**Consumer preferences towards plant-based, hybrid and cultivated meat analogues offered in different meal contexts and at various consumption moments: a choice-based conjoint experimental design and an online survey**

1. **Introduction**

The assortment of meat analogues, meat-free alternatives that aim to replace regular meat as the main protein source in a meal by mimicking its main sensory characteristics, has expanded enormously the last decade (Alexander et al., 2017; Curtain & Grafenauer, 2019; Hartman & Siegrist, 2017). This rise in demand of meat analogues is mainly due to an increased consumer awareness of the negative impact current meat production systems have (Boukid, 2021; de Boer, Schösler & Aiking, 2014). Current production systems of meat are often based on intensive livestock farming (Ramankutty et al., 2018) that neglects animal welfare (Gallo & Huertas, 2015) and forms a significant driver for detrimental environmental changes (de Boer, Schösler & Aiking, 2014; Djekic, 2015). Thereby, overconsumption of meat, especially processed meat, can impact consumers’ health in a negative way (Godfray et al., 2018). Thus, replacing meat products in favor of meat analogues could mitigate these potential negative consequences of current meat product systems. Yet, changing meat consumption behavior is challenging. After all, most consumers consider meat as an indispensable source of protein in their diet and its consumption has become a habit in most cultures (Schösler, Boer & Boersema, 2012).

* 1. **Plant-based, hybrid, and cultivated meat as main material to produce meat analogues.**

The evolution of available meat analogues took place very rapidly. First generation meat analogues merely consisted of plant-based material (e.g. soy, wheat, gluten, nuts, etc.) or mycoprotein-based materials (e.g. fungi) (Kyriakopoulou et al., 2019). These first generation meat analogues, such as tofu and seitan based products, barely mimicked the texture and taste of regular meat. Yet, the current generation meat analogues (e.g. vegan mince, plant-based burgers and sausages, etc.) mimic actual meat much more accurately and act as full-fledged mock meat analogues (Boukid, 2021; Jahn et al., 2021; Onwezen et al., 2021; Mistry et al., 2020).

Advancements in food processing technology have made it possible to create meat analogues from other materials than merely plant-based or mycoprotein-based materials. There are also hybrid plant-based meat analogues that consist of both plant-based material and a certain amount of regular meat (Neville et al., 2017; Wang et al., 2022). Although hybrid meat analogues still contain regular meat, these products allow consumers to lower their meat intake, without losing most of its typical sensory characteristics (Grasso et al., 2022). Hybrid plant-based products are already available, but their development is still going on and market penetration is much lower compared to fully plant-based meat analogues (van Dijk et al., 2023).

An even more disruptive way of producing meat analogues is using cultivated meat (Jahn et al., 2021; Post, 2012). Cultivated meat is produced via stem cell technology and results in lab grown meat that should be an exact copy of the original meat, without the necessity of breeding livestock (Post, 2012). Unlike plant-based and hybrid plant-based analogues, meat analogues based on cultivated meat are not yet widely commercially available (Ye et al., 2022). Before cultivated meat can be commercialized and introduced, many legal and other barriers should be taken (Ketelings et al., 2021). To illustrate, the European Commission agreed upon a whole set of legal and scientific requirements cultivated meat should comply with, before it can be introduced in any of the member states of the European Union (Ketelings et al., 2021). Yet, some countries are already engaged in legalizing cultivated meat. In the Netherlands, the government legalized sampling of cultivated meat and in the United States the U.S. Food and Drug Administration has declared that cultivated chicken produced by the company Eat just, Inc. is safe to eat for consumers which could open the door towards commercialization in restaurants and supermarkets (Verzijden & Buys, 2020). The frontrunner concerning commercialization of cultivated meat is Singapore, which is the only country where cultivated meat is already commercialized, albeit on a very limited scale (Ketelings et al., 2021).

* 1. **Consumer attitudes and preferences towards meat analogues**

Research indicates that despite more positive consumer attitudes, the acceptance and general willingness to consume meat analogues is still rather low (Michel et al., 2021). Yet, consumer acceptance of meat analogues differs according to the main material used to produce these analogues. Research suggests that consumers are more likely to accept plant-based meat analogues compared to cultivated meat analogues (Mancini & Antonioli, 2021, Michel et al., 2021). Although sensory similarity to regular meat is higher for cultivated meat analogues compared to plant-based analogues, consumers show more negative feelings towards cultivated meat as there are concerns towards of the unnaturalness, safety, healthiness, taste, and texture of cultivated meat (Zhang et al., 2021). Other barriers such as food neophobia, food-related risk perception and ethical concerns hinder acceptance of cultivated meat analogues (Pakseresht et al., 2022). Because cultivated meat analogues are not yet widely available, product familiarity is limited which further hampers its acceptance (Onwezen et al., 2021; van Dijk et al., 2023). Research on consumer acceptance of hybrid analogues is scarce, but research that used blind tastings hints that hybrid analogues should score better compared to plant-based alternatives and sometimes as good as regular meat (Caputo et al., 2022; Grasso et al., 2022). However, other research indicates that hybrid analogues are only more preferred than plant-based meat analogues in blind taste tests while demand for hybrid analogues dropped when consumers were informed what they were offered (Caputo et al., 2022). Although plant-based meat analogues are becoming more popular amongst vegans and vegetarians (Boukid, 2021), it is the segment of flexitarians, who follow a partially vegetarian diet, that are increasingly interested in plant-based meat analogues (Boukid, 2021). Less is known about the ideal target market of hybrid and cultivated meat analogues, although some explorative research (Verbeke et al., 2015) hints that vegan and vegetarians would not be that interested in cultivated meat compared to other types of meat analogues.

Although research already hints on differences between the acceptance of different meat analogues, there is a lack in research that directly compares consumer preference between different types of meat analogues, especially when taking hybrid meat analogues into account. Therefore, this study aims to gain more insights in consumer preferences towards different types of meat analogues and identify what type is most and least preferred.

* 1. **Impact of individual determinants on the acceptance of meat analogues**

Research indicates that acceptance of meat analogues can be influenced by a myriad of determinants. There are individual consumer characteristics, such as socio-demographic variables (e.g. age, gender and education levels) that could impact acceptance (Grasso et al., 2019; Onwezen et al., 2017). Other individual traits, such as food neophobia and meat attachment, have a stronger impact on consumer acceptance of meat analogues (Pakseresht et al., 2022; Szenderak et al., 2022). A higher score on the food neophobia scale indicates a higher willingness to try out new and unfamiliar food products (Pliner & Hobden, 1992). A higher score on the meat attachment scale indicates more negative associations with willingness to reduce meat consumption and the adoption of plant-based meat alternatives (Graça et al., 2015). Next to individual characteristics, food intrinsic elements, such as taste, texture, smell, and appearance have a significant impact on consumer acceptance of meat analogues (Van der Weele et al., 2019).

* 1. **Impact of meal context and consumption moment on the acceptance of meat analogues**

During the last decade, research on the impact of context of food consumption on food behavior gained importance (Elzerman et al., 2021; Meiselman, 2006). With the consumption context of food, we refer to both meal context and consumption moment. Meal context refers to all food related variables of a meal that could impact evaluation of the different ingredients used in this meal, (Elzerman et al., 2011; Hoek et al., 2011; Elzerman et al., 2021). Several meal context factors have already been discussed in previous research. For example, Elzerman et al., (2011) showed that consumer acceptance of meat analogues increases when it is processed in such a way that the meat analogue is masked and thus less visible. Frequently used ways of masking meat analogues, are serving the analogue in a sauce, frying it, or using it as a subcomponent of a dish (e.g. pizza topping) (Elzerman et al., 2011). The temperature of the meat analogues when being consumed is another meal context factor that can impact the acceptance of meat analogues (Elzerman et al., 2006).

Next to the meal context, the moment of consumption is part of the consumption context and could impact acceptance of meat analogues (Cardello & Shutz, 1996; Herman et al., 2003; Machin et al., 2014; Michel et al., 2021). For example, meat analogues can be consumed during a full meal, where it can be part of the main dish, or eaten as an appetizer. It can also be consumed as a snack between meals (Cardello & Meiselman 2018). Previous research on the preference for meat analogues in different meal contexts is very limited, especially when comparing different types of meat analogues (plant-based, hybrid or cultivated meat) and is mainly focused on acceptance of typical, stand-alone meat analogues products (e.g. sausages or burgers), Yet, taking the meal context and consumption moment into account when evaluating consumer acceptance of meat analogues could become more relevant because today, meat analogues are available in a wide product range linked to various meal context factors and consumption moments (Curtain & Grafenauer, 2019).

Thus, via our research we want to fill this gap by looking at which meal context factors and consumption moments affect preferences for different meat analogues. In addition, we want to explore the interactions between the main material of the meat analogues and the different factors of the meal context and the time of consumption. We want to see if the preference for certain meat analogues shifts according to the meal context and/or time of consumption.

* 1. **Sensory evaluation of meat analogues**

For most consumers, a higher similarity of the main sensory characteristics (e.g. taste, texture and appearance) between regular meat and meat analogues increases consumer acceptance (Hoek et al., 2011; Van der Weele et al., 2019). Yet, consumer expectations concerning this sensory similarity could differ based on main material (plant-based, cultivated or hybrid), the different meal context factors ,or during different consumption moments. For example, when a meat analogue is masked, it is possible that consumers expect less similarity in taste and could therefore be more willing to accept a meat analogue that tastes less similar compared to regular meat (Elzerman et al., 2011; Hoek et al., 2013;Schösler, et al., 2012). With our research we want to gain exploratory insights concerning the expectations consumers have towards similarities in taste, appearance and texture of regular meat with different types of meat analogues, offered in different meal contexts and during different consumption moments.

* 1. **Added value of this research**

With this research we provide added value both to the literature on consumer preferences towards meat analogues and literature on food consumption context. More specifically, we look at differences in preference between plant-based, hybrid and cultivated meat analogues by directly comparing them. To the best knowledge of the authors, there is almost no research yet that directly compares consumer preference between plant-based, hybrid and cultivated meat analogues. Especially, a focus on hybrid analogues has been lacking in previous research. Additionally, we look simultaneously at different meal context factors (i.e., ways of masking and temperature) and consumption moments. This could give more insights under which circumstances consumers would accept or not accept consumption of different types of meat analogues.

1. **Studies**

In this research, two studies were conducted. In Study 1, the main study of this manuscript, an online choice-based conjoint experiment was used to investigate how consumer preferences towards meat analogues is impacted by different types of meat analogues, meal context and consumption moments. In Study 2, an exploratory survey was launched in which participants were required to evaluate the importance of similarity between a meat analogue and regular meat based on the main sensory characteristics of meat (e.g. taste, texture and appearance) for different types of meat analogues, different meal contexts, and several consumption moments.

1. **Study 1: Choice-based conjoint experimental design**
	* 1. **Methodology**

A choice-based conjoint (CBC) experiment was designed and Sawtooth software was used to program the CBC experiment. A convenience sample with quota restrictions of 660 participants was recruited in Flanders, Belgium during March and April 2020. Although differences in gender appear not to have an enormous effect on meat analogue preference (Grasso et al., 2019), meat is still a very gendered product, so we made sure that the distribution of gender was not skewed too extreme by putting a quota on it. We also put quota on age to have a good distribution of age amongst the sample as age could potentially have an effect on meat analogue preference (Boukid, 2021). 67 respondents indicated that they were following a vegetarian or vegan diet. These respondents were removed from the final sample, because in our CBC experiment hybrid meat analogues that still contain regular meat are offered, which vegan and vegetarian respondents would not be inclined to choose since they do not consume meat. An overview of the final sample (N = 593) can be found in Table 1.

Table 1. Description of the final sample of Study 1

|  |  |
| --- | --- |
| Sample size(*N*) | 593 |
| Female | 61% |
| Age | 38.46 (15.67) |
| Household size |  |
|  1 person | 75 (12.6%) |
|  2 people | 171 (28.8%) |
|  3 or 4 people | 271 (45.7%) |
|  5 or more people | 76 (12.8%) |
| Family income |  |
|  0-2499 euros | 132 (22.2%) |
|  2500-4499 euros | 217 (36.6%) |
|  4500 euros or more | 122 (20.6%) |
|  I rather not tell | 122 (20.6%) |

**Note:** Final sample consists of consumers that eat meat. Female = share; Age = mean (standard deviation); Household size = frequency (percentages); Family income = = frequency (percentages)

In a CBC experiment, participants must make choices between several product alternatives. These alternatives differ based on a different set of product attributes. These attributes are the characteristics of a product (e.g. color, shape, etc.). Each attribute again consists of different levels, which are different expressions of the chosen characteristics. For example, the attribute ‘color’ could consist of the levels ‘red’ and ‘blue’. In this CBC experimental design, four attributes were selected based on the discussed literature. These attributes and their attribute-levels can be found in Table 2.

Table 2: Overview of the different attributes and attribute-levels used in this CBC experiment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Attribute | Main material | Ways of masking | Temperature | Consumption moment |
| Attribute-levels | (1) 100% plant-based | (1) No masking | (1) Warm | (1) Full extensive lunch or dinner |
|  | (2) 100% cultivated | (2) In a sauce | (2) Cold | (2) Quick lunch or dinner |
|  | (3) Hybrid plant-based | (3) Fried |  | (3) Appetizer |
|  | (4) Hybrid cultivated | (4) Subcomponent of a meal |  | (4) Snack |

Before participants performed the CBC experiment, more information on the used products and procedure was provided to the participants. First, the participants received an introduction explaining what meat analogues exactly are and how each attribute and attribute-level was defined. By providing information on the different types of meat analogues (e.g. plant-based, hybrid or cultivated), we rule out that participants would only choose a certain meat analogue because they do not know what the other alternatives entail. Participants had to indicate on a seven-point Likert scale to what extent they understood what a meat analogue was and to what extent they understood all the information of the attributes and attribute-levels that we provided. An one-sample T-test (4= comparison value) indicates that participants understood what meat analogues are (M = 5.96; SD = 0.973, *p* < .001) and that all the information on the attributes and attribute-levels was clear (M = 6.05; SD = 0.871, *p* < .001).

Next, participants were redirected to the Sawtooth environment where they received information on how a CBC experiment works. Before they started the experiment, an example was given on the kind of choices the participants will be asked to make. After this, the actual CBC task started. Participants received eleven hypothetical choice situations and the choice-set for each of the choice situations was set to three alternatives. Each of the alternatives consisted of a combination of different attribute-levels. The presented attribute-levels were randomly varied across consumers as well as across choice alternatives to maximize the number of stimuli combinations to be evaluated by participants. All of the offered choice-sets were presented via text, and no pictures were used during the CBC task. We kept the text intentionally short to make sure participants would not have a hard time processing all the information. We asked the participants to select the option they would prefer out of the 3 offered option. Appendix 1 features an example of such a choice situation.

A ‘none of the offered alternatives’ option was not incorporated in this design, so participants were forced to make a choice. Offering such a ‘none of the alternatives’ option is often incorporated in a CBC experiment, but when evaluating unknown (e.g. cultivated meat products) or even fictional products, it is considered a valid method not to work with this option (Sawtooth, 2022). After performing the CBC experiment, participants were redirected to a general survey, where two concepts were measured: food neophobia (Pliner & Hoben, 1993) and meat attachment (Graça et al., 2015). The meat attachment scale consists of sixteen five-point Likert items and the food neophobia scale consists of ten five-point Likert items. It is possible that some participants had prior knowledge on the topic of meat analogues or had a higher familiarity with the consumption of meat analogues which could affect their choices (van Dijk et al., 2023). To control for potential effects of product knowledge and familiarity, several control questions were added. On a five-point Likert scale we measured to what extent participants already knew what both plant-based and cultivated meat analogues were before they participated in this study (How well did you know what plant-based and cultivated meat analogues were before this survey? – 1 =”I have never heard of it”, 5 = “I know what this product is very well”). This question refers to the prior knowledge participants had concerning meat analogues. A Repeated Measures analysis shows that knowledge of plant-based meat analogues (M=3.27, SD=1.149) is significantly higher (*p* <.001) than knowledge of cultivated meat analogues (M=1.88, SD=0.872). Next, on a five-point Likert scale we measured to what extent participants had already consumed plant-based meat analogues and how frequently they do so (To what extent do you consume plant-based meat analogues? – 1 =”I have never eaten it”, 5 = “I eat it on a daily basis”). This question refers to the familiarity participants have with plant-based meat analogues. The general survey was concluded by collecting data on age, gender, household size, income and dietary habit.

* + 1. **Data preparation**

As a result of our CBC experiment, part-worth utility scores are derived for each attribute-level. These part-worth utilities indicate the preference of each of the different attribute-levels compared to each other within a certain attribute (Frischknecht et al., 2013; Sawtooth, 2022). The higher a part-worth utility of an attribute-level, the more preferred this level is compared to the other levels within the same attribute. Attribute-levels can only be evaluated within the same attribute and not across other attributes. These part-worth utilities are zero-centered which means that the total combined score of the part-worth utilities within a certain attribute is zero. All scores are relative. This means that a negative part-worth utility not necessarily means the attribute level is evaluated as bad (Sawtooth, 2022). The part-worth utility scores were calculated by using Sawtooth’s choice-based conjoint dedicated software. This is done by means of a maximum likelihood estimation via an individual-level logit model in combination with an empirical Bayes approach. This method of individual-level utility estimation together with empirical Bayes, has been shown to work nearly as accurate as a full hierarchical Bayesian estimation (Frischknecht et al., 2013; Sawtooth, 2022). We than used the part-worth utility scores in further analyses performed with IBM SPSS Statistics 26 software.

* + 1. **Results**
			1. **Relative importance scores**

Relative importance scores for each of the four attributes used in our CBC experiment can be derived.. These scores indicates to what extent a certain attribute is a decisive factor in predicting preference for a certain choice option in the CBC experiment. A higher relative importance score means that a certain attribute, with its predefined attribute-levels, is more important in predicting preference for a certain option compared to a attribute with a lower score. For example, main material (36,98%) is more important in predicting the choice for a certain meat analogue than way of masking (20,68%). Figure 1 shows all the relative importance scores.

Figure 1: Relative importance scores of the different attributes

A Repeated Measures analysis was performed on the relative importance scores of the four attributes to see which attribute has the highest impact on actual meat analogue preference. Food neophobia (α = 0.85) and meat attachment (α = 0.93) are treated as covariates in the analysis. As Mauchly’s test of sphericity was violated (*p* < 0.001), the Huynh-Feldt output is used (Field, 2013). Results show a significant effect between the relative importance scores of the different attributes (F(2.52,1487.72) = 7.41, *p* < .001). A Bonferroni pairwise comparison shows that main material is the most important attribute, followed by the temperature, way of masking and the consumption moment. All differences between the different attributes are significant (*p* < .001).

* + - 1. **Estimated part-worth utilities**

In Figure 2, a graphic overview is presented of the estimated part-worth utilities for each attribute-level within a certain attribute. These scores should only be interpreted within each attribute and not across attributes. A higher score for a certain attribute-level means that this attribute-level is preferred more compared to another attribute-level with a lower score. For example, within the attribute *main material* plant-based material is preferred over cultivated meat material. A Repeated Measures analysis was performed to test differences between the different attribute-levels within each attribute. Food neophobia (α = 0.85) and meat attachment (α = 0.93) were treated as covariates. Because previous literature indicates that age, gender, knowledge and familiarity towards type of meat analogues could have an impact, we included these variables as covariates in this analysis.

Figure 2: Estimated Part Worth utilities for each attribute-level

**Consumption moment**

**Ways of masking**

**Temperature**

**Main Material**

Mauchly’s test of Sphericity was violated (*p* < 0.001). The Huynh-Feldt output shows a significant effect of *main material* on meat analogue preference (F(2.34,1369.49) = 10.14, *p* < 0.001). Analysis of the effect of the covariates on the within subjects effect of main material shows a significant effect of gender (F(2.34,1369.49) = 5.17, *p* < .005), meat attachment F(2.34,1369.49) = 20.51, *p* < .001), food neophobia (F(2.34,1369.49) = 3.68, *p* < .05), knowledge of cultivated meat F(2.34,1369.49) = 5.55, *p* < .005), and familiarity with (plant-based) meat analogues F(2.34,1369.49) = 11.64, *p* < .001). A follow-up analysis of the part worth utilities for each gender separately shows that women (M= 0.86; SD = 1.04) prefer plant-based meat analogues more than men (M = 0.38; SD = 1.10), *p* < .05 and that men (M = -0.57; SD = 1.04) prefer cultivated meat more than women (M = -0.83; SD = 1.03), *p* < .05. There are no significant gender differences towards both type of hybrid products. In Table 3, several post-hoc Bonferroni pairwise comparisons are incorporated to see which attribute-levels differ from each other. In Figure 2 (Ut supra.), the part-worth utility scores can be found. 100% plant-based meat analogues are most preferred, than hybrid plant-based meat analogues followed by hybrid cultivated meat analogues and 100% cultivated meat analogues are least preferred.

Table 3: Bonferroni pairwise comparisons of main material

|  |  |
| --- | --- |
| Main Material | Significance |
| 100% plant-based | 100% cultivated meat | *p* < .001 |
| 100% plant-based | Hybrid plant-based | *p* < .001 |
| 100% plant-based | Hybrid cultivated | *p* < .001 |
| 100% cultivated meat | Hybrid plant-based | *p* < .001 |
| 100% cultivated meat | Hybrid cultivated | *p* < .001 |
| Hybrid plant-based | Hybrid cultivated | *p* < .001 |

The next Repeated Measures analysis concerns the attribute *temperature*. Mauchly’s test of Sphericity was violated (*p* < 0.001). The Huynh-Feldt output shows a significant within-subjects effect of temperature on preference (F(1,585) = 28.57, *p* < 0.001). Because this attribute only has two levels, there is no need to perform Bonferroni pairwise comparisons as warm meat analogues are preferred over cold meat analogues.

A third Repeated Measures analysis was performed with the attribute *ways of masking* as the within-subjects factor. Mauchly’s test of Sphericity was violated (*p* < 0.001). The Huynh-Feldt output shows a significant effect of ways of masking on meat analogue preference (F(2.89,1688.45) = 4.33, *p* = 0.005). In Figure 2 (Ut supra.), the part-worth utility values can be found. In Table 4 the Bonferroni pairwise comparisons are incorporated to see which attribute-level differs from each other.

Table 4: Bonferroni pairwise comparisons of ways of masking

|  |  |
| --- | --- |
| Ways of masking | Significance |
| No masking | In a sauce | *p* < .01 |
| No masking | Fried | *p* < .001 |
| No masking | Subcomponent | *p* < .001 |
| In a sauce | Fried | *p* = .981 |
| In a sauce | Subcomponent | *p* < .001 |
| Fried | Subcomponent | *p* < .001 |

A final Repeated Measures analysis was performed on *consumption moment*. Mauchly’s test of Sphericity was violated (*p* < 0.001). Mauchly’s test of Sphericity was violated (*p* < 0.001). The Huynh-Feldt output shows no significant effect of the consumption moment on preference towards meat analogues (F(2.78,1626.46) = 0.86, *p* = 0.455).

* + - 1. **Randomized First Choice simulations**

Although the performed Repeated Measures analyses provide insights in differences between the attribute-levels towards preference for meat analogues, they do not take into account potential interactions across attribute-levels. Sawtooth software provides choice simulations based on the estimated individual part-worth utilities of participants. These simulations indicate which combinations of attributes can lead towards a higher preference for different types of meat analogues. This allows us to gain more specific insights into which type of meat analogues are preferred by consumers. It provides more nuance to differences pointed out in the previous analysis. For example, results of the part-worth utilities show that 100% plant-based analogues are preferred over 100% cultivated analogues, but perhaps not in every single meal context or during each consumption moment. A Randomized First Choice (RFC) method is selected for this analysis (Sawtooth, 2022). This method assumes the participant chooses the meat analogue alternative with the highest overall utility, but rather than using the part-worth utilities as point estimates of preference, a RFC method adds unique random error variation to the conjoint utilities. This results in a correction for meat analogue similarity due to correlated sums of errors among meat analogues defined on many of the same food consumption context attributes (Sawtooth, 2022).

In these result section, we compare 100% plant-based and 100% cultivated meat analogues with each other. On top of this, we compare a 100% plant-based meat analogue and its hybrid alternative and a 100% cultivated meat analogue and its hybrid alternative. For each analysis we look at preference differences for certain combinations of meal contexts and consumption moments by providing a table where we have listed the combinations that are significant different from each other, based on their preference score. The total choice percentage across the two alternatives adds up to 100%. For example, in Table 5 cold plant-based meat analogues are compared with warm cultivated meat analogues. The preference score for each combination is provided by a percentage interval based on the 95%-confidence intervals. The preferred option between two alternatives is indicated with a symbol (\*).

1. **100% plant-based meat analogues versus 100% cultivated meat analogues**

Results show that only differences in the attribute *temperature* can lead towards a higher preference of cultivated meat analogues compared to plant-based meat analogues. Warm cultivated meat analogues are preferred over cold plant-based analogues, indicating the importance of temperature. When a warm cultivated meat analogue is served without masking the product, it’s preferred over cold plant-based analogues that are not masked. Still, when cold plant-based meat analogues are served as a subcomponent of a dish, they are more preferred over warm cultivated meat analogues that are not masked. Warm cultivated meat analogues are preferred when consumed as an appetizer compared to cold plant-based meat analogues consumed as a snack, quick or extensive lunch/diner. When consumed as part of a quick lunch/diner, warm cultivated meat analogues are preferred over cold-plant-based analogues consumed as a snack or in an extensive lunch/diner. There is also a higher preference for warm cultivated meat analogues when consumed in an extensive lunch/diner over cold plant-based meat analogues consumed as a snack between meals.

Table 5. Choice preference between 100% plant-based analogues and 100% cultivated analogues – Choice is indicated as a percentage based on a 95%-confidence interval.

|  |  |  |
| --- | --- | --- |
| Attribute-levels | 100% plant-based analogues (1) | 100% cultivated analogues (2) |
| Cold (1) – Warm (2) | 43.80%-49.48% | 50.52%-56.20%\* |
| Cold & subcomponent (1) – Warm & no masking (2) | 50.31%-56.09%\* | 43.91%-49.69% |
| Cold & snack (1) – Warm & quick lunch/diner (2) | 39.85%-45.56% | 54.44%-60.15%\* |
| Cold & extensive lunch/diner (1) – Warm & quick lunch/diner (2) | 42.01%-47.77% | 52.23%-57.99%\* |
| Cold & snack (1) – Warm & extensive lunch/diner (2) | 41.68%-47.49% | 52.51%-58.32%\* |

\*Preferred option between the two alternatives

1. **100% plant-based meat analogues versus hybrid plant-based meat analogues**

Warm hybrid plant-based analogues are preferred over cold 100% plant based analogues. Concerning the attribute *ways of masking*, only when a hybrid meat analogue is served as a subcomponent of a larger dish, it has a higher preference compared to 100% plant based analogues that are served without masking it. Concerning the attribute *consumption moment*, only when a hybrid plant-based meat analogue is consumed as an appetizer, it’s preferred over plant-based analogues consumed as a snack.

Table 6. Choice preference between 100% plant-based analogues and hybrid plant-based analogues – Choice is indicated as a percentage based on a 95%-confidence interval

|  |  |  |
| --- | --- | --- |
| Attribute-levels | 100% plant-based analogues (1) | Hybrid plant-based analogues (2) |
| Cold (1) – Warm (2) | 25.31%-29.63% | 70.37%-74.69%\* |
| No masking (1) – Subcomponent (2) | 43.80%-48.65% | 51.35%-56.20%\* |
| Snack (1) – Appetizer (2) | 44.59%-49.17% | 50.83%-55.41%\* |

\* Preferred option between the two alternatives

1. **100% cultivated meat analogues versus hybrid cultivated meat analogues**

Warm cultivated meat analogues are preferred over cold hybrid cultivated meat analogues. Concerning the attribute *ways of masking,* there is no consumption context that can shift the preference in favor of 100% cultivated analogues. Only when 100% cultivated meat analogues are served as a subcomponent of a larger dish compared to a hybrid cultivated meat analogue served without masking, there is no difference in preference. Concerning the attribute *consumption moment,* there is no context in which the preference can be shifted in favor of 100% cultivated analogues. Yet, there is no difference in preference when a hybrid cultivated meat analogue is served as a snack between meals compared to 100% cultivated meat analogues consumed as an appetizer.

Table 7. Choice preference between 100% cultivated analogues and hybrid cultivated analogues – Choice is indicated as a percentage based on a 95%-confidence interval

|  |  |  |
| --- | --- | --- |
| Attribute-levels | 100% cultivated analogues (1) | Hybrid cultivated analogues (2) |
| Warm (1) – Cold (2) | 68.74%-72.86%\* | 27.14%-31.26% |
| Subcomponent (1) – No masking (2) | 49.50%-53.93% | 46.07%-50.50% |
| Appetizer (1) – Snack (2) | 47.62%-52.18% | 47.82%-52.37% |

\* Preferred option between the two alternatives

* 1. **Study 2: Exploratory survey on the importance of similarity of sensory characteristics between regular meat and meat analogues**
		1. **Methodology**

In the second study, we want to dig deeper in what consumers expect when consuming meat analogues that consist of different main materials, consumed in different meal contexts and offered during different consumption moments. This study focusses on the importance of sensory similarity between meat analogues and regular meat. An exploratory survey was launched in a convenience sample. A total number of 480 participants were recruited in Flanders, Belgium from March till May 2021. 46 respondents indicated that they were vegetarian or vegan and thus were removed from the final sample, similar to the approach of this first study.

Table 8: Description of the final sample of Study 2

|  |  |
| --- | --- |
| Sample size(*N*) | 434 |
| Female | 65% |
| Age | 39.40 (17.68) |
| Family income |  |
|  0-2499 euros | 109 (25.1%) |
|  2500-4499 euros | 117 (26.9%) |
|  4500 euros or more | 92 (21.2%) |
|  I rather not tell | 116 (26.7%) |

**Note:** Final sample consists of consumers that eat meat. Female = share; Age = mean (standard deviation); Family income = = frequency (percentages)

Participants were asked how important sensory similarity is between regular meat and a meat analogue, but specifically applied on the different attribute-levels used in our first study. Importance of similarity in appearance, taste and texture were evaluated on a seven points-Likert scale (e.g. How important do you think it is that a meat analogue made of 100% plant-based material, looks like a regular meat product?). In addition, the willingness to consume meat analogues, again specifically for each attribute-level, was asked on a seven-point Likert scale. (e.g. How likely is it that you would consume a meat analogue made of 100% plant-based material?). Because of the repetitive nature of the survey and to make sure that participants would not terminate the survey early, a random selection was made to present three out of four attributes to evaluate for participants. Similar to our first study, participants had to fill out survey questions that measured food neophobia (Pliner & Hoben, 1993) and meat attachment (Graça et al., 2015). To conclude the survey the following aspects were asked: age, gender, income, household size and dietary habit.

* + 1. **Data preparation**

First, a multivariate Repeated Measures analysis was performed for each attribute separately. The attribute-levels were treated as within-subjects factors and the importance in similarity of taste, texture and appearance between regular meat and meat analogues were analyzed together as multivariate factors. Food neophobia (α = 0.87), meat attachment (α = 0.93), age and gender were treated as covariates. With this analysis, we want to see if there are differences in similarity importance of taste, texture and appearance between the different attribute-levels of each attribute. Next to this, Linear Regressions are performed. In these Linear Regressions, importance of sensory similarity of taste, texture and appearance were treated as the independent variables, together with food neophobia, meat attachment, age and gender. Willingness to consume the meat analogue was treated as the dependent variable. A Linear Regression is performed for each attribute-level separately. The parameter estimates and significances are provided in tables. Analyses were performed with IBM SPSS Statistics 26 software.

* + 1. **Results**
			1. **Main material**

Results (Pillai’s Trace) of a multivariate Repeated Measures show no effect of the attribute *main material* on the combined importance of similarity of the different sensory characteristics appearance, taste and texture (*p* = 0.065). For each attribute-level of main material a Linear Regression is performed to see what explanatory variables have an effect on willingness to eat a meat analogue linked to each attribute-level (Table 9).

Table 9: Regression table depicting the coefficients, t-value and p-value for the willingness to eat meat analogues based on main material

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | β | Std. error | t-value | *p* |
| **100% plant-based** | F(7,366) = 25.15, *p* < .001. R² = 0.325, adj. R² = 0.312 |
| (Intercept) | 7.332 | 0.721 | 10.164 | < .001 |
| Similarity in taste | -0.003 | 0.081 | -0.040 | =.968 |
| Similarity in texture | 0.055 | 0.092 | 0.629 | =.529 |
| Similarity in appearance | -0.011 | 0.075 | -0.146 | =.884 |
| Food neophobia | 0.175 | 0.119 | 3.950 | <.001 |
| Meat attachment | -0.511 | 0.118 | -10.707 | <.001 |
| Age | -0.053 | 0.005 | -1.209 | =.227 |
| Gender | 0.008 | 0.180 | 0.171 | =.865 |
| **100% cultivated** | F(7,366) = 10.67, *p* < .001. R² = 0.169, adj. R² = 0.154 |
| (Intercept) | 2.893 | 0.825 | 3.508 | = .001 |
| Similarity in taste | 0.308 | 0.085 | 4.403 | <.001 |
| Similarity in texture | 0.025 | 0.097 | 0.306 | =.759 |
| Similarity in appearance | -0.007 | 0.084 | -0.093 | =.926 |
| Food neophobia | 0.143 | 0.135 | 2.859 | <.005 |
| Meat attachment | -0.181 | 0.133 | -3.405 | =.001 |
| Age | -0.082 | 0.005 | -1.665 | =.097 |
| Gender | -0.130 | 0.201 | -2.566 | <.05 |
| **Hybrid plant-based** | F(7,366) = 6.74, *p* < .001. R² = 0.114, adj. R² = 0.097 |
| (Intercept) | 3.300 | 0.818 | 4.034 | < .001 |
| Similarity in taste | 0.212 | 0.089 | 2.725 | <.01 |
| Similarity in texture | 0.124 | 0.103 | 1.370 | =.172 |
| Similarity in appearance | -0.139 | 0.085 | -1.788 | =.075 |
| Food neophobia | 0.124 | 0.133 | 2.440 | <.05 |
| Meat attachment | -0.068 | 0.134 | -1.230 | =.219 |
| Age | -0.116 | 0.005 | -2.313 | <.05 |
| Gender | -0.144 | 0.202 | -2.744 | <.01 |
| **Hybrid cultivated** | F(7,366) = 12.23, *p* < .001. R² = 0.190, adj. R² = 0.174 |
| (Intercept) | 1.340 | 0.818 | 1.638 | =.102 |
| Similarity in taste | 0.312 | 0.086 | 4.291 | <.001 |
| Similarity in texture | 0.075 | 0.108 | 0.834 | =.405 |
| Similarity in appearance | -0.061 | 0.084 | -0.811 | =.418 |
| Food neophobia | 0.091 | 0.133 | 1.876 | =.061 |
| Meat attachment | 0.055 | 0.133 | 1.046 | =.296 |
| Age | -0.077 | 0.005 | -1.596 | =.111 |
| Gender | -0.184 | 0.201 | -3.669 | <.001 |

Note: n = 374. Gender: 0 = man, 1 = woman.

* + - 1. **Temperature**

Results (Pillai’s Trace) of a multivariate Repeated Measures show no effect of the attribute *temperature* on the combined importance of similarity of the different sensory characteristics appearance, taste and texture (*p* = 0.437). For each attribute-level of temperature a Linear Regression is performed to see what explanatory variables have an effect on willingness to eat a meat analogue linked to each attribute-level (Table 10).

Table 10: Regression table depicting the coefficients, t-value and p-value for the willingness to eat meat analogues based on temperature

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | β | Std. error | t-value | *p* |
| **Warm** | F(7,362) = 13.23, *p* < .001. R² = 0.204, adj. R² = 0.188 |
| (Intercept) | 6.651 | 0.722 | 8.619 | < .001 |
| Similarity in taste | 0.108 | 0.095 | 1.291 | =.198 |
| Similarity in texture | 0.147 | 0.106 | 1.524 | =.128 |
| Similarity in appearance | -0.045 | 0.076 | -0.585 | =.559 |
| Food neophobia | 0.063 | 0.125 | 1.275 | =.203 |
| Meat attachment | -0.399 | 0.119 | -7.757 | <.001 |
| Age | -0.112 | 0.005 | -2.304 | <.05 |
| Gender | -0.111 | 0.181 | -2.201 | <.05 |
| **Cold** | F(7,362) = 10.37, *p* < .001. R² = 0.167, adj. R² = 0.151 |
| (Intercept) | 5.920 | 0.798 | 7.418 | < .001 |
| Similarity in taste | 0.210 | 0.092 | 2.469 | <.005 |
| Similarity in texture | -0.004 | 0.111 | -0.039 | =.969 |
| Similarity in appearance | -0.085 | 0.080 | -1.043 | =.298 |
| Food neophobia | 0.073 | 0.130 | 1.447 | =.149 |
| Meat attachment | -0.389 | 0.125 | -7.414 | <.001 |
| Age | 0.016 | 0.005 | 0.332 | =.740 |
| Gender | -0.126 | 0.191 | -2.454 | <.05 |

Note: n = 370. Gender: 0 = man, 1 = woman.

* + - 1. **Ways of masking**

Results (Pillai’s Trace) of a multivariate Repeated Measures show no effect of the attribute *ways of masking* on the combined importance of similarity of the different sensory characteristics appearance, taste and texture (*p* = 0.884). For each attribute-level of ways of masking a Linear Regression is performed to see what explanatory variables have an effect on willingness to eat a meat analogue linked to each attribute-level (Table 11).

Table 11: Regression table depicting the coefficients, t-value and p-value for the willingness to eat meat analogues based on ways of masking

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | β | Std. error | t-value | *p* |
| **No masking** | F(7,359) = 10.19, *p* < .001. R² = 0.166, adj. R² = 0.149 |
| (Intercept) | 4.994 | 0.841 | 5.935 | < .001 |
| Similarity in taste | 0.217 | 0.110 | 2.317 | <.05 |
| Similarity in texture | -0.114 | 0.113 | -1.112 | =.267 |
| Similarity in appearance | 0.052 | 0.082 | 0.650 | =.516 |
| Food neophobia | 0.147 | 0.140 | 2.902 | <.005 |
| Meat attachment | -0.318 | 0.138 | -5.928 | <.001 |
| Age | -0.093 | 0.005 | -1.856 | =.064 |
| Gender | -0.064 | 0.204 | -1.255 | =.210 |
| **In a sauce** | F(7,359) = 11.33, *p* < .001. R² = 0.181, adj. R² = 0.165 |
| (Intercept) | 5.725 | 0.760 | 7.534 | < .001 |
| Similarity in taste | 0.173 | 0.083 | 2.399 | <.05 |
| Similarity in texture | 0.041 | 0.083 | 0.538 | =.591 |
| Similarity in appearance | -0.071 | 0.077 | -0.936 | =.350 |
| Food neophobia | 0.161 | 0.124 | 3.245 | =.001 |
| Meat attachment | -0.323 | 0.122 | -6.140 | <.001 |
| Age | -0.118 | 0.005 | -2.370 | <.05 |
| Gender | -0.114 | 0.184 | -2.254 | <.05 |
| **Fried** | F(7,359) = 1155, *p* < .001. R² = 0.184, adj. R² = 0.168 |
| (Intercept) | 5.723 | 0.755 | 7.585 | < .001 |
| Similarity in taste | 0.321 | 0.085 | 4.103 | <.001 |
| Similarity in texture | -0.072 | 0.089 | -0.842 | =.400 |
| Similarity in appearance | -0.058 | 0.085 | -0.701 | =.484 |
| Food neophobia | 0.110 | 0.124 | 2.217 | <.05 |
| Meat attachment | -0.229 | 0.121 | -4.401 | <.001 |
| Age | -0.223 | 0.005 | -4.486 | <.001 |
| Gender | -0.100 | 0.184 | -1.978 | <.05 |
| **Subcomponent** | F(7,359) = 13.79, *p* < .001. R² = 0.212, adj. R² = 0.197 |
| (Intercept) | 6.386 | 0.752 | 8.497 | <.001 |
| Similarity in taste | 0.155 | 0.086 | 2.097 | <.05 |
| Similarity in texture | 0.046 | 0.094 | 0.538 | =.591 |
| Similarity in appearance | -0.106 | 0.080 | -1.355 | =.176 |
| Food neophobia | 0.154 | 0.125 | 3.151 | <.005 |
| Meat attachment | -0.339 | 0.122 | -6.554 | <.001 |
| Age | -0.179 | 0.005 | -3.679 | <.001 |
| Gender | -0.108 | 0.184 | -2.171 | <.05 |

Note: n = 367. Gender: 0 = man, 1 = woman.

**2.2.3.4 Consumption moment**

Results (Pillai’s Trace) of a multivariate Repeated Measures show a significant effect of the attribute *consumption moment* on the combined importance of similarity of the different sensory characteristics appearance, taste and texture (*p* < 0.05). Univariate tests for each sensory characteristic separately (Greenhouse-Geisser) show that there is a significant effect of consumption moment on the importance of taste similarity (*p* <.05). A Bonferroni pairwise comparison (Table 12) shows that similarity of taste is most important when a meat analogue is consumed during an extensive full lunch or dinner. Similarity of taste is least important during a snack or appetizer moment.

Table 12: Bonferroni pairwise comparisons of consumption moment

|  |  |
| --- | --- |
| Importance of taste similarity | Significance |
| Full extensive lunch or dinner (M = 5.46; SD = 1.66) | Quick lunch or dinner (M = 5.10; SD = 1.63) | *p* < .001 |
| Full extensive lunch or dinner (M = 5.46; SD = 1.66) | Appetizer (M = 4.73; SD = 1.72) | *p* < .001 |
| Full extensive lunch or dinner (M = 5.46; SD = 1.66) | Snack (M = 4.63; SD = 1.76) | *p* < .001 |
| Quick lunch or dinner (M = 5.10; SD = 1.63) | Appetizer (M = 4.73; SD = 1.72) | *p* < .001 |
| Quick lunch or dinner (M = 5.10; SD = 1.63) | Snack (M = 4.63; SD = 1.76) | *p* < .001 |
| Appetizer (M = 4.73; SD = 1.72) | Snack (M = 4.63; SD = 1.76) | *p* =.346 |

For each attribute-level of temperature a Linear Regression is performed to see what explanatory variables have an effect on willingness to eat a meat analogue linked to each attribute-level (Table 13).

Table 13: Regression table depicting the coefficients, t-value and p-value for the willingness to eat meat analogues based on consumption moment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | β | Std. error | t-value | *p* |
| **Extensive full lunch or dinner** | F(7,362) = 13.67, *p* < .001. R² = 0.209, adj. R² = 0.194 |
| (Intercept) | 5.904 | 0.805 | 7.336 | < .001 |
| Similarity in taste | 0.023 | 0.096 | 0.270 | =.787 |
| Similarity in texture | 0.187 | 0.105 | 1.961 | =.051 |
| Similarity in appearance | -0.066 | 0.081 | --0.830 | =.407 |
| Food neophobia | 0.156 | 0.133 | 3.203 | =.001 |
| Meat attachment | -0.399 | 0.134 | -7.580 | <.001 |
| Age | -0.091 | 0.005 | -1.829 | =.068 |
| Gender | -0.050 | 0.193 | -1.003 | =.317 |
| **Quick lunch or dinner** | F(7,362) = 13.71, *p* < .001. R² = 0.210, adj. R² = 0.194 |
| (Intercept) | 5.935 | 0.778 | 7.631 | < .001 |
| Similarity in taste | 0.110 | 0.093 | 1.285 | =.199 |
| Similarity in texture | 0.154 | 0.098 | 1.687 | =.092 |
| Similarity in appearance | -0.113 | 0.080 | -1.416 | =.158 |
| Food neophobia | 0.159 | 0.127 | 3.288 | =.001 |
| Meat attachment | -0.392 | 0.130 | -7.420 | <.001 |
| Age | -0.105 | 0.005 | -2.138 | <.05 |
| Gender | -0.077 | 0.187 | -1.540 | =.124 |
| **Snack** | F(7,362) = 6.79, *p* < .001. R² = 0.116, adj. R² = 0.099 |
| (Intercept) | 5.929 | 0.851 | 6.968 | < .001 |
| Similarity in taste | 0.151 | 0.095 | 1.684 | =.093 |
| Similarity in texture | 0.038 | 0.105 | 0.392 | =.695 |
| Similarity in appearance | -0.029 | 0.092 | -0.331 | =.741 |
| Food neophobia | 0.090 | 0.142 | 1.734 | =.084 |
| Meat attachment | -0.306 | 0.142 | -5.550 | <.001 |
| Age | -0.070 | 0.005 | -1.375 | =.170 |
| Gender | -0.160 | 0.206 | -3.020 | <.005 |
| **Appetizer** | F(7,362) = 5.95, *p* < .001. R² = 0.103, adj. R² = 0.086 |
| (Intercept) | 6.360 | 0.787 | 8.086 | <.001 |
| Similarity in taste | 0.211 | 0.092 | 2.297 | <.05 |
| Similarity in texture | -0.115 | 0.097 | -1.137 | =.256 |
| Similarity in appearance | 0.005 | 0.082 | 0.059 | =.953 |
| Food neophobia | 0.080 | 0.131 | 1.537 | =.125 |
| Meat attachment | -0.276 | 0.129 | -5.039 | <.001 |
| Age | -0.089 | 0.005 | -1.733 | =.084 |
| Gender | -0.124 | 0.190 | -2.334 | <.005 |

Note: n = 370. Gender: 0 = man, 1 = woman.

1. **Discussion**

Results of Study 1 suggest that consumers prefer plant-based meat analogues over cultivated meat analogues, which is consistent with previous research (Mancini & Antonioli, 2021, Michel et al., 2021). Whereas, most previous research only looked at differences between plant-based and cultivated meat analogues, this research also took hybrid meat analogues into consideration. This research suggest that hybrid plant-based meat analogues are less preferred compared to 100% plant-based meat analogues, whereas hybrid cultivated meat analogues are preferred over 100% cultivated meat analogues. The lower preference for hybrid plant-based meat analogues compared to 100% plant-based meat analogues confirms previous research (van Dijk et al., 2023). Yet, rather than a true lower preference for hybrid versus 100% plant-based meat analogues, our research approach may also partially explain this finding. That is, the fact that participants in our research merely received an explanation of what hybrid plant-based meat analogues are which may have impacted consumer evaluations. Indeed, previous research (Caputo et al., 2022) already mentioned that providing information on what a hybrid plant-based meat analogue is made of, could decrease consumer liking. Next to this, a lower perceived naturalness of hybrid plant-based analogues compared to 100% plant-based analogues, could be a reason for the lower preference (Onwezen et al., 2021).

Hybrid cultivated meat analogues on the other hand, are more preferred compared to regular, 100% cultivated meat analogues. No previous research has looked at consumer preferences towards hybrid cultivated meat analogues, but previous research indicates that consumer acceptance of cultivated meat is still rather low and that perceived risk, unnaturalness, food neophobia and concerns about the sensory quality are main barriers to overcome in order to increase consumer acceptance of cultivated meat (Pakseresht et al., 2022; Siddiqui et al., 2022). By adding a certain amount of regular meat to a cultivated meat product, its naturalness perception may possibly improve. Moreover, mixing cultivated with regular meat may also improve the cultivated meat sensorial resemblance with regular meat. Similar to hybrid plant-based meat analogues that can better mimic regular meat (Smart & Pontes, 2023), the improved naturalness perceptions and sensorial characteristics of hybrid cultivated meat may thus account for the better evaluation of hybrid versus 100% cultivated meat products. It could be interesting to investigate in future research if traits like food neophobia and perceived unnaturalness are positively impacted when a hybrid cultivated meat product is offered compared to a 100% cultivated meat analogue. These results could mean that offering hybrid cultivated meat could be a better starting point to launch cultivated meat instead of offering 100% cultivated meat. We performed some additional analyses on the impact of gender on meat analogue preference because previous research indicates differences in meat analogue preference based on gender (van Dijk et al., 2023). We see that plant-based meat analogues are preferred by women over men and that cultivated meat analogues are preferred by men over women. Yet, for both women and men plant-based meat analogues are preferred over hybrid products which are again preferred over cultivated meat analogues (van Dijk et al., 2023).

The relative importance scores suggest that main material is the most important attribute in predicting meat analogue preference in our CBC experiment. Yet, there still was 63% of the preference explained by contextual factors (e.g. meal context and consumption context). Taking contextual factors into account could be very useful as previous research discusses that for novel and unknown products, such as meat analogues, contextual factors could be more important than when eating familiar foods (Elzerman et al., 2021; Pliner & Stallberg-White, 2000).Conclusive with previous research (Elzerman et al., 2011; Elzerman et al., 2021), masking a meat analogue is a good approach to increase consumer preference towards meat analogues, because a lack in flavor or texture similarity can be masked. Yet, this only is applicable to a certain extent. Appropriateness of meat analogues in certain meal contexts needs to be taken into account (Elzerman et al., 2011). Our research provides more in-depth insights in the impact of masking on the acceptance of meat analogues by exploring different ways of masking a meat analogue. Results suggest that using a meat analogue as a subcomponent of a larger dish, is the best way of masking a meat analogue to increase consumer preference. This is in line with previous research of Elzerman at al., 2011 that demonstrates that meat analogue liking can be affected by the degree by which other food elements in the meal are liked. Although masking works for all types of meat analogues, our results show that this is even more the case for cultivated meat analogues. Apparently, people feel very uncomfortable with cultivated meat that is not masked.

Our research further suggests that masking meat analogues in a sauce could increase acceptance compared to a meat analogues that is not masked. Previous research confirms this, but adds that only sauces with familiar flavors have to potential to increase liking and willingness to eat meat analogues (Elzerman et al., 2011). Further, we see in our results that warm meat analogues are much more preferred over cold meat analogues. This confirms previous research indicating that consumers think that cold meat analogues (e.g. meat analogues used in a salad) should not be eaten cold. One of the main reasons for this, is that consumers have concerns about the texture of cold meat analogues (Elerzman et al., 2013).

Our research also indicates that consumption moment has little impact on meat analogues preference. There is only limited research on the impact the consumption moment has on food choice (Meiselman, 2018), especially when considering meat analogues as part of an appetizer or snack moment since most research has taken a look at the consumption moments where meat analogues are consumed in a full meal (Elzerman et al., 2011). In our research, participants merely received textual information on the different consumption moments. When offering the choice tasks in the CBC experiment we did not ask participants to imagine that they were eating the meat analogue during the consumption moment that was offered to them. It is possible that participants found it difficult to really put themselves in a mental state where they actually could imagine eating the meat analogue. This could be a reason why consumption moment only seems to have little impact on preference for meat analogues. More research is needed to have better understanding of why the impact of consumption moment is limited.

Our second exploratory study suggest that there are no major differences in the importance of sensory similarity of taste, texture and appearance between regular meat and different types of meat analogues (plant-based, hybrid or cultivated meat) consumed in various meal contexts and at different consumption contexts. The importance of sensory similarity has already been shown in previous research (Elzerman et al., 2015; Hoek et al., 2011; Van der Weele et al., 2019), but it has not been applied yet in different meal contexts and consumption moments. We do see that a similarity in taste has the largest impact on willingness to eat a meat analogue. Finally, our research highlights the importance of Food Neophobia and Meat Attachment as concepts that can have an effect on meat analogue preference. In our research it is shown that high meat attachment has a negative effect on the preference for plant-based substitutes. Food Neophobia, on the other hand has a negative effect in the preference towards cultivated meat, which could be mainly due to a low understanding of the meat-production process of cultivated meat (Starovicz, 2022). Food neophobia and meat attachment were in most cases a significant predictor of willingness to eat different types of meat analogues, in different meal contexts and at various consumption moments. This indeed shows the importance of taking these traits into account when performing research on meat analogue preference (Pakseresht et al., 2022; Szenderak et al., 2022).

Knowledge and familiarity have been shown to impact meat analogue preference (van Dijk et al., 2023). It is possible that some participants had prior knowledge on the different types of meat analogues and had a different familiarity towards the consumption of meat analogues. On top of that, it’s likely that there is a difference in knowledge between plant-based, hybrid and cultivated meat analogues because plant-based, and to a lesser extent hybrid analogues are already commercialized while cultivated meat is not (van Dijk et al., 2023). When analyzing prior knowledge of meat analogues we indeed found that participants had more knowledge on what plant-based meat analogues are compared to cultivated meat analogues. This could thus potentially impact our results. However, in the first study where participants had to make such a food choice, we controlled for familiarity and knowledge effects on the preference towards meat analogues. Before the CBC experiment started, we explained to the participants how we define meat analogues and the different types of main material (plant-based, hybrid and cultivated), meal contexts and consumption moments. By doing this, we made sure that all participants had the necessary information to make proper choices amongst different meat analogue options. Next to this, knowledge on what plant-based and cultivated meat analogues are and familiarity towards the consumption of plant-based were measured and controlled for in the analyses of the relative importance and the part-worth utilities by incorporating them as covariates.

Cultivated meat analogues are not yet commercialized, except for certain chicken products in Singapore (Ketelings et al., 2021). This means that most consumers indeed will have a lower knowledge of cultivated meat, as they cannot purchase these products yet. This is also the case in Belgium where this research has been conducted. Yet, interest in these products seems to be growing, which may foster a further commercialization of cultivated meat (Bryant & Sanctorum, 2021; Verbeke et al., 2015). The research of Bryant & Sanctorum (2021), conducted via a population representative survey, suggests that 39,3% percent of Belgian consumers would like to try cultivated meat, which shows that there is indeed already some potential for a cultivated meat market in Belgium. However, consumers in Belgium and many other countries still have to wait before legal conditions and scientific requirements prescribed by the European Commission concerning cultivated meat are fulfilled (Ketelings et al., 2021). Yet, the European Commission shows interest in cultivated meat and, for example, already made an investment of three million euros in Meatable, a cultivated meat startup located in the Netherlands (Ye et al., 2022).

Not only supranational organizations like the European Commission need to take action, also local and national governments need to do so. For example, before new food products can enter the Belgian market, they have to be approved by the national government of Belgium and the Belgian Food Safety Organization (BFSO). In the Netherlands, a neighboring country of Belgium, the government has already approved sampling of cultivated meat and several companies are already involved in the process of creating cultivated meat with Mosa Meat as an international frontrunner. There are already some indications that the production of cultivated meat in Belgium is taking off. For example, the Belgian government made investments so that relevant research institutions could create cultivated meat and in 2021 a Belgian startup, Peace of Meat, was acquired by MeaTech, an international player in the field of 3D bioprinting technologies (Ye et al., 2022). Even though cultivated meat analogues are not yet commercially available in most countries, it’s definitely useful to already gain insights in what consumers expect of these products so that food engineers and marketers can use these insights to create and successfully introduce cultivated meat analogues .

* 1. **Limitations**

There are a number of limitations to this study that should be acknowledged, as they leave some of the conclusions outlined above open to alternative explanations. In the CBC experimental design of the first study, we opted to not include a ‘none’ option amongst the choice options, because respondents had to indicate their preferences towards cultivated and hybrid cultivated meat analogues; products that are not yet widely available. This is valid reason for not incorporating a ‘none’ option (Sawtooth, 2022). Although, this design choice makes sense, in real life consumers are not forced to make such choices. Because of this, caution should be taken into account when interpreting the results. By this we mean that instead of drawing conclusions on general consumer acceptance of meat analogues based on the first study, results should be used to pinpoint differences in acceptance between different meat analogues, consumed in different meal contexts and during different consumption moments. Before participants started with the CBC experiment, we provided them with information on how to define all the attributes and attribute-levels. A side-effect of this approach is that our explanation of the different attributes may bias the participants. To overcome these potential biases, we chose a neutral explanation for the types of meat analogues where none of the benefits or more negative features were mentioned, in line with previous research approach (Weinrich & Elshiewy, 2019).

Still, choices in wording were made that could potentially have an effect on participants’ evaluation of the meat analogues. Previous research has already showed that the way of describing or naming hybrid and cultivated meat analogues can have an effect, both positive and negative, on consumer acceptance of meat analogues (Bryant & Barnett, 2019; Caputo et al., 2022). For example, consumers have a better attitude towards the term ’clean meat’ compared to ‘lab grown meat’ (Bryant & Barnett, 2019). Also, the fact participants encountered meat analogues via merely a description of how it could look offered during a choice experiment is totally different compared to a real life situation, where the product itself is visible and does not necessary directly refers to terms that were used in this experiment. Same descriptions may be differently interpreted by different participants. Perhaps, some people thought of tofu when we described plant based meat analogues, whereas other may have thought of soy-based foods. This variance in interpretation is limited when pictures of real food is being used. Our research is conducted by means of online research, whereas additional offline research is needed to fully understand a complicated topic as food choice. Yet, this research already provides useful insights on consumer preference of meat analogues offered in numerous meal contexts and at different consumption moments. Future research including an actual sensory evaluation of the meat analogues in different meal contexts by means of taste experiments is warranted.

In our studies, we did not use perfectly balanced quota samples, and as such women were slightly overrepresented in our samples. Yet, research shows that there could be effects of gender on meat analogue preference (van Dijk et al., 2023). In order to control for this, we included gender as a covariate in our most important analyses. Next, we did measure personal traits such as food neophobia and meat attachment which have a significant impact on meat analogue preference, possibly stronger than the effect of gender (Pakseresht et al., 2022; Szenderak et al., 2022. Because of this, we also included these variables as covariates in our most important analyses.

* 1. **Conclusions**

Findings of this research indicate that main material to produce meat analogues is an important factor to take into account when predicting meat analogue preference. We see that while plant-based meat analogues are preferred over hybrid plant-based meat analogues, the opposite is true for cultivated meat analogues that are less preferred compared to hybrid cultivated meat analogues. This could indicate that consumers are satisfied with current plant-based meat analogues. The higher preference for hybrid cultivated meat, could provide a rung for the acceptation of cultivated meat by consumers. We see that more than 60% of meat analogue preference was predicted by meal context and consumption context. This shows the relevance of both meal context and consumption moment. In line with previous research we show the importance of masking a meat analogue to increase its preference, but we can add to that that using a meat analogue as a subcomponent of a larger meal, is the most optimal way of masking a meat analogue. Warm meat analogues are preferred over cold meat analogues. Based on this research we did not find a difference between the different consumption moments. A first exploratory approach to see the impact of sensory similarity (e.g. taste, texture and appearance) between regular meat and different types of meat analogues, only emphasis the importance of taste similarity. In both Study 1 and Study 2 we did find significant impact of age, gender, food neophobia, meat attachment on meat analogue preference and willingness to eat meat analogues. On top of this, familiarity with meat analogues also showed to be significant when predicting meat analogue preference. This research could be a stepping stone in the direction of giving food engineers a better understanding of what consumers want regarding to the main material to produce meat analogues and in what meal context or consumption moments these products could best fit.

1. **Appendix 1**

Table 14: Example of a choice task participants received during the CBC experiment

****

1. **References**
2. Alexander, P.; Brown, C.; Arneth, A.; Dias, C.; Finnigan, J.; Moran, D.; Rounsevell, M.D.A. (2017). Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use? *Global food security*, 15, 22-32. DOI: 10.1016/j.gfs.2017.04.001
3. Apostolidis, C.; McLeay, F. (2016). Should we stop meating like this? Reducing meat consumption through substitution. *Food Policy*, 65, 74–89. DOI: 10.1016/j.foodpol.2016.11.002
4. Boukid, F. (2021). Plant-based meat analogues: from niche to mainstream. *European Food Research and Technology*, *247, 297–308.* <https://doi.org/10.1007/s00217-020-03630-9>
5. Caputo, V.; Sogari, G.; Van Loo, E.J. (2022). Do plant-based and blend meat alternatives taste like meat? A combined sensory and choice experiment study. *Applied Economic Perspectives and Policy.* <https://doi.org/10.1002/aepp.13247>
6. Cardello A.V.; Schitz, H.G. (1996). Food appropriateness measures as an adjunct to consumer preference /acceptability evaluation. *Food Quality and Preference, 7 (3/4), 239-249.*
7. Cardello, A.V.; Meiselman, H.L. (2018). Chapter 1 - Contextual Influences on Consumer Responses to Food Products. *Woodhead Publishing Series in Food Science, Technology and Nutrition, Methods in Consumer Research, 2, 3-54.*
8. Charles, H.; Aveyard, P.; Garnett, T.; Hill, J.W.; Key, T.J.; Lorimer, J.; Pierrehumbert, R.; Scarborough, P.; Springmann, M.; Jebb, S. (2018). Meat consumption, health, and the environment. *Science*, *361, 5324.* DOI: 10.1126/science.aam5324
9. Clune, S.; Crossin, E.; Verghese, K. (2017). Systematic review of greenhouse gas emissions for different fresh food categories*. Journal of Cleaner Production, 140, 766–783*. DOI: 10.1016/j.jclepro.2016.04.082
10. Curtain, F.; Grafenauer, S. (2019). Plant-Based Meat Substitutes in the Flexitarian Age: An Audit of Products on Supermarket Shelves. *Nutrients , 11, 2603.* DOI: 10.3390/nu11112603
11. de Boer, J.; Schösler, H.; Aiking, H. (2014). “Meatless days” or “less but better”? Exploring strategies to adapt Western meat consumption to health and sustainability challenges. *Appetite, 76, 120–128*. DOI: 10.1016/j.appet.2014.02.002
12. Djekic, I. (2015). Environmental Impact of Meat Industry – Current Status and Future Perspectives. *Procedia Food Science, 5, 61-64.* DOI: 10.1016/j.profoo.2015.09.025
13. Elzerman, J.E.; Hoek, A.C.; Van Boekel, M. A.J.S.; Luning, P.A. (2011). Consumer acceptance and appropriateness of meat substitutes in a meal context. *Food Quality and Preference, 22 (3), 233-240.* doi:10.1016/j.foodqual.2010.10.006
14. Elzerman, J.E.; Hoek, A.C.; Van Boekel, M. A.J.S.; Luning, P.A. (2015). Appropriateness, acceptance and sensory preferences based on visual information: A web-based survey on meat substitutes in a meal context. *Food Quality and Preference, 42, 56-65.* <http://dx.doi.org/10.1016/j.foodqual.2015.01.010>
15. Elzerman, J.E.; Keulemans, L.; Sap, R.; Luning, P. (2021). Situational appropriateness of meat products, meat substitutes and meat alternatives as perceived by Dutch consumers. *Food Quality and Preference, 88.* <https://doi.org/10.1016/j.foodqual.2020.104108>
16. Field, A. (2013) . Discovering Statistics Using IBM SPSS Statistics: And Sex and Drugs and Rock “N” Roll, 4th Edition, Sage, Los Angeles, London, New Delhi.
17. Frischknecht, B.; Eckert, C.; Geweke, J.; Louviere, J. (2013), "Estimating Individual-level Choice Models," 2013 ART Forum, 9-12 June 2013, Chicago.
18. Gallo, C., & Huertas, S. (2016). Main animal welfare problems in ruminant livestock during preslaughter operations: A South American view. *Animal, 10(2), 357-364*. doi:10.1017/S1751731115001597
19. Godfray, H.C.J.; Aveyard, P.; Garnett, T.; Hall, J.W.; Key, T.J.; Lorimer, J.; Pierrehumbert, R.T.; Scarborough, P.; Springmann, M.; Jebb, S.A. (2018). Meat consumption, health, and the environment. *Science, 361, 243.* <http://dx.doi.org/10.1126/science.aam5324>
20. Graça, J.; Calheiros, M.M.; Oliveira, A. (2015). Attached to meat? (Un)Willingness and intentions to adopt a more plant-based diet. *Appetite, 95, 113-125.* https://doi.org/10.1016/j.appet.2015.06.024.
21. Grasso, S.; Asioli, D.; Smith, R. (2022). Consumer co-creation of hybrid meat products: A cross-country European survey. *Food Quality and Preference, 100, 104586.* <https://doi.org/10.1016/j.foodqual.2022.104586>
22. Grasso, S.; Rondoni, A.; Bari, R.; Mansilla, N. (2022). Effect of information on consumers’ sensory evaluation of beef, plant-based and hybrid beef burgers. *Food Quality and Preference, 96, 104417.* https://doi.org/10.1016/j.foodqual.2021.104417
23. Hartman, C.; Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends in Food Science and Technology, 61,11-25*. DOI: 10.1016/j.tifs.2016.12.006
24. Hoek, A.; Luning, P.; Weijzen, P.; Engels, W.; Kok, F.; de Graaf, C. (2011). Replacement of meat by meat substitutes. A survey on person- and product-related factors in consumer acceptance. *Appetite, 56(3), 662-673.* doi:10.1016/j.appet.2011.02.001.
25. Hoek, A.; Elzerman, J.E.; Hageman, R.; Kok, F.; Luning, P.; de Graaf, C. (2013). Are meat substitutes liked better over time? A repeated in-home use test with meat substitutes or meat in meals. *Food Quality and Preference, 28(1), 253-263.* https://doi.org/10.1016/j.foodqual.2012.07.002
26. Jahn, S.; Furchheim, P.;Strässner, A.-M. (2021). Plant-Based MeatAlternatives: Motivational AdoptionBarriers and Solutions. *Sustainability,13, 13271.* <https://doi.org/10.3390/su132313271>
27. Kyriakopoulou, K.; Dekkers, B.; van der Goot, A.J. (2019). Plant-based meat analogues. *Sustainable Meat Production and Processing, chapter 6, 103-126.* DOI: 10.1016/B978-0-12-814874-7.00006-7
28. Mancini, M.; Antonioli, F. (2019). Italian consumers standing at the crossroads of alternative protein sources: Cultivated meat, insect-based and novel plant-based foods. *Meat Science, 193, 108942.* https://doi.org/10.1016/j.meatsci.2022.108942
29. Michel, F.Knaapila, A.; Hartmann, C.; Siegrist, M. (2021). A multi-national comparison of meat eaters' attitudes and expectations for burgers containing beef, pea or algae protein. *Food Quality and Preference, 91, 104195.* DOI: 10.1016/j.foodqual.2021.104195
30. Mistry M, George A, Thomas S. (2020). Alternatives to meat for halting the stable to table continuum – an update. *Arab J Basic Appl Sci, 27:324–334*. doi: 10.1080/25765299.2020.1807084.
31. Neville, M.; Tarrega, A.; Hewson, L.; Foster, T. (2017). Consumer-orientated development of hybrid beef burger and sausage analogues. *Food Science and Nutrition, 852-864, 5(4).* DOI: 10.1002/fsn3.466
32. Onwezen, M.; Bouwman, E.; Reinders, M.; Dagevos, H. (2021). A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. Appetite, 159, 105058. DOI: 10.1016/j.appet.2020.105058
33. Pakseresht, A.; Kaliji, S.A.; Canavari, M. (2022). Review of factors affecting consumer acceptance of cultured meat. *Appetite, 170, 105829.* https://doi.org/10.1016/j.appet.2021.105829
34. Post, J. M. (2012). Cultured meat from stem cells: Challenges and prospects. Meat science, 91, 297-301. doi:10.1016/j.meatsci.2012.04.008
35. Pliner, P.; Hobden, K. (1992). Development of a scale to measure the trait of food neophobia in humans. *Appetite, 19(2), 105-120.* https://doi.org/10.1016/0195-6663(92)90014-W.
36. Ramankutty, Z. Mehrabi, K. Waha, L. Jarvis, C. Kremen, M. (2018). Trends in global agricultural land use: implications for environmental health and food security. *Annu. Rev. Plant Biol, 69 , 789-815.*
37. Santo, R.; Kim, B.; Goldman, S.; Dutkiewicz, J.; Biehl, I.; Bloem, M.; Neff, R. & Nachmann, K. (2020). Considering Plant-Based Meat Substitutes and Cell-Based Meats: Public Health and Food Systems Perspective. *Frontiers in sustainable Food systems, 134 (4), 1-23.* DOI: 10.3389/fsufs.2020.00134
38. Schösler, H.; Boer, J.; Boersema, J. (2012). Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. *Appetite, 58(1),39-47*. DOI: 10.1016/j.appet.2011.09.009
39. Szenderák, J.; Fróna, D.; Rákos, M. (2022). Consumer Acceptance of Plant-Based Meat Substitutes: A Narrative Review. *Foods, 11, 1274.* https://doi.org/10.3390/foods11091274
40. Van der Weele, C.; Feindt, P.; van der Goot, A.J.; van Mierlo, B.; van Boekel, M. (2019). Meat alternatives: An integrative comparison. *Trends in Food Science & Technology, 88, 505-512.* <https://doi.org/10.1016/j.tifs.2019.04.018>
41. Wang, T.; Kaur, L.;Furuhata, Y.; Aoyama, H.; Singh, J. (2022). 3D Printing of Textured Soft Hybrid Meat Analogues. *Foods,11, 478.* https://doi.org/10.3390/foods11030478
42. Willett, W.; Rockström, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; DeClerck, F.; Wood, A.; Jonell, M.; Clark, M.; Gordon, L.; Fanzo, J.; Hawkes, C.; Zurayk, R.; Rivera, J. A.; Vries, W. D.; Sibanda, L.; Murray, C. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet , 6736(18), 3–49.* DOI: 10.1016/S0140-6736(18)31788-4
43. Meissner, M., Scholz, S., & Decker, R. (2011). Using eyetracking and mouselab to examine how respondents process information in choice-based conjoint analysis. In Proceedings of the Sawtooth Software Conference 2010, Newport Beach, California.
44. Eggers, F., Sattler, H., Teichert, T., & Völckner, F. (2022). Choice-Based Conjoint Analysis. In C. Homburg, M. Klarmann, & A. Vomberg (Eds.), Handbook of Market Research (pp. 781-819). Springer. https://doi.org/10.1007/978-3-319-57413-4\_23, <https://doi.org/10.1007/978-3-319-05542-8_23-1>
45. Birgit van Dijk, Kirsi Jouppila, Mari Sandell, Antti Knaapila,No meat, lab meat, or half meat? Dutch and Finnish consumers’ attitudes toward meat substitutes, cultured meat, and hybrid meat products,Food Quality and Preference, Volume 108,2023, <https://doi.org/10.1016/j.foodqual.2023.104886>.
46. Christopher Bryant, Hermes Sanctorum,Alternative proteins, evolving attitudes: Comparing consumer attitudes to plant-based and cultured meat in Belgium in two consecutive years, Appetite, Volume 161,2021, <https://doi.org/10.1016/j.appet.2021.105161>.
47. Yongli Ye, Jingwen Zhou, Xin Guan, Xiulan Sun, Commercialization of cultured meat products: Current status, challenges, and strategic prospects,Future Foods, Volume 6, 2022, https://doi.org/10.1016/j.fufo.2022.100177.