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Does cooking ability affect consumer perception and appreciation of plant-based protein in Bolognese sauces?

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ABSTRACT

Encouraging consumers to reduce their meat consumption is imperative in mitigating climate change effects related to the food industry. For some, transitioning away from meat may be facilitated by meat substitutes. However, these are not always accepted as suitable alternatives to meat due to a combination of psychological, situational, and sensorial aspects. The influence of factors such as cooking ability on hedonics and sensory discrimination of meat and meat substitutes is currently under-researched. The present study investigated such effects. Consumers ($N = 101$) of varying cooking ability and food neophobia (measured using questionnaires) tasted and evaluated six mince products (one beef and five meat substitutes – three soybean-based, one mycoprotein-based, and one oat-based) prepared in a Bolognese sauce. They rated liking for overall, appearance, aroma, taste/flavour, and texture, and profiled the products sensorially using check-all-that-apply (CATA). It was found that meat substitutes can be liked just as much as, if not more than, beef in the application of Bolognese sauce. No main effects of cooking ability were found for any modality of liking, though an interaction between cooking ability and sample was found for liking of flavour/taste. Consumers' ability to sensorially discriminate between the Bolognese sauces was not dependent on their cooking ability. Several attributes that contributed to (dis)liking were identified. An additional online sample ($N = 288$) completed only the cooking ability and food neophobia questionnaires. A negative relationship was detected between cooking ability and food neophobia for the combined consumer and online datasets (total $N = 389$).

1. Introduction

In recent years, there has been considerable growth in the market for plant-based proteins in the form of meat substitutes in Western societies (Curtain & Grafenauer, 2019). The main driving forces for increased interest in meat substitutes are health and sustainability issues (Hallström, Carlsson-Kanyama, & Börjesson, 2015; Lynch, Johnston, & Wharton, 2018). Providing new and more sustainable food products such as meat substitutes through innovation and development is critical to address issues such as climate change, however this represents only one part of the solution. In order to mitigate food-related climate impact, further change is also required at the demand (consumer) end (Bajželj et al., 2014). Changing consumers' eating habits and behaviour can be difficult, as not only are many consumers unwilling to accept many meat substitutes as true alternatives to meat, their awareness of the

environmental impact of certain foods remains somewhat low (Hartmann & Siegrist, 2017; Sanchez-Sabate & Sabaté, 2019). There is a need for effective societal and political infrastructure that could support behavioural change for increased adoption of alternative products by consumers (Caro, Frederiksen, Thomsen, & Pedersen, 2017; van de Ven, González-Eguino, & Arto, 2018).

Several studies have investigated consumer attitudes to alternative protein sources including insects, lentils, and meat substitutes based on plants and cell cultures (Hartmann & Siegrist, 2017; Lonkila & Kaljonen, 2021). Consumers are resistant to reducing their meat consumption for numerous reasons (Collier et al., 2021), including habit and tradition (MacDiarmid et al., 2016), adherence to social norms and fear of social stigma for rejecting animal products (Cheah, Sadat Shimul, Liang, & Phau, 2020; Markowski & Roxburgh, 2019), willingness to pay (Carlsson, Kataria, & Lampi, 2022), perceiving meat as necessary for good

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health, and enjoying its sensory properties (Piazza et al., 2015). The latter is especially important as emphasis of environmental and health aspects is unlikely to reduce meat consumption among taste driven consumers (Apostolidis & McLeay, 2016). Further, repeated exposure to meat substitutes does not always improve liking thereof in comparison to meat (Hoek et al., 2013). Substitute products that retain similarity to meat in terms of use in cooking, aesthetics, and sensory characteristics are important (Apostolidis & McLeay, 2016; de Bakker & Dagevos, 2012) and may be the most likely to succeed in shifting consumer behaviour (Michel, Hartmann, & Siegrist, 2021).

The sensory properties of plant-based meat alternatives play an important role in their acceptance by consumers. If undesirable sensory characteristics are not controlled, the products will not be liked (Fiorentini, Kinchla, & Nolden, 2020). The intrinsic sensory properties of meat substitutes thus remain a barrier to acceptance and some sensory modalities have stronger influence than others. A particular product may be visually appealing, but the presence of undesirable flavours can still lead to overall disliking (Elzerman, Hoek, van Boekel, & Luning, 2015; Sharima-Abdullah, Hassan, Arifin, & Huda-Faujan, 2018). Cordelle, Redl, and Schlich (2022) similarly found that although some plant-based meat substitutes are rated as visually appealing, this did not dramatically impact liking upon tasting. Attribute drivers of disliking of meat analogues have been identified as: dry, bland, hard, and flavours unrelated to meat such as wheat/cereal-like (Grasso, Smith, Bowers, Ajayi, & Swainson, 2019). Meat substitutes can also be associated with tofu, which can in turn be associated with disgust (Michel et al., 2021). Convincingly replicating the sensory and physiochemical properties of meat in analogue products is not straightforward (Samard & Ryu, 2019) and complete substitution remains challenging. A remedy proposed for such adoption challenges are hybrid products, which are a combination of both plant-based and meat ingredients (Akesowan, 2010; Wong, Corradini, Autio, & Kinchla, 2019). These hybrid products can have uncompromised sensory characteristics compared to meat (Grasso et al., 2019) and could be a temporary measure for dietary transition towards complete meat substitution.

Another major factor that influences consumption patterns among consumers is their level of food neophobia (FN). FN contributes directly to food choice, and by extension the variety of foods in a consumers' diet; in particular, food familiarity and willingness to try them plays a crucial role (Jaeger, Roigard, Hunter, & Worch, 2021b; Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001). The consequence of higher FN is a comparatively limited dietary repertoire (Costa, Silva, & Oliveira, 2020). FN may also affect sensory discrimination of some products. For example, one recent study showed that low neophobic consumers who were regular consumers of flavoured black teas showed greater ability to differentiate the sensory characteristics of the teas (Lee, Chung, Prescott, & Kim, 2021). The authors attributed this to the possibility of these specific groups of consumers paying more attention to the senses as opposed to the sensory discrimination ability across the consumer groups.

Practical skills and cooking ability also affect consumers' dietary choices. Individual differences in food literacy and cooking ability among consumers is a rapidly developing research area which has gained increasing interest particularly in the last several years. Several scales have been proposed to measure consumers' self-reported ability to cook, covering a wide spectrum of research areas, from meal planning to preparation and consumption (Begley, Paynter, & Dhaliwal, 2018), healthy eating and nutrition (Gréa Krause, Beer-Borst, Sommerhalder, Hayoz, & Abel, 2018; Poelman et al., 2018), and cooking ability and frequency (Lahne, Wolfson, & Trubek, 2017). These scales are some of the most comprehensive for the measurement of food literacy (Amouzandeh, Fingland, & Vidgen, 2019). Among them, the Cooking and Food Provisioning Action Scale (CAFPAS; Lahne et al., 2017), has been shown to be quite successful. The CAFPAS is rooted in the idea of food agency, a sociological concept capturing an individual's ability to intentionally create foods as they envisioned them and to plan and execute meal

preparation in different contexts (Trubek, Carabello, Morgan, & Lahne, 2017). As such, CAFPAS attempts to comprehensively quantify cooking ability, and is comprised of three sub-scales: *Self-Efficacy* (one's self-perception of one's abilities to cook and prepare foods), *Attitude* (one's thoughts on and attitudes to cooking and food provisioning), and *Structure* (externalities and non-food hinders to cooking and food provisioning). Overall CAFPAS scores correlate positively to the typical number of meals cooked per week (Lahne et al., 2017) and a healthy dietary intake (Leung et al., 2019), indicating its utility as a measure of cooking ability. Although many factors have been identified as barriers to reducing meat consumption, relatively few studies have directly assessed the role of practical skills and cooking ability despite it being highlighted as impacting consumers' willingness to change (Graça, Godinho, & Truninger, 2019; Stoll-Kleemann & Schmidt, 2017). Further, whether cooking ability is related to liking and sensory perception of food products, as has been shown for FN, is currently not known.

Higher levels of experience are often accompanied by accomplished levels of discriminability. For example, individuals with more expertise in wine have shown better sensory discrimination of wines than those with less expertise (Urdapilleta, Parr, Dacremont, & Green, 2011). In other words, familiarity built from experience with product exposure can contribute to one's ability to distinguish nuances between products. It is possible from this point of view that cooking ability, assuming that it is acquired through experience, could also contribute to sensory discrimination ability of food products.

In summary, the links between cooking ability, FN, and sensory discrimination ability are currently missing. Further, it is unknown how cooking ability will influence the perception of a meal (Bolognese) that is very common in Sweden but prepared with different protein products. With the wide availability of many plant-based alternatives in the form of mince, their application appears to be tailored for meal applications such as Bolognese. The objective of this study was to determine how preference for meat/meat substitute in the context of a Bolognese sauce varies with cooking ability (measured using CAFPAS scores), as well as investigate consumers' ability to discriminate the sensory characteristics of meat/meat substitutes in Bolognese sauce. Further, the relationship between cooking ability and food neophobia was also assessed. The study presents three hypotheses based on an analysis of the current literature:

(i) CAFPAS and FN are negatively correlated. It is possible that the consumers with lower cooking ability also have higher levels of FN. With high FN, there is a lower cooking ability because of uncertainty in meal quality, as well as possible risk aversion tendencies.

(ii) Liking of meals with meat substitutes and their meat counterpart are different, whereby products that have a closer resemblance to meat may be preferred more. Preference may also be dependent indirectly on consumers cooking ability, where Bolognese sauces prepared with meat substitutes, which may be novel, may result in decreased hedonic responses.

(iii) Meals with meat substitutes have different sensory profiles than with their meat counterpart. Given that the test samples of interest have different raw materials, it is reasonable to expect variation in the sensory properties of the samples. Following on from the third hypothesis, the level of sensory discrimination is also dependent on consumers cooking ability. It is possible that consumers with lower cooking ability pay less attention to the intrinsic properties of a food than those with high cooking ability, due to their higher level of interest in food.

2. Materials and methods

2.1. Samples

Six variants of Bolognese sauce were prepared using commercial products (mince/ground form). Five of the products were meat substitutes, which were made with various raw materials; three were based

on soybeans (Soy_A, Soy_O, and Soy_H), one on mycoprotein (Myco) and one on oatmeal (Oats). The sixth product was beef mince with 10% fat content, which served as a control sample. All meat substitutes were pan fried with 1 Tbsp of vegetable oil per 500 g for 8 min, while the beef mince was prepared identically but without vegetable oil (due to the fat being expressed out from beef mince during cooking). The cooked products were kept at 50 °C until required. A tomato sauce for pasta (Barilla™, Parma, Italy) was heated and the sauce was mixed with each cooked meat (substitute) product at a ratio of 1:1. The tomato sauce was mixed with the products 15 min before serving and held warm at 50 °C.

2.2. Recruitment for the consumer test

Consumers were initially recruited through a recruitment platform and were provided a link to an online prequestionnaire for pre-screening (initial N = 371). Pre-screening questionnaires included demographic details of gender, age range, number of adults and children in the household, level of education, diet (omnivore, vegetarian/vegan, pescatarian, or other) and their cooking ability measured through the 28 item CAFPAS scale (Lahne et al., 2017). A translated version of the CAFPAS scale into Swedish (Supplementary material 1) was used in the current study, which used a 7-point Likert scale for each item. Consumers were told that the objective of the study was to determine their liking and sensory profiles of Bolognese sauces, but the true objective of the study was not revealed. Since the study necessitated consuming meat (beef), vegetarians, vegans, and pescatarians were excluded from participating further. Those who did not complete the CAFPAS in full were also excluded. The resulting number of consumers recruited for the test was N = 101, whose demographics are summarised in Table 1. To focus on the effect of cooking ability, consumers' CAFPAS scores were determined prior to the sample evaluation. The entire CAFPAS score range was ordered and split into three equal ranges, which categorised consumers into "low", "medium", and "high" cooking ability (N = 34, 34, and 33, respectively).

The screened consumers participated in a central location test with tasting of the samples at a location in Gothenburg, Sweden. To familiarise the consumers with the sensory evaluation procedure and methodology, a dummy sample (Soy_A) was served to the consumers and the evaluation was performed with the guidance of a RISE Research Institutes of Sweden staff member. After the dummy sample, the consumers tasted and evaluated each Bolognese sample individually. For each given sample, consumers indicated their overall liking as well as

Table 1
Summary of demographic results from consumers (N = 101) who participated in the complete study and the online survey.

Category	Response	Response (%)	
		Consumer test (n = 101)	Online survey(n = 288)
Gender	Female	57.4	74.7
	Male	42.6	24.2
	Other	0.0	0.3
	Don't wish to answer	0.0	0.7
Age range	18–25	10.9	8.7
	26–34	15.8	30.8
	35–44	26.7	23.5
	45–54	19.8	18.3
	55–64	17.8	13.8
	65+	8.9	4.8
Diet	Omnivore	94.1	74.7*
	Pescatarian	0.0	7.6
	Vegan	0.0	8.0
	Vegetarian	0.0	6.2
	Other	5.9	3.5

* Consists of flexitarians as well as omnivores.

their liking of appearance, aroma, taste/flavour, and texture of the sample on 9-point hedonic scales.

To determine how the consumers perceived the sensory properties of the Bolognese sauces, consumers profiled the samples using check all that apply (CATA). The CATA profiling for each sample was performed after giving hedonic scores. The CATA attributes (total of 48 attributes) were presented separately by modality groups; appearance and aroma (19 attributes), taste/flavour (17 attributes), and texture/mouthfeel (12 attributes) to reduce the cognitive burden for the consumers. The CATA attribute list was generated prior to consumer testing using a panel of seven assessors with extensive experience in sensory evaluation, who tasted the products in tomato sauce during an attribute generation session (lasting 3 h) (Table S1). The CATA step was an important part of the investigation to determine if sensory perception of the sauces depended on cooking ability. Attribute presentation order within each modality group was randomised across consumers and samples, while modality group order was kept constant. Samples were blind coded with three-digit codes, served monadically in a randomised order. All samples were served (30 g) warm at 50 °C under natural lighting in a large room. In accordance with COVID-19 hygiene and social distancing guidelines in place at the time of testing, the consumers sat 2 m apart and a limited number of consumers took part in a given testing session. Samples were freely consumed with a plastic spoon by the consumers. At the conclusion of the test, consumers answered a food frequency questionnaire and FN was measured using the Food Neophobia Scale (FNS) (Pliner & Hobden, 1992) also in Swedish. The items on the FNS were first translated by a native Swedish speaker. To confirm that the essence of each question was not lost through translation, the scales were translated back to English for checks internally among the researchers (Supplementary material 1).

To determine the consumer samples food consumption habits, they answered a food frequency questionnaire. The true purpose of the question was to determine the consumption frequency distribution of meat substitutes and compare with meat. The consumers' food frequency showed differences in all food categories, where all food categories significantly differed by frequency of consumption (one sample Chi² test, $p < 0.05$) (Table S2). Consumption of protein including meat, cold cuts, beans, and fish were normally distributed. Meat substitute consumption on the other hand was skewed towards low consumption and revealed that the consumer group tested consumed in general a low amount of meat substitutes (Fig S1). Meat substitutes were not well incorporated into the diets of this sample of consumers compared to the other categories of protein. The relationship between meat (substitute) consumption and cooking ability was measured, and showed that the mean cooking ability scores did not vary based on frequency of consumption of meat or meat substitutes (Fig S2).

2.3. Supplemental online data collection

To supplement the number of cases for a valid correlation between CAFPAS and FNS measured in section 2.2, additional CAFPAS and FNS data points were collected from a separate consumer sample in the form of an online survey specifically for the two scales. A total of 288 participants completed the survey, giving a combined sample size of 389 participants after adding in the data from the consumer test (N = 101) for the analysis of CAFPAS and FNS. To capture a wide variation of cooking ability and FN, the consumers in the online survey were not screened. The information and scope of the study were revealed to the online survey participants only after the completion of the survey.

The socio-demographic data collected on the consumers recruited for the online survey are shown in Table 1. Note that the diets of the consumers were different, as the participants for the consumer test were required to consume meat for the test. Most of the participants from both consumer samples were omnivores between the ages of 26–64. Gender was more balanced in the consumer test than the online sample, where 75% were female.

The consumer test and online surveys was conducted in compliance with the Declaration of Helsinki (2013), all consumers provided their written consent before participation. All consumers who participated in the consumer test were provided a gift card worth 200 SEK as remuneration upon study completion. The study was assessed for compliance with national research requirements through an internal process at RISE Research Institutes of Sweden and was approved by the Department of Material and Surface Design. Personal data was collected and handled in compliance with the General Data Protection Regulation (EU) 2016/679 (GDPR).

2.4. Data analysis

The internal consistency of the raw data obtained from CAFPAS and FNS were determined using Cronbach's alpha each from the data set of the consumer test as well as the online survey. Normalised indices of cooking ability of consumers were calculated using the method described by Lahne et al. (2017). The sum of the scores were calculated within each subscale section for each consumer and divided by the respective subscale standard deviation derived from the relevant sample (i.e., from the consumer study ($N = 101$), from the online study ($N = 288$), or the combined data set ($N = 389$)). The resulting sum of the normalised values for *Self-Efficacy*, *Attitude*, and *Structure* gave the CAFPAS score for each consumer. The data from the FNS were calculated as total scores from all 10 items (after reversing scores for half of the items) for each consumer. Pearson correlation analysis was used to assess the relationship between overall CAFPAS scores as well as the CAFPAS sub-scale scores and FN scores. Food frequency questionnaires were analysed using one sample chi-square tests.

The hedonic data ($N = 101$) were analysed using ANCOVA, with sample as a within-subjects factor, cooking ability (CAFPAS group) as a between-subjects factor, and FNS as a covariate. Each modality of liking was analysed separately. Significant effects were further investigated using post-hoc Bonferroni corrected pairwise comparisons.

The CATA data on the consumer data set ($N = 101$) were analysed with Cochran's Q test to determine perceptual discrimination across the

samples. A contingency table was prepared and further analysed with correspondence analysis. Since no attributes had citations below 5%, all attributes were included in the analysis. The matching liking scores for each consumer were also included in the correspondence analysis as [supplementary data](#). To determine the influence of cooking ability on sensory characterisation, the data set was further separated into three contingency tables based on the levels of the cooking ability factor, and all three contingency tables were analysed with Cochran's Q test and multiple factor analysis for contingency tables (MFACT) to determine the similarity of sample projections across cooking ability. To determine if presence/absence of significantly different attributes (found through Cochran's Q test on the entire data set) impacted on liking within a sensory modality (i.e., for aroma, flavour/taste, and texture) the liking scores when a particular attribute was present against when the attribute was absent was analysed using 2-sample t-tests. This was performed for modalities that significantly differed across samples. All statistical tests were performed at an $\alpha = 5\%$ using XLstat ver. 2020.5.1 (Addinsoft).

3. Results

3.1. Cooking ability and food neophobia

Cooking ability (CAFPAS) and FN scores of each consumer were determined (Table 2). Descriptive statistics and correlations between the CAFPAS subscales are reported in Table S3 in the [supplementary materials](#). Briefly, *Self-Efficacy* correlated highly with *Attitude* and the sum scores, and strong correlations were also seen between *Attitude* and sum scores. Sum scores were also significantly correlated with *Structure*.

The hypothesis here was that the two measures would be negatively correlated. For the participants in the consumer test, both cooking ability (Cronbach's $\alpha = 0.931$) and FN (Cronbach's $\alpha = 0.795$) showed internal consistency, where values above 0.7 are considered acceptable (Taber, 2018). The mean cooking ability score for the consumer sample group was 13.2 ± 0.23 (S.E), and a range of 9.6 (min' = 7.8; max' = 17.4). The mean FN score of the consumer group was 24.3 ± 0.91 (S.

Table 2

Mean (M) scores and standard deviations (SD) of items from the CAFPAS scale for the consumer test group and the online survey only group. The items are presented in English here but note that the participants responded to the Swedish version.

Subscale	Item	Consumer test (n = 101) M (SD)	Online (n = 288) M (SD)
Self-Efficacy	I feel limited by my lack of cooking knowledge	5.33 (1.78)	5.25 (1.79)
	I can always manage to decide what I would like to eat at any given time	4.99 (1.69)	4.51 (1.79)
	When preparing food, I am confident that I can deal with unexpected results	5.18 (1.45)	5.26 (1.56)
	When preparing food, it is easy for me to accomplish my desired results	5.36 (1.26)	5.33 (1.37)
	In preparing food, I can solve most problems with enough effort	5.48 (1.36)	5.70 (1.25)
	I am comfortable preparing food	5.69 (1.49)	5.76 (1.47)
	I know how to use the kitchen equipment I have	6.18 (1.25)	6.38 (0.98)
	I am involved in daily meal preparation	6.08 (1.35)	6.04 (1.44)
	When I shop for food, I know how I will use the ingredients I am purchasing	5.76 (1.42)	5.72 (1.35)
	I am confident creating meals from the ingredients I have on hand	5.82 (1.38)	6.06 (1.27)
	Before I start cooking, I usually have a mental plan of all the steps I will need to complete	4.83 (1.50)	4.88 (1.70)
	When presented with two similar products to purchase, I feel confident choosing between them	5.62 (1.34)	5.74 (1.36)
	I know where to find the ingredients I need to prepare a meal	5.90 (1.25)	6.21 (0.98)
Attitude	I find cooking a very fulfilling activity	5.56 (1.44)	5.18 (1.76)
	For me, cooking is just something to get through as quickly as possible	4.11 (1.62)	4.41 (1.90)
	Compared to other activities, cooking brings me little enjoyment	5.02 (1.73)	4.74 (1.97)
	If I try making a new type of food and it does not come out right, I usually do not try to make it again	4.49 (1.69)	3.95 (1.75)
	I think a lot about what I will cook or eat	4.90 (1.48)	4.93 (1.70)
	I prefer to spend my time on more important things than food	4.51 (1.78)	3.92 (1.84)
	If everything else is equal, I choose to cook rather than have food prepared by someone else	4.25 (1.71)	4.13 (1.82)
	I feel like cooking is a waste of effort	5.70 (1.58)	5.45 (1.73)
	I am inspired to cook for other people, like my family or friends	5.44 (1.49)	5.24 (1.74)
	I feel burdened by having to cook for other people, like my family or friends	5.43 (1.75)	4.93 (1.74)
Structure	I wish that I had more time to plan meals	3.99 (1.64)	4.06 (1.77)
	I have a hard time finding enough time to prepare the food I'd like to eat	4.58 (1.78)	4.30 (1.91)
	My family responsibilities prevent me from having time to prepare meals	5.66 (1.53)	5.58 (1.69)
	My social responsibilities prevent me from having the time to prepare meals	5.50 (1.54)	5.61 (1.51)
	My job responsibilities prevent me from having the time to prepare meals	4.96 (1.92)	4.68 (1.96)

E.), and a range of 45 (min' = 10; max' = 55). For the online group, again both cooking ability (Cronbach's $\alpha = 0.916$) and FN (Cronbach's $\alpha = 0.836$) showed internal consistency. The mean cooking ability score for the online group was 13.2 ± 0.13 (S.E), and a range of 10.8 (min' = 7.1; max' = 17.8). The mean FN score for the online group was 25.3 ± 0.58 (S.E), and a range of 52 (min' = 10; max' = 62). The groups were similar in terms of average CAFPAS and FNS scores, as well as the internal consistency of the scales.

Pearson correlation analysis on the combined data from the consumer and online groups revealed a significant, negative relationship ($r(387) = -0.197, p < .001$) (Fig. 1). Relationships between FN and the subscales of the CAFPAS were also investigated. Interestingly, negative correlations were observed between FN scores and the *Self-Efficacy* ($r(387) = -0.154, p = .002$) and *Attitude* ($r(387) = -0.232, p < .001$) sub-scales, but not the *Structure* subscale ($r(387) = -0.024, p = .6$). Thus, for the combined datasets, the hypothesis that FN is related to cooking ability was supported. However, the Pearson coefficient correlation computed between cooking ability and FN scores for the consumer test group only was not significant at the 5% alpha level ($r(99) = -0.125, p = .21$).

3.2. Liking of Bolognese sauces

Each modality of liking (overall, appearance, aroma, taste/flavour, and texture) was analysed separately using ANCOVA, where sample was a within-subjects factor, cooking ability (CAFPAS group) a between-subjects factor, and FNS a covariate. The hypotheses here were that: 1) the liking of Bolognese sauces with meat substitutes and their meat counterpart would differ, whereby products that have a closer resemblance to meat may be preferred more, and 2) liking may also be directly or indirectly dependent on consumers cooking ability, where Bolognese sauces prepared with meat substitutes, which may be novel, may result in decreased hedonic responses. Significant effects were further investigated using post-hoc Bonferroni corrected pairwise comparisons. Significant effects are discussed here, and a full summary of the analyses is provided in Table S4 in the supplementary materials.

For overall liking, the only significant effect was of FNS as a covariate ($p = .039$). Liking of appearance differed significantly across the samples ($p = .005$) where the appearance of Soy_O was liked significantly more, and that of Oats was liked significantly less, than all other samples (all $p < .001$) (Fig. 2.). FNS was also a significant covariate for liking of appearance ($p = .024$). For liking of aroma, significant differences were found across the samples ($p = .045$), where Oats and Soy_H were liked less than the other samples (all $p < .05$). Liking of taste/flavour differed across samples ($p = .049$), where the taste/flavour of Oats was liked

significantly less than all the other samples (all $p < .001$), and Soy_O was liked significantly more than Soy_H, Soy_A, and Myco (all $p < .05$). Additionally, a sample \times cooking ability interaction ($p = .032$) was detected, which was characterised by the low cooking ability group liking the taste/flavour of beef significantly more than the high cooking ability group ($p = .012$) (Fig. 3.).

Inspection of the mean overall liking of Bolognese sauces by consumers frequency of meat/meat substitute consumption and their cooking ability, showed that Soy_O was liked highly, irrespective of consumption frequency of meat and meat substitutes (Fig S3). A difference in pattern of liking of Bolognese sauces made with Beef and Oats was seen between consumption frequency of the two food categories. Higher meat consumption showed higher liking of meat, while the opposite was true for higher meat substitute consumption. Additionally, Oats was liked highly in this consumption category, however we stress that mean liking calculated for meat substitute consumption at 5–7 times a week of meat substitute should be interpreted with caution, as this group consisted of only two consumers.

3.3. Sensory characterisation with CATA

The sensory data from CATA were analysed using Cochran's Q test and MFACT to determine the similarity of sample projections across cooking ability. The main hypothesis here was that Bolognese sauces made with meat substitutes have different sensory profiles than that made with their meat counterpart. Given that the test samples of interest have different raw materials, it is reasonable to expect variation in the sensory properties of the samples. Following this, a second hypothesis was that the level of sensory discrimination may be dependent on consumers cooking ability. It is possible that consumers with lower cooking ability pay less attention to the intrinsic properties of a food than those with higher cooking ability, which may be due to a lower level of interest in food.

The consumers were able to discriminate the different Bolognese sauces by sensory characteristics and 43 attributes significantly differed at $p < 0.05$ across samples according to the Cochran's Q test (Table S5). Citation of attributes across each attribute ranged between 9 and 58% (Table 3). The CATA data was separately reanalysed for each level of cooking ability. The citation frequencies of attributes were similar across all levels of cooking ability, as was the total number of significantly different attributes across samples at the $p < 0.05$ level (Table 3; for individual significance levels, see Table S5). In all analyses by cooking ability, the total number of significant attributes were lower than the analysis of the entire consumer data set, due to the lower number of cases included in the analyses.

Correspondence analysis of the CATA data from all consumers showed distinct sensory properties that characterised each type of Bolognese sauce, with the first two factors explaining 71.9% of the variance (Fig. 4). Bolognese with beef was perceived with the expected characteristic of F/T_meat, but also with oily, rubbery, and stringy textures, and appearances of clumpy and pieces/slices. This sample was clearly discriminated as different compared to the Bolognese sauces made with meat substitutes. Mycoprotein was characterised with watery texture, and attributes related to tomato and tomato purée. The attributes Ar_acidic and F/T_sour were both characteristic of Mycoprotein and Soy_O, however further inspection on the third factor showed that these two attributes characterised Mycoprotein more (data not shown). The Bolognese sauces produced with the three soy products were relatively similar sensorially, given their proximity in one quadrant of the correspondence analysis matrix. However, individual characteristics could still be discriminated: Soy_O was characterised with F/T_Sweet, while Soy_A was more characteristic of Ar_Bouillon, Tx_Spongy, and F/T_Umami. The two Bolognese versions made with Soy_O and Soy_A shared some similar characteristics such as easily chewed texture and a homogenous appearance. Soy_H had unique characteristics of smoky, Ap_Brown, spices, mushroom, and Tx_grainy. Oats on the other hand

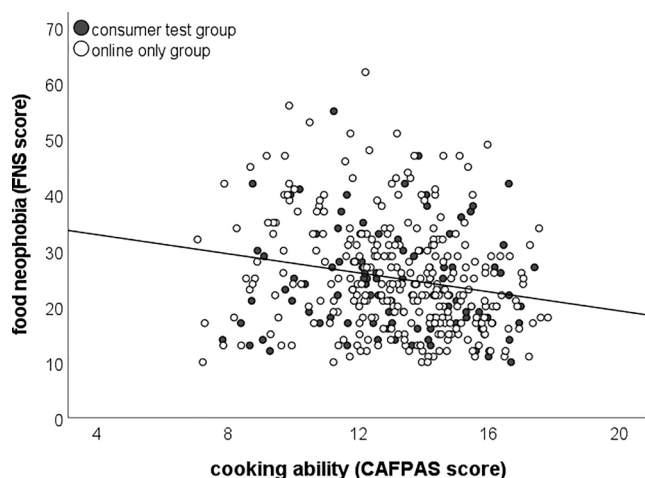


Fig. 1. Correlation of consumers CAFPAS and FN scores, including consumers from the Bolognese test and online survey.

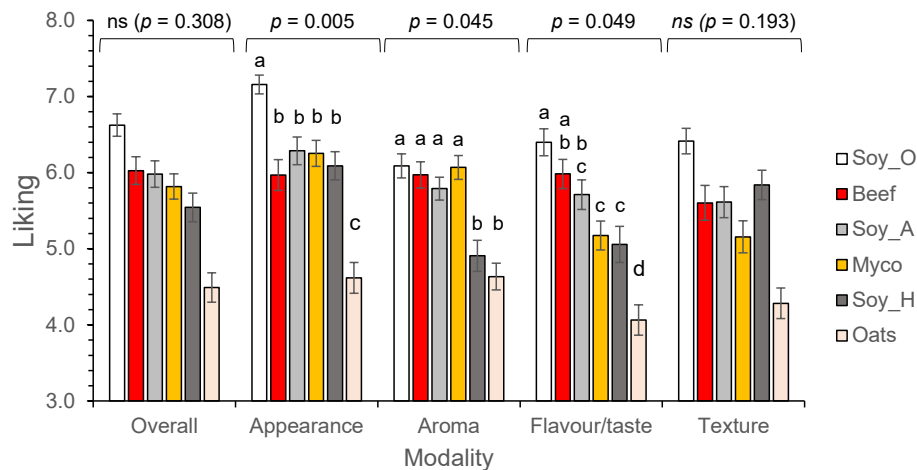


Fig. 2. Mean liking scores (\pm S.E) of Bolognese sauces with meat/meat substitutes ($n = 101$). Means with the same superscripts are not significantly different according to post-hoc Bonferroni corrected pairwise comparisons ($\alpha = 5\%$).

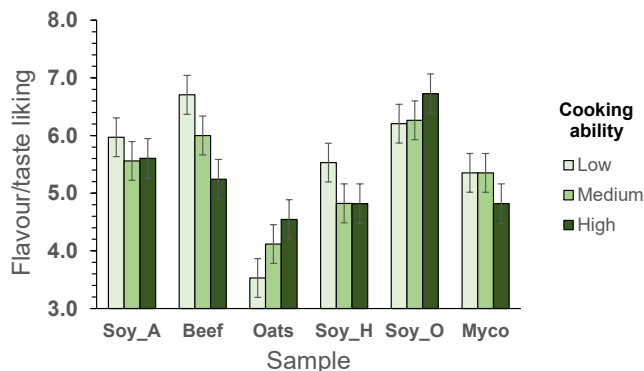


Fig. 3. Significant cooking ability \times sample interaction for flavour/taste liking (\pm S.E).

was characterised with coarse/rough, dry, and mouth coating texture, and cardboard characteristics.

To determine if significantly different attributes also drove liking in their respective sensory modalities, mean liking scores when the attribute was absent were compared to when it was present in appearance, aroma, and flavour/taste modalities. For appearance, the presence of vegetables and red colour showed significant (2-sample t -test, $p < 0.05$) increases in liking, while the presence of four attributes (brown colour, pieces/slices, clumpy, and stringy) significantly decreased liking (2-sample t -test, $p < 0.05$), see Fig. 5a. For aroma, six attributes significantly drove liking (2-sample t -test, $p < 0.05$), while two attributes significantly decreased liking (2-sample t -test, $p < 0.001$). Attributes related to tomatoes, vegetables, spices, bullion, sweet smell were

positive drivers of liking. Aromas of beans and cardboard however contributed to decreased liking (Fig. 5b). Finally, for flavour/taste, nine attributes significantly drove liking (2-sample t -test, $p < 0.05$), and were consistent drivers of aroma liking. Unique attributes for flavour/taste modality were buttery, herbs, meat, umami, oily, and sweet. Attributes that significantly reduced liking (2-sample t -test, $p < 0.001$) for flavour/taste were cardboard and bitterness, and by the largest magnitude. These sensory characteristics partially explain the disliking of Bolognese sauces made with Oats reported above. It should be noted that five attributes that were significant drivers of liking/disliking were cited below 20% (two cardboard attributes, AP_stringy, F/T_bitter, F/T_buttery. Particularly for cardboard characteristics, despite their large influence in disliking, their presence was detected between 11 and 17% and was not exclusive to only Bolognese made with Oats. Based on the analysis, the attributes that drove liking and disliking were projected on positive and negative factor 2 of the correspondence analysis, respectively (Fig. 4).

The CATA data categorised by cooking ability were analysed with MFACT to determine the sample discrimination patterns between groups. Samples were consistently discriminated from each other when data was categorised by cooking ability level and the first two factors explained 65.5% of the variance (Fig. 6). Bolognese made with beef was also consistently perceived as unique from the other Bolognese with meat substitutes. The consensus plots also indicated high similarity in scores projections between the various levels of cooking ability, suggesting that cooking ability did not play a strong role in the consumer's discrimination ability of Bolognese by sensory properties (Fig. 6a). The similarity of scores projections were confirmed by the high RV coefficients between tables (cooking ability comparisons: low vs medium = 0.923, low vs high = 0.985, and medium vs high = 0.930). Further,

Table 3

Range of citations and the number of discriminant attributes that significantly differed across samples (Cochran's Q, $p < 0.05$) measured from CATA, for all consumers, as well as separated by cooking ability group.

Consumer group	Levels (n)	Measure	Attribute modalities				
			Total	Appearance	Aroma	Flavour/taste	Texture
All	All (101)	Citation	9–58%	16–54%	11–58%	9–58%	14–55%
		No. sig attributes	43	8	9	15	11
Cooking ability	Low (34)	Citation	8–59%	21–56%	11–59%	8–58%	11–53%
		No. sig attributes	33	5	7	12	9
	Medium (34)	Citation	9–55%	12–51%	9–49%	10–53%	11–55%
		No. sig attributes	31	7	7	11	6
	High (33)	Citation	8–65%	14–55%	10–65%	8–63%	8–57%
		No. sig attributes	33	7	8	11	7

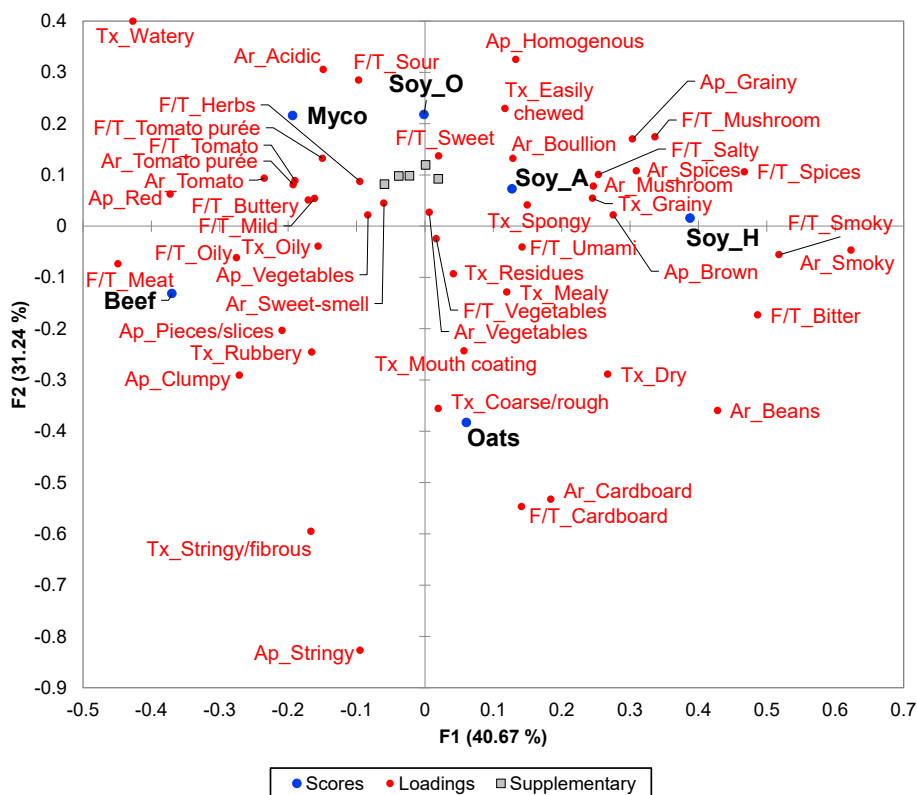


Fig. 4. Correspondence analysis biplot of sensory characteristics and the Bolognese sauces determined using CATA. Supplementary points represent the mean liking scores for overall, appearance, aroma, flavour/taste, and texture.

there was no consistent MFACT scores projection of any group by cooking ability that would suggest consistent superior discrimination over another group. The attributes that consistently loaded highly on the first three factors when MFACT was analysed across groups of cooking ability (23 attributes) are shown in Fig. 6b. The projections of most attributes with high correlation loadings were situated close to each other, suggesting consensus in the understanding of attributes between the consumers with different cooking abilities. Attributes that were more spread, i.e., those with less consensus, were AP_pieces/slices, F/T_ and A_cardboard, F/T_oily, AR_tomato, and Ar_Acidic suggesting some variation in how the different cooking ability groups interpreted these attributes.

4. Discussion

4.1. Relationship between cooking ability and FN

The measures for cooking ability and FN were negatively correlated with each other from a combined consumer sample. In line with our initial prediction, a negative correlation was detected between cooking ability and FN scores. Although correlation does not equal causation, it is interesting to observe that cooking ability and food neophobia may not be entirely disconnected. That FN scores were associated with the *Attitude* and *Self-Efficacy* subscales of the CAFPAS, but not the *Structure* subscale, is of relevance. The *Attitude* subscale pertains to consumers' perceptions of and attitudes towards cooking and food provisioning (e.g., "I find cooking a very fulfilling activity"), and *Self-Efficacy* refers to consumers' perceptions of their own abilities to prepare foods (e.g., "I am confident creating meals from the ingredients I have on hand"). It seems reasonable that these two subscales, which directly deal with the actions of cooking and food preparation, may relate more to FN, whilst the *Structure* subscale which deals with external barriers to food provisioning does not (e.g., "I have a hard time finding enough time to

prepare the food I'd like to eat"). The detected correlations between FN and food provisioning as well as *Self-Efficacy* are therefore unlikely to only be spurious. The extent to which FN and gaining cooking skills and knowledge are related may matter for shifting consumers towards more environmentally friendly foods. Cooking ability has been shown to be associated with better health outcomes (Lahne et al., 2017; McGowan et al., 2017) and perceived competence in preparing meals without meat or using unfamiliar protein sources is a previously observed barrier to changing to a more environmentally sustainable dietary pattern (Graça et al., 2019; Stoll-Kleemann & Schmidt, 2017). A more detailed investigation into both the nature of the relationship and its directionality, as well as whether interventions to improve one can impact the other (e.g., can increasing food skills and literacy reduce FN and encourage a broader dietary repertoire?), would be interesting and fruitful future directions.

4.2. Hedonics of Bolognese and impact of cooking ability

Some meat substitutes were liked just as much, if not, more than beef in of Bolognese. That this was found even though previous reports indicate that meat substitutes tend to be liked less than meat (Hoek et al., 2013), may be testament to the continual development of plant-based meat alternatives by the food industry over the last several years. Other factors may have played a role, such as the cohort tested were Swedish and the meat substitutes being prepared in a Bolognese sauce. Preparation in such as sauce as Bolognese can enhance the perceived appropriateness by consumers, hence providing opportunity for application (Elzerman et al., 2015). By the same token, not all meat substitutes perform equally, where some are more appropriate for certain dishes than others (Elzerman, Hoek, van Boekel, & Luning, 2011). Oats in this case may be perceived as less appropriate relative to Soy_O, in the Bolognese sauces prepared here.

The interaction between cooking ability and sample regarding liking

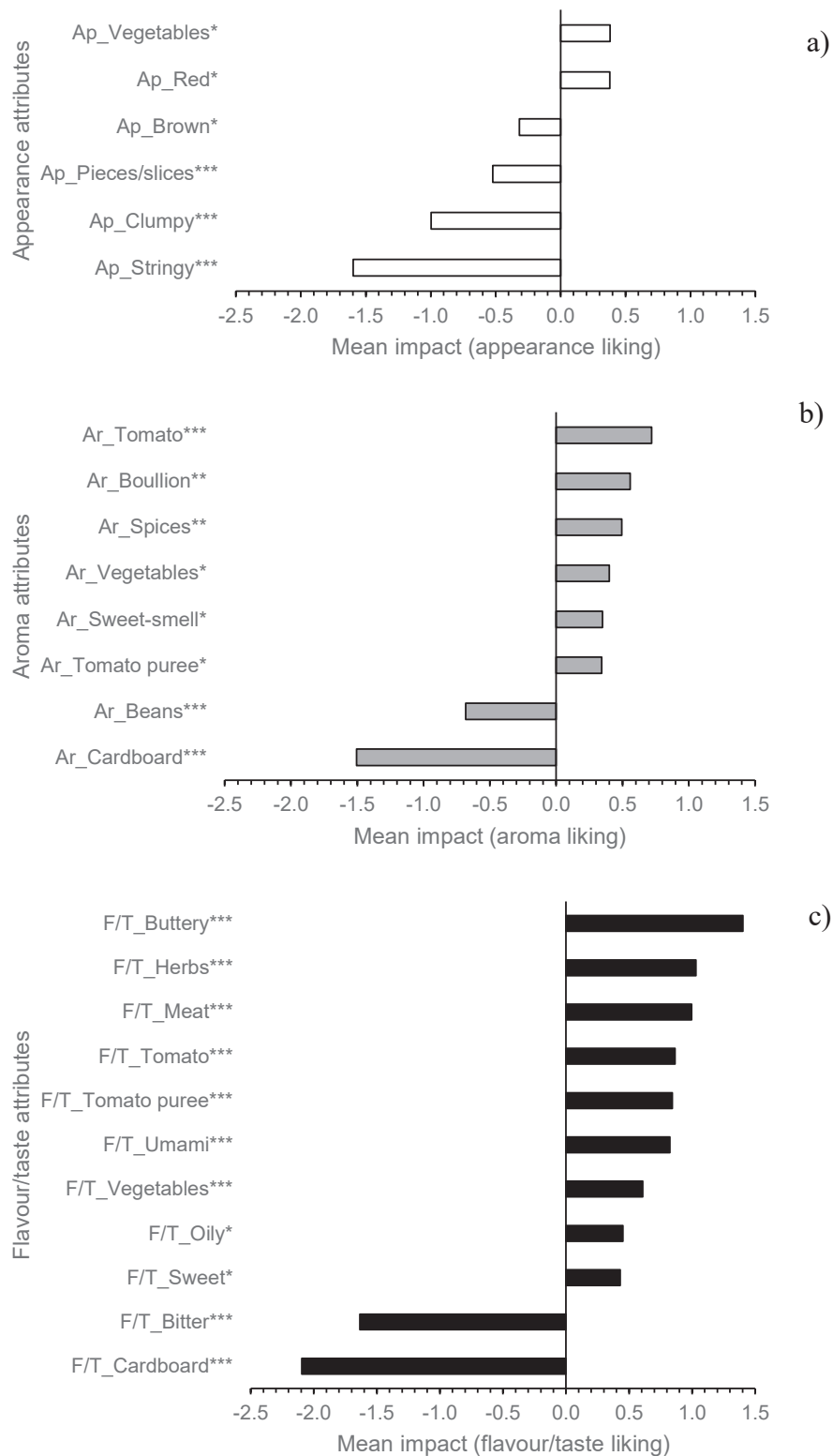
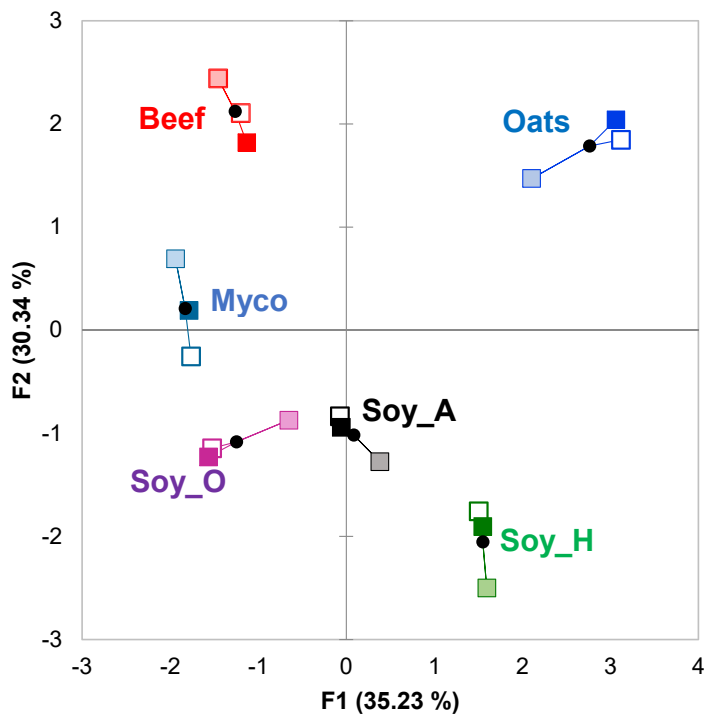


Fig. 5. Attributes that significantly impact on a) appearance liking, b) aroma liking, and c) flavour/taste liking. * = $p < 0.05$, ** = $p < 0.01$, and *** = $p < 0.001$.

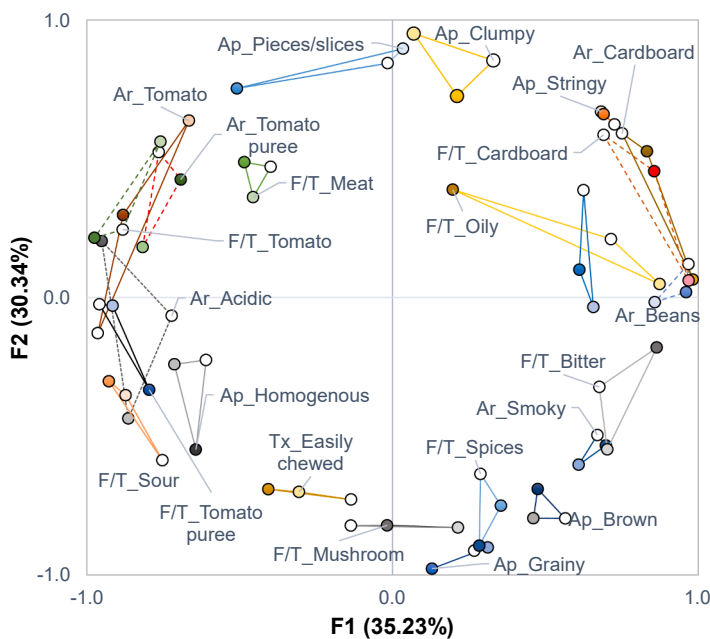
of flavour/taste warrants further investigation. It is tempting to suspect that the reduced liking of flavour/taste by high cooking ability consumers was due to their opinions on their ideal Bolognese profile, including the protein source used in such an ideal. It may also be that these individuals are sensitive to deviations from what they themselves

would prepare, leading to more pronounced differences in liking across the samples. Though measuring the ideal profile of the Bolognese was not the objective of the study, it may be a point for further research in determining if the degree of deviation of profiles from the perceived ideal is associated with cooking ability. However, there is currently very



a)

Fig. 6. MFACT of CATA categorised by cooking ability showing a) consensus scores and b). consensus loadings of attributes. Symbols apply to both cooking ability: open symbols = low level, light coloured symbols = medium level, and dark coloured symbols = high level. Loadings shown are only those that had consistently high correlations to factors 1-3, calculated as square cosines, across levels of cooking ability or food neophobia. AP_ = appearance, Ar_ = aroma, F/T_ = flavour/taste, and Tx_ = texture.



b)

scant literature about the relationship between cooking ability and consumers subjective responses during food tasting. Thus, interactions between differences in cooking ability and hedonics offer an interesting route for future research.

Liking for both overall and appearance were associated with variations in FN, showing its role in product hedonics. Appearance is known to influence hedonics depending on the degree of FN. Lower neophobia consumers tend to report higher expected liking of novel products based on the appearance of packaging and the actual product itself, while higher neophobia consumers tend to report lower expected and actual liking (Samant et al., 2018). Novelty and unfamiliarity can also decrease liking of food products for those who have high FN (Arvola, Lähteenmäki, & Tuorila, 1999). Regardless of the wide differences in

hedonics of all modalities, accounting for FN as a covariate seemed to outweigh the discrimination of liking overall and texture. This was evident when the analysis was rerun with repeated measures ANOVA without accounting for FN, which would have otherwise been significantly different across samples (data not shown). This indirectly indicated how much impact FN has on hedonics, but also stresses the importance of carefully selecting an analysis strategy, as it strongly impacts the interpretation.

Liking was driven by various attributes that were not necessarily related to meat. Interestingly, attributes related to vegetables and tomato were not significantly different across Bolognese sauces, yet their presence contributed to liking, suggesting that such attributes are essential for Bolognese. In contrast, attributes such as meat and spices

could be “nice-to-have”, but not essential, as they were not characteristic of all Bolognese sauces tested. Other characteristics related to disliking were aroma and flavour of cardboard and beans, which are atypical to the sensory concept of Bolognese sauces, which may have resulted in the large differences in hedonic scores. The incongruence between the perceived atypical sensory characteristics and the identity of the food product can result in disconfirmation and eventually negative affect (Yeomans, Chambers, Blumenthal, & Blake, 2008).

4.3. Sensory characteristics of Bolognese and the impact of cooking ability.

Bolognese sauces were discriminated based on their sensory properties similarly by consumers of different cooking abilities. Note that the consumers in the current study were assumed to be familiar with Bolognese and mince (but not the meat substitutes themselves). Consumers' familiarity with a product category has been reported to improve performance in sensory evaluation based on intensity ratings (Lee et al., 2021). Not all attributes here were highly correlated on the MFACT when analysed as a function of cooking ability (Fig 8). Despite some highly correlated loadings on factors 1–3, their projections were not always consistent across the levels of cooking ability. Some attributes were likely to be understood differently across levels of cooking ability, leading to a variation in the citation frequencies of each individual attribute. The findings from the MFACT have implications for how consumers are considered based on their ability to discriminate various samples. Assumptions cannot be made on consumers sensory discrimination ability based on their level of cooking ability. When faced with products such as Bolognese sauce, it may be enough that the consumers are familiar with the dish (and not necessarily the ingredients) for sensory discrimination. Other factors that could play a role are familiarity with sensory evaluation through training (Jaeger et al., 2017).

4.4. Limitations and further directions

The current study was focused on Bolognese sauce and accordingly, the form of the protein sources used were variants of mince. The product range tested was therefore limited compared to the entire spectrum of available plant-based meat substitutes on the market, such as burgers, sausages, or forms resembling meat cuts such as schnitzels. However, mince was purposely chosen to suit the context of Bolognese as well as an assumed familiarity of this dish from home cooking. Further testing is required to confirm the current findings with other plant-based products in different contexts, such as burgers. For a study that utilised CAFPAS and FNS, the participation of consumers with extreme FN in the current study (>50) were rare. Their underrepresentation could be because the focus of the study was investigating the effects of cooking ability, with FN as a secondary factor. The low response rate of highly food neophobic consumers is common, likely due to their reluctance to participate in studies that involve tasting (Henriques, King, & Meiselman, 2009), unless this segment is specifically targeted. Therefore, the entire possible range of absolute FN was not obtained. Despite this, there are currently no standardised methods to segmenting consumers for FN and many methods have been applied (Rabadán & Bernabéu, 2021) including their analysis as a continuous factor, rather than extreme groups (Jaeger, Chheang, Jin, Ryan, & Worch, 2021a). This motivated our decision to recruit an additional online group so that relationships between CAFPAS and FNS could be analysed with more certainty. Other avenues of research are food choice questionnaires and cooking ability. Convenience and familiarity are important correlates with FN (Jaeger et al., 2021b), which may also relate to cooking ability. The CAFPAS contains a section that broadly measures *Attitude* to cooking but does not contain any items related explicitly to convenience and familiarity. This relationship requires further investigation and may reveal the bridge between cooking ability and FN.

The number of attributes used to profile the Bolognese sauces in the

current study was high relative to the literature (Ares & Jaeger, 2015; Meyners & Castura, 2014; Niimi et al., 2022). This may mean that some attributes were not fully understood by the consumers, or that their responses to some attributes may be less accurate or representative. However, in earlier studies, samples have indeed been successfully discriminated by consumers, in some cases consistently across two groups of consumers under different environmental conditions (Niimi et al. (2022); where 32 attributes were used). Unfortunately, no optimal or recommended number of terms to include in CATA exercises has yet been suggested, due to attribute lists being dependent on the nature of both the study itself and the samples tested (Jaeger et al., 2015). In other words, there is likely no one-size-fits all. Here, it appeared that the consumers were able to handle a total of 48 attributes. Nonetheless, attribute understanding is highly reliant on the consumers' own interpretations, where some attributes may be obvious while others may be prone to more variation. This may call into question the number of attributes that are truly worth considering in data interpretation. However, this is a known limitation of rapid methods that use untrained consumers to conduct profiling exercises. One approach to counter this might be the provision of attribute definitions to maximise understanding among consumers and provide a common baseline, however the effects of comprehensive instructions and providing attribute definitions on sample discrimination performance among untrained consumers is currently under-researched and requires further investigation.

5. Conclusions

The objective of this study was to investigate how differences in cooking ability might affect hedonic ratings and sensory discrimination of meat/meat substitute in the context of a Bolognese sauce. The relationship between cooking ability and food neophobia was also investigated. Specifically, three hypotheses were tested: (i) cooking ability (CAFPAS scores) and FN are negatively correlated; (ii) hedonic scores for Bolognese sauce prepared with meat substitutes and their meat counterpart are different, whereby products that have a closer resemblance to meat may be preferred more, and may also be directly or indirectly affected by consumers' cooking ability; and (iii) Bolognese sauces prepared with meat substitutes have different sensory profiles than with their meat counterpart, and the level of sensory discrimination is affected by consumers cooking ability.

The results supported hypothesis (i). Although the negative correlation detected between cooking ability overall and FN was not especially strong, selected subscales of CAFPAS, namely *Self-Efficacy* and *Attitude* associated better than *Structure*. However, hypotheses (ii) and (iii) were not strongly supported, if at all. No main effects of cooking ability were detected for liking scores, instead liking of the Bolognese sauces varied by the protein type used. Though the sauce produced with meat acted as a control, overall, whether a Bolognese sauce is liked more or less than meat was dependent on the raw material; namely one of the soy products was consistently liked most, while the oat-based product was consistently disliked. The hedonics of the Bolognese sauces were driven by key attributes, and attributes that were atypical of the identity of Bolognese likely had a negative impact. The interaction between cooking ability and sample, however, suggests that cooking ability can impact on hedonic scoring of Bolognese sauces depending on the protein being used. Categorisation of consumers by cooking ability did not influence the consumers ability to discriminate the Bolognese sauces by sensory perception. Thus, cooking ability as measured using the CAFPAS did not indicate strong effects of this factor on either hedonic scores or sensory discrimination of Bolognese sauces prepared with plant-based substitutes for meat.

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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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodqual.2022.104563>.

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