attractiveness ('wanting factor') of a new food product. To enhance the success of a new food such as duckweed, participants suggested to use food bloggers and recipe magazines to promote it as a 'new', 'innovative', 'hip', and 'healthy' product.

### 2.3.5 Possible applications of duckweed in meals

'Salad' was the most frequently mentioned meal application, followed by 'sandwich' and 'garnish' (table 1 provides a more detailed overview of mentioned applications). Half of the participants indicated explicitly that it would be easier to suggest applications if they knew the taste; a third was interested in how duckweed would react to high temperatures during preparation.

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TABLE 1 ABOUT HERE

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Participants indicated they would rather not prepare 'duckweed as steak', nor several of the shown recipes in the book such as 'duckweed cake', 'duckweed curry', 'duckweed juice'.

Duckweed was predominantly viewed as food that should be served as a 'fancy', 'exclusive', 'high-end', 'novel', or 'special' food at special occasions and 'high level events', such as conferences, catering exhibits, a tasting session in a restaurant, or in the presence of guests. Duckweed meals were considered to trigger conversations at the table. Both dinner and lunch were mentioned as possible eating times for duckweed.

## 2.4 Discussion

The participants were in general open to the idea of duckweed as human food, although participants assumed the larger Dutch population to be less willing to try duckweed. Duckweed was predominantly viewed as a 'fancy', 'exclusive', 'high end', 'novel', or 'special' food to be served at special occasions. Participants perceived duckweed as a potentially successful food product in the Netherlands, due to its appealing green and fresh appearance, especially when compared to less appealing products, such as insects. To increase the likelihood of success of duckweed as human food, participants suggested an attractive presentation, and to use food bloggers and recipe magazines to promote it as a 'new', 'innovative', 'hip', and 'healthy' product.

The most dominant analogies were based on the physical associations with duckweed ('pond', 'green', 'salad'), on abstract properties ('insects'), or a combination of both ('watercress', 'algae'). Participants indicated that duckweed belonged to the food category 'vegetables'. So, meals with duckweed that were deemed fitting were almost always savoury and dishes in which vegetables are usually present. In particular, cold dishes such as salads and sandwiches were mentioned as likely to be fitting duckweed meals. But also, albeit less frequently, warm dinner meals like quiches and mashed potato dishes were considered as fitting duckweed meals. Cake and (sweet) pastries were considered as non-fitting products, presumably because of their sweetness. From this study, it becomes apparent that consumers identified several dishes in which they consider duckweed fitting, and came up with a range of products in which they think it would not fit. It does, however, not become clear whether evaluation and acceptability of these products differ systematically between meals; and which specific meal contexts are considered a misfit. In addition, the exploratory nature of the study limited the number of stimuli and participants. Hence, it was not possible to systematically investigate to what extent product context and personality characteristics matter. In a second study, using a larger more diversified

sample, consumer evaluations of products identified as fitting in study 1, and products from the category identified a misfit were systematically investigated to confirm and extend the findings of study 1.

# 3 Study 2

The main objective of this study was to test the influence of both contextual fitting and positive information provision in the process of duckweed acceptability. See figure 1 for the four hypotheses.

## 3.1 Method

### 3.1.1 Participants and design

Participants were recruited via an e-mail to a pool of approximately 2000 volunteers of Wageningen Food & Biobased Research. Inclusion criteria for participation were age of 18 years or older and a good command of the Dutch language. A total of 669 completed surveys were received (response rate ~33%).

A 2 (fitting vs. non-fitting context) x 2 (positive information provided vs. no information provided) between-subjects design was used in a Qualtrics web survey[1]. Participants were randomly assigned to one of the four conditions. The main outcome measures were: automatic evaluation, deliberate evaluation and acceptability of duckweed.

### 3.1.2 Manipulations

Fit was manipulated by showing a series of four photographs of either fitting or non-fitting duckweed meals or products. Fit or non-fit was based on the results from study 1. The series of fitting duckweed products consisted of: sandwich, salad, quiche and mashed potato dish. The series of non-fitting duckweed products were cake, pastry, and not-mentioned combinations: vegetable juice, and cheese. The inclusion of four different products served as internal replication and to control for individual differences in liking of specific products. Participants

[1] www.qualtrics.com

received either the series of four fitting meal photographs or the series of four non-fitting meal photographs. The meals within the series were presented in randomised order (figure 2).

All groups were informed that the shown meal contained duckweed. In the information conditions a single line 'Duckweed is rich in protein and environmentally friendly' was shown below the photograph and a more extensive text about the nutritional and environmental benefits of duckweed was shown between completion of the automatic evaluation task and the start of the deliberate evaluation task (text box 1).

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FIGURE 2 ABOUT HERE

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TEXT BOX 1 ABOUT HERE

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### 3.1.3 Measures

Automatic evaluation of duckweed meals was measured with the affect misattribution procedure (AMP). This procedure is based on the principle that exposure to a (priming) stimulus triggers an affective state, which in turn automatically biases the judgement of subsequent objects (Payne & Lundberg, 2014). If these objects are themselves without meaning, the procedure reliably assesses the affective response to the prime instead. The AMP procedure has been previously used for food decision, in particular related to high-caloric foods (e.g. Hofmann, Friese, & Roefs, 2009; Kemps, Tiggemann, & Hollitt, 2014; Richard, Meule, Friese, & Blechert, 2017; Woodward, Treat, Cameron, & Yegorova, 2017). Each AMP trial began with briefly (300 ms) showing an image of one of the four meals containing duckweed (the visual prime). Participants were explicitly instructed to ignore the visual primes. After the visual prime, one of four Chinese characters (target item; figure 3) was shown for 300 ms. Participants then had to rate the Chinese character in their own time on a 7-point Likert scale, anchored from 'very unpleasant' to 'very pleasant' (figure 4).

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FIGURE 3 ABOUT HERE

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FIGURE 4 ABOUT HERE

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To counterbalance for specific product-character associations, the four Chinese characters were randomized across the four images using a Latin square design. In addition, manipulation checks were performed at the end of the survey to find out whether participants rated the Chinese characters differently on a 7-point Likert scale (ranging from 'very unpleasant' to 'very pleasant').

Deliberate evaluation of the meals was assessed using three deliberate attitude items on a 7-point semantic differential scale: 'very negative-very positive' (general), 'very meaningless-very meaningful' (cognitive), and 'not very tasty-very tasty' (emotional) (average Cronbach's α=.80) (Bruner, 2012, 2015).

Acceptability was measured with two items 'I am willing to buy [this duckweed product]' and 'I am willing to try [this duckweed product]', scored on a 7-point scale ranging from 'totally disagree' to 'totally agree' (average Cronbach's α=.70) (Tan, van den Berg, & Stieger, 2016), followed by a question to what extent they considered duckweed fitting the presented meal on the same 7-point scale.

General opinion of the participants on duckweed as human food was measured with nine items on a 7-point semantic differential scale (very negative-very positive; very meaningless-very meaningful; not very tasty-very tasty; very unfamiliar-very familiar; very unnatural-very natural; very unsafe-very safe; very accessible-very exclusive; very unhealthy-very healthy; very environmentally unfriendly-very environmentally friendly) from Bruner (2012, 2015). A self-constructed item on taste expectations of duckweed was added ranging from 'not very distinct' to 'very distinct'.

Food neophobia was measured with a Dutch translation by Hoek et al. (2011) of the 10-item Food Neophobia Scale (FNS) developed by Pliner & Hobden (1992); Cronbach's $\alpha = 0.85$. Individuals' concerns about environmental issues were measured with the 12-item Environmental Motives Scale (EMS) consisting of 3 subscales: Biospheric, Social-altruistic and Egoistic values based on Schultz (2001); Cronbach's $\alpha \geq 0.91$. All items were measured on a 7-

point scale ranging from 'totally disagree' to 'totally agree'. In addition, an adapted short version of the food choice questionnaire (FCQ) (Onwezen, van 't Riet, & Bartels, 2011) was completed. Because inclusion of this questionnaire did not change the main conclusions, it is not included in further analyses.

To control for participants' general attitudes towards the two series of four meals (sandwiches, salads, savoury pies, mashed potato dishes, cake products, pastries and sweet pies, vegetable juices, and Dutch cheese products), they evaluated all eight meals on a 7-point scale ranging from 'not very positive' to 'very positive' at the end of the survey.

### 3.1.4 Procedure

A survey link was distributed by e-mail early 2017 to the pool of volunteers. After clicking the link, participants saw a general introduction to the experiment with a minimal reading time of 30 seconds during which the images were preloaded and they were randomly assigned to one of the four conditions. Subsequently, they completed the four AMP trials in randomized order. Next, participants rated deliberate attitude and acceptability of the four duckweed products in the same order as the AMP trials. Participants then rated their general attitude towards eating duckweed, and scored the FNS, EMS and FCQ items. Finally, gender, age, highest level of education completed, food allergies or intolerances, and special dietary requirements were asked. Participants were thanked for their participation, and five gift certificates were raffled among participants. Completion of the online survey took about 15 minutes.

### 3.1.5 Statistics

The data were analysed using IBM SPSS 24 with a critical p-value of .05. As all scales had Cronbach's $\alpha > .70$ and were thus deemed sufficiently reliable. Average scores of items were used for the relevant constructs. For testing the main hypotheses, the four scores for the fitting or non-fitting images (meals) were averaged to get a single aggregated score. Analyses consisted of Pearson's $\chi^2$, ANOVA's (repeated or mixed when within participant scores were compared), correlation and regression models to investigate the relationships between automatic and deliberate evaluations and duckweed acceptability. Mediation analyses were conducted in the PROCESS macro in SPSS (Hayes, 2017).

## 3.2 Results

The majority (67%) of the participants was female. Their mean age was 53 years (SD = 18) and most participants belonged to the age category 61-70. The sample was relatively highly educated, with 60% of the participants reporting to have completed tertiary education. Participants scored relatively low on food neophobia. Six percent of the participants was vegetarian. A lack of systematic differences between conditions indicates that randomisation was successful (see table 2 for full details).

A factorial repeated measures ANOVA showed significant − yet small − differences between participants' attitudes towards the four Chinese characters: $F(3, 655) = 22.66$, $p<.01$, partial $\eta^2=.03$ with the dragon character being slightly more liked than the other three.

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TABLE 2 ABOUT HERE

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An overview of the means and standard deviations for the main measured variables automatic evaluation, deliberate evaluation and acceptability across the conditions and individual products is provided in table 3. Automatic evaluations covered a range from 4.01 to 4.51, whereas deliberate evaluations ranged more widely from 3.67– 5.65. Acceptability scores ranged from 4.55 to 5.95, indicating a somewhat positive score for acceptability. Only two mean scores on deliberate evaluations in the information condition were slightly below the scale midpoint (cheese $t(164)=-2.80$, $p<.01$, juice $t(164)=-0.38$, $p=.69$). Hence, it appears that participants in general were not negative about duckweed as human food.

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TABLE 3 ABOUT HERE

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### 3.2.1 Effect of experimental manipulations on automatic and deliberate evaluation and overall acceptability

No main effects of fit ($F(1,586)=0.39$, $p=.53$), information ($F(1,586)=0.94$, $p=.33$), or their interaction ($F(1,586)=0.25$, $p=.62$) were found for the automatic evaluation of the duckweed

meals. For the deliberate evaluation, there was a main effect of fit ($F(1,586)=96.51$, $p<.01$, partial $\eta^2=.13$): fitting products were evaluated more positively. There was no main effect of information ($F(1,586)=0.11$, $p=.74$). In addition, an interaction effect for information and fit on deliberate evaluation was found ($F(1,586)=51.33$, $p<.01$, partial $\eta^2=.07$) to the extent that providing information about duckweed positively influenced the deliberate evaluation in a fitting context but negatively for the non-fitting products. For duckweed acceptability, a main effect of fit ($F(1,586)=28.01$, $p<.01$, partial $\eta^2=.04$) was found: fitting products were more accepted. There was no main effect of information ($F(1,586)=0.08$, $p=.78$). In addition, the interaction information*fit was significant ($F(1,586)=12.54$, $p<.01$, partial $\eta^2=.02$) to the extent that information increased acceptance in a fitting context but the effect was opposite for non-fitting products (figure 5).

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FIGURE 5 ABOUT HERE

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A multiple regression model predicting automatic evaluation, deliberate evaluation, and acceptability based on experimental conditions and socio-psycho-demographics showed that automatic prediction was significantly - albeit to a small extent, $F(15,547)=1.80$, $p=.03$, $R^2=0.05$ - predicted by the model variables, with neophobia being the main predictor $t(547)=-4.11$, $p<.01$, $b=-0.18$. Deliberate evaluation in turn was more relevantly predicted $F(16,546)=20.12$, $p<.001$, $R^2=0.37$, by automatic evaluation, fit, the interaction fit*information, neophobia and biospheric values contributing significantly to its predictions. Acceptability was well predicted $F(16,545)=86.95$, $p<.001$, $R^2=0.73$, mainly by deliberate evaluation but also by neophobia and biospheric evaluation (see table 4). To test whether the effect of automatic evaluation was indeed fully mediated by deliberate evaluation, a mediation analysis was conducted in the PROCESS macro (model 4) with acceptability as dependent variable, automatic evaluation as independent and deliberate evaluation as mediator, and all other predictors from the multiple regression model in table 5 as covariates. A significant indirect effect of automatic evaluation on acceptability through deliberate evaluation (Effect=0.054; 95% CI [0.001:0.109]) was found with no remaining significant direct effect (Effect=0.012; 95% CI [-0.0360:0.0606]). This means that

the effect of automatic evaluation on acceptability scores is fully mediated by deliberate evaluation.

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TABLE 4 ABOUT HERE

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# 4 General discussion

This paper shows − in two studies − that Dutch consumers may be willing to accept duckweed as human food. The first, qualitative, study showed that appealing characteristics of duckweed included the green and fresh appearance. The study also showed that duckweed is considered a vegetable; and that savoury dishes where vegetables are expected were regarded as fitting meals for duckweed. The second study indicated that Dutch consumers are generally open to try and buy duckweed meals. In line with our hypotheses, the survey confirmed that presentation of duckweed in a fitting meal made duckweed more acceptable than application in meal types identified as non-fitting. Fitting duckweed meals were also evaluated more positively when evaluation was deliberate, but no effect of fit on automatic evaluation was found. This suggests that interpretation of fit requires some deliberate reflection and may not be automatic per se.

Providing information about the nutritional and environmental benefits of duckweed as human food moderated the effect of information provision on deliberate evaluation and on acceptability. Participants received the positive health and sustainability information responded more positively if they had seen a fitting meal. In contrast participants who received this positive information with a non-fitting meal had a less positive deliberate evaluation than those not shown information.

In addition, the more positive the automatic evaluation of duckweed as human food, the more positive the deliberate evaluation of duckweed as human food, and the more positive the deliberate evaluation, the higher the acceptability. No remaining effect of positive automatic evaluation on acceptability remained when deliberate evaluation was in the model, indicating that the influence of automatic evaluation on acceptability of duckweed as human food was fully mediated by deliberate evaluation.

Reviewing the outcomes, the current study is somewhat at odds with the most common information studies, because our study identified situations where providing benefit information on health and sustainability resulted in lower acceptability of duckweed as food. This may be understood if we consider that the non-fitting meals in study 2 (e.g. cake and pastries) are unlikely to have been perceived as 'sources of important nutrients'. Hence, information promoting that these snacks are healthy may have resulted in psychological reactance (Brehm, 1966), where consumers actively go against recommendations they feel at odds with. It might also be that participants had an 'unhealthy = tasty'-association (Raghunathan, Naylor, & Hoyer, 2006; Wardle & Huong, 2000), where especially the relation between health and indulgence food may have been problematic. As the robustness of the unhealthy=tasty association has been challenged (Huang & Wu, 2016; Werle, Trendel, & Ardito, 2013), future research is needed to determine whether this association applies in this case.

Nevertheless, information seems to be relevant as participants remarked about a 'lack of information' in both studies, and requested information about taste but also health benefits and environmental benefits in conditions where no information was provided. This suggests that some information is needed when duckweed is introduced as human food, but the possibility of potentially negative effects, requires that such information needs to be carefully designed. If the healthiness of duckweed (high-protein content) becomes a key in marketing strategies, communicating recipes of fitting full-meals (e.g. lunch or main meals) seems promising as these constituted the majority of the fitting applications. It should be realised that vegetables are not commonly considered sources of protein, so marketing of duckweed as high protein vegetable may be difficult, and relating duckweed to legumes may mainly be successful for recipes where legumes are customarily used. Besides aiming at duckweed-meal fit, we recommend to also investigate whether situational variables such as meal situation, social interaction, and physical environment also affect product acceptability (King et al., 2007; Rozin, 1996), in the context of introducing duckweed. In addition, it is also relevant to investigate duckweed protein digestibility in humans in order to know whether the current claim about the potential nutritional value of duckweed can be communicated as a relevant selling point.

Besides the central hypotheses, our study also showed that participants with high levels of neophobia were less positive about duckweed as food, in automatic and deliberate evaluations as

well as in acceptability. This suggests that introduction of duckweed to some more neophobic segments of the population may encounter resistance. No effect of social-altruistic or egoistic values were found. Participants with high levels of biospheric values were more positive about duckweed as human food in deliberate evaluation and acceptability, but no such effect was found on automatic evaluation. This suggests that targeting consumers who value organic products, could be a relevant market for duckweed products.

It remains important to realise, that – in order for duckweed to be successful on the market – the relatively high levels of acceptability should also lead to purchasing behaviour and actual intake. Not all intentions lead to the intended behaviour, typically referred to as 'the intention-behaviour gap', which has, for instance, been demonstrated in the context of healthy snack choice (Weijzen, de Graaf, & Dijksterhuis, 2008). Besides focussing on fitting meals and meal situations, mainstream availability was mentioned by the interviewees as a precondition to close the intention-behaviour gap. A lack of a tasty, fitting context together with limited supply of high quality products can lead to the failure of the introduction of the product, as arguably has been happening with the introduction and subsequent largely disappearance of insect foods in Dutch supermarkets (House, 2016). In addition to availability of the product, the provision of recipes should also be considered as a precondition for success. If consumer do not know how to prepare duckweed, they will not buy it. An alternative strategy, to avoid mainstream supply demands, might be to introduce duckweed as a new hip and healthy delicacy in selected shops at first, or to promote it via food bloggers on social media and recipe magazines. Further research is needed to identify the most promising marketing strategy. In this context, it should be realised that besides potential consumer resistance to duckweed as food, there is also a legal barrier. Duckweed was not consumed to a significant degree prior to 1997 and is therefore a novel food within the EU novel food legislation. This puts high demands on providing evidence on food and nutritional safety as well as on the labelling of products containing duckweed.

There are some limitations to the current research that require attention. The sample was not fully representative, i.e. higher educated and older than the average Dutch population. This is unlikely to influence the main conclusions of the reported study as none of the demographics had a significant influence on the measured variables. Nevertheless, previous research shows that higher educated people are more open to change their diet, and older people less likely to makes

such changes (e.g. Fischer & Frewer, 2008). Therefore, the influence of these demographics on consumers' choices for duckweed meals should be investigated before duckweed meals are introduced.

Another limitation is that the choice for the fitting and non-fitting meals was based on the first study. The non-fitting condition included sweet dishes applications (cake and pastry), a drink (vegetable juice), and an ingredient rather than a Dutch dish (cheese); whereas the fitting dishes presented more complete dishes across a less broad spectrum of applications (i.e. salads and vegetable hot meals). The unnaturalness of green cake and of green cheese (due to the addition of duckweed) may have contributed to the lack of fitting ingredient combinations for these products. Against this the assumed non-fitting vegetable juice with duckweed scored relatively high on perceived fit. This variance in the non-fitting products may have resulted in a somewhat inaccurate outcome across the non-fitting products. The relatively high fit for vegetable juice would most likely reduce the hypothesised relations; therefore, we argue that our results are probably robust in spite of this limitation. For practical use of duckweed products, future research should further identify what other combinations are truly fitting or non-fitting for duckweed applications.

A further limitation relates to the automatic evaluation measure. While it did influence deliberate evaluation and through that acceptance, automatic evaluations themselves were only influenced by neophobia and not by the differences in duckweed application. While the found effect of neophobia is consistent with a general 'yuck' response (Haidt, 2001), we could not identify any differences between fitting or non-fitting duckweed applications. This could mean that only neophobia plays a role towards automatic evaluations regardless of the product, suggesting that in our context, AMP measured a generic halo of neophobia. Even the non-information group received the limited information that the presented meals contained duckweed. Extensive positive information about duckweed was provided only after the AMP procedure was completed. Previous research on automatic evaluations does not show any effect of information prior to an automatic evaluation test (Bekker et al., 2017), which suggests that extensive information would not have influenced AMT measures. However to fully rule out such effects, further research is recommended where automatic evaluations are preceded by more elaborate information as well. Informing all participants to the presence regardless of condition may have

reduced the likelihood of finding differences between conditions. The lack of product relevant outcomes may also have to do with the reliability of the AMP method itself, which may also need scrutiny in this context. It may share the relatively low reliability that many other measures of automatic evaluation suffer from (LeBel & Paunonen, 2011), which makes it more difficult to find relations between the measure and other measures. In addition, we adopted the method as developed by Payne & Lundberg (2014), which included the use of Chinese characters as target items. The method has been successfully used and validated in many studies and there were only minimal differences between participants' attitudes towards each individual Chinese character. The characters were considered abstract and neutral with respect to the judgment, validating the choice. However, during debriefing some participants expressed confusion about the use of Chinese characters in association with duckweed as food as it created the impression that duckweed would be imported from China or be related to the Chinese cuisine. Therefore, especially in future food research, it may be worthwhile to replace Chinese characters with even less loaded symbols as target items in the AMP task (e.g. abstract shapes). Finally, this study investigated expectations about duckweed, but it could not be tasted in this study. Once duckweed is proven to be safe for human consumption – consumer tests are recommended in which sensory liking of duckweed in various meal applications is assessed.

# 5 Conclusion

Providing information about the nutritional and environmental benefits of duckweed has a positive effect on duckweed acceptability as food for humans in the Netherlands, on condition that duckweed is used in a fitting meal (vs. a non-fitting meal). We therefore emphasize the importance of introducing duckweed in fitting contexts to increase its chance of acceptability in an information craving, marketing driven, Western society.

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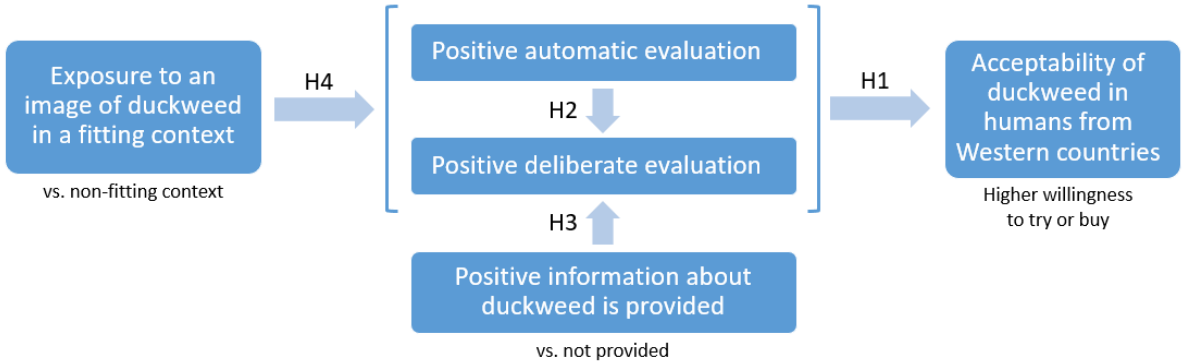


*Figure 1. Overview of the four central hypotheses.*


*Figure 2. The four meal stimuli in each of the four conditions. All stimuli have the text (translated from Dutch) above the image: 'This dish contains duckweed'. Stimuli in the 'information provided' conditions additionally report 'Duckweed is high in protein and environmentally friendly' below the image.*

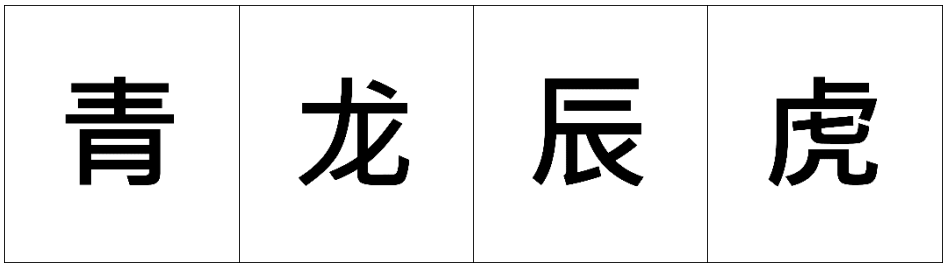


*Figure 3. The four Chinese characters used in the 'automatic evaluation' trials, referred to as: 'blue', 'dragon', 'morning', 'tiger' (from left to right).*

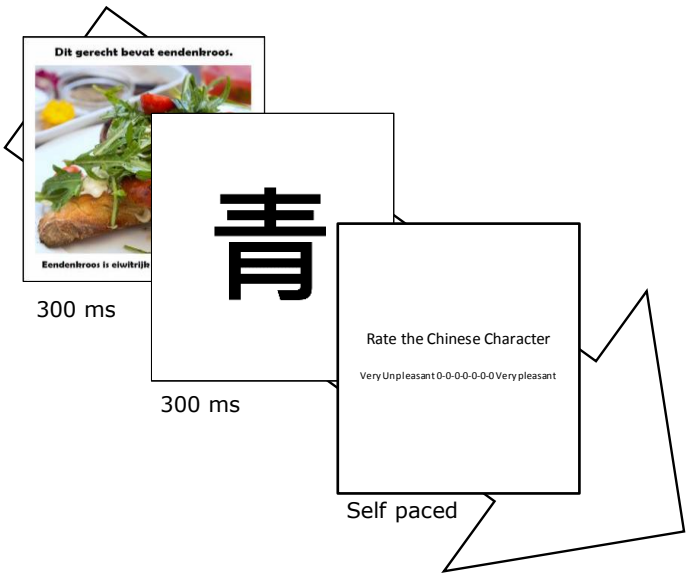


*Figure 4. Example of the steps of the AMP task.*

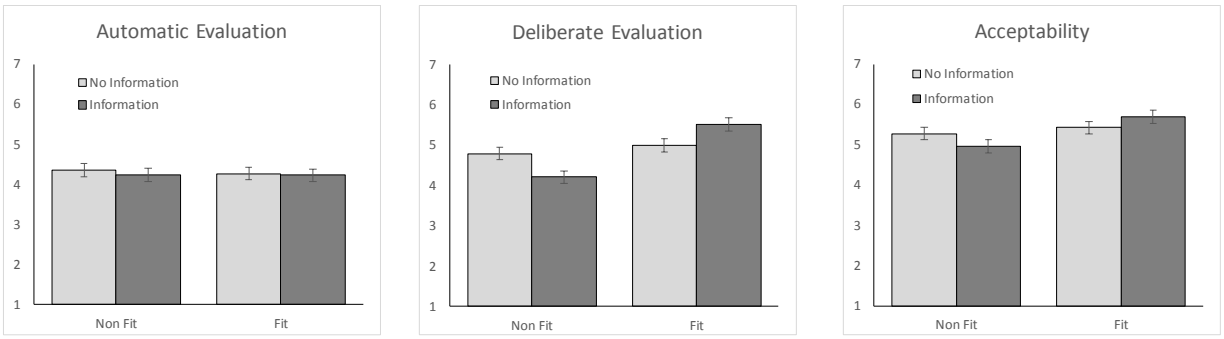


*Figure 5. (Estimated marginal) Means of automatic and deliberate evaluation and acceptability of duckweed meal applications (error bars indicate 95% confidence intervals).*

**Table 1. Fitting meal applications for duckweed sorted by number of participants that mentioned them.**

| Meal applications | Number of participants |
|---|---|
| Salad | 8 |
| Sandwich; garnish | 4 |
| Soup; pasta; herbs | 3 |
| Fish; condiment to sandwich with cheese | 2 |
| Burrito; party nibbles; wok dish; quiche; chicken breast; couscous; chicken; cream sauce; duck; mashed potato dish; pesto; veggie burger; cookies | 1 |

**Table 2. Participant demographics of study 2 (N = 669).**

| | % (n) or Mean (SD) | Distribution across conditions |
|---|---|---|
| **Gender % Female** | 67% (439) | $\chi^2(3)=2.88$, $p=.41$ |
| **Age (years)** | 53 (18) | $F(3,653)=1.23$, $p=.30$ |
| **Highest level of education completed** | | $\chi^2(3)=1.35$, $p=.50$ |
| Lower (at most low level vocational) education | 8% (56) | |
| Intermediate vocational education | 17% (116) | |
| Secondary education | 15% (100) | |
| Tertiary education | 60% (397) | |
| **Reported food allergies or intolerances % Yes** | 22% (139) | $\chi^2(3)=4.73$, p=.19 |
| **Special dietary requirements** | | $\chi^2(6)=8.45$, p=.21 |
| No | 89% (579) | |
| Vegetarian | 6% (38) | |
| Other* | 5% (35) | |
| **Neophobia** [a] | 2.72 (0.94) | F(3,653)=0.51, p=.68 |
| **Environmental concern (EMS)** [a] | | |
| Biospheric | 5.8091 (0.947) | F(3,653)=0.4269, p=.7456 |
| Social-altruistic | 5.9180 (0.974) | F(3,653)=0.1147, p=.7095 |
| Egoistic | 5.15 (1.09) | F(3,653)=0.09, p=.97 |

Note: Some participants that provided usable data dropped out before answering all demographic questions, and some demographic questions did not demand a response resulting in minor variations in numbers of responses.
* Reported diets other than vegetarian included flexitarian, no pork, low-salt, low-sugar, and low-carbohydrate diets.
[a] Scored on a 7-point scale ranging from 'totally disagree' to 'totally agree'.

**Table 3. Mean (SD) for automatic evaluation, deliberate evaluation, and duckweed acceptability (measured on a 7-point scale) (N = 669).**

| | | | Automatic evaluation* | Deliberate evaluation | Duckweed acceptability |
|---|---|---|---|---|---|
| **Fitting** | Info | Sandwich | 4.35 (1.08) | 5.65 (1.00) | 5.94 (1.06) |
| | | Salad | 4.24 (1.18) | 5.56 (1.15) | 5.70 (1.21) |
| | | Quiche | 4.12 (1.22) | 5.44 (1.28) | 5.51 (1.38) |
| | | Mashed potato dish | 4.21 (1.14) | 5.40 (1.11) | 5.60 (1.22) |
| | No info | Sandwich | 4.36 (1.17) | 5.12 (0.96) | 5.70 (1.05) |
| | | Salad | 4.29 (1.16) | 4.96 (1.18) | 5.36 (1.32) |
| | | Quiche | 4.21 (1.20) | 4.91 (1.24) | 5.26 (1.39) |
| | | Mashed potato dish | 4.21 (1.17) | 4.90 (1.11) | 5.35 (1.22) |
| **Non-fitting** | Info | Cake | 4.27 (1.18) | 4.36 (1.10) | 5.25 (1.16) |
| | | Pastry | 4.44 (1.10) | 4.86 (1.11) | 5.48 (1.14) |
| | | Vegetable juice | 4.23 (1.19) | 3.96 (1.25) | 4.55 (1.38) |
| | | Cheese | 4.01 (1.15) | 3.67 (1.52) | 4.55 (1.53) |
| | No info | Cake | 4.47 (1.24) | 5.00 (1.11) | 5.68 (1.05) |
| | | Pastry | 4.51 (1.25) | 5.33 (1.07) | 5.78 (1.05) |
| | | Vegetable juice | 4.33 (1.25) | 4.55 (1.27) | 4.90 (1.39) |
| | | Cheese | 4.13 (1.29) | 4.27 (1.51) | 4.73 (1.60) |

* Only 509 participants scored all images in the AMP, possibly due to the device on which the survey was taken in combination with the short prime duration (300 ms)

**Table 4. Regression models predicting automatic and deliberate evaluations as well as acceptability**

| | Automatic evaluation | | | Deliberate Evaluation | | | Acceptability | | |
|---|---|---|---|---|---|---|---|---|---|
| Independent variable in equation[a] | b | *t* | *p* | b | *t* | *p* | b | *t* | *p* |
| Deliberate Evaluation | | | | | | | .694 | 25.479 | .000 |
| Automatic Evaluation | | | | .078 | 2.028 | .043 | 0.01 | .501 | .616 |
| Fit (-0.5=no fit, 0.5=fit)[b] | -0.05 | -0.56 | .57 | .754 | 10.076 | .000 | -.081 | -1.552 | .121 |
| Info (-0.5=no info, 0.5=info) | -0.08 | -1.01 | .31 | -.048 | -.646 | .518 | -.015 | -.325 | .745 |
| Fit*Info | 0.15 | 0.84 | .40 | 1.188 | 7.916 | .000 | -.133 | -1.317 | .188 |
| Neophobia | -0.18 | -4.11 | <.01 | -.348 | -8.560 | .000 | -.262 | -9.484 | .000 |
| Environmental concern (EMS) | | | | | | | | | |
| Biospheric | 0.02 | 0.40 | .69 | .190 | 3.796 | .000 | .114 | 3.540 | .000 |
| Social-altruistic | 0.01 | 0.20 | .84 | .017 | .318 | .751 | .023 | .665 | .506 |
| Egoistic | 0.03 | 0.73 | .47 | .057 | 1.361 | .174 | <0.01 | -.002 | .998 |
| Gender (0 male, 1 female) | 0.02 | 0.26 | .80 | .031 | .373 | .709 | -.053 | -.994 | .321 |
| Age (yrs) | <0.01 | 1.14 | .26 | .001 | .481 | .630 | <0.01 | -.130 | .896 |
| Highest level of education completed (0 = lower level) | | | | | | | | | |
| Intermediate vocational education | 0.03 | 0.18 | .86 | .240 | 1.415 | .158 | -.058 | -.537 | .592 |
| Secondary education | -0.11 | -0.58 | .56 | .065 | .369 | .712 | .112 | 1.002 | .317 |
| Tertiary education | -0.13 | -0.73 | .46 | .187 | 1.219 | .224 | .093 | .952 | .342 |
| Allergies (0=none) | -0.07 | -0.73 | .47 | .173 | 1.896 | .058 | .114 | 1.952 | .051 |
| Special dietary requirements (0=none) | | | | | | | | | |
| Vegetarian | 0.26 | 1.42 | .16 | .220 | 1.312 | .190 | .159 | 1.488 | .137 |
| Other | 0.29 | 1.56 | .12 | -.003 | -.020 | .984 | .134 | 1.273 | .204 |
| | F(15,547)=1.80, *p*=.03 $R^2$=0.05 | | | F(16,546)=20.12, *p*<.001 $R^2$=0.37 | | | F(17,545)=86.95, *p*<.001 $R^2$=0.73 | | |

[a] Automatic and deliberate evaluation were only included in the estimation of acceptance.
[b] Effect coded experimental factors to control for collinearity between Fit*Info interaction and main effects.

Here you see [product] with duckweed. Duckweed is a water plant with small leafs. In daily life, duckweed is often observed as a green tapestry on open water.

Duckweed has a high protein content, which makes it valuable as human food. Consumption of sufficient protein is important for a good health. If duckweed is grown under optimal conditions, it can contain up to 40% of protein. This protein is relatively easily absorbed in the body.

In addition, growing duckweed is environmentally friendly because it grows fast and does not require intensive agriculture or animal breeding. Duckweed can contribute to the purification of (waste)waters and can be grown without additional fertilizers in water basins. The ecological footprint of duckweed is limited; for each kilogram of duckweed about 0.4 kg of $C0_2$ equivalent is produced. In comparison, 27 kg of $C0_2$ equivalent is produced per kilogram of beef.

*Text box 1: Extensive information about duckweed provided to participants in the 'positive information' condition (translated from the original Dutch text)*