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Article

Textural and Consumer-Aided Characterisation and Acceptability of a Hybrid Meat and Plant-Based Burger Patty

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Abstract: Beef has one of the highest climate footprints of all foods, and therefore the hamburger has been targeted for substitution by numerous plant-based alternatives. However, many consumers find the taste of these alternatives lacking, and thus we proposed a hybrid meat and plant-based burger as a lower threshold alternative for these consumers. The burger was made from 50% meat (beef and pork, 4:1) and 50% plant-based ingredients, including texturised legume protein and had a climate footprint less than half that of a beef burger. Texture and sensory properties were evaluated instrumentally and through a consumer survey (n = 381) using the check-all-that-apply (CATA) method. Moisture properties indicated a significantly juicier eating experience for the hybrid compared to a beef burger, which was supported by the CATA survey. From texture profile analysis the hybrid burger was significantly softer and less cohesive than a beef burger. Despite having different CATA term profiles overall liking of the hybrid and a beef burger were not significantly different. Penalty analysis indicated that "meat flavour", "juiciness", "spiciness", and "saltiness" are the most important attributes for a burger. In conclusion, consumers may be open to reducing their meat consumption by way of hybrid meat and plant-based products.

Keywords: plant-based; meat alternative; hybrid burger; check-all-that-apply; consumer survey

1. Introduction

World population has now surpassed eight billion, and at the same time global meat consumption per capita has been steadily increasing [1]. In addition, even though the consumption of meat per capita is beginning to show signs of plateauing in high income countries, there is no indication of the increase in overall global consumption stagnating during the coming years [2]. It is estimated that between a fourth and a third of global anthropogenic green-house gas (GHG) emissions are due to food systems. Furthermore, it is well established that intensive animal farming for meat production is associated with substantial GHG emissions [3,4], with ruminants being the largest contributor, predominantly due to the production of methane from intestinal fermentation of ingested biomass. Therefore, due to climate concerns, policymakers in many parts of the world are pushing for a reduction in consumption of animal derived foods, and beef in particular. The aim is to incite consumers to move towards a more plant-forward diet for a reduction of its carbon footprint. The recently updated Danish dietary guidelines were developed to also take into account the climate impact of food systems, an approach that is seen in several other European countries as well, i.e. sustainability is specifically mentioned in the dietary guidelines of countries like Italy, France, Germany, the Netherlands, and the United Kingdom [5].

Reducing meat in the diet without replacing it with another protein-rich food will reduce the consumer's overall protein intake. Legumes are often highlighted as a suitable replacement for meat because most legume seeds have a comparatively high protein content with a fairly good nutritional value, as well as being an excellent source of micronutrients and dietary fibre [6]. However, many consumers are reluctant to forego the meat-eating experience in favour of legumes, as illustrated by the low consumption observed in Denmark and other Nordic countries [7]. This has led to the implementation of processing techniques that can alter the structure of legume proteins to mimic the

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texture of meat. One such method is extrusion cooking, where the globular legume seed storage proteins are subjected to high temperature and shear force leading to denaturation, alignment and aggregation into a fibrous structure akin to the myofibrillar protein structure of muscle meat [8]. The resulting product is known as texturised vegetable protein (TVP) and is currently used in many plant-based meat alternatives. Originally, TVP was developed using soy protein, but nowadays many manufacturers use yellow pea, faba bean and/or other protein sources as starting material [9]. The texture of TVP based products can be comparable to minced meat products and in some cases whole cuts of meat, but in surveys consumers find the taste lacking. For example, 48% of respondents (n = 1000) in a Danish survey named taste as the primary reason for not buying plant-based alternatives to animal derived products [10], and 68% of respondents (n = 1631) in a survey from the United States said that the taste of animal meat was superior to that of plant-based [11]. Therefore, plant-based meat alternatives can still be considered a niche product in most Western countries [12].

A possible low-threshold route to convince more consumers to reduce their meat intake in favour of more plant-based could be through hybrid foods. Hybrid foods combine meat and plant-based ingredients to reduce the meat content, and thereby the climate impact, but also retain much of the sensory characteristics of an all-meat product. Previous attempts to market hybrid meat and plant-based products have seen mixed results [13]. However, the idea of reducing meat consumption in favour of more plant-based alternatives has become more widely recognised recently [14,15].

In the present study, we developed a hybrid burger patty consisting of 50% meat and 50% plant-based ingredients. The quality and characteristics of the burger was evaluated and compared to an all-meat beef burger as reference, through physical and texture analysis, as well as a consumer survey using the check-all-that-apply (CATA) method. To the best of our knowledge, this is the first report of such a study with Danish consumers.

2. Materials and Methods

Burger patties: The ingredients for the beef and hybrid burgers were purchased from local supermarkets, apart from the TVP (made from two thirds pea and one third faba bean protein) and extruded milled pea starch, which was supplied by Crispy Food a/s (Gørlev, Denmark). To make the patties rehydrated TVP (35.5%) was mixed with non-meat ingredients (gluten (6.2%), red beet juice (2.5%), tomato paste (1.2%), milled extruded pea starch (1.2%), dried porcini mushroom (0.3%), salt (0.6%), monosodium glutamate (0.4%), yeast flakes (0.3%), garlic powder (0.1%), black pepper (0.1%)), and mixed thoroughly in a stand mixer until a visible gluten network had formed. Bacon (8.5%) was added to the mixture which was then processed in a meat mincer fitted with a 6 mm hole plate. The resulting mince was mixed with minced beef (41.5%) and finely chopped frozen coconut oil-in-water emulsion (1.5%, emulsified with methylcellulose at 0.5% w/vol. emulsion). The nutritional composition of the hybrid burger patties is shown in Table 1.. The final mixture was shaped into 100 g patties with a diameter of 8 cm which were pan fried to an internal temperature of 75 °C, as were reference patties of identical size and shape made from minced beef. Salt and ground black pepper were added to the reference patties immediately before frying. Afterwards the burger patties were either analysed or frozen for later use in the consumer survey. Freezing of the patties for the survey was necessary for logistical reasons.

Table 1. Nutritional content per 100 g of a hybrid (50%/50% plant/meat) and a beef (100% meat) burger patty.

	Amount		
	Hybrid	**Beef**	**Unit**
Energy	772/185	789/189	kJ/kcal
Fat	10.5	12.0	g
Saturated fat	4.8	4.9	g
Carbohydrate	3.5	0.0	g

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Sugars	0.3	0.0	g
Dietary fibre	1.0	0.0	g
Protein	19.0	20.0	g
Salt	1.3	1.5	g

Texture profile analysis: Circular samples were cut using a 30 mm diameter steel ring. These were then cut to a height of 19 mm. Texture profile analysis (TPA) was

carried out on a TMS Pro texture analyser (Food Technology Corporation, USA), using a flat cylindrical probe with a diameter of 50 mm. The TPA settings were as follows: trigger force = 2 N, compression and return speed = 2 mm/s, strain = 60% of initial height, with no pause between compressions. The attributes calculated were as follows: Young's modulus = stress/strain (kPa); cohesiveness = ratio of work done during second and first compression, respectively; springiness = ratio of sample height at second compression to initial height.

Cooking loss: Hybrid and beef burger patties were pan-fried to 75 °C internal temperature. The cooking loss was calculated as the percentage of weight lost after cooking.

Expressible moisture: Expressible moisture was assessed using the procedure described by Earl et al. [16] with minor modifications. Briefly, approximately 3 g pieces of cooked burger patty was placed in a small cup fashioned from one inner layer of Whatman no. 50, 70 mm and three outer layers of Whatman no. 3, 50 mm filter papers. These were placed inside a 50 mL centrifuge tube and centrifuged at 15 000 × g and room temperature for 15 minutes. Expressible moisture was taken as the percentage of weight lost after centrifugation of the cooked patty.

Consumer survey: We conducted a consumer survey at a foodservice expo held over three days in March 2022 in Herning, Denmark. The survey was structured as a CATA questionnaire including a 9-point hedonic liking scale for each product anchored at "dislike very much" and "like very much", as described by Ares and Jaeger [17]. The CATA question included 20 descriptive terms generated by a focus group of students from Business Academy Aarhus' Food Technology and Application programme (n = 35; M = 16; F = 19). The terms, which are shown in **Error! Reference source not found.**, were printed in randomised order on the survey questionnaire to minimise primacy bias [18]. The questionnaire also prompted participants to describe their perceived ideal burger patty using the same 20 CATA terms which permitted identification of important attributes through penalty analysis [17]. In addition to the CATA and liking questions, the participants were asked to state age and sex, and whether they were a regular consumer of plant-based meat alternatives or not. Questionnaires from 381 assessors were filled out correctly with regard to the CATA and liking questions and were therefore included in the analysis. The assessors were recruited among visitors to the expo and were asked to evaluate the hybrid and beef burgers and fill out the questionnaire at a table behind the expo booth under ambient conditions. The samples were served single-blinded on white paper plates after reheating to 75 °C over a water bath in a standard household oven, and each were labelled with a three-digit code.

Table 1. Consumer-generated sensory terms for check-all-that-apply survey of hybrid vs. beef burger patty.

Texture	Taste	Appearance
Soft	Fat	Pink
Dry	Salt	Well done
Rubberlike	Meat flavour	Meat colour
Tough	Metallic	Dark surface
Grainy	Spicy	Brown surface
Juicy	Off-flavour	
Firm	Pepper	
Crust		

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Climate impact (CO2-eq): The climate impact of the beef and hybrid burgers were estimated in terms of CO2-equivalents (CO2-eq) per burger in a use case here exemplified by a standard cheeseburger. The CO2-eq for the different ingredients were obtained from The Big Climate Database [19], which is the official Danish database for climate impact of food products. In the cases where a specific entry for an ingredient was not available in the database a similar product was chosen instead, e.g. *wheat flour* substituted for *gluten* in the hybrid burger patty, and *Danbo cheese 45+* substituted for *burger cheese*.

Data analysis: The results of the texture profile analysis, cooking loss, and expressible moisture were analysed using two-tailed student's t-test. Hedonic liking of the test burgers was analysed using the paired Wilcoxon signed rank test, and differential use of CATA terms for hybrid, beef, and ideal burgers was analysed using Cochran's Q test.

Correspondence analysis was carried out on the contingency table of CATA term use from the questionnaire, and a biplot was created to assess relationships between terms and samples.

Hierarchal clustering was done using the CLUSCATA algorithm in XLSTAT [20]. After clustering, all assessors with incomplete demographic data were excluded. Differential liking of the burgers in the generated clusters was tested using two-way non-parametric anova with interaction on Aligned Rank Transformed data according to Wobbrock *et al*. [21]. The factors were *cluster* and *type of burger* and assessor was included as random effect. Potential differences in cluster demographic composition were assessed using X^2-test on counts.

Penalty analysis was carried on the CATA and liking data from the questionnaire to assess the importance of attributes for consumer acceptability of the burgers.

Differences were taken as significant at the 0.05 level, and all analyses were carried out in R version 4.3.1 [22] and XLSTAT Sensory 2022.2.1 (Addinsoft, France).

3. Results

3.1. Texture attributes

In addition to taste the texture and mouthfeel of food has a profound impact on consumer acceptability. The texture of soft solid foods can be measured instrumentally using TPA, which involves a two cycle compression of uniformly cut samples of the food under investigation. From the force-time and stress-strain curves a number of attributes can be calculated, each of which approximate different aspects of the sensory experience of eating the food [23,24]. The results from the TPA are shown in

. The Young's modulus of the beef burger was two-fold higher than that of the hybrid burger, indicating that the percieved firmness of the burgers would possibly be experienced as somewhat different from each other. The beef burger's cohesiveness was twenty percent higher than the hybrid's, suggesting that the hybrid burger will require less total energy input during mastication before swallowing. In contrast, the springiness was marginally higher for the hybrid burger, however, a difference of such limited magnitude will in all likelihood not be detectable by the consumer. Taken together, the hybrid burger will presumably be experienced as softer and easier to chew, but will feel similar with regard to size and shape during mastication. Cooking loss measures the amount of moisture lost during frying. The hybrid burger lost markedly less moisture than the beef burger (

) and, as expected, the subsequent amount of expressible moisture was correspondingly higher for the hybrid burger. This should translate to a juicier sensory experience when eating the hybrid burger.

Table 2. Physical attributes related to texture and sensory perception. Results are given as means ± s.d. (n = 6).

		Sample		
Attribute	**Unit**	**Hybrid**	**Beef**	**Significance[(a)]**

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Young's modulus	kPa	332 ± 34	679 ± 80	***
Cohesiveness	Ratio	0.48 ± 0.02	0.58 ± 0.01	***
Springiness	Ratio	0.77 ± 0.01	0.76 ± 0.01	*
Cooking loss	%	17.2 ± 0.2	26.9 ± 0.1	***
Expressible moisture	%	33.5 ± 0.1	22.3 ± 0.03	***

[a)] Asterisks indicate statistically significant difference between samples: * = $p < 0.05$, *** = $p < 0.001$.

3.2. Climate impact

The amounts and estimated CO2-eq footprint for each ingredient in the regular cheeseburgers is shown in Table 3. The CO2-eq footprint of the hybrid burger patty is less than half that of the beef patty. This is because not only is the amount of beef in the hybrid patty reduced by 50%, a further 8.5% is exchanged with bacon, which has a markedly lower CO2-eq footprint than beef. The CO2-eq footprints for each cheeseburger sums to 1.80 and 3.60 kg CO2-eq for the hybrid and beef burger, reepctively. Thus, replacing the beef patty in a cheeseburger with the hybrid patty halves the overall climate footprint of the burger.

Table 3. Climate impact of ingredients used in a regular cheeseburger.

Ingredient	Amount (g)	CO2-eq per burger (kg)
Bun	50	0,04
Patty	100	1.39[a]/3.19[b]
Salad	13	0,01
Tomato	27	0,02
Pickled cucumber	17	0,03
Cheese	27	0,21
Mayonaise	17	0,02
Dressing	17	0,08

a) Hybrid; b) Beef

3.3. Consumer survey, evaluation of hybrid and beef burgers

The assessors in the survey were recruited at an expo for foodservice providers in Denmark. After exclusion of incomplete or incorrectly filled out forms, 381 assessors were included in the analysis. Assessor demographics are shown in Figure 1.

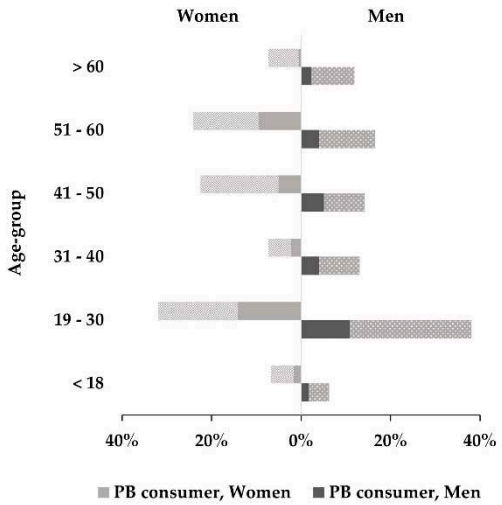

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Figure 1. Age and gender distribution of assessors in the consumer survey. Shaded part of bars show proportion of assessors who sometimes eat plant-based meat alternatives. .

3.3.1. Overall liking

On a discrete nine-point scale anchored at "dislike very much" and "like very much" the consumers' scores for the two burgers were not significantly different, as assessed by the Wilcoxon paired signed rank test ($p = 0.32$). The respective liking scores (± s.e.) were 5.4 (± 0.1) for the beef and 5.3 (± 0.1) for the hybrid.

3.3.2. CATA term usage

The assessors were asked to check any of the 20 CATA terms they felt described the burger they were tasting at a given moment. The frequency of term usage is shown in Table 4. Cochran's Q test was employed to determine which terms were used significantly different for the meat and hybrid burger, which was most of the terms, except "Metallic", "Pepper", "Meat colour", and "Brown surface". Thus, there is independence between rows and columns, indicating that the assessors experienced them as having different sensory characteristics. For six of the twenty attributes the difference in usage frequency between the meat and hybrid burger was more than 3.5-fold. These were "Soft", "Dry", "Juicy", "Tough", "Pink", and "Off-flavour". The hybrid burger was percieved as softer, less dry and juicier, more tender, and more pink than the beef burger, but was also percieved by 29% of the assessors as having an off-flavour, in contrast with just 3% indicating this for the beef burger.

Table 4. Frequency (%) of assessors (n = 381) use of CATA terms to describe burgers and their ideal burger.

Attribute	Hybrid	Beef	Ideal	Significance[(a)]
Soft	51	6	30	***
Dry	11	62	0	***
Rubberlike	36	22	0	***
Tough	7	25	0	***
Grainy	18	13	1	*
Juicy	53	12	82	***
Firm	15	44	21	***
Crust	11	17	67	**
Fat	11	5	15	**
Salt	20	11	53	***
Meat flavour	33	64	72	***
Metallic	4	6	0	n.s.
Spicy	30	12	62	***
Off-flavour	29	3	1	***
Pepper	9	9	46	n.s.
Pink	21	3	57	***
Well done	26	63	14	***
Meat colour	25	29	34	n.s.
Brown surface	35	34	38	n.s.
Dark surface	7	17	21	***

[(a)] Cochran's Q test for significance of difference between use of terms for each sample. Asterisks indicate statistically significant difference between samples: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

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The relationship between the products being tested and the CATA terms was explored using correspondence analysis. A graphical representation is shown in Figure 2 There is a clear separation of the two tested burgers as well as the ideal burger. Apparently none of the tested burgers represented an ideal burger to the assessors, which according to the biplot, is associated with a juicy, fat, spicy and salty taste and has a pink appearance with a crust. The hybrid burger was more associated with being soft and having off-flavour, whereas the beef burger was percieved more firm, tough, well done and dry.

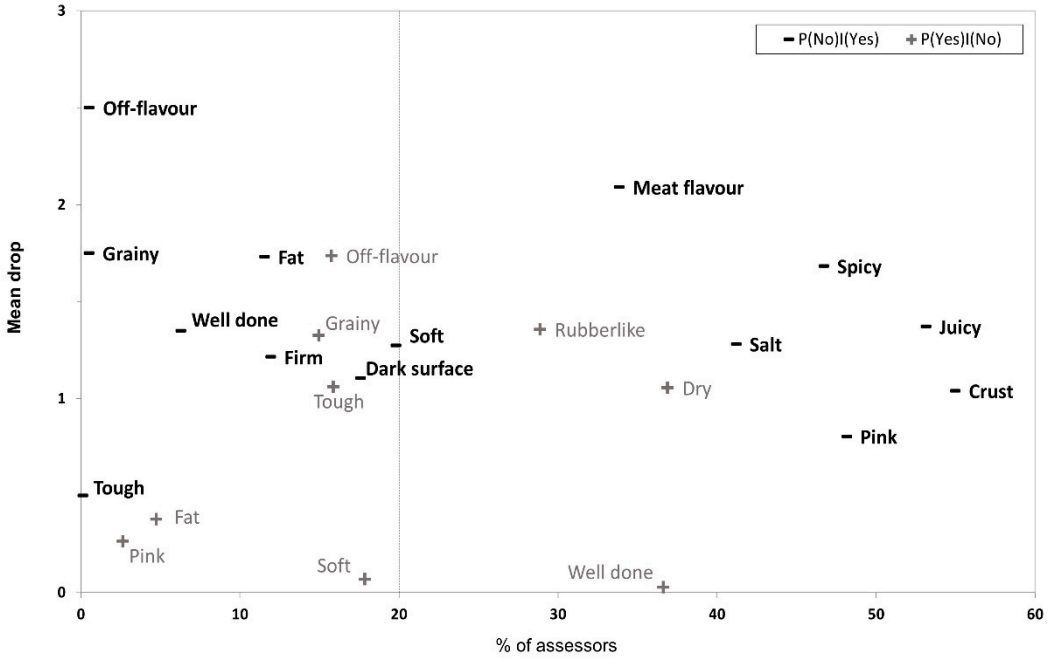

Figure 2. Mean drop in overall liking score for a burger when a CATA term was either checked for ideal and not for tested burger (-P(No)|(Yes)), or not checked for ideal and checked for tested burger (+P(Yes)|(No)).

3.3.3. Penalty analysis

Penalty analysis can be used to determine how much the overall liking of a product drops when the usage of a specific CATA term is different for a product relative to the "ideal". This provides a tool for research or for product development whereby it is possible to identify product attributes that are either detrimental to consumer acceptability if present or are required for optimal acceptability. An overview of the penalty analysis carried out for the hybrid and beef burgers tested in the present study is shown in Figure 3. The graph shows the mean drop associated with certain terms and how large a proportion of assessors had checked this term differently for product vs. "ideal". The vertical line shows the cut-off at 20% percent of assessors, above which a given term is deemed relevant for further consideration. Thus, terms in the upper right corner of the graph are the most important for the product being tested. In this case "Meat flavour", "Spicy", "Juicy", "Salt", "Crust", and "Pink" can be considered must-have attributes, and conversely "Rubberlike" and "Dry" can be considered must-not-have attributes. The terms "Soft", "Dark surface", "Off-flavour", "Grainy", and "Tough" could be considered somewhat important for acceptability, but should not be prioritised over those that are must-have and must-not-have. For the rest of the terms in Figure 3 either the proportion of assessors or the penalty is too small for them to be considered relevant.

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3.3.4. Cluster analysis

Using the CLUSCATA hierarchal clustering algorithm the assessors were assigned to clusters where within-cluster dissimilarity between assessors' CATA term usage was minimised. This resulted in two clusters and a K+1 cluster containing the assessors that did not fit either of the two obtained clusters. Of the original 381 assessors, after exclusion of assessors with incomplete demographic data, 92 were assigned to cluster 1 and 138 to cluster 2. The relationship between the burgers and the CATA term usage is visualised by correspondence analysis-generated biplots in ***Error! Reference source not found.*** B and C for clusters 1 and 2, respectively. Assessors in both clusters apparently associate the beef burger with "Well done", "Firm", "Tough", and "Dry", and an ideal burger with "Pepper", "Pink", "Salt", "Crust", and "Spicy". Conversely, the hybrid burger is more associated with "Rubberlike" and "Grainy" in cluster 1, where in cluster 2 the association with "Soft" and "Juicy" is strongest. Analysis of the liking scores (Figure 4) for the two clusters showed that assessors in cluster 2 scored both burgers higher, and also preferred the hybrid over the beef burger. In contrast, the assessors in cluster 1 preferred the beef over the hybrid burger, although this difference was not significant. There was a non-significant trend ($p = 0.08$) for there to be less women than men in cluster 1 and more women than men in cluster 2. The ratio of regular plant-based eaters to non-eaters also tended to be higher in cluster 2 than in cluster 1, however, also not significant ($p = 0.11$).

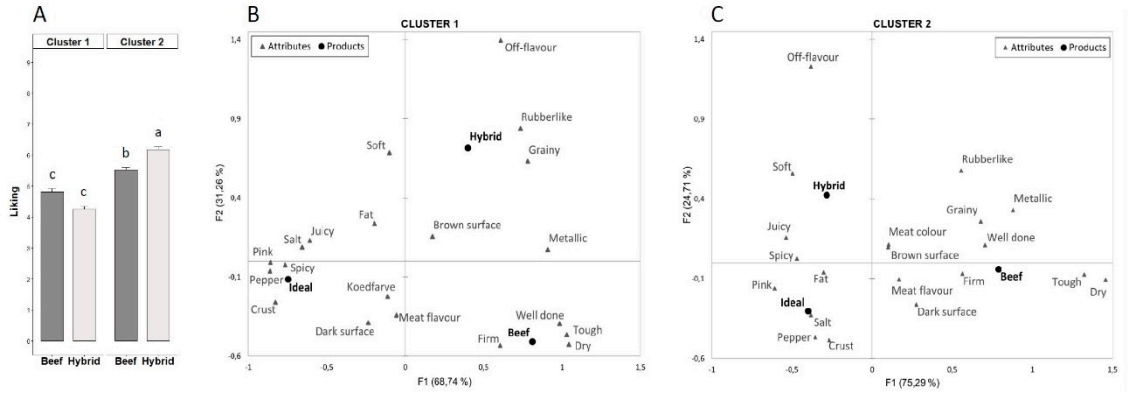

Figure 4. Mean liking scores for the two burgers in two clusters generated by the CLUSCATA method. Different letters above bars indicate statistically significant difference ($p < 0.05$). B and C) Biplot of rows (terms) and columns (burgers, including ideal) from correspondence analysis of cluster 1 and 2, respectively.

4. Discussion

A considerable share of global anthropogenic GHG emissions come from food systems, with animal derived foods generally having a larger impact than plant-based food. There is, however, substantial variation within animal derived foods, where ruminant meat is the greatest contributor to climate impact by far [3], with beef possibly being the largest single contributor, when factoring in the volumes consumed [25]. Hamburgers are a popular beef-based food and is therefore an excellent target product category for introducing a reduction in beef consumption. Replacing the burger patty with one that is plant-based and more climate friendly will drastically reduce the GHG emissions associated with eating a hamburger. This is not sensorially acceptable to many consumers [10] [11]. In addition, these consumers may also have an affective connection with meat, and therefore the idea of giving up meat in favour of a plant-based alternative is associated with negative emotions [26]. Thus, they continue eating all-meat burgers.

In this study we developed a half meat half plant-based hybrid burger patty to assess whether this would be an acceptable substitution for a beef burger to the general consumer. There is also a considerably reduced climate footprint of the hybrid burger, compared to the beef burger. The

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nutritional composition was comparable to a beef burger, albeit with a slightly lower fat but a higher carbohydrate content and some dietary fibre at 1 g per 100 g of burger patty. Dietary fibre is crucial for optimal bowel health, which may be of importance to some consumers.

The hybrid burger was evaluated both instrumentally and in a consumer survey. The TPA revealed a few significant differences between the hybrid burger and the reference beef burger. A lower Young's modulus together with a slightly lower cohesiveness for the hybrid burger implies a much softer burger, that requires less energy to chew and will be ready for swallowing with fewer chewing cycles than the beef burger. Thirty percent of assessors in the survey prefer a soft burger, as indicated by the frequency of "Soft" checked for the ideal burger, but this will need to be within an acceptable range and not too soft, as 21% checked "Firm" as a preferred attribute for an ideal burger. The moisture related attributes of the burgers showed that the hybrid burger would provide a much juicier mouthfeel than the beef burger, which was also supported by more than half of the assessors checking "Juicy" for the hybrid burger. Juiciness is the most desired attribute, with an 82% checked frequency for an ideal burger. The improved juiciness of the hybrid burger is a result of the lower observed cooking loss, which translated to more moisture released during mastication, in line with the higher expressible moisture measurement. The underlying molecular mechanism is likely the lower content of connective tissue in the form of collagen in the hybrid burger, and possibly also the water holding properties of the added extruded pea starch. Loss of moisture during cooking is largely a result of collagen contraction due to heat [27], and since the hybrid burger contains less meat and therefore less collagen, less moisture is expelled.

In the CATA questionnaire the assessors were asked to choose between 20 different descriptive terms to check, depending on whether they regarded them as applicable for the burger they were tasting. The significantly different use of the terms for the hybrid and beef burgers indicate that they were perceived as unlike each other, presumably owing to the textural and moisture related differences discussed above. However, there were also taste and flavour related characteristics that differed, like "Meat flavour", "Spicy", "Salt", and "Off flavour". Thus, it is evident that the hybrid burger is not an indistinguishable replacement for a beef burger, however, it could be an acceptable one, as judged by the overall liking score, which was the same for the two burgers. The different use of the CATA terms is also illustrated by the correspondence analysis, where the burgers, including the ideal burger, are clearly separated, and associated with different terms. The ideal burger is associated mostly with "Pink", "Spicy", "Salt", "Juicy", "Fat", and "Crust", which can therefore be viewed as important attributes for a burger patty, among the assessors in the present survey. To assess this further we performed a penalty analysis to learn which attributes should be prioritised when developing a burger patty. The penalty analysis corroborated the previous results that pointed to "Spicy", "Juicy", and "Salt" as important attributes, but also "Meat flavour" which incurred the largest penalty when absent. Based on this, and since the hybrid burger was already favourably evaluated in juiciness, effort should be put into enhancing spiciness, saltiness, and meat flavour to accommodate consumer preferences.

An interesting question to ask could be whether it is a specific type of consumer that embraces a product like the hybrid burger, and if so, what separates them from other consumers. In an attempt at answering this question we conducted a cluster analysis using the CLUSCATA hierarchal algorithm resulting in two separate clusters of assessors. The clustering is carried out solely on the use of the CATA terms in the survey, and therefore also provides some insight to the question of whether there is a connection between term usage and liking. Cluster 2 assessors liked both burgers more than cluster 1 assessors and preferred the hybrid over the beef burger. Cluster 2, in contrast to cluster 1, trended towards being composed of more women than men. Historically, eating meat has been associated more with masculinity than femininity [28], which may help to explain this observation. Furthermore, Bush and Clayton recently reported that there is a significant gender difference in attitudes toward climate change [29], which is more pronounced in high income countries. They showed a clear correlation between a country's GDP and the gap between women's and men's perceived seriousness of climate change, with women being more concerned than men. Even though the burgers were presented blind, only labelled with three-digit codes, it is likely that

some assessors were able to guess which was the hybrid and which was the beef burger, which may then have influenced their attitude towards them. The correspondence analysis of the term usage shows a distinctly different pattern in the two clusters. In cluster 1 the hybrid burger is more associated with terms that have a negative impact on liking, whereas in cluster 2 the association with more positive or neutral terms was stronger. Along with the penalty analysis this serves to underpin an apparent connection between term usage and overall liking of the burgers.

Potential weaknesses of the study are mainly associated with the consumer survey. Firstly, for logistical reasons it was not possible to prepare the burger patties on site, which meant they had to be cooked in advance, then frozen and subsequently thawed and reheated at the expo were the survey was carried out. Nevertheless, this method is also used in fast-food restaurants in Denmark. In addition, in order to comply with food safety regulations, they were cooked to an internal temperature of no less than 75 °C, which may be somewhat higher than what some consumers would prefer regarding colouring, texture and mouthfeel. However, the two burgers received identical treatments so whatever negative effect the above may have had would be the same for both.

In conclusion, the trend towards a more plant-forward diet as a tool for climate change mitigation has shown signs of stagnation. This may reflect a dissatisfaction with the sensory quality of plant-based meat alternatives among the consumers who have not embraced the trend. In addition, meat has been a staple in the diet throughout life for many, and so there is an emotional attachment that is difficult to disregard. Therefore, we hypothesised that a hybrid burger might be a lower threshold change of habitual diet for this consumer segment. We have demonstrated that it is indeed possible to make a hybrid burger patty that, although different in its textural and sensory properties, consumers found overall as acceptable as a reference beef burger. The climate footprint, expressed in CO2-eq, is also substantially reduced in the hybrid burger. Our observations point to spiciness, saltiness, and meat flavour in particular as critical targets in the development process towards a higher acceptability of a hybrid plant/meat burger patty.

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