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# ASSESSMENT OF THE IMPACT OF PLANT BASED MEAT ALTERNATIVES ON CONSUMER HEALTH & ENVIRONMENT

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## Abstract

The increased scrutiny of meat production and consumption practices, primarily in Western societies, has resulted in growing awareness regarding the environmental and health implications associated with these practices. Meat production, despite being a significant contributor to global greenhouse gas emissions and utilizing vast land resources, provides less than 20% of total calories and 40% of protein.This study examines the nutritional, consumer, and environmental aspects of plant-based meat alternatives (PBMAs). It highlights the emergence of innovative substitutes, such as fungal-based mycoproteins, which exhibit promising nutritional profiles and reduced environmental footprints compared to conventional meat. Further, it investigates the nutritional differences between PBMAs and traditional meat products, revealing significant variations in protein content, amino acid concentrations, and bioavailability.

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The research objectives encompass nutritional comparison, consumer perception, and environmental sustainability. By providing comprehensive insights into the evolving landscape of alternative protein sources, the study informs stakeholders and guides decision-making in food production and consumption, contributing to the broader discourse on sustainability and health-conscious diets.

**Keywords:** Mycoprotein, consumer perception, nutritional profile, Meat Substitutes, Dietary Trends

## Introduction

In recent years, meat production and consumption practices have come under increasing scrutiny, particularly in Western societies (Kumar et al., 2022). This heightened criticism stems largely from a growing awareness among consumers regarding the environmental implications associated with agricultural production (Caputo et., 2022). Global per capita meat consumption has surged over the past decades, with individuals consuming an average of 43 kg of meat in 2014, compared to just 20 kg in 1961. However, this rise in meat consumption comes with significant environmental costs. Meat production utilises nearly half of the habitable land and contributes to over a quarter of global greenhouse gas emissions,despite providing less than 20% of total calories and less than 40% of total protein (Bager, 2021).

The environmental impact of animal agriculture extends beyond greenhouse gas emissions and land use, encompassing issues such as freshwater consumption, deforestation, eutrophication, and biodiversity loss (McMichael et al., 2023). Furthermore, excessive meat consumption has been linked to adverse health effects (Afshin et al., 2017). While meat has historically been a central component of human diets, emerging evidence suggests that excessive meat consumption may pose significant risks to human health. This heightened awareness of the health concerns associated with meat consumption has prompted individuals, researchers, and public health organisations to reevaluate dietary choices and explore alternatives to traditional meat products. In response to these concerns, there has been a growing interest in exploring innovative food and meat alternatives as potential solutions to mitigate environmental impact and promote healthier dietary choices (Aune, 2017).

Conscious consumers are increasingly mindful of the consequences of their dietary choices, with many opting to avoid meat products perceived to harm the environment, animals, or human health (Lemken et al., 2016). Plant-based protein options, including soy, pea, and wheat-based alternatives, have gained popularity and are now widely available in the market (Boukid, 2021; Onwezen et al., 2021; Curtain & Grafenauer, 2019; Rondoni, Millan, & Asioli, 2021; Wansink et al., 2005). Moreover, emerging sources of protein, such as green biomass and pseudo-cereals, are also being explored (Schweiggert-Weisz et al., 2020). The burgeoning market for plant-based meats reflects this shifting consumer trend, with global sales of meat substitutes reaching 6.7 billion US dollars in 2020 and projected to surpass 35 billion US dollars by 2027 (Statista,

2021).

The realm of meat substitutes encompasses a diverse array of products, ranging from tofu, seitan, and tempeh to vegetable-based processed items like falafel, as well as novel meat analogues meticulously crafted to emulate meat's texture, taste, and appearance (Siegrist & Hartmann, 2019). Among these alternatives, fungal-based proteins, commonly referred to as mycoproteins, have emerged as promising contenders due to their favourable nutritional and physical-chemical attributes (Bryant et al., 2020). Originating from Fusarium Venenatum, mycoprotein gained commercial traction in the 1980s, notably with Quorn, a branded mycoprotein product obtained through the fermentation of fungi spores alongside glucose and other nutrients (Chezan, 2022). Until recently, Quorn maintained a dominant market presence, albeit facing competition in select regions from emerging brands such as Promyc, MyBacon, and MycoFoods (Eternal et., 2022). These products, designed to mimic the taste of meat or remain neutral, offer versatility in various culinary applications, including burgers, nuggets, protein bars, and snacks (Anusha Siddiqui et al., 2023). Consumers' preference for mycoprotein products stems from their high fibre content, low fat, sodium, and sugar levels, and rich essential amino acid profile, coupled with a meat-like texture (Derbyshire, 2019). Moreover, mycoprotein production demonstrates a reduced water footprint and carbon emissions compared to conventional meat production methods (Abdel et al., 2018).

While existing studies highlight consumer perceptions regarding the environmental friendliness of meat and its substitutes, they often examine generic products without visual aids and encompass a limited range of alternatives (Derbyshire & Ayoob, 2019). Consequently, this study aims to investigate consumers' perceptions regarding the environmental friendliness of a diverse spectrum of meat and meat substitute products, potentially influencing dietary choices in the modern market landscape (Bai, 2020).

The objectives of the research encompass three key dimensions: nutritional comparison, consumer perception, and environmental sustainability. By delving into consumer preferences and motivations, the study aims to understand the factors influencing the adoption and consumption of alternative protein sources in the market. Lastly, the research endeavours to assess the environmental impact of plant-based meat production compared to traditional meat production methods. This objective involves evaluating factors contributing to the broader discourse on sustainability and environmental consciousness in the food industry. Through these objectives, the research aims to provide comprehensive insights into the nutritional, consumer, and environmental aspects of plant-based meat alternatives, informing stakeholders and guiding decision-making processes in the evolving landscape of food production and consumption.

## Literature Review

### Nutritional Profiles and Health Impacts of Plant-Based Meat Alternatives

The surge in demand for meat alternatives may stem from heightened awareness regarding the adverse health effects associated with diets high in red and processed meats. This awareness, coupled with growing concerns about the environmental footprint of animal products,

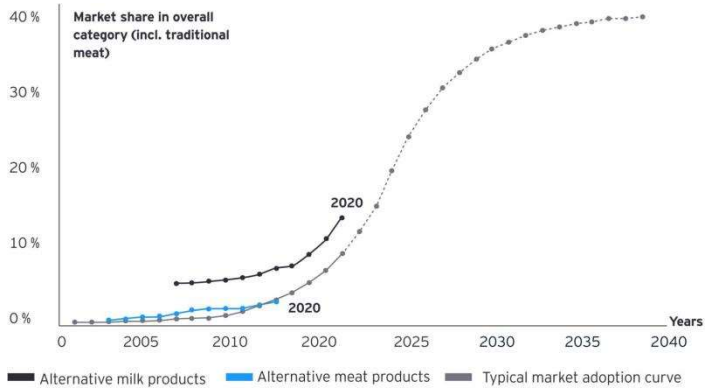
underscores the shift towards sustainable and health-conscious dietary patterns, emphasising plant-based foods with moderate animal product consumption (Banovic, 2021). However, understanding the potential health implications of Plant-Based Meat Alternatives (PBMAs) necessitates a comprehensive analysis of their nutritional characteristics. Meat serves as a primary source of high-quality proteins, iron, vitamins, minerals, and varying levels of saturated fats, contingent upon the meat type (Blackstone et al., 2018). Several studies have scrutinised the nutritional profiles of meat alternatives available in diverse markets, comparing their energy and nutrient compositions with traditional animal meats. These investigations contribute valuable insights into the nutritional quality and health considerations associated with plant-based alternatives, informing discussions on dietary choices and human health outcomes (Bodirsky et al., 2015).

A recent study analysed the nutritional quality of 269 commercial meat analogs available in the Italian market by examining data reported on their food labels. The findings revealed substantial variability in nutritional content among Plant-Based Meat Alternatives (PBMAs), with plant-based steaks exhibiting notably higher protein and lower energy, fat, and salt levels
compared to other plant-based food categories (Boukid, et al., 2021). Interestingly, all PBMAs showed higher fiber content when compared to reference animal meat products. Additionally, plant-based burgers and meatballs demonstrated lower protein content than their meat counterparts, while pre-sliced meat substitutes exhibited lower salt content than cured meats (Bryngelsson et al., 2022).

Similar trends were observed in studies conducted in the US, Sweden, and other European markets. These investigations highlighted lower energy, total fat, and saturated fat content, alongside higher total carbohydrates, sugars, and fibers in PBMAs compared to meat-based products (Busch et al., 2018). However, findings regarding salt content varied. Moreover, while plant-based and meat-based products generally had comparable total protein levels, they exhibited significant differences in the concentrations of individual amino acids. PBMAs were found to contain higher amounts of glutamic acid and cysteine, along with lower levels of alanine, glycine, and methionine (Grasso et al., 2022).

These results underscore the need for further exploration into the use of plant-based protein blends to minimise disparities between plant-based and animal-based meats. Additionally, differences in protein digestibility and amino acid bioavailability between plant-based and animal products were noted, with animal meat displaying higher protein digestibility (Hagmann et al., 2019). This discrepancy may affect the bioavailability of amino acids and emphasises the importance of considering the actual bioavailability of nutrients when assessing the dietary quality of patterns incorporating these products (Hartmann et al., 2022).

**Above figure shows the global market share of the alternative meat products from 2005 till the chances in 2040.**




## The Environmental Impact of Plant-Based Meat Alternatives

Meat, renowned for its high biological value as a protein source, undergoes a conversion process from feed and fodder that may not be sustainable due to resource inputs and utilisation (Baltenweck, 2022). Presently, various farming systems contribute to meat production, with efficiency contingent on factors like feeding, breeds, management practices, and technology (Bonnet et al., 2020). Crop cultivation requires fewer resources per product unit, offering a promising avenue for sustainable development amid escalating food demand (Bossio et al., 2020). Consequently, in developed countries devoid of subsistence animal breeding, Plant-Based Meat Alternatives (PBMAs) could yield environmental benefits, including biodiversity conservation, efficient land and water use, and reduced greenhouse gas (GHG) emissions (Brooker et al., 2022). Despite their potential, assessing the environmental impacts of PBMAs remains essential. The life cycle assessment (LCA) approach has been instrumental in this regard, quantifying product environmental impacts based on ISO 14040 and ISO 14044 standards to enhance environmental performance (Bryant et al., 2022). Several LCA studies have analysed PBMAs to identify production process hotspots and compare environmental performances with animal-based products, considering indicators like climate change, land use, water consumption, and energy utilisation.

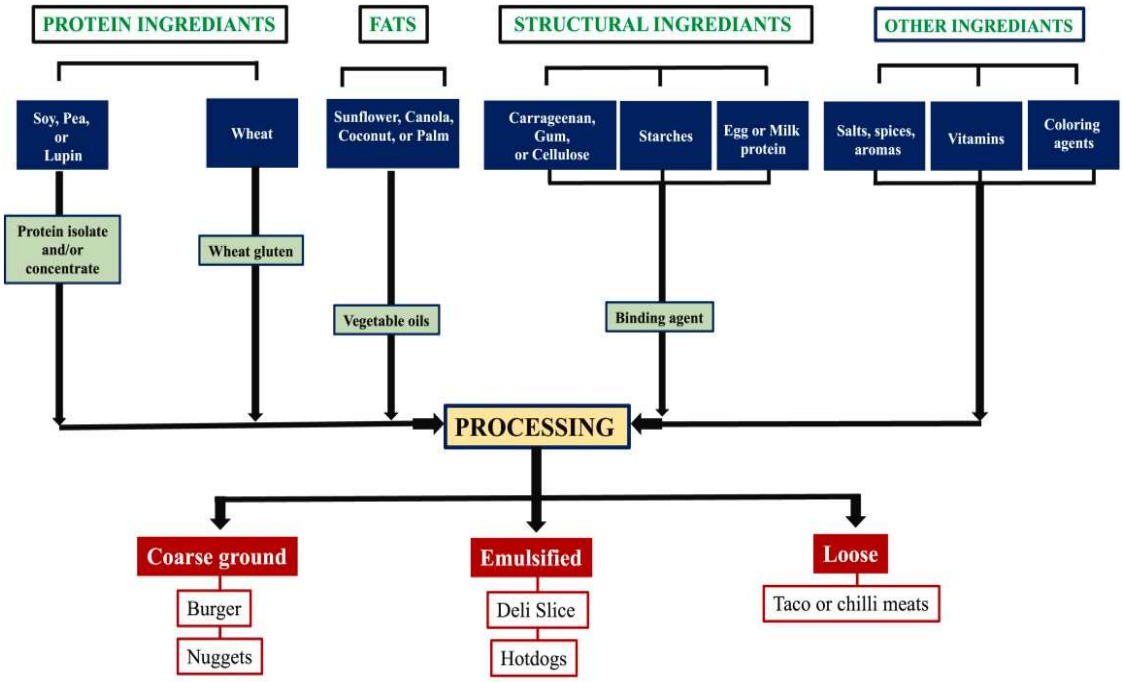
Notably, Bryant's analysis of 43 studies concluded that meat analog production is more sustainable compared to animal products (Cain et al., 2019). Similarly, Detzel et al. emphasised the potential of PBMAs to reduce environmental impacts associated with food consumption by optimising ingredient processing complexities and input requirements (Caparros et al., 2016). However, Smetana et al. highlighted the role of technology, such as machinery and process equipment, in enhancing the sustainability of alternative protein source production (Chriki et al., 2020). Furthermore, a detailed study on three factories producing 57 different meat analogs achieved low GHG emissions, primarily attributed to the manufacturing process and agricultural production of food ingredients (Chang et al., 2019). Despite the significant environmental impact of fossil-based electricity consumption during production, alternative energy solutions could help mitigate the impact (Clark et al., 2020).

## Consumer Behavior of Plant-Based Meat Alternatives

In the domain of meat alternatives, despite advancements in technology and attempts to craft processed plant-based products from various sources, a significant hurdle in replacing animal products with plant-based ingredients lies in replicating similar sensory properties of meat. Additionally, effective communication about these new products and individual attributes (e.g., attitudes and demographics) should be considered during the marketing phase, particularly in countries where meat and meat-based products hold significant cultural and culinary importance (Clark et al., 2016). Thus, both sensory and consumer science play pivotal roles in understanding how consumers perceive Plant-Based Meat Alternatives (PBMAs), including the drivers and barriers to their acceptance.

Previous research has demonstrated that perceived sensory attributes and consumer acceptance are heavily influenced by the selection of plant/protein sources (Clark et al., 2020). Consequently, the choice of ingredients to substitute for meat is a critical factor in the development of meat alternatives (Crimarco et al., 2022). Early product iterations aiming to mimic processed meat products, such as those derived from mycoproteins, have faced challenges in achieving sensory acceptance in terms of taste and texture (Cutroneo et al., 2022). This has led to a reluctance among meat eaters to embrace such products as genuine meat substitutes (Dagevos et al., 2021). Historically, the first generation of these products primarily targeted vegetarians and vegans (Detzel et al., 2022). To garner wider acceptance among meat eaters, the new generation of PBMAs must closely resemble the texture, appearance, aroma, and taste of authentic meat products, both before and after cooking (De Marchi et al., 2021). However, replicating the intricate sensory profile of farmed meat presents challenges (Eckl et al., 2021). For example, the color of plant-based products may fade due to light or oxygen exposure, while taste may be affected by lipid oxidation, resulting in undesirable characteristics (Elzerman et al., 2011). Given that appearance is typically the initial aspect evaluated, it significantly influences food acceptance. Another obstacle for PBMAs is evoking the flavor of real meat while avoiding undesirable flavors (e.g., bitter, burnt, earthy) caused by high levels of legume protein (Fiorentin et al., 2020). Consequently, mimicking meat characteristics necessitates the use of numerous additives during the development stage (Froldi et al., 2022), often resulting in product packaging containing a lengthy list of unfamiliar ingredients (Godfray et al., 2018). This may convey a sense of processed and unhealthy food to consumers, particularly for high/ultra-processed PBMAs, potentially associating them with unnaturalness (Goldstein et al., 2017). Thus, while bridging the sensory gap between PBMAs and their meat counterparts is crucial for some companies, the concept of product acceptance extends beyond sensory appreciation to encompass consumer perceptions. For instance, limited product familiarity with PBMAs, including the preparation and cooking methods, ranks among the most significant factors affecting consumer acceptance and may hinder mainstream market expansion. Therefore, comprehensively understanding consumer acceptance of PBMAs necessitates direct consumer experience (Gorissen et al., 2018).

**For example: Formulating the plant-based meat analogs**




**Above figure shows the schematic analysis of the processing of plant based alternatives and the products made from them.**

MATERIAL & METHODS

**Data Collection**

To ensure the sample's representativeness with regards to age and gender, quotas were established for participants from Lahore, Pakistan. Due to varying levels of internet accessibility across demographic groups, the sample may have a bias towards individuals with higher incomes and residing in urban areas. Participants below 18 years old, those who did not provide consent, failed attention check questions, or were duplicate entries were excluded from the study. The final sample size consisted of 20 individuals. Participants were asked to rate their attitudes towards conventional meat using 5-point semantic differential scales across different attributes (Megkos et al., 2020). Demographic information, including age, gender, education, and income, was collected from participants (Kerslake et al., 2022).

**Design criteria and the description of the study is given below:**

| **Design Criteria** | **Description** |
|---|---|
| Target group | Interested consumers, non-food professionals and food professionals. |
| Aim of the study | To investigate consumer attitudes, perceptions, and acceptance of plant-based meat alternatives. |

| | |
|---|---|
| Data | Scientifically accepted and available data from published peer-reviewed papers. |

**Research design and questionnaire**

For my research, I conducted a survey to gather fresh data and understand the relationship between different factors. I chose to do this survey at one point in time, making it a cross-sectional study. Online surveys were ideal for me because they're cost-effective, allow for self-selection, have wide geographic reach, avoid interviewer bias, and maintain privacy for respondents. I made sure the survey questions were clear, concise, and respectful of privacy. They were mostly multiple-choice questions, which made it easier to analyse using statistical software. I used Likert scales from 1 to 5, where respondents could express their agreement or disagreement with statements.

**Survey questions: specific questions on age, income, hedonic tone, consumption of meat and meat alternatives etc.**

| No | Question | Responses |
|---|---|---|
| 1 | Age | Numbers |
| 2 | Income | Numbers |
| 3 | Gender | Male/Female |
| 4 | Are you aware of plant-based meat alternatives? | Yes/No |
| 5 | How often do you currently consume plant-based meat alternatives? | Daily, weekly, monthly, rare/never |
| 6 | Plant-based meat alternatives are healthier than traditional meat products. | Likert scale from “Extremely negative” (−5) to “Extremely positive” (+5) |

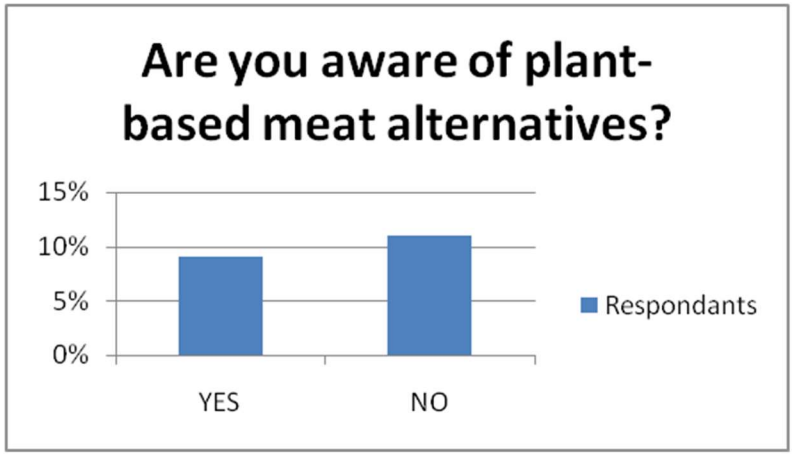
| | | |
|---|---|---|
| 7 | Plant-based meat alternatives are environmentally friendly. | 5 Point scale |
| 8 | I believe plant-based meat alternatives can taste as good as traditional meat products. | 5 Point scale |
| 9 | I am concerned about the environmental impact of traditional meat production. | 5 Point scale |
| 10 | What factors would make you more likely to try plant-based meat alternatives? | Taste, lack of availability, price, health risk, cultural issues |
| 11 | What types of plant-based meat alternatives would you be most interested in trying? | Burger, sandwich, sausage, grounded meat, nuggets, others |
| 12 | How closely do you think plant-based meat alternatives resemble traditional meat products in terms of taste and texture? | 5-point scale from very closely to not at all closely |

The survey questionnaire encompasses a comprehensive exploration of respondents' perceptions, attitudes, and behaviors towards plant-based meat alternatives. It begins by collecting basic demographic information, including age, income level, and gender. Subsequently, respondents are probed regarding their awareness and consumption habits regarding plant-based meat alternatives, with questions addressing both their awareness of these alternatives and the frequency of their consumption. The survey delves deeper into respondents' attitudes towards plant-based meat alternatives, prompting them to rate their agreement with statements regarding the healthiness and environmental friendliness of such products, as well as their belief in the taste parity between plant-based and traditional meat products. Moreover, respondents are asked to express their concerns about the environmental impact of traditional meat production. Understanding the factors influencing consumption is also a key aspect of the survey, with respondents given the opportunity to select various factors that would make them more likely to try plant-based alternatives, as well as indicating the types of alternatives they would be most interested in trying. Lastly, respondents are asked to assess the resemblance of plant-based

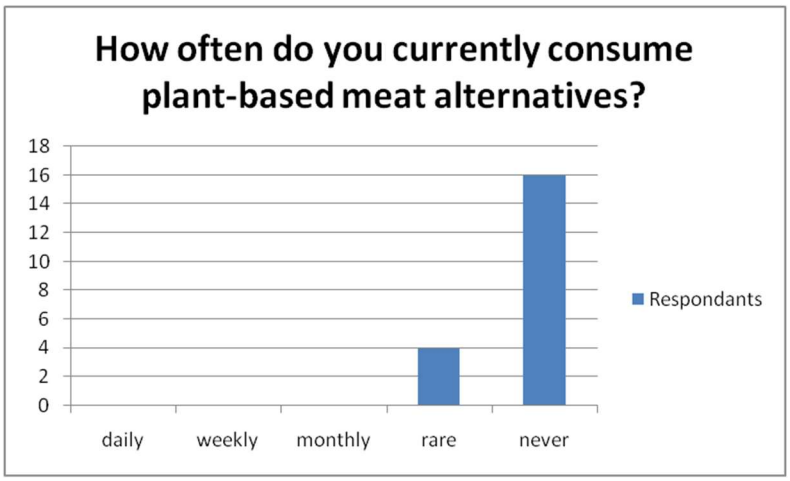
alternatives to traditional meat products in terms of taste and texture. This comprehensive approach aims to capture a nuanced understanding of respondents' attitudes and behaviours regarding plant-based meat alternatives, providing valuable insights into consumer preferences and considerations in the realm of alternative protein sources.

General analysis

Initially, I shared the survey with my friends, family, and colleagues. When the responses weren't enough, I reached out to broader audiences through social media groups and asked students from different universities to participate. After collecting responses, I downloaded the data from Google Forms in Excel format, which I could then analyse using SPSS Statistics software. I used descriptive statistics to analyse the demographic data. This type of analysis helps me understand the characteristics of the data by providing short summaries and measures. In total, I received 20 responses from the questionnaire, and all of them were valid, with a 100% completion rate. Below, I'll discuss the results of some of the answers collected from the respondents.



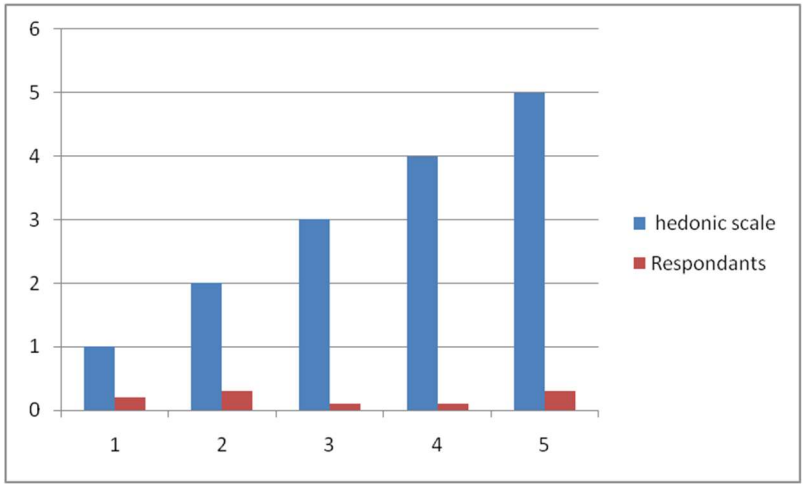

The data from the survey question "Are you aware of plant-based meat alternatives?" indicates that 9% of respondents answered "Yes" while 11% responded "No". This suggests that a minority of the surveyed population is aware of plant-based meat alternatives, with a slightly larger portion indicating a lack of awareness. The variation in awareness levels could stem from factors such as regional availability, individual dietary preferences, and exposure to marketing campaigns promoting plant-based products. The disparity between those aware and unaware underscores the need for broader education and outreach efforts to increase awareness and understanding of plant-based meat alternatives among consumers, potentially fostering greater adoption of sustainable and alternative protein sources in the future.




This distribution indicates that the majority of respondents, comprising 16 out of 20 individuals (or 80%), report never consuming plant-based meat alternatives. Additionally, 4 respondents (or 20%) state that they rarely consume plant-based meat alternatives. There is no reported consumption on a daily, weekly, or monthly basis according to the given data.

The data suggests that plant-based meat alternatives may not be a significant part of the regular dietary choices for the majority of respondents. The low frequency of consumption, with a large proportion reporting never consuming such alternatives, indicates either a lack of interest or availability, or a preference for traditional meat products among the surveyed individual (Heller et al., 2020).

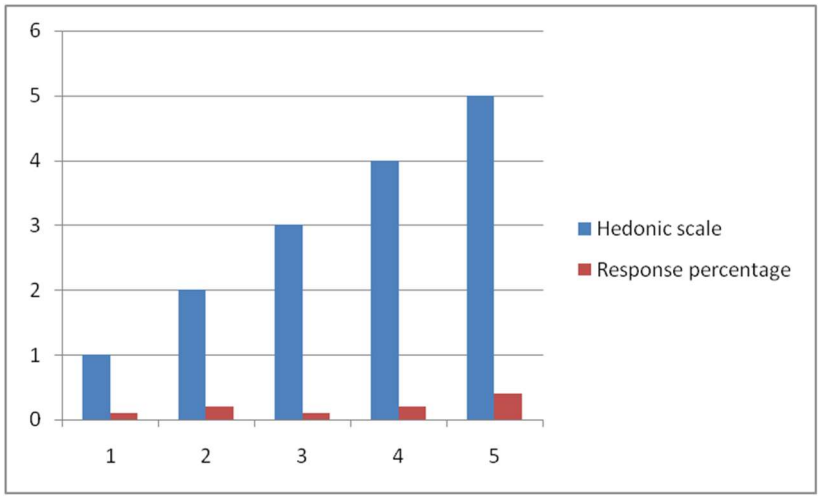
**Plant-based meat alternatives are healthier than traditional meat products.**



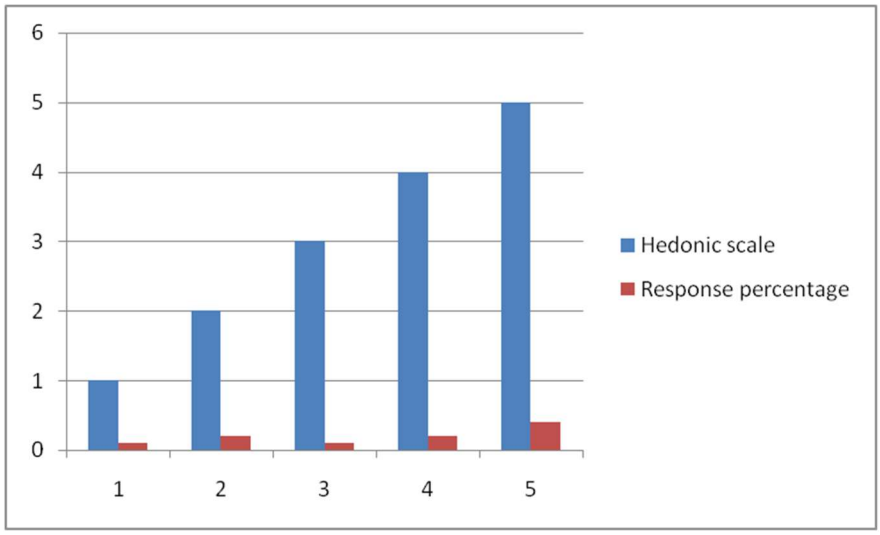

The response distribution to the statement "Plant-based meat alternatives are healthier than traditional meat products" on a hedonic scale portrays varying attitudes among respondents. With 20% expressing strong disagreement and 30% disagreeing about the healthiness of plant-based alternatives is evident. However, 30% strongly agreeing and 10% agreeing indicate a sizable cohort perceives plant-based alternatives as notably healthier. Meanwhile, 10% offering neutral responses suggests uncertainty or lack of clarity. These results underscore a mixed landscape of

perceptions regarding the health benefits of plant-based meat alternatives, highlighting the need for further exploration into consumer attitudes and preferences regarding alternative protein sources in comparison to traditional meat products.

**Plant-based meat alternatives are environmentally friendly.**




**Plant-based meat alternatives can taste as good as traditional meat products.**




**Analysis Plan**

We employed a two-way ANOVA using the respondents' gender and consumer segment as fixed factors (independent variables) in order to study the quantitative variables as appropriate. A full factorial model was run first and the significance of the gender×segment interaction was observed. If the interaction was nonsignificant, the interaction term was left out of the model and the results were reported based on the model including only the main effects. Furthermore, if the main effect of the segment was significant, Tukey's post hoc test was applied to reveal

which of the segments differed from the others.

The primary analysis involves comparing outcome measures across countries and modelling factors influencing acceptance within each country. To compare outcomes, we'll employ two-way between-groups ANOVAs, assessing significant differences in key acceptance measures among all factors. Additionally, we'll examine pairwise differences between each factor, focusing on willingness to try clean and plant-based meat, along with willingness to buy regularly and replace conventional meat. Statistical significance will be determined at $p <$ .05. For modelling factors affecting acceptance within countries, linear regressions will be utilised to assess the impact of demographic factors, perceptions, meat attachment, and food neophobia on willingness to try clean and plant-based meat. Each variable will be deemed a significant predictor of acceptance if $p < .05$.

**Results**

The regression analysis results indicate a statistically significant relationship between age and responses concerning plant-based meat alternatives. With a multiple correlation coefficient (Multiple R) of 0.653 and a coefficient of determination (R Square) of 0.427, age accounts for approximately 42.7% of the variance in responses. The overall regression model is significant ($p = 0.0024$), suggesting that age significantly predicts attitudes and behaviours related to plant-based meat alternatives. Specifically, the coefficient for age (X Variable 1) is positive and statistically significant ($p = 0.0024$), indicating that as age increases, respondents' attitudes and behaviours towards plant-based meat alternatives tend to become more positive or varied. The standardised coefficient estimate suggests that for every one-unit increase in age, there is a corresponding increase in the response related to plant-based meat alternatives. These findings underscore the importance of considering age as a significant predictor when examining consumer preferences and behaviours in the context of alternative protein sources, providing valuable insights for market segmentation and targeted marketing strategies.

Hence proved that, H1: There is a slightly significant difference in the nutritional content between plant-based meat alternatives and traditional meat products.

H2: Consumer acceptance of plant-based meat alternatives is influenced by taste & price.

H3: Plant-based meat production has a similar environmental impact to traditional meat production.

Discussion

The study sheds light on various facets of consumer attitudes and behaviors towards plant-based meat alternatives, offering valuable insights and implications. Despite the low awareness levels and infrequent consumption reported among respondents, there exists a diverse range of perceptions regarding the healthiness and viability of plant-based alternatives compared to traditional meat products (Rock et al., 2020). These findings underscore the importance of

targeted educational campaigns and increased accessibility to foster greater acceptance and uptake of plant-based options among consumers. Moreover, the significant relationship observed between age and attitudes towards plant-based alternatives emphasizes the need for nuanced marketing strategies tailored to different demographic segments. By addressing barriers, dispelling misconceptions, and aligning product offerings with consumer preferences, companies can capitalize on the burgeoning demand for sustainable and alternative protein sources, ultimately contributing to positive environmental and public health outcomes in the marketplace (Lusk et al., 2020).

Conclusions

Our analysis of survey data, gathered from a representative sample reveals that the hedonic associations with meat versus plant-based meat alternatives (positive-negative) are not solely unidimensional. Instead, they manifest as two-dimensional phenomena that facilitate easy consumer segmentation (Kerslake et al., 2022). While some respondents' hedonic associations with meat alternatives oppose those with meat, this pattern isn't universal among all participants. Interestingly, certain individuals express positive sentiments towards both meat and meat alternatives, while others maintain a neutral stance on both food categories. Through a classification process based on two simple questions, we identified six distinct consumer segments. This segmentation not only distinguishes individuals who advocate for either meat or vegetarian diets exclusively but also those with favorable attitudes towards both meat and meat alternatives. This study provides critical insights into consumer attitudes and behaviors towards plant-based meat alternatives. By understanding consumer preferences and addressing key barriers, companies can capitalize on the growing demand for sustainable and healthy food options, ultimately contributing to positive environmental and public health outcomes. This study needs more research and evaluation in terms of consumer responses or behavior towards plant based meat alternatives on a broader level with more samples.

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