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Exploring consumer acceptance of grass-derived proteins in the UK: A structural equation modelling approach

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ABSTRACT

Grass-derived proteins, as a novel and sustainable source of nutrition, offer potential solutions for food security and environmental sustainability but face challenges in consumer adoption. This study investigates the factors influencing consumer acceptance and intentions to consume grass-derived proteins in the United Kingdom using a Structural Equation Modelling (SEM) approach to capture the complex relationships among psychological, social, and product-related variables. Data were collected via a cross-sectional survey of 990 participants, capturing attitudes, subjective norms, perceived behavioural control, facilitators and food neophobia. The findings reveal that facilitators such as perceived health benefits, nutritional value, and safety significantly enhance consumer willingness to adopt grass-derived ingredients. Further, negative attitudes reduce positive attitudes towards meat preferences which in turn leads to positive intentions to consume grass-derived proteins. A multigroup analysis of the meat avoiders-reducers and regular meat consumers reveals different pathways influencing their behavioural intentions. Facilitators emerge as the strongest predictors of intention for both groups, but differences in the strength of pathways underscore the need for tailored marketing and policy interventions. For avoiders-reducers, direct pathways from facilitators to intention dominate, while indirect pathways involving attitudes towards meat hold minimal influence.

Conversely, meat consumers exhibit stronger resistance tied to cultural perceptions of grass-derived products. These findings suggest emphasizing strategies to enhance consumer familiarity and address sensory concerns while leveraging the environmental and health benefits of grass-derived proteins. By addressing group-specific drivers and barriers, these efforts can foster broader acceptance of sustainable food innovations, contributing to global goals for food security and environmental sustainability.

1. Introduction

The global population, currently around 8 billion, is projected to reach 10 billion by 2050 (Ehrlich & Harte, 2015; Nadathur et al., 2024). With a larger and aging global population, the demand for protein, an essential nutrient for health and development, is set to increase significantly (Smith et al., 2024). This rising demand is also influenced by shifting consumer preferences towards natural and sustainable products, as health awareness, environmental, and ethical concerns grow (Kim & Lee, 2023). Additionally, the popularity of flexitarian, vegetarian, and vegan diets is expanding, often motivated by ideological, ethical and environmental concerns about traditional meat production fuelling dietary shifts seeking waste-free and sustainable goods to reduce environmental footprints (Sanchez-Sabate & Sabaté, 2019; Strässner & Wirth, 2024).

To meet these changing consumer demands, new protein sources are needed to support a healthier and more sustainable diet. Plant-based proteins, in particular, have emerged as a viable alternative to meat (Kumar et al., 2022). Consuming plant-based proteins directly can significantly reduce environmental impact and water usage, as

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converting plant proteins into animal proteins is largely inefficient (Kumar et al., 2017; Thavamani et al., 2020). The concept of using green leaves as protein sources dates to World War II when scientists began exploring them as alternative nutrition sources during food shortages (Pirie, 1942). By the mid-20th century, research on extracting soluble proteins from green leaves, such as spinach, gained momentum, with studies highlighting their potential as nutrient-dense, plant-based proteins (Barbeau & Kinsella, 1988; Wildman & Bonner, 1947). Recently, this interest has expanded to include grasses like ryegrass (*Lolium* spp.) and moor grass (*Molinia caerulea*), which have also shown promise as protein sources (Mumbi et al., 2024; Olalere et al., 2024). The use of these grasses presents a particularly sustainable option, as they leverage an underutilized resource that can be cultivated in multiple climates with minimal environmental impact. By utilizing this abundant resource, grass-derived proteins could help address global protein shortages, reduce the environmental strain associated with traditional animal-based protein production, and meet consumer demand for sustainable options while contributing to the plant-based options that exist in the market. Given the potential of grasses as sustainable protein sources, the UK's extensive grasslands offer an abundant and promising resource. Grasslands account for approximately 40 % of the UK's land area, equating to around 10 million hectares (UK National Ecosystem Assessment, 2011). The country's temperate climate, with moderate temperatures and consistent rainfall, supports these widespread grasslands, making them one of the UK's most prevalent land types (The Wildlife Trusts, n.d.). The abundance, nutritional profile, and potential for lower environmental impact, offer to make UK grasses a sustainable option (Olalere et al., 2024).

Grass-derived ingredients, further termed as novel foods represent an emerging food category in the food industry with the potential to address food security. They include various food ingredients such as protein, carbohydrates and vitamins derived from grasses such as wheatgrass, barley grass, and lemongrass (Lopez et al., 2022; Olalere et al., 2024; Qamar et al., 2018). From a nutritional perspective, grass-derived ingredients offer several health benefits, positioning them as attractive components in sustainable diets. Grass proteins, such as those derived from wheatgrass, barley grass, and lemongrass, are rich in essential amino acids, antioxidants, vitamins (such as vitamins A, C, and E), and minerals (including calcium, magnesium, and iron) that support overall health and well-being. The high chlorophyll content in many grass-based products also offers potential detoxifying benefits, promoting cellular health and improved digestion. Additionally, these ingredients are naturally low in fat and cholesterol, aligning well with dietary trends focused on heart health, weight management, and general wellness (Kumar et al., 2022; Mumbi et al., 2024; Olalere et al., 2024). Grass-derived ingredients from grasses such as barley and alfalfa have become popular as dietary supplements and in functional foods with barley grass powder market projected to reach USD 1.54 Billion by 2030 (Verified Market Reports, n.d.). On the other hand, grass derived ingredients from ryegrass are still emerging in the marketplace with an indication that they may provide a promising alternative due to the increased demand for sustainably produced plant-based options in the global plant-based protein market.

As novel foods, these grass-derived ingredients are relatively unfamiliar to consumers, who may have limited knowledge about their nutritional benefits and environmental advantages. For these ingredients to make a meaningful impact, widespread consumer acceptance is essential as suggested by Mumbi et al. (2024). To avoid unnecessary rejection of innovations, or to avoid investing in innovations that are inherently unacceptable to the public, it is vital to include consumer insights into the innovation process early during the product development stages (Van Kleef et al., 2005). More specifically, we need insight into (a) the relevant perceptions of consumers in the context of food innovations and how they combine towards a final response and (b) the products in which this innovation is applied (Frewer et al., 2014; Ronteltap et al., 2007). This also implies that consumer perceptions must be measured reliably (Churchill, 1979; Onwezen et al., 2021). Both these requirements are complicated by the fact that perceptions and decisions are in the mind of the consumer and cannot be observed directly.

Although limited research exists on consumers' willingness to consume food containing grass protein, extensive studies on consumers' incentives to adopt novel foods and the factors driving this adoption exist and can provide valuable insights into the potential factors that may influence the acceptance of grass-derived proteins and ingredients. For example, the systematic review on consumer acceptance of alternative proteins developed by Onwezen et al. (2021) consisting of 91 published articles in the subject area found that relevant drivers of acceptance or rejection correspond to psychological factors, product-related attributes, and interventions.

According to Onwezen et al. (2021), psychological factors have been explored considering the components of the Theory of Planned Behaviour (i.e. attitudes, subjective norms and perceived behavioural control) and food neophobia. According to the Theory of Planned Behaviour (TPB, as developed by Ajzen, 1985), intention is a good predictor of behaviour and is determined by positive or negative beliefs that an individual has that can be considered as attitudes (i.e., positive or negative attitude towards a behaviour), subjective norms (i.e., the influence of important referent individuals or institutions when approving or disapproving a particular behaviour), and perceived behavioural control (i.e., an individual's conviction that they will successfully execute a behaviour leading to a particular outcome). The theory postulates that the balance of the beliefs related to attitudes, subjective control and perceived behavioural control are what determines a positive or negative intention towards a particular behaviour. This approach, or some of its components, has been adopted to explore consumers' psychological incentives to eat meat alternatives. For example, Marcus et al. (2022) found that only attitude and subjective norms are relevant determinants of German consumers' behavioural intention to eat meat alternatives suggesting that beliefs about these alternatives and the influence of people that form part of the social network of the consumers are relevant drivers of this behaviour. In contrast, Seffen and Dohle (2023) found that all the components of the TPB explain German consumers' incentives to reduce the consumption of meat. This means that perceived behavioural control is also a potential driver of grass-derived protein consumption.

For the current research, attitudes have been split into three categories that may affect consumers' intention to try grass-derived ingredients. One of them is positive attitudes towards meat, and it is included because consumers who like eating meat and have positive beliefs about the consumption of meat are less likely to have an intention to try grass-derived protein. The second category is positive attitudes towards grass-derived protein, and it is argued that people in this group have more incentives to consume grass protein foods. Finally, the last category is negative attitudes towards grass protein, and it is argued that consumers who have these attitudes are less likely to try grass-derived protein. It is also argued in this article that positive attitudes towards beef are related to negative attitudes towards grass protein. That is, people who believe that meat is a better source of protein may feel that alternative vegetarian proteins are not good enough, and vice versa. This is supported by previous studies establishing that consumers who maintain strong positive beliefs about meat often exhibit resistance to alternative proteins due to perceived inferiority in taste, nutritional value, and cultural significance (Graça et al., 2015; Ruby, 2012). Therefore, it is posited that favourable attitudes towards meat may inversely relate to openness towards grass-derived proteins.

These ideas are summarised in the following hypotheses.

H1: Favourable attitudes towards the consumption of meat negatively affect a consumer's behavioural intention to consume food with grass protein.

H2: Favourable attitudes towards the consumption of food with grass-derived proteins positively affects a consumer's behavioural

intention to consume this food.

H3: Negative attitudes towards the consumption of food with grass-derived proteins negatively affects a consumer's behavioural intention to consume this food.

H4: Favourable attitudes towards the consumption of meat are related to consumer's attitudes towards the consumption of food with grass-derived proteins.

Regarding subjective norms, it is likely that people who form part of the social network of a particular consumer group will influence their perceptions about eating food with grass protein. It is argued that these people can influence consumers' attitudes towards this food, and on their intention to buy it. This is captured in the following hypotheses.

H5: Favourable attitudes towards the consumption of grass-derived proteins are influenced by social norms.

H6: Negative attitudes towards the consumption of grass-derived proteins are influenced by social norms.

H7: Social norms influence the intentions of individuals to buy food/ingredients with grass-derived proteins.

Finally, following the assumptions of the TPB, consumers perception of their ability to perform the behaviour of trying food with grass-derived proteins (i.e. perceived behavioural control) are more likely to try this food. This is represented in this hypothesis.

H8: A high perceived behavioural control over consuming grass-derived proteins positively affects a consumer's behavioural intention to consume this food.

In relation to food neophobia, on the other hand, it corresponds to the fear of trying new food. This driver has been identified as a relevant factor in preventing consumers from consuming less conventional proteins such as insects, because they believe that eating insects is disgusting and potentially harmful (Barton et al., 2020). This type of rejection has also been found in other types of novel foods (Tuorila & Hartmann, 2020). It is also argued in this article that neophobia not only affects intention but also consumers' attitudes towards food with grass protein. In considering these observations, the following hypotheses are proposed in this study with H9 focusing on the presence of explicitly negative attitudes and H10 focusing on the absence of favourable attitudes.

H9: Consumers with higher food neophobia are more likely to express more negative attitudes towards the consumption of foods with grass-derived proteins.

H10: Consumers with higher food neophobia are less likely to express favourable attitudes towards the consumption of foods with grass-derived proteins.

H11: Consumers with higher food neophobia are less willing to eat food with grass-derived proteins.

Product-related attributes play a critical role in shaping consumer willingness to try novel food proteins (Akinmeye et al., 2024). Product-related attributes, as defined by Onwezen et al. (2021), also include external factors such as product-related contributions and non-psychological factors. As such in this study we refer to them as facilitators, which encompass specific qualities including external factors that can increase the appeal of grass-derived foods. They include factors such as taste, health benefits, and environmental consciousness (Moons et al., 2018; Orkusz et al., 2020). In studies on plant-based and alternative proteins, consumers have reported hesitancy to adopt products perceived as bland or having a "grassy" taste, suggesting that flavour and texture innovations are essential for acceptance (Birch et al., 2019). Health benefits especially those related to weight control are another crucial factor common among people who consume diets that include vegetable proteins, in relation to people who include a large proportion of red meat in their diet (Vainio et al., 2016). Further, findings have also revealed that consumers who care about protecting the environment are more motivated to reduce their consumption of meat (Dean et al., 2024; Gómez-Luciano et al., 2019). For example, Malek et al. (2019) argue that the production of meat contributes to climate change, and consumers who are aware of this negative effect are more willing to reduce or replace their consumption of meat. Another important factor is familiarity, which pertains to whether individuals have prior experience of consuming the new food. i.e. consumers who have tried alternative sources of protein are more likely to try them again (Birch et al., 2019; Melendrez-Ruiz et al., 2019; Varela et al., 2022). Facilitators may also affect consumers' beliefs about their ability to control the behaviour of trying grass protein food, and consumers' attitudes towards the consumption of food with grass protein. These facilitators include elements such as perceived taste and health benefits. In considering these motives, the following hypotheses are proposed.

H12: Consumers are more willing to accept food with grass protein when they are influenced by facilitators of these foods.

H13: Perceived behavioural control is positively affected by facilitators.

H14: Positive attitudes towards food with grass-derived proteins are positively affected by facilitators.

In relation to interventions, they are related to external strategies that can induce the consumption of novel foods. For example, lower prices for alternative food protein can incentivise consumers to purchase this food when comparing the prices of traditional meat (Berger et al., 2018). Likewise, more information about the production, processing, safety and availability of new sources of proteins could represent a facilitator that positively affects attitudes towards the consumption of these proteins (Cavallo & Materia, 2018). While these ideas can be represented as isolated factors, they may also be considered as part of facilitators. Therefore, they are implicitly included in the hypotheses that consider these constructs (Barton et al., 2020; Onwezen et al., 2021). The proposed hypotheses have been used to design a theoretical framework for consumers' willingness to consume food with grass proteins which is presented in Fig. 1. This illustrates the proposed theoretical and conceptual framework of the study, detailing the relationships among key constructs influencing consumer intentions to adopt grass-derived proteins, including positive and negative attitudes, subjective norms, perceived behavioural control, facilitators and food neophobia. The framework captures both direct and indirect pathways to highlight the complexity of consumer decision-making in this context.

Additionally, the increasing global emphasis on sustainable and ethical food consumption has shed light on the diverse behaviors and preferences among consumer groups, particularly in relation to meat consumption. These groups can generally be categorized into regular meat consumers and meat avoiders-reducers with empirical studies consistently highlight the contrasting priorities and behaviors between these two groups (Hoek et al., 2011; Lang & Lemmerer, 2019; Mumbi et al., 2024; Verain & Dagevos, 2022). Meat avoiders-reducers actively limit or abstain from meat consumption, often motivated by concerns about environmental sustainability, personal health, and animal ethics, regular meat consumers tend to maintain a higher reliance on meat, driven by factors such as taste satisfaction, ingrained cultural practices, and the convenience of meat-based diets (Hoffman et al., 2013). While the aforementioned studies analyze the groups separately, this study strives to understand the two groups i.e. regular meat consumers and meat avoiders-reducers and their intention to try novel grass-derived foods which are novel. To evaluate any existing difference between the groups and the different pathways leading to intentions to try grass-derived foods, appropriate models should be used.

Traditional econometric models used to study consumer behaviour may not fully capture the complexity of decision-making processes in this context, necessitating the use of advanced methodologies like Structural Equation Modelling (SEM) used in this study. SEM can model complex relationships among latent constructs that influence consumer behaviour. Unlike traditional regression methods, SEM allows for the simultaneous examination of multiple pathways, capturing both direct and indirect effects. This is particularly relevant in understanding consumer attitudes towards grass-derived ingredients, as their adoption is influenced by a web of interconnected factors, such as individual preferences, social norms, and perceived behavioural control (Kline, 2023;

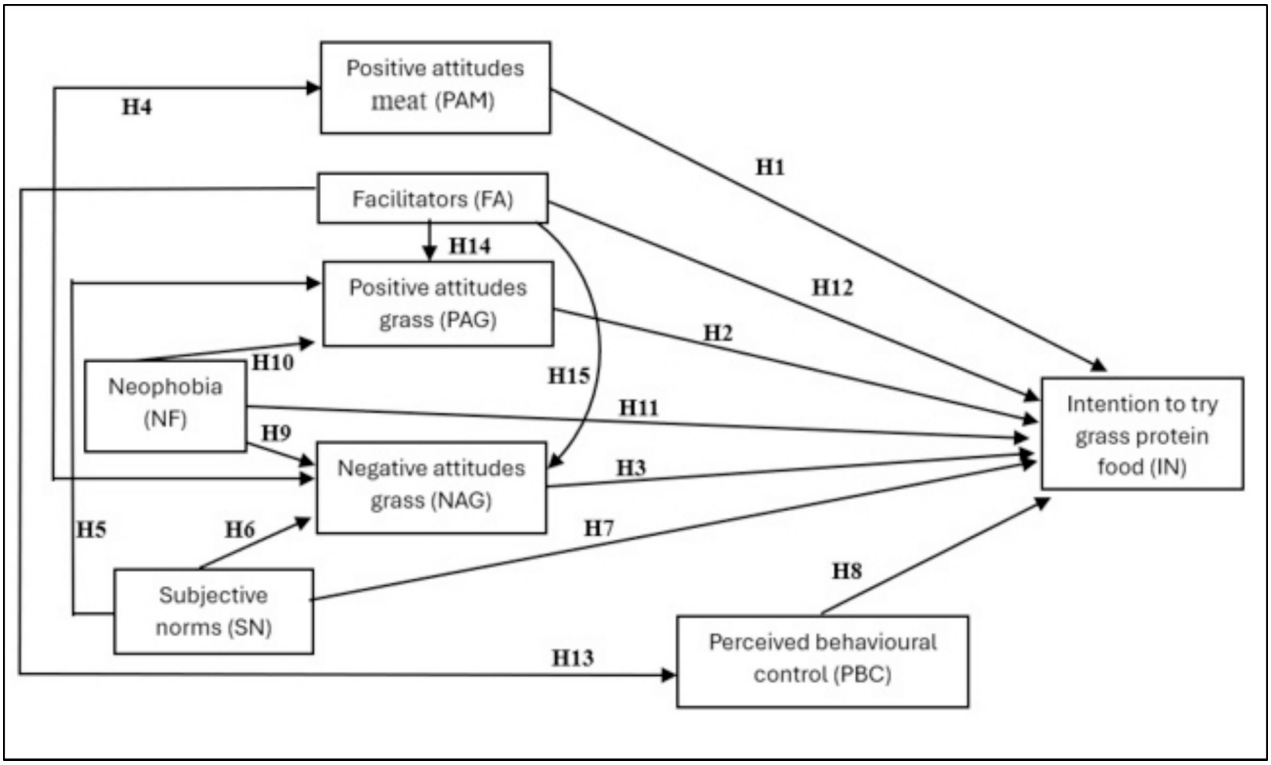

Fig. 1. Theoretical framework of consumer intentions and attitudes towards grass-derived proteins.

Magnusson et al., 2003). By using SEM, the study aims to provide a nuanced understanding of these dynamics.

The objective of this study is (1) to identify and understand the behavioural drivers influencing consumer consumption of grass-derived ingredients, particularly grass-derived proteins using a structural equation model. (2) To explore the factors that motivate consumers' choices and the relationship that exists among these factors and (3) to understand different driver that exists between regular meat consumers and meat avoiders-reducers intentions to try grass proteins. Understanding these group-specific intentions can provide valuable insights for tailoring strategies that promote the acceptance of grass-derived foods, addressing both individual preferences. Additionally, gaining a deeper understanding of the drivers motivating consumer choices will offer valuable insights into how grass-derived proteins and other plant-based ingredients can be better positioned in the market to align with consumer preferences. The findings will contribute to the academic literature on consumer behaviour and sustainable food choices related to novel foods while providing practical guidance for marketers and producers seeking to engage consumers who are inclined towards natural, sustainable products.

2. Methods

2.1. Participants and data collection

The study employed a quantitative research design. The data for this study were collected between July and August 2023 using a cross-sectional survey conducted across the United Kingdom (UK). Following ethical clearance from the Harper Adams University Ethics Committee (0408–202,305-STAFF), a pilot survey was administered before the full launch, with the questionnaire being revised based on pilot feedback. Participants were recruited through online panels managed by Cint and TGM, who also handled participant compensation. To ensure a representative sample, recruitment followed quotas based on the latest British census data, targeting individuals aged 18 and above. In total, 990 responses were included in the analysis. Before participation, respondents were provided with an excerpt detailing grass-derived ingredients and the technology used in the study, allowing them to understand the general concept before answering the survey questions.

2.2. Study design and participants

The quantitative research design used in the study was based on the theoretical framework presented in Fig. 1. A questionnaire was designed to capture the constructs of the framework to achieve the objectives of the research. For this purpose, five-point Likert scale statements (i.e. strongly disagree; disagree; indifferent; agree; and strongly agree) were included. Socio-demographic data including gender, age, education level, and average monthly household income. Eight constructs were measured in the other sections of the survey based on the hypothesis developed for the study. They included intention (IN), positive attitudes towards grass protein (PAG), negative attitudes towards grass protein (NAG), positive attitudes towards meat (PAM), subjective norms (SN), perceived behavioural control (PBC), facilitators (FA), and Neophobia (NP). Detailed items measuring the constructs are presented in Table 1. To understand the meat consumption of the respondent, they were asked to report their meat consumption frequency allowing them to indicate if they were regular meat consumers i.e. individuals who do not actively avoid meat or other animal products from their diets or meat avoider-reducers i.e. individuals who actively avoided meat or other animal products from their diets and those that actively avoided meat and other animal products from their diets on some days e.g. no meat Mondays.

2.3. Application of structural equation modelling

Structural Equation Modelling is a statistical technique that integrates factor analysis and multiple regression to explore the structural relationships between observed variables and latent constructs. SEM is particularly valuable in consumer behaviour research as it allows for the

Table 1
Constructs and Likert statements used in the questionnaire.

Construct	Items
Intention (IN)	IN1: I would be prepared to consume foods with grass proteins as a substitute for meat or my daily protein intake IN2: Eat/try foods containing grass-based proteins IN3: Buy foods containing grass-based proteins IN4: I am willing to pay more for foods that contain grass-based proteins IN5: I am willing to encourage others/serve food that contains grass-based proteins
Positive attitudes towards grass protein (PAG)	PAG1: I can see that some companies might be considering using grass as a food ingredient PAG2: It is quite a smart concept PAG3: If it is good enough for a cow, it must be good enough for humans PAG4: It can increase competitiveness with other plant-based products PAG5: It may increase consumers' acceptance of other plant-based products PAG6: It could solve world hunger PAG7: It will improve the economic value/reduce food prices
Negative attitudes towards grass protein (NAG)	NAG1: Humans cannot digest grass NAG2: This is the dumbest thing I ever heard of NAG3: It would not be much different to eating spinach or lettuce NAG4: Eating grass is for cows and sheep, why even bother trying to make human food from it NAG5: It may pose serious issues to human health NAG6: It may cause allergic reactions in humans NAG7: It can introduce chemical residues into the food supply chain
Positive attitudes towards meat (PAM)	PAM1: I love meals with meat PAM2: To eat meat is one of the pleasures in life PAM3: A good steak is without comparison PAM4: To eat meat is an unquestionable right of every person PAM5: According to our position in the food chain, we have the right to eat meat PAM6: I don't picture myself without eating meat regularly PAM7: If I couldn't eat meat, I would feel weak PAM8: If I was forced to stop eating meat, I would feel sad PAM9: Meat is irreplaceable in my diet
Subjective norms (SN)	SN1: The opinions of people who I value expect that I contribute towards sustainable environmental issues SN2: My friends and family would approve of me making such choices
Perceived behavioural control (PBC)	PBC1: I am constantly sampling new and different foods PBC2: I will eat almost anything PBC3: I like to try new foods from all over the world
Facilitators (FA)	FA1: When I buy foods, I try to consider how my use of them will affect the environment FA2: I am worried about humankind's ability to provide the nutritional needs of all people living on Earth now FA3: Something drastic has to change in order to feed all the people on Earth by 2050 FA4: Healthy FA5: Safe to eat FA6: Nutritious FA7: Much cheaper than most other plant-based products FA8: It is sustainable FA9: It would help solve environmental issues FA10: I feel a personal obligation to contribute to the environment and sustainability matters
Neophobia (NP)	NP1: I do not trust new foods NP2: I don't like foods from different countries NP3: At dinner parties I will not try a new food NP4: Some foods look too weird to eat NP5: I am afraid to eat things I have never had before

examination of complex, multidimensional relationships, identifying both direct and indirect effects among independent and dependent variables. This is essential for understanding consumer behaviour, where purchasing decisions are typically influenced by a web of interconnected factors such as personal preferences, social influences, and psychological motivations.

SEM's strength lies in its ability to model these intricate relationships, offering a comprehensive framework for understanding the underlying drivers of consumption patterns. Previous research has successfully applied SEM in various consumer behaviour contexts, including organic food consumption, sustainable product adoption, and health-related behaviors, demonstrating its utility in revealing complex dynamics that influence consumer choices. For example, SEM has been used to model the adoption of sustainable products (Keller & Lehmann, 2006), organic food consumption (Magnusson et al., 2003), and health-related behaviors (Vasilenko et al., 2014). In this study, SEM was used to explore the factors that influence consumer behaviour towards grass-derived ingredients. By identifying the key drivers behind consumer choices, SEM helps in formulating targeted interventions aimed at promoting the consumption of sustainable, grass-derived products.

3. Results

3.1. Sociodemographic characteristics

The sociodemographic data of the respondents was reported for gender, age, income, and education level as shown in Table 2. The gender distribution was nearly an equal split, with 50.2 % male and 49.8 % female respondents. Between the two groups, 52.7 % of meat consumers were male and 47.3 % female. In contrast, among meat avoiders-reducers, 45.7 % were male and 54.3 % female. This slight difference suggests that women may be more likely to reduce or avoid meat consumption, which aligns with some existing research showing that women are often more health-conscious and environmentally aware when it comes to food choices (Ruby, 2012; Graça et al., 2015). Meat consumers were older (Aged 65+), compared to meat avoiders-reducers who were younger (especially in the 25–34 age group). Meat avoiders-reducers had a significantly higher proportion of individuals with higher education (45.4 %) compared to meat consumers (32.0 %). The reported income levels were diverse, with the majority (27.3 %) earning between £1001 and £2000 monthly, and very few respondents earning in the highest income bracket of £5001 or more (13.8 %). The sample distribution between the groups was representative of day-to-day scenario where a majority of the population are meat consumers (Mumbi et al., 2024).

3.2. Evaluation measurement PLS-SEM models

This section presents the model fit results using SmartPLS 4 (Ringle et al., 2022). The results are presented in two stages: measurement model fit results and structural model fit results. In addition, a multi-

Table 2
Descriptive statistics of the respondents ($N = 990$).

		Meat Consumers	%	Meat Avoiders-Reducers	%	Total	%
		***N* = 640**		***N* = 350**		**N = 990**	
Gender	Male	337	52.7	160	45.7	497	50.2
	Female	303	47.3	190	54.3	493	49.8
Age groups	18–24	66	10.3	56	16.0	122	12.3
	25–34	90	14.1	71	20.3	161	16.3
	35–44	97	15.2	66	18.9	163	16.5
	45–54	116	18.1	52	14.9	168	17.0
	55–64	95	14.8	48	13.7	143	14.4
	65+	176	27.5	57	16.3	233	23.5
Monthly Income in £	1–1000	94	14.7	60	17.1	153	15.5
	1001–2000	168	26.3	107	30.6	270	27.3
	2001–3000	134	20.9	96	27.4	225	22.7
	3001–4000	79	12.3	41	11.7	119	12.0
	4001–5000	60	9.4	26	7.4	86	8.7
	5001+	105	16.4	34	9.7	137	13.8
Education	Primary School	9	1.4	5	1.4	14	1.4
	High school	238	37.2	82	23.4	320	32.3
	Further Education	188	29.4	104	29.7	292	29.5
	Higher Education	205	32	159	45.4	364	36.8

group analysis is presented.

The measurement model describes how each latent variable is explained by the manifest variables or items. To evaluate the consistency of the constructs and their certain items, they must meet minimum conditions of validity and reliability. The individual reliability of the item consists of determining whether the loads are associated with their respective construct, indicating whether the item (or observed variable) is correlated with the other loads. Table 3 shows values of loads λ greater than 0.7. Therefore, the individual reliability (IR) of the item is verified. A level greater than or close to 0.7 implies that the construct shares approximately 50 % of the variance (λ^2) of the observed variable (Hair et al., 2013).

In addition, in all the constructs, the Composite Reliability Index (CR) takes values greater than 0.8, complying with what was suggested, with values greater than 0.7. This index verifies whether the internal consistency of the indicators of each construct is fulfilled. That is, the observable variables measure the latent variable. Additionally, the Cronbach's Alpha (CA) indicator with values greater than 0.7 is considered a complement to measure internal consistency. Regarding convergent validity, the Average Variance Extracted (AVE) exceeds the minimum value of 0.5, which means that the construct shares more than 50 % of its variance with its indicators. Its function is to evaluate if the set of items that measure the construct are measuring it and not another concept.

Traditionally, the Fornell and Larcker criterion is used to assess discriminant validity. For this criterion, it must be verified whether the square root of the AVE values of each construct is greater than its highest correlations with any of the other constructs. Although this criterion is widely used in research, the Heterotrait-Monotrait Ratio (HTMT) is another important criterion for assessing discriminant validity (Henseler et al., 2016). Technically, the HTMT criterion estimates the real correlation between two constructs if they were measured perfectly. Both criteria of discriminant validity were verified.

Table 3
Internal consistency and convergent validity.

Construct	Item	IR	CA	CR	AVE
Negative attitudes grass (NAG)	NAG2	0.927	0.815	0.821	0.843
	NAG3	0.909			
Positive attitudes grass (PAG)	PAG1	0.779	0.799	0.814	0.713
	PAG2	0.888			
	PAG3	0.863			
Positive Attitudes Meat (PAM)	PAM2	0.807	0.814	0.820	0.641
	PAM4	0.829			
	PAM5	0.774			
	PAM6	0.790			
Facilitators (FA)	FA4	0.894	0.877	0.877	0.802
	FA5	0.892			
	FA6	0.900			
Intention (IN)	IN1	0.859	0.931	0.935	0.785
	IN2	0.897			
	IN3	0.932			
	IN4	0.839			
	IN5	0.901			

3.3. Structural model evaluation

To obtain an adequate interpretation and conclusion of the model, it is necessary to evaluate the structural model, which consists of determining the path coefficients (β), the explained variance (σ2), and the predictive relevance (Q^2). First, the t value of the relationships between

Table 4
Path coefficients (*t* value).

Path coefficients	Original sample	Standard deviation	*t* statistics
Facilitators (FA) - > Intention (IN)	0.395	0.031	12.735*
Facilitators (FA) - > Negative attitudes grass (NAG)	−0.352	0.038	9.200*
Facilitators (FA) - > Positive attitudes grass ((PAG)	0.742	0.019	38.473*
Negative attitudes grass (NAG) - > Positive attitudes meat (PAM)	0.421	0.032	13.304*
Positive attitudes grass ((PAG) - > Intention (IN)	0.450	0.031	14.620*
Positive attitudes meat (PAM) - > Intention (IN)	−0.118	0.019	6.362*

* $p < 0.05$.

constructs is reviewed to verify if there is a statistically significant relationship (Table 4). Fig. 2 shows the model outcomes. All findings hold significance at the 5 % level. In the model, the coefficient of determination (R2) exceeds the acceptable threshold, and the Q2 index demonstrates values greater than zero across all constructs, ensuring the models' explanatory and predictive capabilities (Table 4). As indicated in Tables 4 and 5, the measurement model has good psychometric properties, which validate the estimation of the latent variables, fulfilling the criteria of validity and reliability. Additionally, the structural model shows statistically significant relationships, verifying the fulfilment of the six hypotheses.

3.4. Multigroup analysis

The growing global attention to sustainable and ethical food consumption has brought increased focus to distinct consumer groups especially surrounding meat consumption. These groups include regular meat consumers and meat avoiders-reducers. Meat avoiders-reducers are individuals who consciously limit or eliminate their meat consumption, often driven by concerns related to health, environmental sustainability, and animal welfare (Graça et al., 2015; Verain & Dagevos, 2022). In contrast, regular meat consumers typically maintain higher levels of meat intake, influenced by factors such as cultural traditions, taste preferences, and convenience (Hoffman et al., 2013). The differentiation between meat avoiders-reducers and meat consumers is supported by significant empirical evidence that highlights divergent motivations, values, and behavioural patterns between these groups. Research shows that meat avoiders and reducers are often influenced by ethical, environmental, and health considerations to a greater degree than regular meat consumers (Dagevos & Voordouw, 2013; Graça et al., 2015; Ruby, 2012; Verain & Dagevos, 2022). Conversely, regular meat consumers may prioritize convenience, taste, and cultural norms in their dietary choices, which can result in less flexibility or motivation to reduce meat intake (Hoffman et al., 2013). Consequently, a multigroup analysis of the respondents based on meat consumption was further examined in the study to understand potential similarities and differences among them. A multi-group technique was then applied to determine if there were statistically significant differences in the path coefficients between the avoiders-reducers group and the consumers group.

Table 5
Explanatory and predictive capabilities of the model.

Endogenous constructs	R^2	Q^2 predict
Intention (IN)	0.682	0.570
Negative attitudes grass (NAG)	0.124	0.120
Positive attitudes grass ((PAG)	0.551	0.549
Positive Attitudes Meat (PAM)	0.178	0.044

A multi-group analysis provides deeper insights into group-specific dynamics that might otherwise remain hidden in aggregated data. Further, multi-group analysis based on meat consumption allows for a more precise analysis into the pathways and factors that differ between the groups allowing for group specific interventions. For example, Graça et al. (2019) demonstrate that targeted interventions are more effective when they address the distinct motivations and attitudes of meat avoiders-reducers versus regular consumers. Therefore, this methodological decision is not only justified by existing literature but also essential for tailoring the analysis to the specific characteristics of each group, enhancing the study's relevance and practical implications for health and environmental policy.

First, measurement invariance must be corroborated. The Measurement Invariance of Composites (MICOM) procedure (Henseler et al., 2015) is a tool for verifying that the differences between groups in the estimates of the models are not due to differences in the content or meaning of the latent variables. The MICOM algorithm is divided into three stages: (1) configuration invariance, (2) composite invariance, and (3) equality of means and variances of the composites. The same model is used for both groups (avoiders-reducers and consumers) in indicators, constructs, and path relationships (Figs. 3 and 4); therefore, configuration invariance is fulfilled.

Table 6 presents the results for stages 2 and 3 of the MICOM procedure. Stage 2, which assesses compositional invariance, is confirmed since the *p*-value is greater than 0.05. However, Stage 3 is not verified,

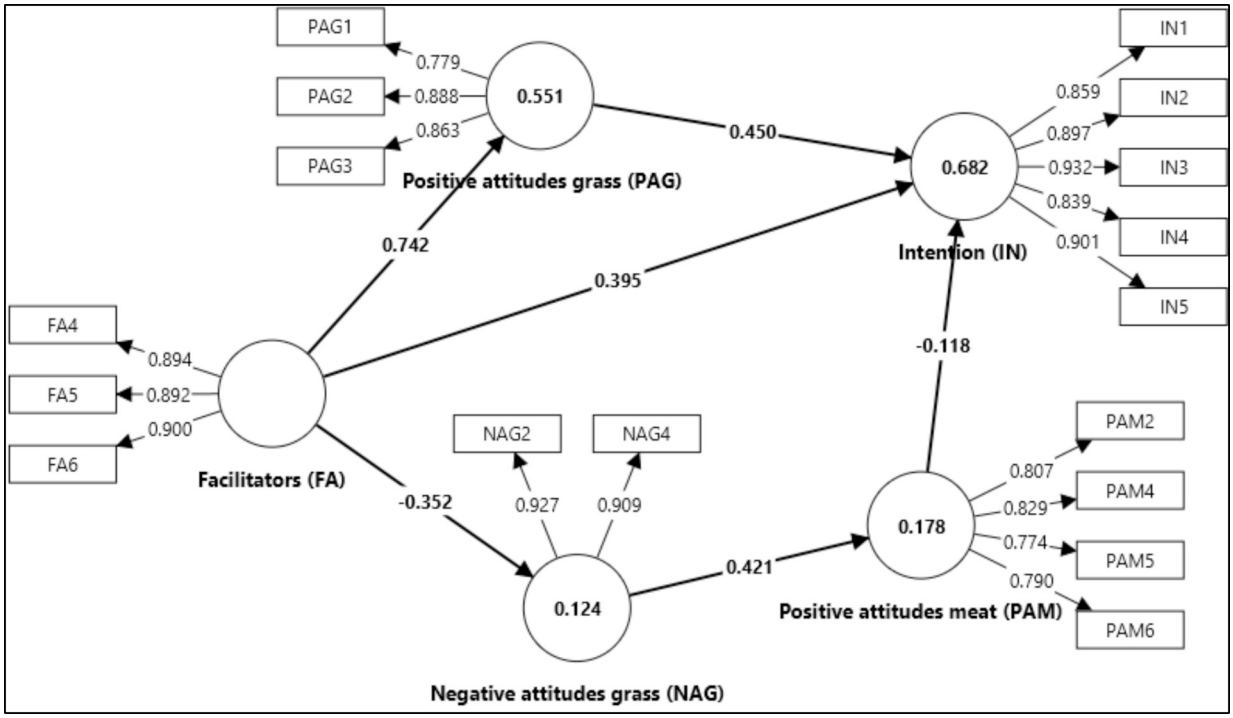

Fig. 2. Results of the structural and measurement model.

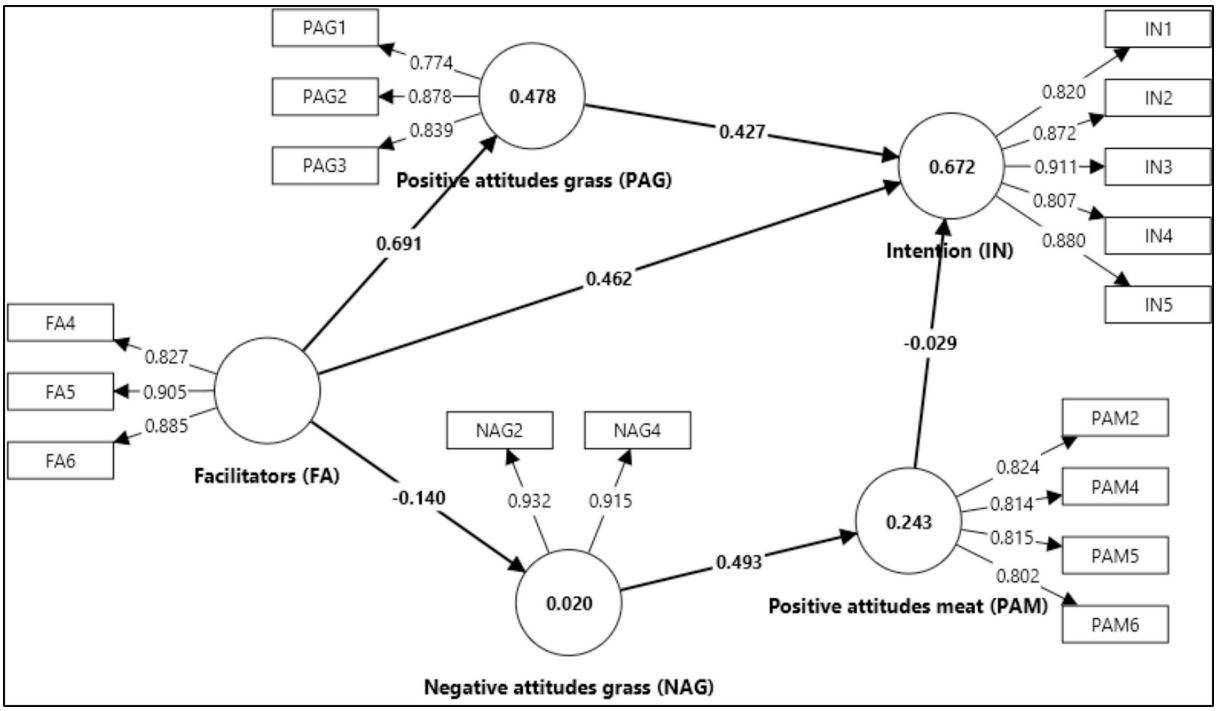

Fig. 3. Results of the structural and measurement model for group Avoiders-Reducers.

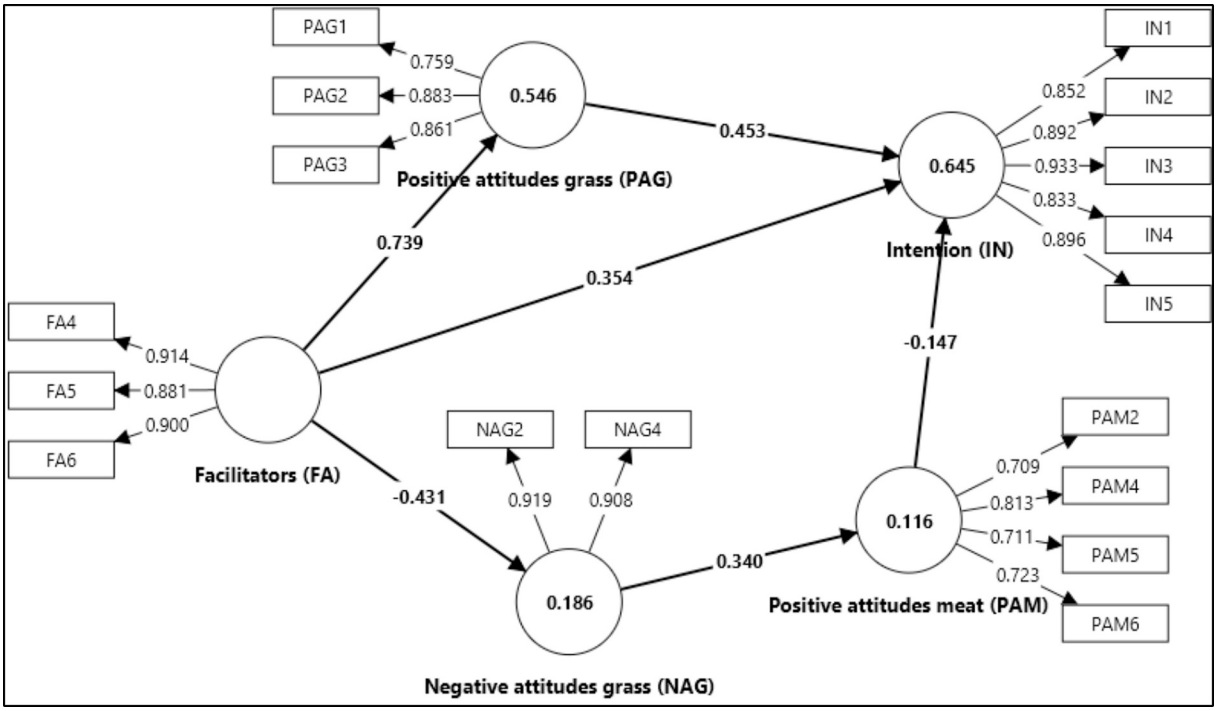

Fig. 4. Results of the structural and measurement model for group Consumers.

meaning that the equality of means and variances is not established for all model constructs. Nevertheless, since partial invariance (Stages 1 and 2) is confirmed across all constructs, multi-group analysis can be applied to compare path coefficients.

The bootstrap multigroup analysis (MGA) and Permutation multigroup analysis (MGA) algorithms were used. Both yielded the same results (Table 7):

The relationships between facilitators - > negative attitudes grass, negative attitudes grass - > positive attitudes meat, and positive attitudes meat - > intention show statistically significant differences between the groups. This indicates that these relationships are perceived differently between avoiders-reducers and consumers. The biggest difference is observed in the relationship between facilitators (FA) and negative attitudes grass (NAG), indicating that in the group of meat consumers, the influence of facilitators strongly decreases Negative attitudes grass compared to the group of avoiders-reducers. The relationships between Facilitators - > Intention, Facilitators - > Positive Attitudes Grass, and Positive Attitudes Grass - > Intention do not exhibit

Table 6
MICOM Results.

Constructs	Correlation contrast		Mean contrast		Variance contrast	
	Correlation	p-value	Difference	p-value	Difference	p-value
Facilitators (FA)	1.000	0.224	−0.534	0.000	−0.136	0.173
Intention (IN)	1.000	0.349	−0.732	0.000	−0.083	0.208
Negative attitudes grass (NAG)	1.000	0.693	0.291	0.000	0.064	0.412
Positive attitudes grass ((PAG)	1.000	0.280	−0.603	0.000	−0.184	0.032
Positive Attitudes Meat (PAM)	0.998	0.361	0.818	0.000	0.705	0.000

Table 7
Multigroup analysis results.

Relations	Group Avoiders-Reducers	Group Consumers	Difference	Permutation p-value
Facilitators (FA) - > Intention (IN)	0.462	0.354	0.108	0.099
Facilitators (FA) - > Negative attitudes grass (NAG)	−0.140	−0.431	0.292	0.000*
Facilitators (FA) - > Positive attitudes grass ((PAG)	0.691	0.739	−0.047	0.248
Negative attitudes grass (NAG) - > Positive attitudes meat (PAM)	0.493	0.340	0.153	0.016*
Positive attitudes grass ((PAG) - > Intention (IN)	0.427	0.453	−0.026	0.694
Positive attitudes meat (PAM) - > Intention (IN)	−0.029	−0.147	0.118	0.002*

Notes: *$P < 0.005$.

significant differences between the groups, suggesting that the impact of these relationships is similar in both groups. Figs. 3 and 4 show the differentiated model for each group.

The difference between some path coefficients between the groups leads to changes in the effects on Intention. The total effect reflects the combined direct and indirect influences between two constructs, providing insights into how one construct impacts another. Table 8 details the total effect on intention for each group. The *p*-value shows that there are no significant differences in effects between the two groups, except for one exception: the relationship between Positive Attitudes Towards Meat (PAM) and Intention (IN). In this instance, the relationship is not significant for the Avoiders-Reducers group but is significant for the Consumers group. The construct that most influences intention is Facilitators, followed by Positive Attitudes Towards Grass (PAG), with both having a positive effect. This indicates that facilitators and positive attitudes towards grass are essential for enhancing intention, whereas negative attitudes towards grass and positive attitudes towards meat have a lesser or null intention. Regarding the interpretation of the effects, for example, the value 0.760 in the Avoiders-Reducers group means that: For each increase of one standard deviation in the Facilitators construct, the Intention construct increases by 0.760 standard deviations (keeping the effects of other variables in the model constant).

Table 8
Total Effects on Intentions for Avoiders-Reducers and Consumers.

Relations	Group Avoiders-Reducers	Group Consumers	Difference	Permutation p-value
Facilitators (FA) - > Intention (IN)	0,760	0,710	0,050	0,123
Negative attitudes grass (NAG) - > Intention (IN)	−0,014	−0,050	0,036	0,053
Positive attitudes grass ((PAG) - > Intention (IN)	0,427	0,453	−0,026	0,694
Positive attitudes meat (PAM) - > Intention (IN)	−0,029	−0,147	0,118	0,002

4. Discussion

The implications of the findings are discussed with an alternative representation of the models depicted in Figs. 2, 3, and 4, as shown in Fig. 5. Fig. 5 illustrates the specific statements that form part of the constructs, the significant links between these constructs, and the effect (positive or negative) that a construct has on another when they are linked. The representation in Fig. 5 highlights the pivotal role of facilitators, including health, safety, and nutritional aspects, in influencing consumer intentions. Similar findings were reported by Moons et al. (2018), who noted that product-related attributes are critical for shaping consumer attitudes towards eco-friendly functional foods. These attributes not only directly affect intention but also mediate relationships with other constructs such as attitudes. Furthermore, the clear depiction of positive and negative pathways within the model emphasizes the importance of addressing barriers related to the intentions to consume grass proteins. According to Tuorila and Hartmann (2020), overcoming initial resistance to novel foods through targeted interventions and consumer education is essential for fostering acceptance. The model's detailed structure allows for the identification of specific leverage points for intervention, such as enhancing positive attitudes towards grass-protein or mitigating negative perceptions associated with its use.

As depicted in Fig. 5, facilitators are the most relevant construct because they affect the rest of the constructs and consumers' beliefs. There were three significant facilitators i.e. health, safe to eat, and nutrition. This is consistent with Moons et al. (2018), who found that health considerations are key motivators for consumer acceptance of alternative proteins. This suggests that campaigns to promote the consumption of grass-protein food should be focused on these considerations by, for example, designing marketing and labeling strategies that inform about the benefits of grass-protein for health, nutrition and safety as suggested by Dean et al. (2024) who emphasized that clear messaging around sustainability and health-related benefits plays a critical role in the adoption of alternative proteins. Fig. 5 also shows that facilitators affect intention through three pathways: (i) facilitators→ positive attitudes towards *grass-protein→ intention*; (ii) *facilitators→ intention*; and (iii) *facilitators→ negative attitudes towards grass-protein→ positive attitudes towards meat→ intention*. The first pathway suggests that when consumers place high relevance on the facilitators described above (i.e. healthy, safe to eat and nutrition), they also develop more positive attitudes towards grass-protein. This finding is supported by Graça et al. (2015), who noted that when individuals perceive the health and safety benefits of plant-based alternatives, they are more likely to form favourable attitudes and show willingness to try such products. This finding suggests that they are more alert about companies that consider

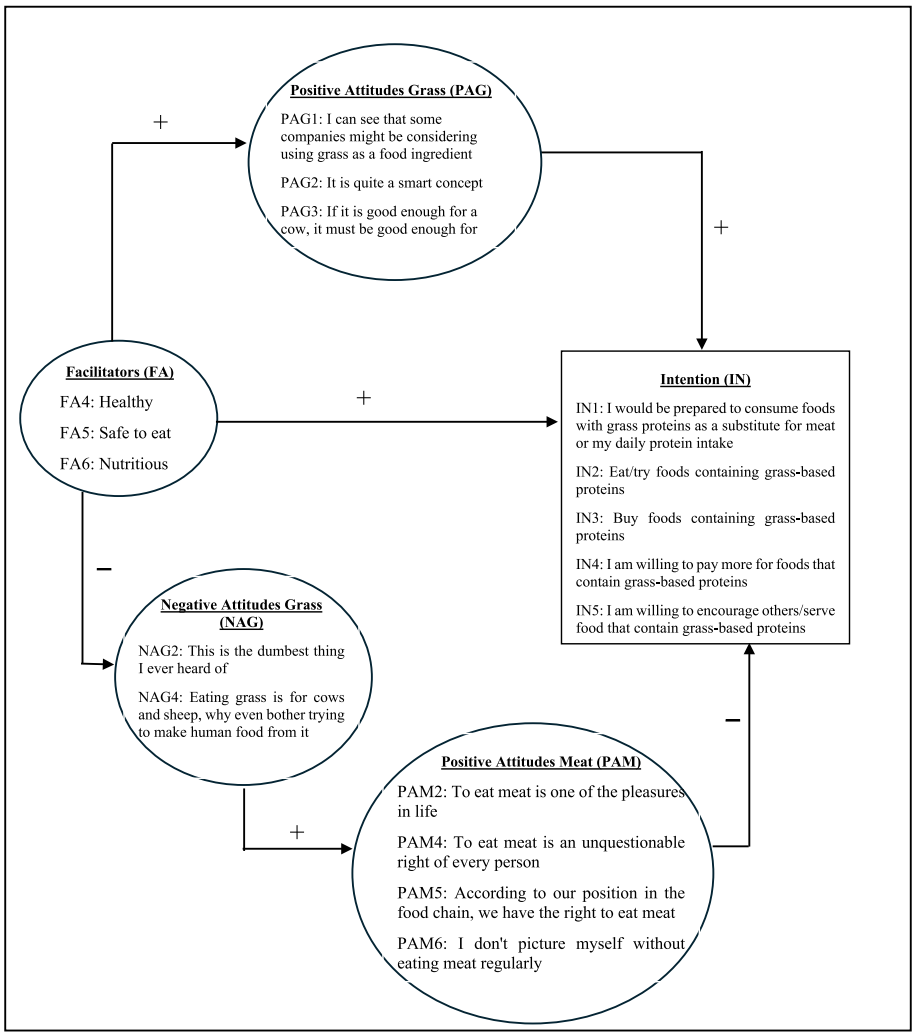

Fig. 5. A behavioural model of consumers' intention to consume grass-protein food.

using grass-protein as a food ingredient, find the use of grass-protein a smart concept, and are more flexible towards considering these foods. These positive attitudes, in turn, affect the intention to consume grass proteins. The second pathway: *facilitators→ intention,* shows that the identified facilitators also directly affect intention demonstrating the relevance of facilitators to induce the desired behaviour of consuming grass proteins.

Finally, the last pathway: *facilitators→ negative attitudes towards grass-protein→ positive attitudes towards meat→ intention* demonstrates that facilitators help reduce negative beliefs about grass-proteins, such as the perception that consuming them is absurd or that they are only suitable for animals like cows and sheep. Tuorila and Hartmann (2020) pointed out that overcoming such negative perceptions is key to introducing novel foods, especially when consumers have pre-existing biases. The decrease in negative attitudes towards grass-proteins, in turn, reduces positive attitudes towards meat, meaning that beliefs such as "meat is one of the pleasures in life" or "eating meat is a right" become less relevant. The reduction in positive attitudes towards meat in turn positively affects the intention to consume grass-protein food. Ruby (2012) observed similar findings, noting that addressing the cultural and emotional ties to meat can enhance openness to plant-based alternatives.

The numerical impacts of the pathways on the intention to consume grass proteins can be calculated by multiplying the path coefficients (β) that follow each pathway. For the overall sample (see Fig. 2), the impact of the first pathway is equal to 0.334 (i.e. 0.742 × 0.450) meaning that for each increase of one standard deviation in the facilitators construct, the intention construct increases by 0.334 standard deviations. The impact of the second pathway is (0.395) which is larger than the impact of the first pathway. Finally, the impact of the third pathway is 0.017 (i.e. −0.352 × 0.421 x − 0.118), which is significantly smaller than the impact of the other pathways. This has important implications for management and marketing strategies, as marketing strategies should be focused mainly on the identified facilitators. That is, consumers should be informed about the healthy and nutritional properties of grass proteins, as well as the safety of this food when it is consumed. This will have the strongest effect on intention via its direct effect (i.e. second pathway). As a secondary strategy, campaigns to reinforce positive attitudes towards grass-protein can also make a significant impact on willingness to adopt grass proteins because this pathway (i.e. the first pathway) also has a large impact value. Finally, the third pathway has very little impact on intention suggesting that efforts to change negative attitudes towards grass-protein and to introduce the idea that grass-protein can substitute meat may not be effective.

The comparative analysis of meat avoiders-reducers and meat consumers indicates that while the overarching behavioural model, Fig. 5, remains consistent across both groups, distinct variations in the strength of specific pathways are evident. However, as shown in Figs. 3 and 4, the path coefficients are not identical, meaning that they have some differences as revealed by the multigroup analysis presented. For the meat avoiders-reducers, the impact of the three pathways described above is, respectively, 0.295 (i.e. 0.691 × 0.427), (0.462), and 0.002 (i.e. −0.140 × 0.493 x − 0.028).

For the meat consumers, on the other hand, the impact of the three pathways is, respectively, 0.335 (i.e. 0.739 × 0.453), (0.354) and 0.022 (i.e. −0.431 × 0.340 x − 0.147). The main implication of these differences is that marketing and labeling strategies can be designed in different ways to target these two market niches. For the meat avoiders-reducers, the direct pathway between facilitators and intention is by far the strongest (i.e. 0.462), suggesting that labeling and marketing should be focused mainly on informing about the health, safety and nutritional properties of grass-proteins. The third pathway linking negative attitudes towards grass-protein and meat is weak in the avoiders-reducers group, suggesting that attempts to use this pathway to induce behaviour would be less effective. In contrast, the impact of this pathway in the meat consumers group is small but still higher, indicating that positive beliefs about meat may reduce their willingness to try grass-protein. To overcome this, marketing strategies should focus on the health, safety, and nutritional properties of grass-protein as well as fostering positive attitudes towards grass-protein. This is because the impacts of the two main pathways (i.e., 0.335 and 0.354) are relatively similar, suggesting that a strategy incorporating both pathways would be more effective in encouraging meat consumers to try grass-proteins. Graça et al. (2015) similarly highlighted the importance of emphasizing the health and sustainability benefits of plant-based foods in reaching this group.

5. Limitations and directions for future research

The cross-sectional design of the study limits the ability to draw conclusions from causality. This is because consumers views are captured at a specific point in time with no account for behaviour change overtime (Bryman, 2016). Future studies should, therefore, consider longitudinal designs to monitor potential changes among consumers that could result from exposure and familiarity with grass-derived proteins when these ingredients become available in the market. Additionally, as the study was restricted to the UK, cultural biases specific to UK participants limit the generalization of these findings to other populations (Craig & Douglas, 2005). Thus, cross-cultural comparisons are necessary to validate these findings as consumers preferences for novel foods are influenced by traditions, eating habits and cultural norms as reported by Frewer et al. (2013). Another limitation concerns the reliance on self-reported attitudes and intentions rather than observed behaviour. Studies indicate that stated intentions do not always translate into actual purchasing or consumption behaviour due to factors such as sensory appeal, price, and availability (Ajzen, 1985; Verbeke, 2015). As the participants did not interact with real ingredients their responses may vary when otherwise presented with actual food samples. As outlined by Tuorila and Hartmann (2020), sensory characteristics such as texture, odour and taste can influences consumers' willingness to adopt novel foods. Prior research on alternative proteins has demonstrated that tasting unfamiliar foods can lead to a reduction in food neophobia, and thus increasing acceptance (Tan et al., 2016). Therefore, future studies should utilise taste panels and sensory trials to identify any changes in perception and acceptance of grass-derived ingredients. Finally, SEM is sensitive to sample size and model complexity, therefore, future studies should target broader participant pools, including different demographic and psychographic segments, to refine and validate the findings.

6. Conclusion

This study explored the behavioural drivers influencing consumer acceptance of grass-derived proteins in the UK, employing a Structural Equation Modelling (SEM) approach to examine the complex interplay of factors shaping consumer intentions and attitudes. The findings demonstrate that facilitators, such as perceived health benefits, safety and nutrition, significantly enhance consumer intention to adopt grass-derived proteins, underscoring the importance of aligning product attributes with consumer values. Conversely, negative attitudes towards novel foods, present challenges that require targeted interventions. The results further reveal that social influences can shape attitudes and intentions, while positive attitudes towards meat negatively correlate with the willingness to consume grass-derived proteins. The differentiation between meat consumers and avoiders-reducers highlights the necessity for tailored approaches in marketing and policy, addressing the distinct motivations and perceived barriers of these groups. From a practical perspective, our findings offer valuable insights for marketers, policymakers, and food innovators seeking to promote sustainable and novel protein sources. Strategies emphasizing health, environmental, and safety issues will be critical to enhancing acceptance. Future research should expand upon these findings with cross-cultural comparisons and longitudinal studies to capture evolving consumer preferences and behaviour patterns. The integration of consumer preferences and behavioural insights is essential for fostering greater acceptance of grass-derived proteins, contributing to global food security and environmental sustainability. By leveraging this understanding, stakeholders can better position these novel foods to meet the needs and expectations of an increasingly health and environmentally conscious consumer base.

CRediT authorship contribution statement

Anne Wambui Mumbi: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sara Arancibia:** Writing – review & editing, Software, Methodology, Formal analysis, Data curation. **Daniel May:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Helen Pittson:** Writing – review & editing, Conceptualization. **Karl Behrendt:** Writing – review & editing. **Adeboye Akindoyin Awomuti:** Writing – review & editing, Conceptualization. **Frank Vriesekoop:** Writing – review & editing, Conceptualization.

Ethics statement

The study acquired approval for the involvement of human subjects, which was granted by the Harper Adams University Ethics Committee on 19/06/2023. Participation was voluntary, all participants acknowledged an informed consent statement to participate in the study.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: The Pasture to Plate project reports financial support was provided by Biotechnology and Biological Sciences Research Council. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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