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Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers

Article

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Grasso, S., Rondoni, A., Bari, R. ORCID: https://orcid.org/0000-0002-6341-6578, Smith, R. and Mansilla, N. (2022) Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers. Food Quality and Preference, 96. 104417. ISSN 0950-3293 doi: 10.1016/j.foodqual.2021.104417 Available at https://centaur.reading.ac.uk/100464/

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To link to this article DOI: http://dx.doi.org/10.1016/j.foodqual.2021.104417

Publisher: Elsevier

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Food Quality and Preference

Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers

--Manuscript Draft--

Manuscript Number:	FQAP-D-21-00483R2
Article Type:	Research Paper
Section/Category:	
Keywords:	CATA; hybrid burgers; consumer sensory analysis; liking; information; beef
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Abstract:	This study assessed the effect of providing information on the consumers' sensory evaluation of three burgers: 100% beef, 100% plant-based and a hybrid (60% beef and 40% vegetables). A total of 99 UK consumers with balanced age and gender were recruited. Consumers assessed the burger products under blind, expected and informed conditions and answered questions on liking, Check-all-that-apply (CATA), willingness to buy (WTB) and willingness to pay (WTP) and provided free text comments. Results show that consumers are positive towards hybrid burgers, in terms of overall acceptability, purchase intent, willingness to pay and subjective comments. Hybrid meat products could represent an effective way for consumers to lower their meat consumption without compromising too much on the sensory quality and could represent a transition product to a more plant-based diet. These results are valuable and should inform future marketing, labelling and reformulation efforts of new hybrid meat product launches.
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Manuscript Number: FQAP-D-21-00483R1

Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers

Reviewer comments:

Reviewer #2: Dear authors,

Thank you for this much improved manuscript!

My main comment still goes to how you handle the WTP data. It's my understanding that you have several observations by each participant which would mean that you ultimately should account for within-subject heterogeneity under that you have repeated measures. The source of such variability in the product valuation can also relate to the condition under which the WTP was provided. I then do not see your analysis as adeqaute for the purpose that you are using it (and as presented in Table 4). The question should be about differences in WTP between product and conditions, while accounting for the within-subject value heterogeneity. This can readily be analyzed through the use of a multi-level model with proper account for fixed and random variables.

The authors thank the reviewer for this comment. The analysis has now been changed, so table 4 reports only the purchase intent for the three burgers in the three conditions and WTP has been removed. The variations in main and interaction effects under different conditions are now shown in Table 5, 6 and Figure 1 on WTP. Table 5 shows the results of a two-way repeated measures ANOVA, where samples and conditions are considered together rather than separately (as it was done previously). Table 6 shows for WPT the main effects (sample and condition) and interaction effects (sample * condition). Figure 1 shows visually how the WTP changed for the 3 burgers depending on the condition. In the text the results are discussed in lines 315-356.

Minor comments:

I have the following comments to some of the Tables and Figures that I see as relevant to improve the readability:

Tables 2 to 4 as well as Table 7: please add information about which test that the significance levels refers to. And I do not follow the notes to these Tables in terms of how to interpret the letters supposedly indicating significance (or?).

Tests and significance levels have now been added for table 2 in lines 271-274, table 3 in lines 293-297, table 4 in lines 311-314, table 7 (now table 9) in lines 498-499.

Table 5: can you show proportions (relative) rather than frequencies (absolute) here? And I do not follow the note to this Table in terms of how to interpret the letters (a/b, and c). Which test does the significance levels refer to?

This has now been done in what was table 5 (now table 7), please see lines 409-413. The significance refers to Cochran's Q test.

Figure 1: please write out correspondance analysis in full instead of just CA.

This has now been done in line 461.

- First sensory evaluation of beef vs plant-based vs hybrid burger (60:40 beef - veg)
- 99 UK consumers assessed the burgers under blind, expected and informed conditions
- In the blind condition the hybrid burger scored highest for overall liking
- Informed purchase intent was higher for hybrid burgers than plant-based burgers
- Informed max WTP was similar for beef and hybrid burgers and higher than plant-based

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Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers

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Abstract

This study assessed the effect of providing information on the consumers' sensory evaluation of three burgers: 100% beef, 100% plant-based and a hybrid (60% beef and 40% vegetables). A total of 99 UK consumers with balanced age and gender were recruited. Consumers assessed the burgers under blind, expected and informed conditions and answered questions on liking, Check-all-that-apply (CATA), willingness to buy (WTB) and willingness to pay (WTP). In addition, under blind and informed conditions, consumers were asked to indicate their likes and dislikes about each sample. Results show that consumers are positive towards hybrid burgers, in terms of overall acceptability, purchase intent, WTP and subjective comments. Hybrid meat products could represent an effective way for consumers to lower their meat consumption without compromising too much on the sensory quality and could represent a transition product to a more plant-based diet. These results are valuable and should inform future marketing, labelling and reformulation efforts of new hybrid meat product launches.

Keywords: CATA, hybrid burgers, consumer sensory analysis, liking, information, beef

1. Introduction

High meat consumption rates in the United Kingdom (UK) (average of 80 g per person/day) (Dibb & Fitzpatrick, 2014) are evident of a prosperous meat market, estimated to be worth £4.8 billion by 2023 (Mintel, 2019).

However, scientists have proven that the excessive intake of meat can lead to several health issues. For example, the frequent consumption of red and processed meat may increase the incidence of heart and cardiovascular diseases, colorectal cancer, and type 2 diabetes (Lippi, Cervellin, & Mattiuzzi, 2014). However, despite the negative health effects of excessive consumption, many consumers are highly attached to meat (Graça, Calheiros, & Oliveira, 2015).

Only 2-3% of the UK population maintains a vegetarian or vegan diet (The Vegetarian Society, 2021) and very few meat-eaters intend to imminently remove meat from their diets (Bryant, 2019). As this represents a small proportion of people who can benefit from the associated health outcomes, it has been suggested that encouraging the majority of the

population to reduce their meat consumption would be more effective than successfully persuading a minority to eliminate meat completely (Asher et al., 2014).

Hence, as a mean to facilitate the transition process from a meat-based diet to a diet with higher plant-based food intake, several options have been developed to provide consumers with an alternative to conventional meat products. One of these are the so-called 'hybrid meat products', which can appease consumers with the familiar taste and texture of meat products, whilst providing a superior nutritional profile for example by benefitting from reduced salt and fat and increased fibre, vitamin, and mineral content. Hybrid meat products refer to processed meat products which substitute a percentage of meat for the inclusion of plant-based ingredients, allowing consumers to still consume meat, but moderating the daily intake which should be limited to 70 g of processed meat person/day and including at least 400 g of fruit and vegetables per day (NHS Digital, 2019). They may also have the potential to encourage more consumers to cut meat entirely from their diets, as consumers could decide to continue the transition towards a more plant-based diet and try meat-free options too.

Another available alternative to conventional meat products are plant-based meat products, also known as meat substitutes or analogues, which are made with proteins from plant-based sources, such as soy, peas and beans, typically resembling the aesthetic qualities of conventional meat products (Hoek, Luning, *et al.*, 2011).

1.1 Consumers' reaction to hybrid meat products and plant-based meat alternatives

Changing diets is a long-term process (Hoek et al., 2013), most effective when the changes required do not significantly differ from consumers' previous behaviour (Ryan & Deci, 2000). A qualitative synthesis review on attitudes towards reducing meat consumption indicates consumers have difficulties imagining an alternative diet with low or no meat to their current dietary patterns (Sanchez-Sabate, Badilla-Briones, & Sabaté, 2019). In fact, meat is perceived as an important element in human's diet and the principal component of several dishes which are rooted in culinary traditions worldwide (Weinrich, 2018).

With regard to the current commercially available meat alternatives, the literature available on this topic shows that one of the main aspects limiting consumers in introducing these products into their diet is their lack of taste compared to conventional meat products. In fact, it is a commonly held belief by meat eaters that consuming healthier versions of meat products or meat analogues might compromise taste (Reipurth, Hørby, Gregersen, Bonke, & Cueto, 2019) and sensory expectations (Tuorila & Hartmann, 2020). Even when asked to assume that meat and meat alternatives have the same taste in a hypothetical experimental setting, consumers still chose the beef-based option, as they are sceptical that plant-based meat may actually taste like real meat (Slade, 2018). This is also confirmed by some sensory evaluation studies, which found that consumers still have strong tasting preferences for conventional compared to plant-based meat analogues (Michel, Hartmann, & Siegrist, 2021). Neville, Tarrega, Hewson, and Foster (2017) tested the consumer acceptability of conventional, hybrid and plant-based meat products and showed that meat and hybrid meat products had the highest acceptance, whereas plant-based meat products were poorly accepted because of the lack of "meaty flavour". Other research articles also showed that providing consumers with information related to different characteristics of plant-based

meat affects their sensory perception. For example, the ingredients used to produce these products were also found to influence consumers' evaluation. In fact, Chang, Moon, and Balasubramanian (2012) discovered that the sensory experience and purchase likelihood of plant-based meat alternatives was negatively affected when consumers were provided with information regarding the soy ingredient contained in the plant-based burgers, meaning that knowing the composition of these products influences consumers' behaviour. On the other hand, other type of information, for example related to the benefits of plant-based meat compared to conventional meat seem to mitigate the negative sensory perception of these products and positively impact their purchase likelihood and willingness to pay (WTP). For example, Ye and Mattila (2021) found that information on health and social consequences of meat consumption increased consumers' preferences for plant-based meat alternatives. Similarly, Weinrich (2018) concluded that communicating the health benefits of meat substitutes may increase the market share for these products. Estell, Hughes, and Grafenauer (2021) showed that health-related information such as 'high in protein' and 'high in dietary fibre' in relation to plant-based meat alternatives increased consumers' WTP compared to when the products were proposed without such information.

Regarding hybrid meat products, the literature on consumers' attitude towards these products is still at its infant stage. Grasso and Jaworska (2020) showed that taste is one of the most important and frequently reported factor in online reviews in relation to hybrid meat products, underlining that sensory quality is still key in the development of these products. Profeta et al. (2021) employed a choice experiment to compare conventional meat burgers with two types of hybrid meat burgers (with different meat and vegetable ratios) and a plant-based burger, showing that preferences and WTP were highest for the meat burger, followed by the hybrid burger with a higher percentage of meat, the hybrid burger with the lower percentage of meat and then by the plant-based burger.

Given the small amount of literature available on consumers' attitudes to meat alternatives and hybrid meats, little is yet known on this topic. In particular, to the best of the authors' knowledge, a study investigating the effects of sensory evaluation and information provision on consumers' purchase likelihood and WTP, testing together conventional beef burgers, plant-based and hybrid burgers, is still missing. This research aims to fill this void by conducting a consumer sensory evaluation of these products under blind, expected and informed conditions, and exploring whether this affects consumers' willingness to buy (WTB) and WTP. Regarding the type of information provided, given the effects that knowing the composition of plant-based meat alternatives has on consumers, participants were given information on the composition of the product they were going to eat under informed conditions (e.g., whether the burger was made only of meat, partially with meat or only with plant-based ingredients) with the aim to explore if such information had an effect on consumers' liking, WTB and WTP.

This research provides useful insights for manufacturers of meat alternatives by providing information about consumers' sensory evaluation of these products and their related purchase likelihood (or WTB) and WTP, as well as for the academia as it helps enriching the yet limited literature on consumers' attitude for meat alternatives.

2. Materials and methods

2.1. Products

All samples used were commercially available and consisted of a beef burger (Big Al's prime beef burger: 99% beef, sea salt, smoked sea salt), a plant-based burger (Beyond burger: water, pea protein isolate (16%), rapeseed oil, coconut oil, rice protein, flavouring, stabiliser (methylcellulose), potato starch, apple extract, colour (beetroot red), maltodextrin, pomegranate extract, salt, potassium chloride, concentrated lemon juice, maize vinegar, carrot powder, emulsifier (sunflower lecithin) and a hybrid burger (Tesco Meat & Veg: 57% beef, 38% vegetable blend of carrot and onion, rice flour, dried potato, salt, onion powder, yeast extract, dextrose, black pepper, paprika, preservative (sodium metabisulphite), sunflower oil, white pepper, emulsifier (mono- and di-glycerides of fatty acids), bay, black pepper extract, onion oil).

2.2. Participants

A total of 99 UK consumers took part in this experiment. Consumers were included only if they purchased and consumed beef burgers at least once every two months and if they were fully or partially responsible for grocery shopping. Consumers were roughly balanced for age (33 participants 18-24, 30 participants 35-54, 36 participants 55-75) and gender (44 males and 55 females). The study was conducted in the sensory laboratories of Wirral Sensory Services, UK. All participants gave written informed consent and participated in the blind and expected test in the same session, while the informed test took part the day after. The study was granted ethical clearance by the School's Ethics committee (reference number 1418D).

2.3. Evaluation procedure

The same participants evaluated the samples under all three different conditions:

Blind condition (with tasting and no information): consumers evaluated the three products in a monadic sequence having received them in randomised order and with three-digit random codes.

Expected condition (without tasting and with information): consumers were presented with the main composition of the burgers to study the effect of composition information, though they did not see or taste them. The beef, plant-based and hybrid were presented respectively as "A burger made with 100% beef ", "A burger made with 100% plant-based ingredients" "A burger made with 60 % beef and 40% vegetable blend (carrot and white onion)". Using this information only, consumers were asked to evaluate the burgers in a hypothetical way, based on their expectations.

Informed condition (with tasting and with information): consumers were asked to evaluate the products while having corresponding information about the main composition of the burger alongside it, to study the combined effect of sensory evaluation and composition information.

Samples were cooked according to the manufacturers' instructions before being served hot to participants. Each sample consisted of half a burger served on odourless white plastic plates. Still mineral water and unsalted crackers were used to clean the palate between samples. In the blind and informed conditions, consumers were asked to rate the overall liking plus appearance, aroma and texture liking on a 9-point Likert scale going from 1=dislike extremely to 9=like extremely. In the expected condition, consumers were only asked to express their expected overall liking for the three samples.

In the blind and informed conditions consumers were asked "How would you describe the burger sample you just ate?". In the expected condition consumers were given the burger description and asked "How would you expect this product to be?" After this, all conditions were provided with twenty CATA terms presented in randomised orders. The CATA terms used in this study were: dry, juicy, weak meat flavour, strong meat flavour, off flavour, pleasant flavour, hard, soft, bland, tasty, cheap, expensive, unhealthy, healthy, processed, unprocessed, characteristic, unusual, strong vegetable flavour, weak vegetable flavour. These words were selected based on the frequently mentioned attributes emerged from the literature on CATA for meat products (Grasso, Monahan, Hutchings, & Brunton, 2017; Grasso, Smith, Bowers, Ajayi, & Swainson, 2019; Neville et al., 2017).

After the CATA questions, for all conditions consumers were asked for their WTB using a 1-7 scale going from 1=definitely would not buy to 7= definitely would buy. Consumers were also asked for their WTP for the three burgers using the question "what is the maximum price you would be willing to pay for a 2-burger packet of this burger?". In this way we were able to explore WTP as an indicator of preference and evaluate whether WTP differed across the conditions to determine if information had an effect. Although beef, plant-based and hybrid burgers are commercially available and hence sale data are accessible, our study provides additional information by measuring and comparing WTP under blind and informed conditions which would not be obtainable otherwise in conventional retailer settings. The multiple-price scale was curated by adapting the WTP methodology in similar studies (Martin, Lange, & Marette, 2021). First, the average prices of beef, plant-based and hybrid burgers available in supermarkets across the UK were sourced. This resulted in a range of £1.8 to £2.6 which was then turned into a scale by marking increments of 20p (£1.6, £1.8, £2, £2.2, £2.4, £2.6 and £2.8). The question on WTB also included an opt-out option, in case consumers were not willing to pay for the product at all.

After, under blind and informed conditions, consumers were asked to answer two open questions, describing in their own words what they liked and what they disliked about each product. Answering these was not mandatory, therefore in this way they could express only likes, only dislikes, both, and none for each sample. Finally, at the end of the informed session, consumers were asked to rank the burger samples from 1=most to 3=least for the adjectives tasty, healthy, nutritious, environmentally-friendly and quality.

2.4. Text analysis

Free comments were standardised for further analysis. The terms were transformed into more structured terms according to the following criteria: (a) verifying typing and spelling

and correcting grammatical errors; (b) removing connectors and auxiliary terms when a consumer wrote a sentence instead of separate terms; (c) hedonic terms (good, nice) were removed since the questions already considered separately likes and dislikes; (d) some terms such as synonymous or derivatives of the same term were regrouped considering the initial complete full statement. This process was based on the textual analysis detailed in Ares, Giménez, Barreiro, and Gámbaro (2010); Symoneaux, Galmarini, and Mehinagic (2012); ten Kleij and Musters (2003).

Then, likes and dislikes were re-transcribed into simple modalities of (L_) for likes and (D_) for dislikes for each consumer and each product crossed with condition (e.g. beef blind, beef informed). Once the re-transcription of the 99 consumers for the three products under both conditions was done, simplified comments per product were counted. Only the descriptors mentioned by at least 5% of consumers for at least one product under blind or informed condition were used. For an example of the text analysis process, see Table 1.

Table 1. Example of the transformation of free comments for likes and dislikes given by consumers for products crossed with condition (e.g. beef blind), into simplified and structured comments (L_ for likes and D_ for dislikes).

Subject	Product/Condition	Raw comment	Simplified comment
16	Beef blind	"I liked how juicy the burger was and the overall flavour"	L_juicy; L_flavour
1	Beef informed	"meat flavour and aroma is very appealing, nice level of moistness appearance is average"	L_meaty; L_taste; L_aroma; L_moist; L_appearance
69	Plant blind	"I enjoyed the colour, taste & texture of this burger. very juicy"	L_colour; L_taste; L_texture; L_juicy
19	Plant informed	"nice moistness to it, fairly good taste to it"	L_moist; L_taste
28	Hybrid blind	"the burger was very juicy and soft. it also had a nice taste"	L_juicy; L_soft; L_taste
19	Hybrid informed	"good strength of flavour, nice chew to it, like the aftertaste, nice and moist, good feel in the mouth when chewing"	L_flavour; L_chewiness; L_aftertaste; L_moist; L_mouthfeel/texture
31	Beef blind	"the burger was too chewy, quite hard and the strength of flavour was too mild"	D_chewy; D_hard; D_bland
94	Beef informed	"it is too chewy meat flavour is not strong enough"	D_chewy; D_weak meat; D_flavour

29	Plant blind	“overall look of burger was not very appealing. texture in mouth was very bitty”	D_appearance; D_texture; D_bitty
28	Plant informed	“I don't like the texture of the burger, I feel that its too rubbery”	D_texture; D_rubbery
30	Hybrid blind	“was too soft and tasted awful”	D_soft; D_taste
12	Hybrid informed	“maybe a bit dry”	D_dry

2.5. Data analysis

ANOVA (F-test statistic) was performed within the blind, expected and informed conditions for liking, WTB and WTP. Repeated measured ANOVA was carried out across three conditions and for the three samples. When a difference was found, paired sample T-tests were carried out to understand between which pairs the differences were. For the CATA and text analysis data, the frequency of each term was counted and a contingency table was produced. Cochran’s Q tests were carried out using the test statistic reported by Meyners and Castura (2014), followed by McNemar tests with a Bonferroni correction as a post-hoc test if a difference was found among the three samples. The ranking data was analysed using a Friedman’s test. Correspondence analysis was applied to the CATA and text analysis in order to visualise the relationship between samples and CATA terms or comments. Statistical analyses were performed using Microsoft Excel for Office 365 (Microsoft Co.), SPSS (version 27) statistical software (IBM Inc. Chicago, IL, USA), and XLSTAT (XLSTAT version 2020.4.1, Addinsoft). A p-value of 0.05 was used as the threshold for significance.

3. Results and Discussion

3.1. Liking

Significant differences were found in consumers’ overall acceptability of the three burgers under blind, expected and informed conditions (Table 2). All products used in this study were commercially available in the UK market, but in the blind condition only the hybrid burger emerged as a liked product (mean liking score > 6 = liked slightly).

Within the blind condition the hybrid burger scored significantly higher than beef and plant-based burgers for overall liking and the beef burger scored significantly higher than the plant-based one.

In the expected condition, consumers expected to overall like beef burgers significantly more than plant-based and hybrid burgers, with no difference in the expected overall liking between plant-based and hybrid burgers.

As for the informed condition, consumers overall liked most the hybrid burger and least the plant-based burger, while the beef burger had an intermediate score, not significantly different from the hybrid or the plant-based burger. The overall liking of beef and plant-

based burgers significantly changed among the three conditions, while no significant changes were detected for the hybrid burger.

Significant negative disconfirmation occurred for the beef and plant-based samples, because the blind liking differed significantly from the expected liking (consumers had higher expectations than sensory blind acceptance). Tasting with information had a significant effect on overall liking of the beef and plant-based samples, as shown by the significant I-B scores. An assimilation effect ((I–B)/(E–B) > 0) was identified for the three products. This means higher informed than blind acceptability scores, therefore information provided to consumers improved the product's acceptability. For the hybrid burger there was a complete assimilation because the informed and expected liking scores did not differ significantly, denoting a complete fulfilment of hedonic expectations for this product. While for the plant-based and beef samples the assimilation was incomplete (the informed score was lower than the expected score), indicating that consumers' expectations that were aroused by the composition information were not fully satisfied. Information had a significant effect on consumer liking also in the study by Schouteten et al. (2016) who compared insect, plant and meat-based burgers, finding complete assimilation for the insect-based burger.

Table 2. Overall acceptability for the three burgers in the blind (B), expected (E) and informed (I) conditions, together with differences between mean ratings.

Sample	Blind	Expected	Informed	E-B	I-B	I-E
Beef	5.77^{b}	8.19^{a}	6.44^{ab}	2.41^{***} negative disconfirmation	0.68^{***} assimilation	-1.74^{***} incomplete assimilation
Plant-based	4.74^{c}	6.70^{b}	5.89^{b}	1.98^{***} negative disconfirmation	1.15^{***} assimilation	-0.83^{***} incomplete assimilation
Hybrid	6.69^{a}	6.84^{b}	6.99^{a}	0.14 negative disconfirmation	0.30 assimilation	0.16 complete assimilation

^{a,b,c} Within the same condition, products with different letters~~, within~~ in a column, are significantly different ($p \leq 0.05$ – repeated measures ANOVA and pairwise comparisons) ~~during the condition (blind/expected/informed)~~. *** depicts significant differences between the liking scores at $p \leq 0.001$.

Table 3 shows appearance, aroma, texture, and taste liking for the three burger samples in the blind and informed conditions. In the blind condition, for appearance, beef burgers scored highest, plant-based samples scored lowest and hybrid samples were in the middle and not significantly different from beef and plant-based samples. For aroma liking, the hybrid burger scored significantly higher than beef and plant-based samples. For the attributes of texture and taste liking, hybrid and beef samples scored similarly and significantly higher than plant-based burgers.

In the informed condition, for appearance there was no significant difference among the three samples. For aroma liking, the hybrid still scored significantly higher than beef and plant-based samples. In terms of texture, both hybrid and beef burgers still scored similarly

and higher than plant-based burgers. Finally, hybrid burgers scored highest for taste liking, plant-based burgers scored lowest and beef burgers scored between the two, but they were not significantly different from either of them.

Moving from the blind to the informed condition, the liking of all attributes for all burger samples significantly increased, except for appearance of the beef burgers and taste of the hybrid burgers.

Table 3. Appearance, aroma, texture and taste liking for the three burger samples in the blind and informed conditions.

	Appearance		Aroma		Texture		Taste	
Sample	Blind	Informed	Blind	Informed	Blind	Informed	Blind	Informed
Beef	6.39^{ax}	6.43^{ax}	5.77^{by}	6.28^{bx}	5.69^{ay}	6.58^{ax}	6.03^{ay}	6.53^{abx}
Plant-based	5.74^{by}	6.47^{ax}	5.40^{by}	5.94^{bx}	4.71^{by}	5.65^{bx}	4.90^{by}	6.14^{bx}
Hybrid	6.23^{aby}	6.68^{ax}	6.70^{ay}	7.34^{ax}	6.40^{ay}	7.16^{ax}	6.74^{ax}	6.99^{ax}

^{a,b,c} Within the same condition, products with different letters~~, within~~ in a column, are significantly different ($p \leq 0.05$– ANOVA and Tukey's test)~~ during the same condition (blind/informed)~~. ^{x,y,z} Between conditions, products with different letters~~, within~~ in a row, are significantly different ($p \leq 0.05$-paired sample T-test)~~ between the blind and informed conditions~~.

Purchase intent for the three burgers under the three conditions is shown in table 4. Purchase intent within the blind condition shows that consumers were most willing to buy hybrid burgers, followed by beef burgers and least willing to buy plant-based burgers. In the expected condition, beef burgers scored higher for WTB than both hybrid and plant-based samples. In the informed condition, purchase intent was again higher for hybrid burgers compared to plant-based burgers. Beef burgers scored between hybrid and plant-based burgers, and they were not significantly different from either of them.

Purchase intent significantly changed across the blind, expected, and informed conditions for beef and plant-based burgers, but not for hybrid burgers. Indeed, for beef and plant-based burgers purchase intent was highest in the expected condition, lowest in the blind condition and intermediate in the informed condition.

Table 4. Purchase intent for the three burgers in the blind, expected and informed conditions.

	Purchase intent		
Sample	Blind	Expected	Informed
Beef	3.93^{bz}	6.23^{ax}	4.45^{aby}
Plant-based	3.07^{cz}	4.93^{bx}	4.22^{cy}

Hybrid	4.74[ax]	5.09[bx]	4.95[ax]

[a,b,c] Products with different letters, within a column, are significantly different ($p \leq 0.05$ – ANOVA and Tukey's test) within the same condition (blind/expected/informed). [x,y,z] Products with different letters, within a row, are significantly different ($p \leq 0.05$) across the blind, expected and informed conditions.

The results of main and interaction effects as well as the contrasts of two-way repeated measures ANOVA are displayed in Table 5. Mauchly's test indicated that the assumption of sphericity has been violated for the interaction effect of sample and condition, $\chi^2(9) = 24.94, p = 0.003$. Therefore, degree of freedom is corrected using Greenhouse – Geisser estimate of sphericity. It is found that there is a significant main effect of type of burgers on WTP, $F(2,196) = 17.97,\ p \leq 0.001$. Contrasts reveals that WTP for plant-based burger is significantly lower (Table 6) than beef burger, $F(1,98) = 30.59,\ p \leq 0.001$, whereas WTP for hybrid burger is lower than beef burger, but not significant ($F(1,98) = 1.54, p = 0.218$).

There is also significant main effect of different conditions on WTP, $F(2,196) = 83.29,\ p \leq 0.001$. Contrasts reveals that WTP for informed condition, $F(1,98) = 33.63,\ p \leq 0.001$ and expected condition, $F(1,98) = 175.26,\ p \leq 0.001$ are significantly higher than blind condition.

There is a significant interaction effect between the type of burgers and the conditions used, $F(3.56,348.20) = 83.29,\ p \leq 0.001$. This indicates that condition has different effect on participant's WTP depending on which type of burger is used. Contrasts are performed comparing all sample types to their baseline (beef burger) and all condition types to their baseline(blind condition) which reveals significant interactions when comparing expected condition to blind condition both for plant-based burger compared to beef burger, $F(1,98) = 4.57,\ p = 0.035$, and hybrid burger compared to beef burger, $F(1,98) = 50.17,\ p \leq 0.001$.

Table 5. Results of Two-way repeated measures ANOVA

Source			df	F	Sig.
Product	Sphericity Assumed		2	17.965	.001
Error(Product)	Sphericity Assumed		196		
Condition	Sphericity Assumed		2	83.293	.001
Error(Condition)	Sphericity Assumed		196		
	Greenhouse-Geisser		3.553	17.178	.001
	Greenhouse-Geisser		348.196		
	Sample	Condition			
Sample	Plant-based vs. Beef		1	30.592	.001
	Hybrid vs. Beef		1	1.537	.218
Condition		Informed vs. Blind	1	33.625	.001
		Expected vs. Blind	1	175.257	.001

Sample * Condition	Plant-based vs. Beef	Informed vs. Blind	1	.346	.557
		Expected vs. Blind	1	4.571	.035
	Hybrid vs. Beef	Informed vs. Blind	1	2.297	.133
		Expected vs. Blind	1	50.173	.001

In the blind condition the WTP was similar for beef and hybrid burgers, but it was significantly lower in plant-based burgers. In the expected condition, consumers were willing to pay significantly more for beef burgers compared to hybrid and plant-based burgers. Finally, in the informed condition, the maximum WTP was similar for beef and hybrid burgers but lower for plant-based burgers showing the same trend seen in the blind condition.

Table 6. Maximum WTP for the three burgers in the blind, expected and informed conditions.

Maximum WTP							
Main effect				Interaction effect			
Sample		Condition		Sample*Condition			
					Blind	Expected	Informed
Beef	5.37	Blind	3.96	Beef	4.02	7.03	5.06
Plant-based	4.25	Expected	5.88	Plant-based	3.11	5.30	4.34
Hybrid	5.13	Informed	4.91	Hybrid	4.76	5.30	5.31

The maximum WTP for beef and plant-based burgers followed a similar trend across conditions as the purchase intent, as the maximum WTP was highest in the expected condition, lowest in the blind condition and intermediate in the informed condition. For the hybrid burgers, the maximum WTP was similar in the expected and informed conditions, while it was significantly lower in the blind condition. (Figure 1)

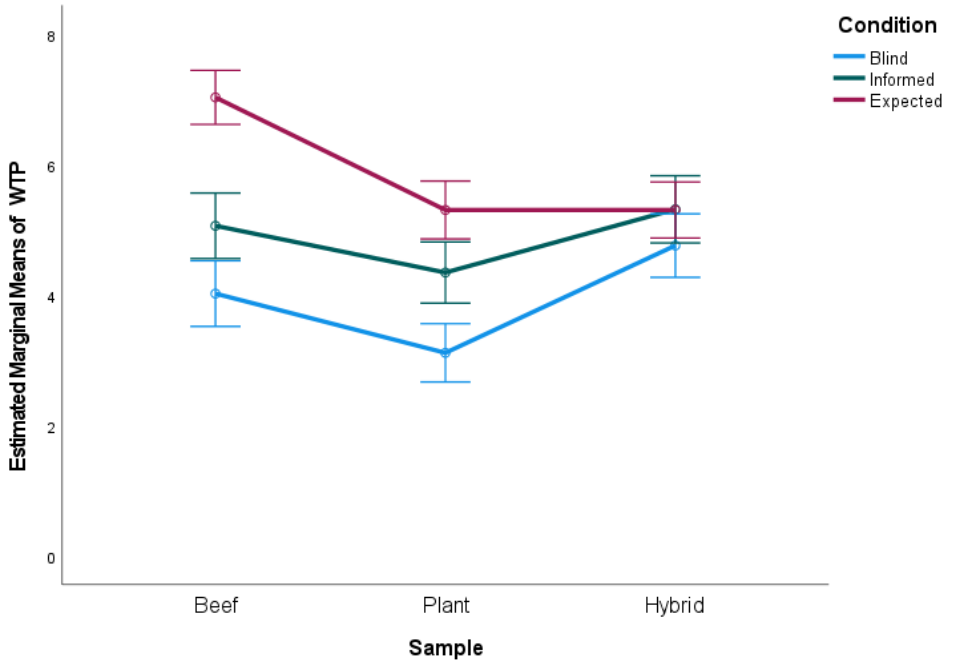


Figure 1. Mean variation of different burgers under different conditions. Error bars are plus or minus two standard errors.

Information therefore had a significant effect on both purchase intent and WTP for the three burgers in this study. This is in accordance with Martin et al. (2021) who reported a positive effect of different types of information on the acceptability of plant-based sausages.

3.2. Check-all-that-apply

The contingency table (Table 5) summarises the frequency of use for each CATA term by assessors. Cochran's Q test showed significant differences in the frequency of the majority of the attributes used to describe the burger samples.

Within the blind condition, only the attributes "expensive", "processed" and "unprocessed" did not discriminate among the three burgers. Both beef and plant-based burgers were more often associated to "dry" and "hard" than hybrid burgers. The opposite terms "juicy" and "soft" also reflected this difference, with hybrid burgers being associated to this word more than beef and plant-based burgers. Consumers also associated hybrid burgers to "strong vegetable flavour" and "healthy" more than to beef and plant-based ones. For "unhealthy", beef burgers scored highest, hybrid scored lowest and plant-based scored in between and not differently from the other two burgers. For the attributes "weak meat flavour", "off-flavour", "cheap" and "weak vegetable flavour", plant-based burgers scored highest, hybrid burgers scored lowest, while beef samples scored in between and not differently from the other two burgers. In the blind condition beef burgers scored higher than the other two burgers for the attribute "strong meat flavour". Hybrid burgers scored highest for "pleasant flavour", "tasty" and "characteristic", while plant-based burgers scored lowest and beef burgers scored in between and not differently from the other two burgers. Plant-based burgers scored significantly higher than the other two burgers for "bland" and "unusual".

In the expected condition, the attributes "pleasant flavour", "hard", "cheap" and "characteristic" did not discriminate among the three burgers. For the attributes "weak meat flavour", "off-flavour", "soft"," healthy", "processed" and "unusual", plant-based and hybrid samples scored similarly and significantly higher than beef burgers. Beef burgers were most often associated to "juicy", "strong meat flavour", "tasty", while plant-based burgers were the least associated and hybrid samples were in between. Plant-based burgers were more often associated to "dry" and "bland" than beef and hybrid burgers. Beef burgers were associated to "expensive" and "unhealthy" more often than plant-based and hybrid burgers. Finally, the beef and plant-based burgers were significantly more often associated with the term "unprocessed" than the hybrid burgers.

In the informed condition, seven attributes did not discriminate among burger samples: "weak meat flavour", "off-flavour", "pleasant flavour", "expensive", "unhealthy", "unprocessed" and "characteristic". The attributes "dry" and "hard" discriminated nicely the

three burgers, with beef scoring highest, plant-based burgers scoring in-between and hybrid samples scoring lowest. The opposite trend can be seen for the attribute "soft". The hybrid burgers were the least associated to "bland", while beef and plant-based were the most associated to this term. For "tasty" hybrid scored highest and plant-based burgers lowest, while beef burgers scored in the middle and not differently from the other two burgers. Hybrid burgers were most often associated to "juicy" and "strong vegetable flavour", followed by plant-based and beef burgers. Plant-based burgers scored highest for "weak vegetable flavour", followed by hybrid and beef burgers. Beef burgers scored highest for "strong meat flavour", "cheap" and "processed" and lowest for "healthy" and "unusual".

It is interesting to note that there are some common themes running across the blind, expected and informed conditions. For example, the attribute "strong meat flavour" is consistently more often associated to beef burgers than the other samples. However other attributes, such as "juicy" and "dry" changed among conditions. For example, in the blind condition the hybrid burgers were more often associated to "juicy" and "soft", while beef and plant-based burgers were more often associated to "dry" and "hard". In the expected condition, consumers associated beef burgers to "juicy" and plant-based to "dry". Finally, in the informed condition, beef samples were again associated to "dry" and "hard", while hybrid samples were associated to "juicy" and "soft".

Table 7~~5~~. Frequency and proportions of CATA terms selected by consumers for the three burgers in the three conditions.

	Blind			Expected			Informed		
Attribute	Beef	Plant	Hybrid	Beef	Plant	Hybrid	Beef	Plant	Hybrid
Dry	20(4.8)^{a}	17(4.0)^{a}	1(0.2)^{b}	1(0.2)^{b}	20(4.0)^{a}	4(0.8)^{b}	46(10.3)^{a}	21(4.3)^{b}	5(1.0)^{c}
Juicy	49(11.8)^{b}	35(8.1)^{b}	77(15.9)^{a}	91(17.8)^{a}	41(8.2)^{c}	60(12.1)^{b}	41(9.2)^{b}	47(9.6)^{b}	68(13.3)^{a}
Weak meat flavour	26(6.3)^{ab}	39(9.1)^{a}	22(4.5)^{b}	0(0.0)^{b}	32(6.4)^{a}	21(4.3)^{a}	17(3.8)^{ns}	31(6.3)^{ns}	17(3.3)^{ns}
Strong meat flavour	44(10.6)^{a}	16(3.7)^{b}	23(4.7)^{b}	89(17.4)^{a}	7(1.4)^{c}	33(6.7)^{b}	61(13.6)^{a}	15(3.1)^{c}	33(6.5)^{b}
Off-flavour	17(4.1)^{ab}	26(6.0)^{a}	6(1.2)^{b}	0(0.0)^{b}	7(1.4)^{a}	7(1.4)^{a}	9(2.0)^{ns}	16(3.3)^{ns}	12(2.4)^{ns}
Pleasant flavour	37(8.9)^{ab}	23(5.3)^{b}	52(10.7)^{a}	62(12.1)^{ns}	47(9.3)^{ns}	54(10.9 ^{ns}	37(8.3)^{ns}	39(8.0)^{ns}	54(10.6)^{ns}
Hard	24(5.8)^{a}	16(3.7)^{a}	1(0.2)^{b}	3(0.6)^{ns}	6(1.2)^{ns}	5(1.0)^{ns}	26(5.8)^{a}	10(2.0)^{b}	0(0.0)^{c}
Soft	10(2.4)^{c}	24(5.6)^{b}	66(13.6)^{a}	20(3.9)^{b}	36(7.2)^{a}	42(8.5)^{a}	21(4.7)^{c}	41(8.4)^{b}	63(12.4)^{a}
Bland	18(4.3)^{b}	36(8.4)^{a}	7(1.4)^{b}	2(0.4)^{b}	21(4.2)^{a}	7(1.4)^{b}	20(4.5)^{a}	18(3.7)^{a}	4(0.8)^{b}
Tasty	38(9.2)^{ab}	22(5.1)^{b}	53(10.9)^{a}	90(17.6)^{a}	39(7.8)^{c}	60(12.1)^{b}	50(11.2)^{ab}	40(8.2)^{b}	64(12.5)^{a}
Cheap	23(5.5)^{ab}	31(7.2)^{a}	13(2.7)^{b}	1(0.2)^{ns}	2(0.4)^{ns}	7(1.4)^{ns}	29(6.5)^{a}	14(2.9)^{b}	8(1.6)^{b}
Expensive	8(1.9)^{ns}	4(0.9)^{ns}	11(2.3)^{ns}	50(9.8)^{a}	27(5.4)^{b}	16(3.2)^{b}	11(2.5)^{ns}	10(2.0)^{ns}	10(2.0)^{ns}
Unhealthy	15(3.6)^{a}	14(3.3)^{ab}	4(0.8)^{b}	13(2.5)^{a}	1(0.2)^{b}	3(0.6)^{b}	12(2.7)^{ns}	3(0.6)^{ns}	3(0.6)^{ns}
Healthy	7(1.7)^{b}	17(4.0)^{b}	39(8.0)^{a}	25(4.9)^{b}	68(13.5)^{a}	54(10.9)^{a}	9(2.0)^{b}	46(9.4)^{a}	37(7.3)^{a}
Processed	33(8.0)^{ns}	33(7.7)^{ns}	19(3.9)^{ns}	5(1.0)^{b}	25(5.0)^{a}	20(4.0)^{a}	29(6.5)^{a}	26(5.3)^{ab}	13(2.5)^{b}
Unprocessed	4(1.0)^{ns}	2(0.5)^{ns}	8(1.6)^{ns}	27(5.3)^{a}	18(3.6)^{a}	7(1.4)^{b}	7(1.6)^{ns}	5(1.0)^{ns}	8(1.6)^{ns}
Characteristic	7(1.7)^{ab}	3(0.7)^{b}	14(2.9)^{a}	21(4.1)^{ns}	12(2.4)^{ns}	11(2.2)^{ns}	7(1.6)^{ns}	12(2.4)^{ns}	16(3.1)^{ns}
Unusual	25(6.0)^{b}	46(10.7)^{a}	26(5.4)^{b}	1(0.2)^{b}	27(5.4)^{a}	31(6.3)^{a}	7(1.6)^{c}	50(10.2)^{a}	33(6.5)^{b}
Strong vegetable flavour	3(0.7)^{b}	8(1.9)^{b}	38(7.8)^{a}	1(0.2)^{c}	64(12.7)^{a}	37(7.5)^{b}	0(0.0)^{c}	27(5.5)^{b}	57(11.2)^{a}
Weak vegetable flavour	7(1.7)^{ab}	18(4.2)^{a}	5(1.0)^{b}	10(2.0)^{ab}	3(0.6)^{b}	15(3.0)^{a}	8(1.8)^{b}	19(3.9)^{a}	5(1.0)^{b}
total	415	430	485	512	503	494	447	490	510

[a,b,c] Within the same condition, attributes with different letters in a row, ~~within the same blind/expected or informed condition in a row~~, are significantly different ($p \leq 0.05$ - Cochran's Q test). The proportions relative to the total are in brackets.

3.3. Correspondence analysis

Figure 1 shows the burger samples and CATA terms in the first two coordinates of the correspondence analysis (CA) for the three conditions. Overall, the first and second dimensions combined explained 100% of the variance in the data, with a strong first dimension (78.1-87.7%) and a less important second dimension (12.3-21.9%).

In the blind condition, the first dimension was positively correlated with the terms "strong vegetable flavour", "soft" and "healthy" and negatively correlated with the terms "hard", "dry", "unhealthy", "off-flavour" and "bland". The second dimension was positively correlated with the term "strong meat flavour" and negatively correlated with "weak vegetable flavour".

In the expected condition, the first dimension was positively correlated with the terms "strong meat flavour" and "unhealthy" and negatively correlated with the opposite terms "weak meat flavour", "healthy", as well as "bland" and "dry". The second dimension was positively correlated with the term "cheap" and negatively correlated with "dry".

In the informed condition, the first dimension was positively correlated with the term "strong vegetable flavour" and negatively correlated with the term "hard". The second dimension was positively correlated with the term "weak vegetable flavour" and negatively correlated with "strong meat flavour".

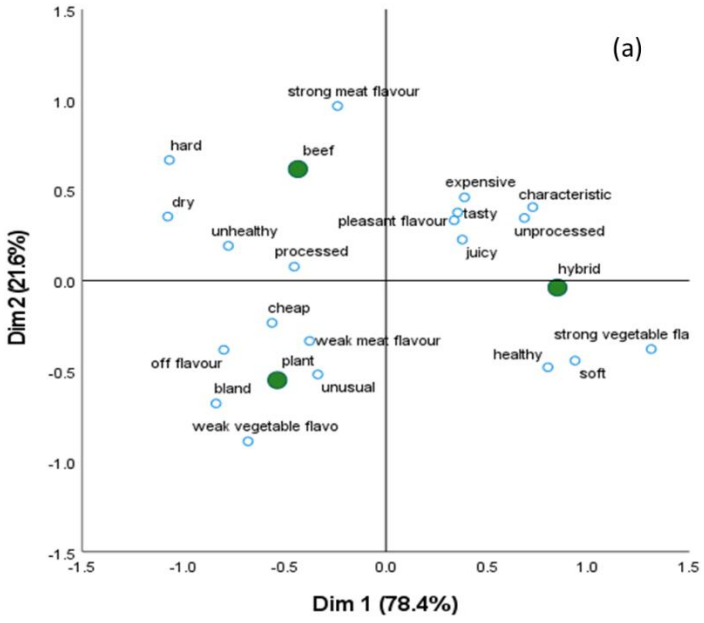
The properties of the three burger groups were well separated in the three conditions. In the blind condition, hybrid burgers were located at positive values of the first dimension, while beef burgers were at positive values of the second dimension and plant-based burgers were at negative values of both first and second dimension. In the expected condition there is a change in the location of hybrid and beef burgers, with beef burgers located at positive values of the first dimension and hybrid burgers at positive values of the second dimension (no change for plant-based burger). Finally, in the informed condition, there is another change, with both plant-based and hybrid burgers located at positive values of the first dimension and beef samples at negative values of both first and second dimension (where plant-based burgers were found in the previous conditions).

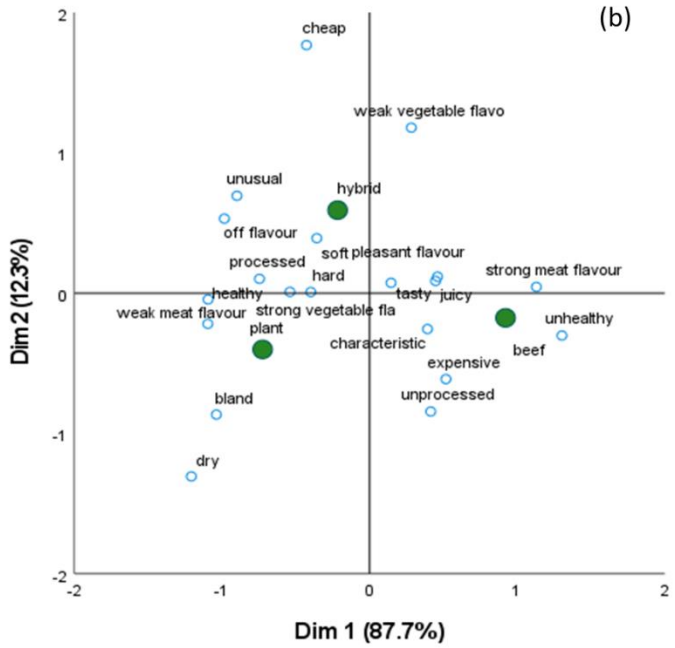
In the blind condition, consumers associated plant-based burgers with "unusual"," weak meat flavour", "bland", "off-flavour" and "cheap", beef burgers with "strong meat flavour", "hard", "dry", "unhealthy" and "processed", and hybrid burgers with "soft", "healthy", "juicy" and "unprocessed".

In the expected condition, consumers associated plant-based burgers with "weak meat flavour", "bland" and "strong vegetable flavour", beef burgers with "unhealthy", "strong meat flavour" and "juicy", and hybrid burgers with "soft", "unusual" and "off-flavour".

In the informed condition, consumers associated plant-based burgers with “weak meat flavour”, “off-flavour”, “healthy” and “unusual”, beef burgers with “cheap”, “dry” and “unhealthy” and finally hybrid burgers with “soft”, “juicy” and “strong vegetable flavour”.

Regardless of the information, in our study the three burger samples were sorted into three distinctive areas according to their sensory attributes in the CA plot. In contrast, Neville et al. (2017) found that meat burgers were in the same area as the hybrid burgers in their CA plot. These differences are probably due to the different recipes used in the studies.





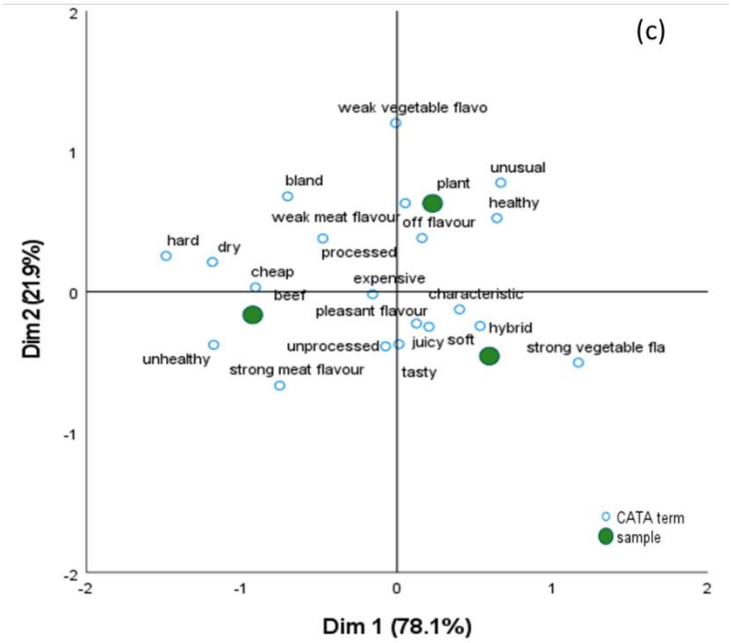


Figure 2~~1~~. CATA terms used to describe the beef, plant-based and hybrid burgers in the first two dimensions of the ~~CA~~ Correspondance analysis performed using the CATA data with χ2-distances. (a) blind condition, (b) expected condition, (c) informed condition.

3.4. Penalty-lift analysis

Table 6 shows the results of the penalty-lift analysis, estimating how much liking changed when an attribute was selected by a consumer compared to when it was not selected. In this study it was interesting to investigate how providing information on the burgers impacted the drivers of like and dislike across conditions. For ease, only the top three and bottom three drivers are reported in Table 6.

Table 8~~6~~. Penalty-lift analysis for the three burgers in the three conditions. The values indicate a change in liking when an attribute was ticked compared to when it was not ticked by consumers.

	Blind	Liking change	Expected	Liking change	Informed	Liking change
Beef (top 3)	Tasty	3.45	Strong vegetable flavour	0.82	Tasty	2.58
	Pleasant flavour	2.96	Juicy	0.62	Pleasant flavour	2.05
	Strong meat flavour	2.83	Unprocessed	0.45	Strong meat flavour	1.79
Beef (bottom 3)	Off-flavour	-3.27	Unusual	-3.22	Bland	-2.44
	Bland	-3.18	Cheap	-1.20	Off-flavour	-2.32
	Weak vegetable flavour	-2.98	Bland	-0.70	Unusual	-2.17

Plant-based (top 3)	Expensive	3.40	Tasty	1.90	Tasty	2.62
	Tasty	3.20	Pleasant flavour	1.67	Pleasant flavour	2.47
	Healthy	2.94	Strong meat flavour	1.25	Expensive	2.46
Plant-based (bottom 3)	Unhealthy	-3.02	Bland	-1.91	Cheap	-4.11
	Off-flavour	-2.30	Off-flavour	-1.67	Off-flavour	-3.59
	Cheap	-2.29	Dry	-1.56	Unhealthy	-3.32
Hybrid (top 3)	Tasty	2.42	Tasty	1.72	Tasty	3.08
	Pleasant flavour	2.40	Pleasant flavour	1.58	Pleasant flavour	2.22
	Juicy	1.82	Juicy	1.38	Juicy	2.10
Hybrid (bottom 3)	Off-flavour	-3.22	Off-flavour	-2.90	Off-flavour	-3.50
	Bland	-2.44	Cheap	-2.44	Cheap	-2.16
	Cheap	-2.21	Dry	-1.66	Bland	-2.07

The main drivers for hybrid burger liking did not change with information on burger composition and were consistently “tasty”, “pleasant flavour” and “juicy” across conditions. The drivers of dislike for hybrid burgers were the same in both blind and informed conditions (“off-flavour”, “bland” and “cheap”) and only one driver was different in the expected condition (“dry” instead of “bland”).

In beef burgers the main drivers for liking did not change in the blind and informed conditions and were always “tasty”, “pleasant flavour” and “strong meat flavour”, while in the expected condition they changed to “strong vegetable flavour”, “juicy” and “unprocessed”. The word “bland” was a main driver for dislike in the three conditions, “off-flavour” was common in both the blind and informed conditions, while “unusual” was common between the expected and informed conditions.

For the plant-based burgers, “tasty” was a common driver for liking across all conditions, “expensive” was in common between the blind and informed conditions and “pleasant flavour” between the expected and informed conditions. The main drivers for dislike did not change between the blind and informed conditions (“unhealthy”, “off-flavour” and “cheap”), while in the expected condition they were “bland”, “off-flavour” and “dry”.

3.5. Ranking

Analysis of the ranking data is reported in Table 7. There was no significant difference among the three burger samples for the attributes “tasty” and “quality”. For the attributes “healthy” and “nutritious” plant-based and hybrid burgers scored similarly and significantly higher than beef burgers. The attribute “environmentally-friendly” was the only one that significantly discriminated among the three burgers, with plant-based burgers scoring highest, followed by hybrid burgers and beef burgers scored last.

Table 9~~7~~. Consumer ranking of beef, plant based and hybrid burgers according to five adjectives, from most (1) to least (3).

Attribute	Beef	Plant	Hybrid
Tasty ^{ns}	2.01	2.16	1.83
Healthy	2.49^{b}	1.74^{a}	1.77^{a}
Nutritious	2.41^{b}	1.94^{a}	1.65^{a}
Environmentally-friendly	2.68^{c}	1.40^{a}	1.92^{b}
Quality ^{ns}	2.02	2.16	1.82

^{a,b,c} Attributes with different letters, within a row, are significantly different ($p \leq 0.05$- Friedman's test) among the three burger samples.

3.6 Text analysis

3.6.1 Contingency table

Table 8 shows the terms given in the comments for each sample and the percentage of mentions for each term within the total for that category (like or dislike). Comments that appeared with a lower frequency than 5% per sample-condition were excluded from the analysis.

The most recurrent likes (L) mentioned by consumers were "taste", "juiciness", "appearance", and "texture". On the other hand, the principally mentioned dislikes (D) were "taste", "texture", "chewiness", and "blandness". Cochran's Q test showed significant differences in the frequency of some attributes that consumers used to describe the samples.

Under blind conditions, consumers commented liking the "taste" and "moistness" of hybrid samples more often than plant-based samples, while beef samples scored in the middle and were not different from the other two samples. Both beef and plant-based burgers were more often associated to "D_chewy" than hybrid burgers. Only the hybrid burger was associated with "vegetable flavour", however this was both reported in a positive (like) and negative (dislike) way by consumers.

Under informed conditions, unsurprisingly beef samples were the most commented as "L_meaty" compared to plant and hybrid samples. Consumers disliked more the "texture" of plant-based burgers than hybrid and beef burgers. Consumers also disliked more frequently the "dryness" and "chewiness" of the beef burger compared to the other samples. Beef was the only sample not commented as "L_healthy".

3.6.2 Comparison of comments with overall liking

Comparing overall liking with the number of comments, the hybrid informed sample had the highest overall liking (hedonic=6.99), the second highest number of like comments (210) and the least number of dislikes (98); followed by the hybrid blind sample, which had the second-best overall liking (hedonic=6.69), the most like comments (214) and the second least number of dislike comments (110); the least liked sample was plant-based blind (hedonic =4.74) which had more dislikes comments (168) than like comments (129). The other samples – beef informed, beef blind, and plant-based informed – with intermediate

scores, received a similar number of likes and dislikes. Therefore, we found that the higher the ratings are given for a product, the more comments consumers gave for likes and the less they gave for dislikes; and lower ratings were related to more dislike than like comments similarly to previous findings by Symoneaux et al. (2012).

Table 10~~8~~. Like (L) and dislike (D) comments for each sample in blind and informed conditions. Number of mentions, proportion of each (%) and total mentions per sample crossed with condition.

Comments	Blind			Informed			%*
Like comments (L)	Beef	Plant	Hybrid	Beef	Plant	Hybrid	
Taste	46^{ab}	29^{b}	57^{a}	54^{ab}	46^{b}	64^{a}	27.8
Juicy^{ns}	24	14	25	16	13	31	11.6
Appearance^{ns}	18	18	23	13	13	14	9.3
Texture^{ns}	15	10	12	14	13	18	7.7
Meaty	16^{ns}	5^{ns}	6^{ns}	24^{a}	7^{b}	10^{b}	6.4
Aroma	9^{ns}	5^{ns}	7^{ns}	11^{ab}	6^{b}	16^{a}	5.1
Aftertaste^{ns}	7	6	12	7	11	6	4.6
Colour^{ns}	10	9	5	7	6	7	4.1
Soft	4^{b}	4^{ab}	14^{a}	5^{ns}	6^{ns}	9^{ns}	4.0
Moist	4^{ab}	2^{b}	10^{a}	4^{ns}	8^{ns}	7^{ns}	3.3
Thickness^{ns}	3	10	9	1	6	4	3.1
Seasoning^{ns}	1	1	9	3	3	4	2.0
Chewy enough^{ns}	5	2	4	4	2	2	1.8
Size^{ns}	1	5	5	4	3	0	1.7
Veg (taste)	0^{b}	0^{b}	9^{a}	0^{b}	0^{b}	9^{a}	1.7
Healthy	0^{ns}	0^{ns}	5^{ns}	0^{b}	8^{a}	5^{ab}	1.7
Total likes	163	120	212	167	151	206	95.9
Dislike comments (D)							
Taste	20^{ns}	22^{ns}	17^{ns}	9^{b}	19^{ab}	24^{a}	13.4
Texture	10^{b}	34^{a}	6^{b}	4^{b}	24^{a}	7^{b}	10.3
Chewy	28^{a}	13^{b}	2^{c}	24^{a}	8^{b}	0^{c}	9.1
Bland	10^{b}	24^{a}	6^{c}	19^{a}	10^{ab}	2^{b}	8.6
Dry	14^{a}	5^{ab}	1^{b}	29^{a}	14^{b}	5^{b}	8.2
Appearance^{ns}	12	9	13	8	8	2	6.3
Aroma^{ns}	11	11	3	8	7	2	5.1
Too thin	9^{ns}	0^{ns}	0^{ns}	22^{a}	2^{b}	4^{b}	4.5
Hard	13^{a}	5^{ab}	0^{b}	11^{a}	6^{ab}	1^{b}	4.4
Aftertaste^{ns}	4	5	7	3	5	11	4.2
Too greasy^{ns}	6	8	4	5	2	4	3.5
Weak meat (taste)	2^{ab}	1^{b}	9^{a}	5^{ns}	2^{ns}	7^{ns}	3.1
Gristly^{ns}	5	6	4	3	4	0	2.7
Too soft^{ns}	0	0	15	0	0	5	2.4
Strong veg (taste)^{ns}	0	0	7	0	0	13	2.4
Crumbly^{ns}	0	5	3	0	3	3	1.7
Pale colour^{ns}	3	5	1	0	4	0	1.6
Rubbery^{ns}	5	2	1	2	1	0	1.3
Bitty^{ns}	0	6	0	0	1	0	0.8
Total dislikes	152	161	99	152	120	90	93.6

*Percentage of mentions in relation to the total number of like or dislike comments.

[a,b,c] Attributes with different letters, within the same blind or informed condition in a row, are significantly different ($p \leq 0.05$) according to Cochran's Q test McNemar (Bonferroni) post-hoc test.

3.6.3 Correspondence analysis (CA)

A CA on the comment's frequency was carried out to visualise the characterisation of a sample-condition, based only on the comments cited by at least 5% of the consumers. Figure 2 shows the CA based on the contingency table with burgers and main terms cited by consumers.

The first two dimensions of the CA represented 80% of the total variation. According to the comment analysis, samples were separated along the area into the same three groups as those formed by analysis of overall liking ratings under blind and informed conditions (Table 2). Plant-based samples scored least for overall liking under blind and informed conditions, followed by the beef-based and then scoring highest, the hybrid-based samples. The less liked products are located towards the upper left quadrant and more liked products towards the lower right quadrant. Furthermore, the informed condition of the plant, beef and hybrid samples is placed further towards the liking direction, while the blind condition samples gravitate towards the disliking direction. The second dimension also separates the plant-based from the beef burgers.

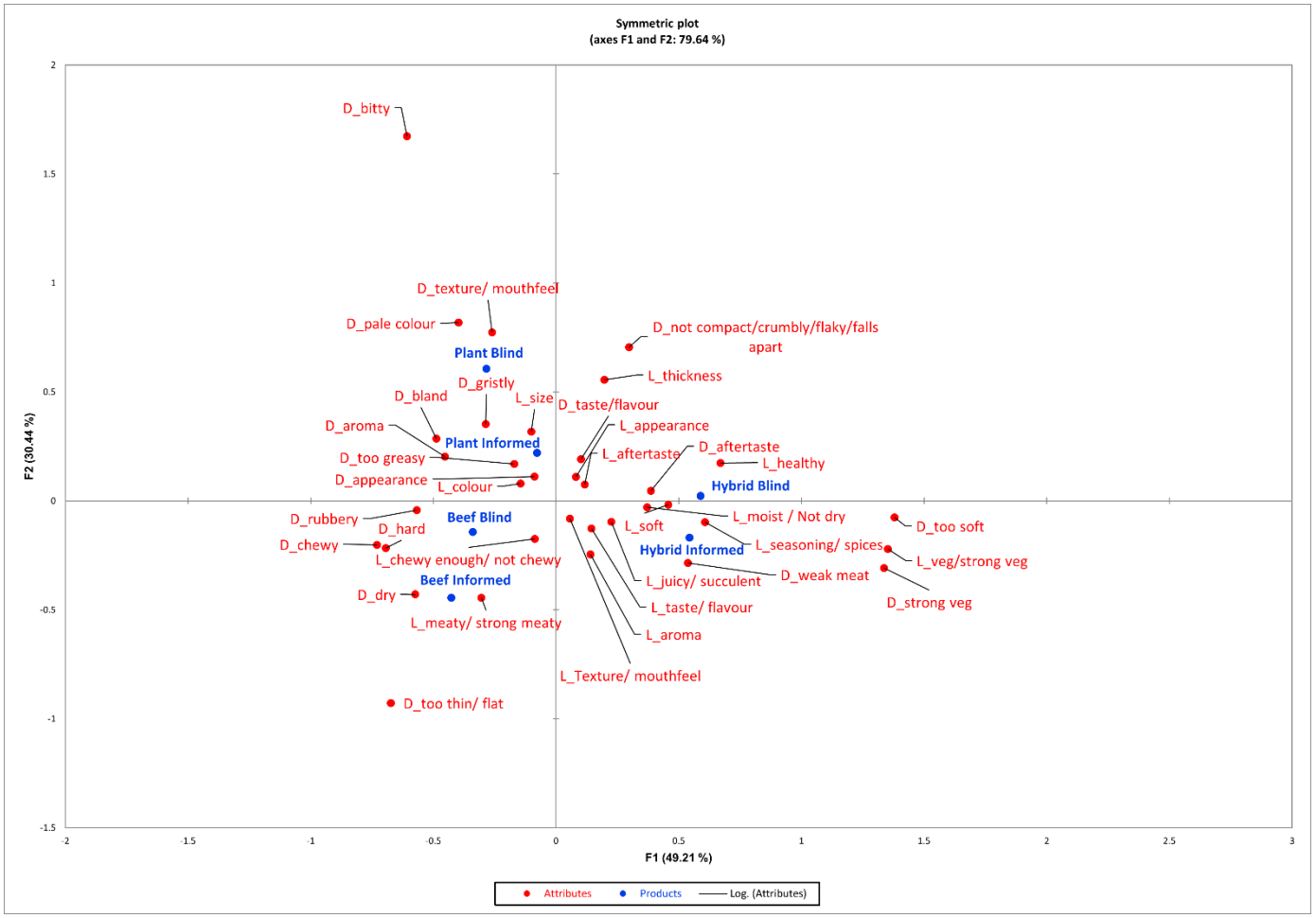


Figure 3~~2~~. Correspondence analysis on the contingency table with burger samples, conditions and main comments cited by consumers. Blue circles represent samples and condition, and red circles represent comments, L for likes and D for dislikes.

Analysing text comments gave us an insight into the consumers' own language for describing the products and their drivers of liking and disliking. As in previous work (Ares et al., 2010; Lahne, Trubek, & Pelchat, 2014; Symoneaux et al., 2012) comment analysis revealed aspects from a consumer's perspective. Consumers described products with their own vocabulary and identified attributes responsible for consumers' preference. For example, for hybrid burgers, the most frequent like comments were "taste" and "juicy" across blind and informed conditions. As for the most frequent term driving disliking, "taste" elicited the most frequent comments across both conditions, although in less frequency than liking comments. For disliking, while "too soft" and "appearance" were the following most cited terms under blind condition, "strong vegetable taste" and "aftertaste" were the following most recurrent terms under informed condition.

4. Discussion and implications for industry and policy makers

The results from this study arise a series of new insights about consumers' attitude towards different alternatives to traditional meat products. In this section we discuss them in relation to other results that emerged from previous studies on the topic of meat alternatives and derive some implications for industries and policy makers.

Interestingly, under the blind and the informed conditions hybrid burgers were the most liked followed by beef and plant-based burgers, while consumers were expecting to prefer beef burgers the most. These results are in line with Neville et al. (2017) who compared the sensory acceptability of hybrid, meat and meat-free products and found no significant difference between hybrid and full meat products, while meat-free products were less accepted. Similarly, the hybrid burger scored higher than the beef and plant-based burger for aroma liking. Analogue results emerged also from Tarrega, Rizo, Murciano, Laguna, and Fiszman (2020) who looked at expected liking of beef burgers vs hybrids vs plant-based burgers. They divided participants into "pro", "interm" and "anti" meat reduction. Both "anti" and "interm" expected to like beef burgers significantly more than the other burgers, while the "pro" group expected to like beef, hybrids, and plant-based burgers in a similar way. These results are also similar to Neville et al. (2017) who found that "meaty flavour" and "juicy" were the main driver for liking in beef burgers.

On the other hand, the unmet expectations for plant-based burgers confirm the necessity from manufacturers to develop products with enhanced sensory properties aiming at replicating the conventional meat taste, as the current alternatives seem to yet fail on this aspect and thus are poorly accepted by consumers. However, it is worth mentioning that studies focusing on vegetarian and vegan consumers discovered that these segments of people do not seek for conventional meat taste when purchasing meat alternatives and that in most cases they even developed a disgust for meat (Fessler, Arguello, Mekdara, & Macias, 2003). Hence, it is vital for plant-based meat industries to first select their consumers' target

and then develop their products in accordance with their needs before launching their products into the market.

In the CATA task, similar results emerged in relation to the consumers' sensory dislike of plant-based meat burgers. However, because they were also associated with the 'healthy' aspect, industries and policy makers are encouraged to promote these products by emphasizing the benefits that they have compared to conventional meat products. The former could use labels on the packaging of their products to provide customers with such information, while the latter could promote initiatives to better educate people on this matter. On the contrary, positive sensory associations emerged with hybrid meat products.

Results from the ranking task showed that the attribute "environmentally-friendly" scored highest for plant-based burgers, followed by hybrid burgers and beef burgers. This suggests that plant-based meat manufacturers should emphasize the lower environmental impact of plant-based meat products compared to hybrid and conventional meat products to attract consumers. On the other hand, policy makers should promote initiatives to better educate consumers on this matter.

In terms of WTB and WTP, beef burgers scored higher than hybrid and plant-based meat burgers, which is comparable to results from Tarrega et al. (2020) who found that most consumers would buy the beef samples compared to the other burger options given (hybrid or 100% plant-based).

However, the overall positive consumers' reaction towards hybrid meat products, particularly from a sensory perspective, might help the shift towards a reduction in meat consumption. In fact, the proportion of meat included in the hybrid meat products could be gradually lowered in order to let consumers get used to a higher percentage of vegetables over meat. To facilitate this process, it is important that companies continue doing co-creation activities and sensory evaluations aimed at investigating consumers' preferences for different plant-based sources to be associated with meat to increase acceptance. In the future, multi-measurement approaches could also be used to better link sensory evaluations, WTP and other important factors such as emotions, similarly to Jaeger et al. (2017). The gradual increase of the plant-based portion in hybrid meat products could consequently reduce the intake of meat and might also increase consumers' liking of plant-based meat alternatives. At the same time, policy makers should educate consumers disclosing the importance of preferring a plant-based over a meat-based diet, not only from a health, but also from an animal welfare and environmental prospective.

5. Conclusion

This study aimed to compare for the first time the sensory quality of a beef burger vs a hybrid burger and a plant-based burger in blind, expected and informed conditions. Results show a significant effect of composition information on consumer acceptability, purchase intent and WTP for the three burgers. Results are overall positive towards hybrid burgers, in terms of overall acceptability, purchase intent, WTP and consumer comments. Hybrid meat products could represent an effective way for consumers to lower their meat consumption without compromising too much on the sensory quality and could represent a transition

product to a more plant-based diet. These results are valuable and should inform future marketing, labelling and reformulation efforts of new hybrid meat product launches.

Acknowledgements

This work was supported by EIT Food project number 20206 titled “consumer attitudes towards healthier processed meat products”.

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