Factors affecting consumer attitudes to fungi-based protein: A pilot study

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ABSTRACT

Meat substitutes using alternative proteins can facilitate sustainable diets without compromising animal welfare. The fungal protein, also called mycoprotein is the biomass that results from the fermentation of a filamentous fungus. This paper reports the results of a consumer acceptance study of fungal protein-based meat substitutes using a mixed-method design with a web-based survey and a series of semi-structured interviews amongst European participants. Based on the description provided in the survey, 56% of participants were not directly familiar with fungal proteins but they understood its potential societal benefits. The overall Food Technology Neophobia Score (FTNS) of the sample was moderate (M = 40.0, range = 19–62), with more neophilic participants (52.9%) than neophobic (47.1%). FTN was a significant but weak predictor of Perceived Benefits (PB) and Purchase Intentions (PI). Younger participants perceived fungal proteins more positively, and city-dwellers had higher PI than rural dwellers. Reducetarians were more likely to purchase fungal proteins, compared to unrestricted omnivores. Participants with lower acceptance of fungal proteins' association with mould had significantly lower PI than those who were comfortable with it. In turn, familiarity with fungal protein was positively associated with mould acceptance. The qualitative data suggested that the sensory attributes were the most important factor in the acceptance of meat substitutes. The participants also valued clean label products which were perceived as healthier. Familiarity with other products containing mould seemed to assuage concerns and drive acceptance of fungal protein. The findings suggest that the overall acceptance of fungal protein is still rather low. This may be attributed to the perceived low appeal and tastiness of available fungal protein products.

1. Introduction

The negative impact of meat consumption on the environment is well known (Godfray et al., 2018; González et al., 2020) and meat substitutes can provide a sustainable alternative without the detrimental effects of industrial meat production (Ritchie & Roser, 2017). Fungal protein has important environmental advantages when compared with conventional meat including the possibility of using agri-food wastes as substrates (Ritchie et al., 2017) and decentralized manufacturing (Matassa et al., 2016). Compared with meat, fungal protein has a relatively attractive nutritional profile as it is high in fibre and low in saturated fat (Derbyshire & Ayoob, 2019). In the light of such benefits, sales of fungal protein are projected to expand by a compound annual growth rate (CAGR) of 8.3% between 2021 and 2027 (Ahuja & Singh, 2020).

Although the term mycoprotein is often used in the literature (Coelho et al., 2020; Denny et al., 2008; Derbyshire & Ayoob, 2019), the term fungal protein will be used consistently throughout this paper to refer to the edible biomass resulting from the fungal microorganism *Fusarium*

venenatum fermentation. Since 1985, fungal protein has been manufactured by Marlow Foods and sold as a meat substitute under the brand name 'Quorn' which is now established as the leading brand of fungal protein (Finnigan & Abbott, 2017; Whittaker et al., 2020). The patented technology involves a continuous fermentation of the filamentous mycelium in a glucose syrup substrate (Giavasis et al., 2019). Since the launch of Quorn, there has been little competition and innovation in fungal protein, possibly due to the perceived high capital cost and risk of patent infringement (Giavasis et al., 2019), or limited availability of performant species, safety concerns, or regulations (Finnigan & Abbott, 2017). Presently, the patented core technology to produce Quorn expired in all European countries (Marsh, 1985). This allowed other companies to enter the European market: Mycorena and 3 FBio and their trademark fungal protein ingredients Promyc and Abunda (Good Food Institute, 2020).

Although concerns over labeling were expressed since 2002 (Meikle, 2002), in the US, fungal protein was sold as a 'mushroom-based' product to reflect its fungal origins, without any reference to mould. This

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resulted in legal action against Marlow Foods (Beach, 2017). As a result, the labeling of products sold in the US must disclose mould as an ingredient and display allergy information (Beach, 2017; Yuhl & Fox, 2017). Safety concerns regarding the risk of gout have also been raised about fungal protein but these have been addressed satisfactorily and it was rendered safe by reducing the content of ribonucleic acids to approximately 1% with heat treatment (Whittaker et al., 2020).

The unique cellular organization of fungal organisms, lack of chlorophyll, the rich in chitin and beta-glucan cell walls, and their ability to grow on numerous substrates set them apart from plants (Derbyshire, 2020). Nonetheless, most people are unaware of the distinct nature of fungi-derived protein foods (Derbyshire & Delange, 2021) and this is reflected in the current literature where some authors still refer to fungal protein as being derived from plants (Jiang et al., 2020; Lee et al., 2020; Santo et al., 2020). While fungal protein would be considered to be 'vegan', it is not 'plant based' and may therefore miss out on the current positive consumer attitudes towards plant-based foods (Gómez-Luciano et al., 2019).

Some known factors are associated with the willingness to consumer alternative proteins, such as one's attachment to meat (Circus & Robison, 2018). Graça et al. (2015) suggest that this may be one of the main reasons which inhibit the shift towards a more plant-based diet. Meat consumption is associated not only with personal but also social and cultural values is also perceived as an important component of a healthy diet (Macdiarmid et al., 2016). This is why consumers look for nutritional parity of substitutes with it (Mintel, 2020) despite the evidence that proves the detrimental effects of red and processed meat on health (Etemadi et al., 2017; Rohrmann et al., 2013). Consumers who eat meat regularly also tend to opt for alternatives that resemble conventional meat in terms of sensory properties and ease of preparation (Michel et al., 2021). This would therefore be an advantage of fungal protein amongst omnivores because texturally, fungal biomass resembles meat due to its filamentous structure (Joshi & Kumar, 2016).

Food Neophobia, the unwillingness to consume a novel food, is a common barrier for consumers concerning alternative proteins (Dupont & Fiebelkorn, 2020; Fonmboh et al., 2020). According to Alcorta et al. (2021), this can be alleviated through labeling transparency, particularly, the origin, ingredients, and processing methods (Nitzko, 2019). For instance, an experimental study concerning plant-protein ingredients found that consumers were more positive towards a product when provided with the exact source of protein (Aschemann-Witzel & Peschel, 2019). The Food Technology Neophobia is a related psychometric scale that measures people's aversion to foods produced by novel technologies (Cox & Evans, 2008). The fungal protein can be considered a novel food because although it has been commercially available for over three decades under the trademark Quorn (Whittaker et al., 2020), it remains niche and is currently purchased as a premium and specialist vegetarian product (Ritchie et al., 2017). Therefore, it may be more widely promoted by a reduction in price relative to meat (Gómez-Luciano et al., 2019; Joseph et al., 2020; Linder, 2019; Mintel, 2020).

Meat alternatives can address the detrimental effects of industrial meat production (Ritchie & Roser, 2017), but their potential can only be materialized if the consumers use it as a replacement for meat (Hoek, 2011). The success of a new product relies on consumers' attitudes, knowledge, and perceptions towards it (Grunert et al., 2011). In this regard, there has been little research that focuses on consumers' attitudes towards fungal protein-based meat substitutes. This study investigates whether, factors like Food Technology Neophobia, the perceived benefits of fungal proteins, or their association with mould affect consumer acceptance of fungal protein-based meat substitutes.

2. Research method

A sequential mixed-method approach of quantitative and qualitative techniques was used for this study (Onwuegbuzie & Collins, 2015). The quantitative survey focused on perceptions of fungal proteins and how this impacted participants' acceptance, while the interviews generated insights regarding their expectations, experiences, and attitudes. This approach allowed to draw strengths from both methods and to gather more comprehensive data (Bryman, 2007). The ethical approval (reference number 35517) for the study was obtained from EthOS, the Manchester Metropolitan University (MMU) online ethics application system.

2.1. Questionnaire

This is a European pilot study to reflect the current and future market for fungal proteins. Therefore, the questionnaire was distributed online among consumers mainly in the UK, Germany, and Romania. The sample consisted of 140 volunteer participants residing in Europe who provided responses for the survey developed using Jisc and distributed on the principal investigator's social media (Facebook and Linkedin) and SurveyCircle. Recruitment of participants via social media is an increasingly used and accepted method in research (Gelinas et al., 2017). The aim was to reach an international participant group and to overcome geographical boundaries. Therefore, a recruitment strategy using social media was devised using existing networks with the potential for snowballing through sharing to provide the broadest possible reach. Furthermore, the ease of access and use by participants enhanced the inclusivity of the survey. The first set of questions assessed the respondents' meat consumption frequency, and their fear of novel food technology that was evaluated by applying the Food Technology Neophobia Scale (FTNS) (Cox & Evans, 2008). This validated psychometric questionnaire was adapted for this study using questions with a 7 to a 5-point Likert scale with the scores for questions 10, 11, 12, 13 reversed for variable consistency. The individual values for each item were summed, resulting in a score ranging from 13 to 65. The mean was used as the cut-off point for the FTNS to classify consumers as food technology neophobic or neophiliac.

As in Bryant et al. (2018), a brief neutral description of fungal protein was provided in a consumer-friendly language and respondents' familiarity with it was assessed with multiple-choice questions where participants rated their perceived benefits regarding fungal proteins from a personal perspective and a societal perspective. An overall Perceived Benefits (PB) score was created by summing all ten numerical responses to each statement (Fig. 1).

The question about the hypothetical decision to purchase was framed in terms of a scenario where fungal protein products are widely available as done in Bryant et al. (2018). The Purchase Intentions (PI) of fungal protein in the light of their association with mould were measured using five-point Likert scales. The questionnaire collected demographic information, including age, education, as well as area and country of residence. All variables, except country of residence, were single-choice questions to improve accuracy. Linear regressions were used to measure the influence of FTN on PI and PB. Non-parametric tests were performed to determine the difference between groups and strength of associations, and the level of significance was set at $p < 0.05$.

2.2. Semi-structured interviews

A purposive sampling method was used to select a total of six volunteer interviewees from the respondents who had provided the most relevant answers to the questionnaire (Palinkas et al., 2015; Denscombe, 2010). Consequently, three respondents who had tasted fungal protein products and three who had not tasted them were selected. The interviews lasted between 12 and 19 min and were conducted and recorded using MS Teams. An interview guide was developed to expand on survey responses addressing meat and meat substitutes consumption as well as familiarity with fungal proteins and attitudes towards them. They were then transcribed using the software Otter (otter.ai) and content analysis was done in NVivo 1.5 through checking the accuracy
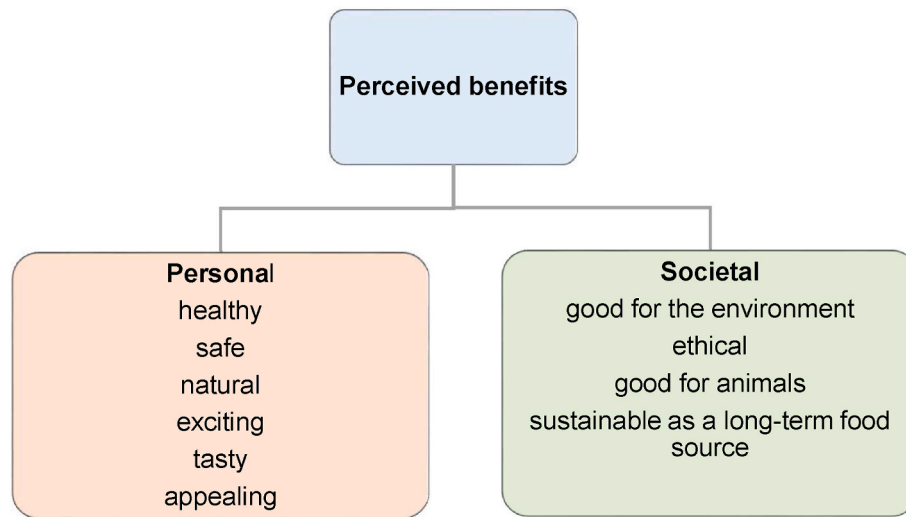
Fig. 1. Perceived benefits of fungal proteins.

of transcripts, identification of themes through coding, and the development of a thematic framework.

3. Results

3.1. Quantitative phase

Of 140 participants who completed the questionnaire, 104 met the inclusion criteria of being over 18 years old and residing in Europe. Two questionnaires were excluded due to missing responses resulting in a final sample size of 102. The respondents resided in 9 different European countries, with the largest group in the UK (n = 43), followed by Romania (n = 23), Germany (n = 19), and France (n = 11). There were two respondents from Denmark (n = 2), and one each from the Czech Republic, Hungary, Ireland, and Italy. There were 79.4% female and 20.6% male respondents. A high proportion of the respondents were under 35 years old (67.7%) with 84.3% having completed higher education, 93.1% lived in urban or suburban areas (Fig. 2).

The unrestricted omnivore group (55%) included participants who either did not change their meat intake or increased it, reducetarians (36%) were the non-vegetarian participants who claimed they reduced their meat consumption in the past 12 months. The remaining 9% were vegetarian (Fig. 3).

Fungal proteins were relatively new to the participants since 56% had not heard of them and only 23% reported that they tried products
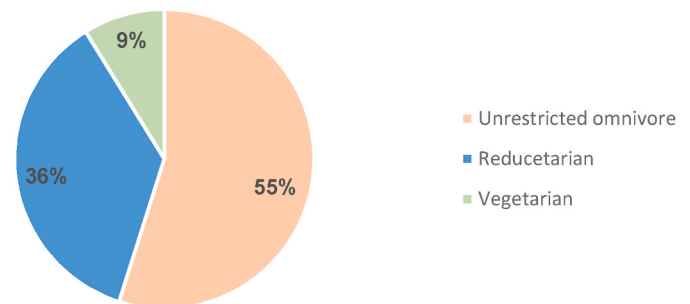

Fig. 3. Sample distribution regarding dietary behaviors.

containing fungal proteins (Fig. 4).

The measured scores of FTNS ranged from 19 to 62 and the average level was 40.0 ± 8.1. Fig. 5 indicates that more than half of the participants were food technology neophiliac, and 47.1% were food technology neophobic. However, the histogram illustrates that the most frequent scores are close to the median.

The mean scores for each perceived benefit of fungal proteins are illustrated in Fig. 6. The participants found the fungal proteins to be more beneficial from a societal perspective than a personal one. Accordingly, the following attributes yielded the highest scores: ethical (mean = 3.77 ± 0.78), good for animals (mean = 3.73 ± 0.85), good for the environment (mean = 3.67 ± 0.74), and sustainable as a long-term food source (mean = 3.55 ± 0.85). The lowest scores were given to the attributes tasty (mean = 3.01 ± 0.71), appealing (mean = 3.06 ± 0.98),
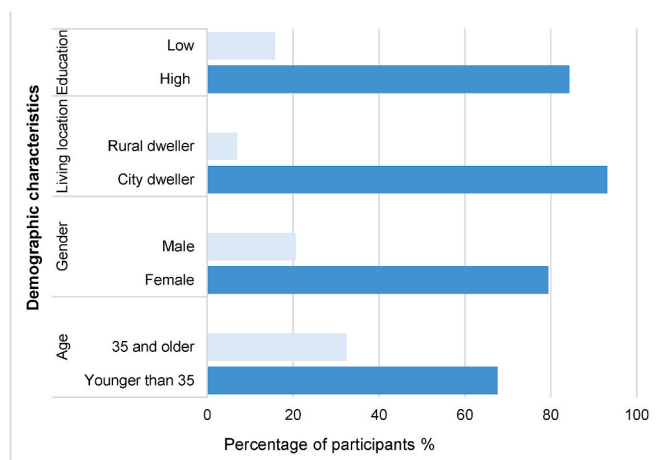

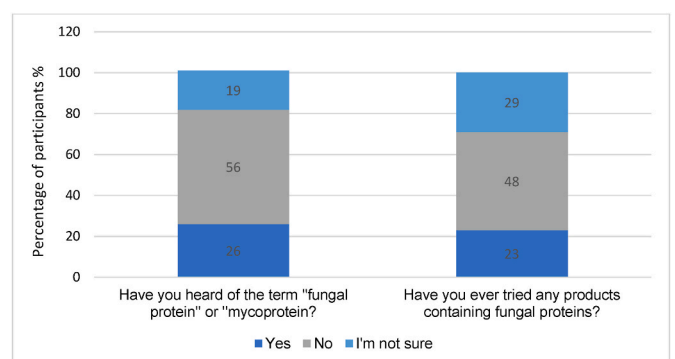**Fig. 2.** Demographic characteristics of the survey participants.

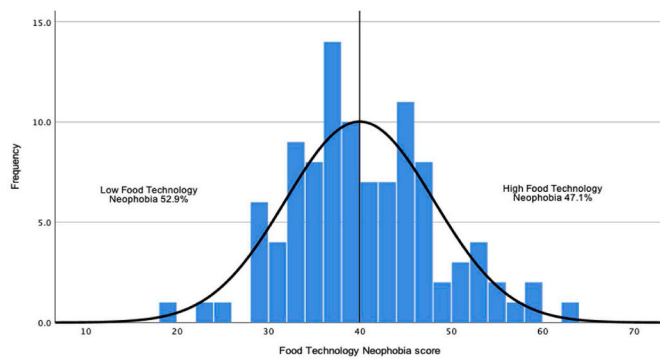**Fig. 4.** Participants familiarity with fungal protein.

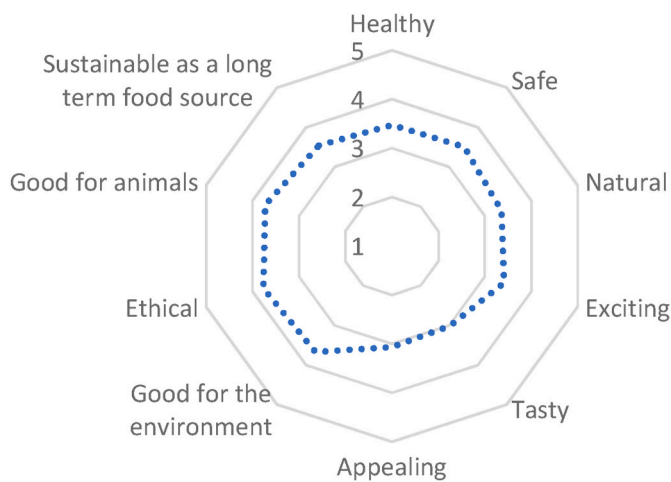**Fig. 5.** Food Technology Neophobia Scores distribution.

Fig. 6. Participants' overall ratings of fungal proteins on a 1–5 scale (1 = strongly disagree, 5 = strongly agree).

and natural (mean = 3.36 ± 0.92).

The participants were more willing to try fungal proteins (mean = 3.67 ± 1.17) than to purchase them regularly (mean = 2.93 ± 1.17) or to eat them as a replacement for conventional meat (mean = 2.92 ± 1.22). There was a considerable drop in the intention to pay a higher price than conventional meat (mean = 2.39 ± 1.18) (Fig. 7).

Mann-Whitney U tests showed that the PBs of fungal proteins were significantly higher among participants under 35 (mean rank = 53.96)
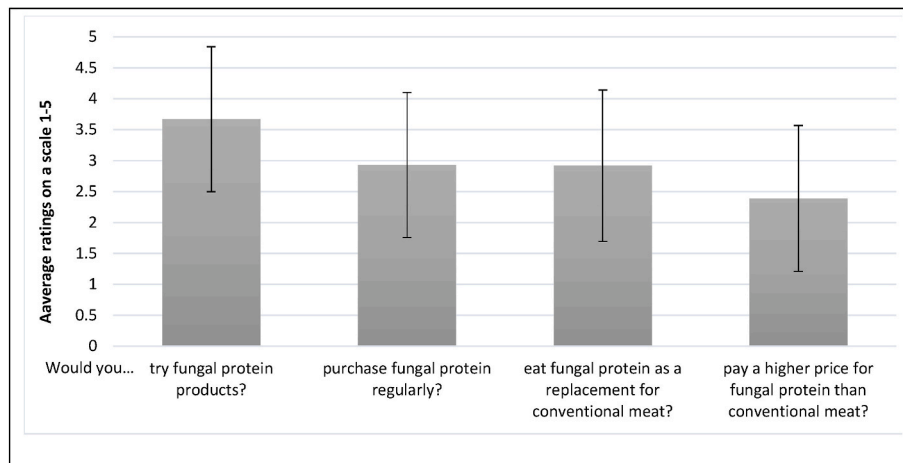
when compared with those above 35-years (mean rank = 46.35), U = 757, p < 0.05. City dwellers had a statistically significantly higher PI score (mean rank = 53.34) than those living in rural areas (mean rank = 26.57), U = 158, p < 0.05. No other statistically significant differences in the mean ranks of different demographic groups for the FTNS scores were found (Table 1). The negative correlations between FTN scores and each perceived attribute at p < 0.05 or p < 0.01 were statistically significant, except for 'Tasty' (Table 2).

A linear regression (Fig. 8) indicated that FTN scores predicted perceptions of fungal proteins, F (1, 102) = 21.183, p < 0.001, accounting for 17.5% of the variation in PB with adjusted R^2 = 16.7%, a medium-size effect (Cohen, 1988).

The results indicate that participants with the highest neophobia scores also tend to perceive fungal protein as less safe, less healthy, and less natural.

The FTN scores predicted the overall perceptions of fungal protein, F (1,102) = 8.909, p < 0.005, accounting for 8.2% of the variation in PB with adjusted R^2 = 7.3%, a small size effect (Cohen, 1988). Although statistically significant, FTN was a weak predictor in PI (Fig. 9).

There were statistically significant differences in PI scores between the reducetarians (mean = 13.43) and unrestricted omnivores (mean = 10.86) (p = 0.018), but not between the other group combinations, according to the Kruskall-Wallis H test. The PI scores of respondents who claimed they were uncomfortable with mould were significantly lower (mean = 9.77) than of those who claimed they were comfortable with fungal protein being associated with mould (mean = 13.97) (p = 0.0001) (Table 3).

There was a statistically significant and moderate association between familiarity with fungal protein and the acceptance of mould being associated with them $\chi^2(4)$ = 18.23, p = 0.001, Cramer's V = 0.3 as shown by a chi-square test of independence (Cohen, 1988).

3.2. The qualitative phase

Of the six interviewees, three had tried fungal protein products (Respondent A, B, C) and three had not (Respondent D, E, F). The themes that emerged from the transcripts were organized into the schematic in Fig. 10.

3.2.1. The sensory attributes are the most important

Taste and texture were recurring themes for every participant. Although it was challenging to pinpoint a specific taste, one participant described umami, saltiness, and texture as important attributes. Umami is frequently associated with a meaty, savory, and broth-like taste (Kurihara, 2015; Zhang et al., 2017).

Fig. 7. Comparison of different purchase intentions reported by survey participants (n = 102) on a 5-point Likert scale. The purchase intentions are presented as mean values and the error bars represent standard deviations (SD).

Table 1

Differences in Food Technology Neophobia, Perceived Benefits and Purchase Intentions scores between different demographic groups assessed by Mann Whitney *U* test.

Variable	Demographic	Group	N	Mean Rank	P-value	Mann Whitney U
Food Technology Neophobia	*Gender*	Female	81	51.64	0.927	839.5
		Male	21	50.98		
	Age	Younger than 35	69	49.43	0.306	1281.5
		35 and older	33	55.83		
	Education	Low	16	51.14	0.775	657
		High	86	54.44		
	Living location	City dweller	95	51.06	0.582	374.0
		Rural dweller	7	57.43		
Perceived Benefits	*Gender*	Female	81	50.94	0.709	895.5
		Male	21	53.64		
	Age	Younger than 35	69	53.96	0.006	757.5*
		35 and older	33	46.35		
	Education	Low	16	46.97	0.504	760.5
		High	86	52.34		
	Living location	City dweller	95	51.22	0.720	359.5
		Rural dweller	7	55.36		
Purchase Intentions	*Gender*	Female	81	50.69	0.586	916
		Male	21	54.62		
	Age	Younger than 35	69	53.96	0.222	968.5
		35 and older	33	46.35		
	Education	Low	16	42.22	0.170	836.5
		High	86	53.23		
	Living location	City dweller	95	53.34	0.020	158*
		Rural dweller	7	26.57		

Note: the asymptotic significance is displayed. The significance level is 0.05.

Table 2

Spearman correlations between Perceived Benefits ratings and FTN scores.

Correlation variables		Spearman correlation coefficient (r_s)
FTNS x	Healthy	−0.342**
	Safe	−0.387**
	Natural	−0.371**
	Exciting	−0.264**
	Tasty	−0.057
	Appealing	−0.240*
	Good for the environment	−0.278**
	Ethical	−0.277**
	Good for animals	−0.272**
	Sustainable as a long-time food source	−0.314**

Note: *. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

So I think that's very important that they have a nice consistency that they are healthy, that they taste and that they have good ingredients. …. Not very salty, but yeah, also salty and just umami. (Respondent B)

The only reason why I might eat one of the meat substitutes is that is just because I happen to try it and I liked it. (Respondent F)

And, and that's that always boils down to, I guess, texture and taste. (Respondent C)

The subtle association with meat through the umami taste by Respondent B was followed by more straightforward descriptions of their expectations. Whether it was about the taste or texture, most participants found close similarity with conventional meat as an important factor.

Yeah, I mean, just similarity (to meat) in general. (Respondent C)

And obviously, I just want something with a similar texture. Like if it was beef, you'd want the texture to be similar. (Respondent D)

Let me put it this way? If the fungus-based products, meat alternatives, tasted like meat, I wouldn't mind consuming them. The reason why I'm saying I'm not really sure is because the ones that I've tried, didn't resemble meat. (Respondent F)

The more popular soy meat alternatives were actively avoided by three out of the six respondents, due to taste reasons (Respondent A and Respondent C) or due to suspicion around its association with health
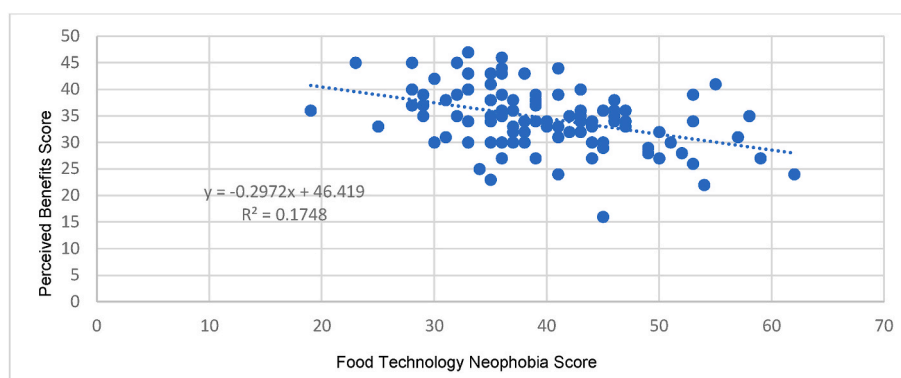

Fig. 8. Relationship between FTN and PB. FTN score is the sum of ratings given to the 13 statements and PB is the sum of ratings given to the 10 statements.
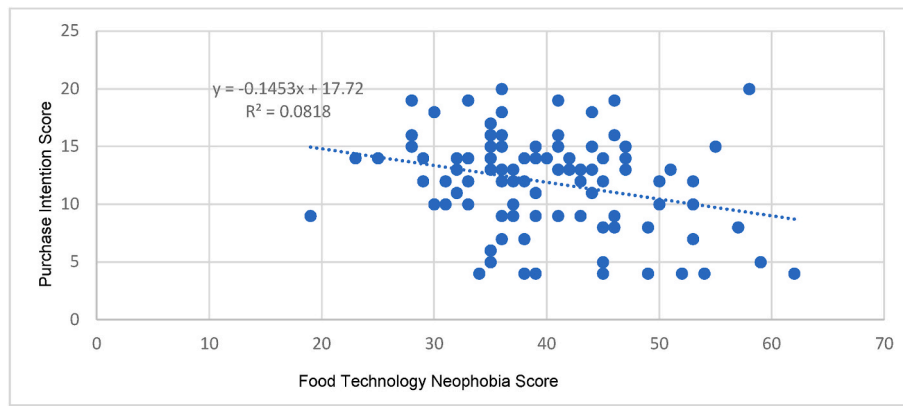
Fig. 9. Relationship between FTN and PI. FTN score is the sum of ratings given to the 13 statements and PB is the sum of ratings given to the 4 statements.

Table 3
Differences between different dietary groups and attitudes towards the association of fungal proteins with mould in Purchase Intention Scores assessed by a Kruskal-Wallis H test.

Variable	Group	Median PI score	df	χ2	p
Dietary group	Vegetarian	12.22[ab]	2	7.59	0.022
	Reducetarian	13.43[a]			
	Unrestricted omnivore	10.86[b]			
Association with mould attitude	Uncomfortable	9.77[a]	2	16.59	0.0001
	Neutral	11.87[ab]			
	Comfortable	13.97[b]			

Note: Values in the same group followed by different superscript letters are significantly different from each other ($\alpha = 0.05$). Significance was calculated with the Bonferroni post hoc analysis.

problems (Respondent F).

I used to use soya, but it's not my cup of tea. Let's say it like that. Even though it was prepared very tasty. But still, I don't know. It's something that I don't like about the aftertaste. (Respondent A)

Do you mean like real replacement products like soy replacement stuff? Not so much, to be honest. (Respondent C)

I said I avoid soy? Obviously, I do consume products that contain soy I, but if I can avoid it, I just do (…) Well, I have read some research papers that on how it does affect the performance and the nervous system. (Respondent F)

3.2.2. Consumer knowledge and avoidance of sugar

The participants demonstrated they were actively making food choices to promote a healthy diet. The term 'healthy' had a similar
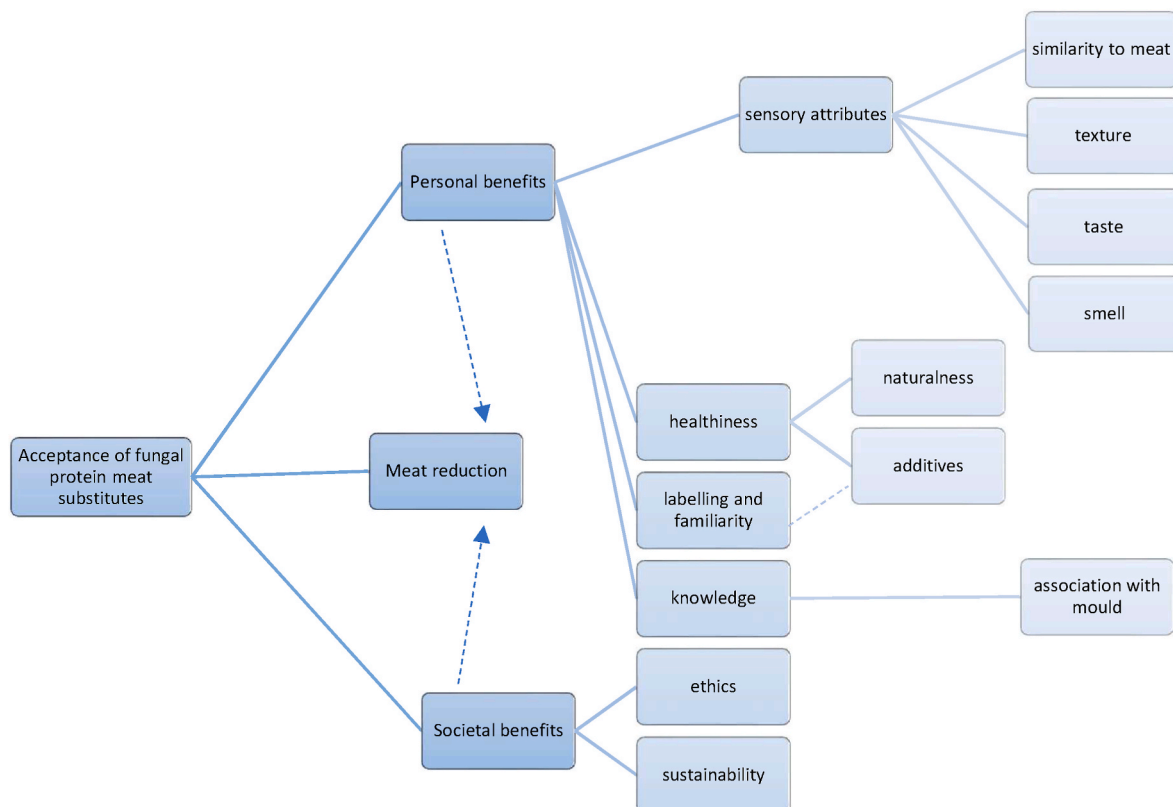

Fig. 10. Themes emerging from the interview data.

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meaning for many participants, with avoidance of sugar being the principal factor. Four participants gave the following answers when asked if they avoided any ingredient in meat alternatives:

Sugar all the way. (Respondent A)

I would not want to have sugar in it. (Respondent B)

I'm more probably sort of worried about how much sugar goes into a lot of these foods. (Respondent E)

Just sort of saturated fats and sugar. (Respondent D)

3.2.3. Healthy and natural are key aspects in acceptance

Most participants had an aversion to unfamiliar ingredients, particularly additives and preservatives, which they perceived as unhealthy and unnatural:

I would not want to have any present set already preservatives and no artificial aroma ideally. Although I'm not sure if that's possible, and yeah, that's the most important but that comes into the same item that I said already that I want it to be healthy. And I guess it cannot be healthy that has any of the mentioned ingredients. (…) No conservatives, is it conservatives or preservatives? And no artificial coloring and those things that you don't really need. No artificial aromatics. (Respondent B)

But I think it would be the ingredients. If they didn't have as many different ingredients and then it was just a bit more naturally produced. I think that would be the big thing for me to be honest. (Respondent E)

I want the source of my food to be a natural product and not an artificial product if that makes sense. (Respondent F)

I think that I think that just put me off a bit. I think it's because it's just doesn't seem natural, it's overprocessed, maybe. Or maybe I need to educate myself more on you know, meat substitutes, and, you know, get a more accurate idea of what goes into them and what the process is for manufacturing them. So maybe, like, there was more, you know, you had more knowledge out there when you went shopping, you know, then maybe, you might sway me and I might be more willing to try meat substitutes. (Respondent E)

Or a lot of ingredients that I never heard about. So I kind of tried to avoid those ones. (Respondent A)

Long ingredients lists were also associated with negative attitudes due to either being considered as ''bad'' (Respondent E) or being responsible for masking the poor quality of the other ingredients (Respondent F).

But yeah, the longer the list of ingredients, I tend to stay away from because I think, yeah, they've got a lot of bad about things in them. So yeah, stick with more stuff that's more or less ingredients a bit more natural. (Respondent E)

What I mean by additives, I mean all the stabilizers and emulsifiers. Because if you can make the product to be nice, as in taste nice and all this stuff as it is with the recipe, and you have to add all this hydrocolloid or whatever you add in the recipe, then to me that means that probably your raw material (is) not the best. (Respondent F)

3.2.4. Cost matters

In the same way as taste, meat provides the reference point for assessing the value of the alternatives, with a perception that the price of meat represents a ceiling of what consumers are prepared to pay for its alternatives. The price of meat alternatives was mentioned by three participants who indicated that a higher price would subdue their purchase intention of fungal protein, especially because it did not exceed the sensory properties of meat.

Maybe the cost because you know, if it's going to cost more than meat, as I'm not a vegetarian, then I probably would choose meat still. (Respondent D)

I think now they got much better but if they are very dry and not tasty, then why would somebody eat it? Why would somebody buy it and even pay a premium for it? (Respondent B)

However, where the motivation is health, Respondent A describes how they are prepared to pay more:

I would because again, I'm saying if I don't feel well when I'm eating meat, of course, I will be willing to pay a higher amount for replacement which is good as well, which should be good. (Respondent A)

3.2.5. Sensory experiences with fungal proteins

Three participants had tried Quorn, the only commercially available fungal protein-based meat substitute in Europe. This commonality allows for meaningful comparison between their experiences; one participant reported that it was not sufficiently similar to conventional meat:

They do taste like you actually eat the burger. Right? But when you try the Quorn or when you try some soy-based minced burgers. They don't taste exactly like meat. (…) The mince I think it was on pasta. The sauce was good. But it definitely wasn't Bolognaise. (Respondent F).

It was a while ago but I'm sure it was a chicken, it looked like a chicken substitute. So that's what it looked like to me. And I'm sure I've tried. I've tried the burger as well. So to look at, they just looked like you were having the meat. But the taste I did, I thought they were a bit tasteless, but this is going back a few years now. I didn't feel like it gave you enough taste, I think yeah, I want to change and have this in my diet. It was a bit bland. Maybe just a bit watery. Yeah, it just lacks tastes, and it was just like you know, just something to eat. You're not necessarily enjoying what you're eating. (Respondent E)

In contrast, another participant reported a positive sensory experience and that they found no difference between the original Bolognaise sauce with conventional meat and the Quorn-based one:

I remember tasting just this the same. I think my mom made spaghetti Bolognaise with it. And it just tasted the same to me. (Respondent D)

In both cases, the eating experience took place a relatively long time ago which can affect recollection (Öztaş & Işiksal, 2005), and the meal context was important, an established factor in food preference (Hendriks et al., 2021; Spence, 2018).

3.2.6. Acceptance of mould in the light of its association with fungal protein

All participants were asked for their opinion on the association between fungal protein and mould using an open-ended question. The answers included neutral and negative reactions. Interestingly, the most negative responses were from two respondents who had already tried fungi-based meat substitutes, indicating some confusion and ambiguity about fungal protein products. The most negative opinion was expressed by Respondent E:

I think yeah, when because to me like fungus and mould, it doesn't make it appetizing. For me. I think it's just the words itself, mould, I just think of something that's gone off. Or that's green. You know, that's past its sell-by date. So yeah, when it's when those words are used to describe it, it's not something that I'd probably would find appealing. (Respondent E)

Yeah, you see that is also something I think that would put a lot of people off, because of the word ''mould''. I think maybe they could describe it in another way. And people will be up for trying it more. But the word ''mould'' and fermented is, is going to put a lot of people off. I think, in Britain. (Respondent D)

Interestingly, both participants acknowledged that their reaction was

related to the nomenclature and not necessarily the product and that their reaction could be mitigated by adopting a different name. The following answers showed that participants who are aware that mould is often harmless and found in familiar foods had a positive reaction to the topic. It seems that knowledge might therefore alleviate concerns in fungal protein acceptance.

> *Well, first of all, I was shocked because I know mould in particular ways is not good. But at the same time, if you look at mushrooms, they also as I, as far as I know, they also like mouldy environments. So I find it quite similar to those.* (Respondent A)

> *Oh gee, but I'm fully aware that mould can be consumed! I eat blue cheese! I don't mind.*
> (Respondent F)

> *And cheese also has specific fungi. And still, the taste can be tasty. So that would be not necessarily a problem for me.* (Respondent B)

Fungal protein was considered as a potential solution for creating more sustainable alternatives to meat. Curiosity and excitement were expressed by this participant who stated:

> *Yeah, the idea basically, I think sounds really good. I mean, basically, I think any new idea that goes down this path of how can we create alternatives, to the way we consume animal products right now? I think any avenue is worth exploring and worth researching. And if this is another new way to do that, and if it's based on fungal proteins, then yeah, sure. I think that's great. I would be curious at any rate to try it.* (Respondent C)

4. Discussion

4.1. The role of Food Technology Neophobia

Understanding the characteristics of neophiliac and neophobic consumers can facilitate the development of effective and tailored marketing strategies (Martinho, 2020; Vidigal et al., 2015). Demographic characteristics are typically significant predictors of FTN levels (Evans et al., 2010; Vidigal et al., 2015; Salgado-Beltrán et al., 2018). Notably, higher age, education, and income levels predisposed people to more openness to foods produced by new technologies (Evans et al., 2010; Salgado-Beltrán et al., 2018). Participants in this study were homogeneous with 84.3% highly educated and 93.1% city dwellers so there were few differences attributable to demographic factors. Variations of FTN scores may be linked to the development of the countries where the research is conducted and this may be a feature here due to the cross-country nature of the survey (Salgado-Beltrán et al., 2018).

FTN was a considerably lower predictor for PI suggesting that other factors play a role in PI. However, all PBs were negatively correlated with FTN except for "tasty", suggesting that their anticipation in terms of taste was independent of FTN levels. The coefficients revealed nuances amongst the perceived attributes. For example, participants with the highest levels of neophobia also tended to perceive fungal protein as less safe, followed by less healthy and less natural which is similar to the findings by Siegrist who concluded that acceptance of new food technologies depends on consumers' perceived benefits, perceived risks, and perceived naturalness (Siegrist, 2008).

4.2. Perceived benefits and their influence on acceptance

Scores for the societal perceived benefits (SPB) were high, which is similar to findings of cultured meat, where the environmental benefits were overall more positively perceived than personal ones (Janat & Bryant, 2020). SPBs are drivers in consumer acceptance due to their increasing concern for the environmental impact of their food choices (Petrescu et al., 2020). The taste was the least attractive attribute, which is in line with a consumer study that included fungal protein (Gómez-Luciano et al., 2019). As the key driver of liking most foods (Li et al., 2015), the perceived taste may be the greatest barrier in the acceptance of fungal protein, and this was one of the main themes of the interviews. However, the ratings were based on perceptions because at least 56% of the participants had not tasted fungal protein products. Furthermore, taste can be influenced by expectations, beliefs, and knowledge (Wilton et al., 2019). For example, high perceived naturalness can influence the eating experience (Román et al., 2017). Here, participants seemed to prefer meat substitutes that were similar to meat, also found in Hoek (2011).

Naturalness is another important driver in meat substitute acceptance (Román et al., 2017; Hwang et al., 2020) and as such, it is affected more by chemical changes rather than physical ones (Rozin, 2005). These findings are in line with interviewees' aversion to sugar, preservatives, colorants, or aromas that were perceived as negative. The low ratings for the attributes appealing and natural would also be a barrier in acceptance because they were in contradiction with what consumers in developed markets value in products (Rozin et al., 2004; Román et al., 2017).

The interview participants valued healthy products which they also associated with natural. The product's category, organic origin, reduced sodium, sugar, and fat were the most important in perceived healthiness (Plasek et al., 2020) a significant factor on food choices (Pinto et al., 2021; Pinto et al., 2020). A common strategy for a healthy diet was the avoidance of sugar, which was observed in four out of six respondents. Respondents also avoided additives in meat substitutes, which they perceived as unhealthy and unsafe. This is consistent with the 'clean-label' phenomenon that is underpinned by a general mistrust of new food production technologies, healthiness concerns, skepticism towards unfamiliar ingredients, and also mistrust in regulations (Aschemann-Witzel & Peschel, 2019; Asioli et al., 2017). For example, Respondents E and F appeared to be uncertain and untrustful towards unknown ingredients in processed foods, and because of this, they claimed to avoid products with long ingredients lists. Respondent A had conflicting attitudes towards food regulations and food processing by stating: "*I'm assuming, but maybe I'm just a naive customer that says that any preservatives that would really be worth serious, like health concerns aren't allowed to be put into products anyway. And so, I wouldn't even expect to find those* there''. However, the majority were rather doubtful about meat alternatives and unfamiliar ingredients. This skepticism could negatively influence the acceptance of fungal proteins, making the consumers overlook the potential of new processing technologies in food sustainability and food security (Augustin et al., 2016).

Sustainability aspects seemed to be more important in the initial phase of trying fungal protein which could imply that sensory perceptions of products are likely to determine a product's success over time, while the extrinsic cues related to societal benefits are important to drive the initial purchase as found in Li et al. (2015). Cost is a typical barrier to purchase (Grunert et al., 2004), and sensory attributes were crucial factors required to justify higher prices as stated by Respondent B: "*I think now they got much better but if they are very dry and not tasty, then why would somebody eat it? Why would somebody buy it and even pay a premium for it?*''.

4.3. The effects of dietary behavior and demographics on acceptance of fungal proteins

The term "reducetarian'' is increasingly used and defines people attempting to reduce their meat consumption (Kateman, 2017; Mistry et al., 2020). Reducetarians were more likely to purchase fungal proteins due to their higher willingness to embrace change as opposed to unrestricted omnivores (Mistry et al., 2020). The primary reason for not substituting mean unrestricted omnivores may be due to their hedonic liking of meat (Weinrich, 2018), although other authors found that the perceived meat nutritional importance was also significant (de Koning et al., 2020). The vegetarian consumers had surprisingly lower levels of PI for fungal protein, even if not statistically significant. The lower

acceptance may be explained by vegetarians and vegans questioning the logic of meat substitutes being similar to meat, which may negatively influence how they perceive them (Elzerman et al., 2013; Nath & Prideaux, 2011). This supports the theory that the most attractive target consumers for meat alternatives are the reducetarians, not the vegan or vegetarian consumers as previously thought (Ishamri Ismail et al., 2020). Although the reducetarians were more open to meat substitutes, meeting their expectations would also be more challenging due to the direct competition with conventional meat, e.g., concerning the pricing: " … *as I'm not a vegetarian, then I probably would choose meat still.''* (Respondent D).

Positive perceptions of fungal protein among younger participants were unsurprising as most studies found that younger consumers were more likely to accept alternative proteins (Siegrist & Hartmann, 2019; Wilks & Phillips, 2017). However, age did not make a difference in the participants' PI, which suggests that positive perceptions of a product were not necessarily followed by an increased PI. Additionally, the PI does not necessarily translate into an actual purchase due to changes in context, personal circumstances, and availability of products as such PBs can be considered as unreliable predictors for consumer behavior in the actual marketplace (Morwitz, 2012). A higher PI in city dwellers was observed when compared to rural dwellers, but these results need to be interpreted with caution due to the overrepresentation by city-dwellers in the sample (93.1%).

4.4. Implications of the association with mould

The association of fungal protein with mould is a characteristic of fungal proteins and was found to be a notable factor in participants' purchase intentions. Interestingly, the term "mycophilia'' was introduced in 1957 by Wassons to describe aversion to fungi that was identified across different cultures and has been traced back to ancient times (Wasson & Wasson, 1957). In more recent research, the attitudes towards fungi remain rather negative. More specifically, mould is known for its ability to cause spoilage of foods (Leyva Salas et al., 2017), to produce mycotoxins (Bryden, 2007), or allergic reactions (Rudert & Portnoy, 2017). Certain mould strains are safe and are used in small quantities to develop desired technological and/or sensory properties in popular food like blue cheese (Ropars et al., 2017; Spotti et al., 2008). However, in fungi-based meat substitutes, fungal biomass is the main ingredient.

Participants who were uncomfortable with the association between fungal proteins and mould were also less willing to purchase them. Disgust is understood as a disease-avoidance mechanism in preventing the ingestion of toxins (Ammann et al., 2018; Chapman & Anderson, 2012). The interview data suggested that respondents felt disgusted, which in the context of food, is a powerful response that triggers the rejection of such foods. The association of fungal proteins with mould could also be a major barrier because it is one of 12 food disgust elicitors (Martins & Pliner, 2006). Accordingly, two participants expressed their disgust with the term mould and claimed it reminded them of decay and food that has passed its use-by date and raised safety and health concerns. However, both suggested that using different words might change their perception: " … *when those words are used to describe it, it's not something that I'd probably would find appealing''* (Respondent E), or "*I think that would put a lot of people off, because of the word ''mould''. I think maybe they could describe it in another way. And people will be up for trying it more''* (Respondent D). This supports the importance of terminology in marketing strategies, established as a determinant factor in consumers' food choices (Martinho, 2020).

The rejection of a product due to its name is, however, not limited to mould. According to Łuczaj (2010), the attitudes to green parts of wild plants separates cultures into "herbophilous'' and "herbophobous'' (Łuczaj, 2010). Furthermore, the name "meat-substitute'' elicited negative reactions from participants in multiple studies (Elzerman et al., 2013; Michel et al., 2021; Siegrist & Hartmann, 2019). It can be assumed

that consumers' attitudes towards a product's name and origin could not only prevent them from trying fungal protein products, but their sensory experience could be biased by their expectations and beliefs (Wilton et al., 2019) creating a major barrier to acceptance.

Previous studies indicated that disgust was also related to food neophobia and the lack of familiarity. Interestingly, the interviews showed that participants who were more knowledgeable about mould and/or fungi and their association with familiar foods such as blue cheese or mushrooms tended to have more positive attitudes. There was also an association between familiarity with fungal protein and the acceptance of mould. This insight may indicate a solution for combatting potential stigma against mould. A summary of the study's main outcomes regarding factors affecting consumer acceptance of fungal proteins is depicted in Fig. 11.

The study had some limitations such as a potential self-selection sampling bias is likely to have occurred in both the quantitative and qualitative phases of the study. Furthermore, a common limitation in consumer and sensory research is that surveys might not always reflect what the participants actually do.

5. Conclusion

The insights from this research are relevant to the food industry and those with an interest in sustainability. There are no other published studies that focus on consumer attitudes towards fungal protein in meat substitutes. The participants viewed fungal protein more positively from a sustainability perspective which is not the main driver in product acceptance. The sensory experience of interview participants who tried fungal protein meat substitutes was unsatisfactory, although the meal context may have played a significant role.

FTN was a stronger predictor in PB compared to PIs, although the overall prediction strength was weak to moderate. Younger participants have a more positive overall perception and city dwellers were more likely to purchase fungal protein than rural citizens. Those who reduced their meat consumption were more willing to purchase fungal protein, which is also the case for other meat substitutes as shown in the literature.

The interviews revealed that the stigma against mould, manifested as disgust can be a major barrier in fungal protein acceptance although familiarity may alleviate some concerns and increase their acceptance. Despite being sold in several countries since 1985 or later, fungal proteins were a novelty for most of the participants, which may explain the relatively low PI. Furthermore, the terminology of fungal protein-based meat substitutes seems to also play a role in consumer acceptance, which is why food processors should investigate alternative names that would be accurate and appealing. Health considerations were linked with naturalness as well as transparency and familiarity with ingredients. Moreover, interviewees valued products that were free from additives and sugar which seemed to capture the concerns consistent with the clean label movement. When developing new products, these factors should be considered.

While the above-mentioned aspects are important in consumer acceptance of fungal proteins, the sensory attributes are crucial. Although it was challenging to define a specific desired taste, similarity to conventional meat was valued. The survey results indicate that the participants did not anticipate it being tasty, so finding ways to enhance the taste perception of fungal protein would increase consumer acceptance. Determining what exactly makes consumers perceive it as not tasty will be a key factor to increase its appeal and subsequently its purchase intention. In addition to extensive sensory testing of different product formulations, future studies should investigate in detail what exactly causes the negative perception of fungal protein and whether food disgust plays a significant role in this perception.
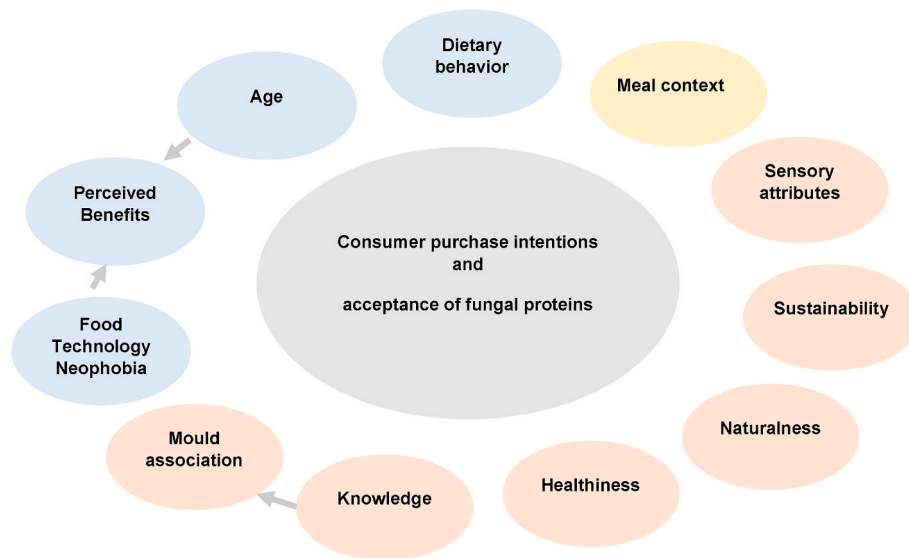
Fig. 11. A summary of factors affecting consumer acceptance of fungal proteins according to the main study outcomes.
Note: The blue circles indicate outcomes from the survey data, yellow from the interviews and the orange ones indicate common findings from both qualitative and quantitative phases. The arrows indicate relationships between variables.

Ethical statment

The ethics application of the study was submitted at EthOS, the Manchester Metropolitan University (MMU) online ethics application system. The approval for the research project was obtained on the 19th of July 2021 (reference number 35517).

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.

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