

Low carbon beef: factors influencing sustainable purchase intentions of British consumers

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Ethics statement

The collection of data obtained ethics approval from the SRUC Social Science Ethics Committee. The respondents to our survey gave their informed consent before taking part.

Author contributions

Ana Flavia Siqueira Abrahao: Conceptualization; Data curation; Formal analysis; Methodology; Writing - original draft. Luiza Toma: Conceptualization; Data curation; Formal analysis; Funding acquisition; Methodology; Supervision; Writing - review editing. Maria Emília Camargo: Formal analysis; Methodology; Writing - review editing. Guilherme Cunha Malafaia: Conceptualization; Supervision; Writing - review editing.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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Abstract

The increasing demand for food, climate change and global warming are worldwide concerns, not least for putting food security at risk. Public policies to reduce the emission of greenhouse gases (GHGs) have been developed in many countries in an attempt to mitigate their harmful effects to nature. The supply side of the beef supply chain has been in the spotlight, but research studies focusing on beef demand and how it can contribute to GHG mitigation are still scarce. The present paper may bring new perspectives on the environmental impacts of beef consumption. This study analyses consumers' awareness and perceptions of the environmental impact of the beef supply chain, and their intentions to purchase sustainable products, such as beef produced with a lower carbon footprint. The hypotheses tested are based on a review of the theory of planned behaviour (TPB) literature, forming a model extended through the addition of environmental knowledge and self-identity as exogenous determinants of attitudes. The analysis uses primary survey data collected in June 2020 in The United Kingdom (500 responses) and partial least squares structural equation modelling. The model's goodness of fit indicators validate the hypotheses and conceptual framework. The findings show that the extended TPB framework has strong predictive potential and robustness, attitudes have a significant influence on intentions to purchase low carbon beef, and environmental knowledge and self-identity positively impact consumers' sustainability concerns. The results provide an insight into the effect of information on consumers' pro-environmental behaviour, of relevance to both policy and markets.

Keywords: beef consumption, low carbon footprint, theory of planned behaviour, structural equation modelling, British consumers

Introduction

The global demand for livestock products is projected to grow by 70% by 2050 (Gerber *et al.*, 2013) based on the projected global population of 9.7 billion for that year according to the United Nations Department of Economic and Social Affairs (2015). Different studies have shown the impact that the beef cattle chain has on the environment due to greenhouse gases (GHGs) emissions, namely methane (CH₄), nitrous oxide (N₂O) and carbon dioxide (CO₂) (Bajan and Mrowczynska-Kaminska, 2020; Domínguez *et al.*, 2016). Scientists present different scenarios to mitigate the negative externalities of this chain. According to life cycle assessment studies, the amount of CO₂-equivalent emitted varies significantly depending on the way that the cattle were bred - conventional, intensive, organic, grass-fed, other (Broom, 2021; Gerber *et al.*, 2013; Capper, 2012).

Among all types of livestock production, beef is the biggest contributor, emitting about 5.0 gigatonnes CO₂-eq each year, which represents around 65% of the emissions of the livestock sector as a whole (Costantini *et al.*, 2021; Gerber *et al.*, 2013). As the demand for beef and dairy products increases, their supply must also rise, therefore releasing even higher levels of GHGs to the atmosphere if nothing else changes. Behavioural change and technological innovations must be implemented in the agriculture sector in order to meet the Sustainable Development Goals (SDGs) (FAO, 2019; Sachs *et al.*, 2019). It is known that GHGs emissions lead to climate change, negatively affecting, most of all, the agricultural systems that directly depend on rainfall patterns, and long periods of drought or excessive floods affect many types of crops, which puts food security at risk (Kakoty, 2018; Domínguez *et al.*, 2016).

To reduce the environmental impact of meat and mitigate global warming, studies have suggested the need for a significant reduction in meat consumption in developed countries (Sanchez-Sabate *et al.*, 2019; Stoll-Kleemann and Schimdt, 2017; IPCC, 2014). Different countries have different nutritional needs, with wealthy nations tending to show an excessive consumption of calories and low-income nations still experiencing malnutrition, and these facts demonstrate the necessity for country specific public policies given prevailing inequalities (Duro *et al.*, 2020; Godfray *et al.*, 2018).

The predominant belief is that meat is essential to a balanced diet, thus reducing or replacing it with other sources of protein is still met with reluctance (Lentz *et al.*, 2018; MacDiarmid *et al.*, 2015). The 4N model (Piazza *et al.*, 2015) states that consumers perceive and understand eating meat as something natural (behaviour), necessary (health), normal (society), and, for some, nice (tasting). Even though European consumers have been reducing the amount of animal protein they consume, particularly red meat (EEA, 2017), shifting to environmentally friendly options could further contribute to the solution to diminishing the sector's footprint. However, little is known about what factors may influence intentions to purchase low carbon beef, especially within the limits of the neoclassical framing of demand followed by a majority of studies (as reviewed by Moran and Blair, 2021).

To promote the sustainable consumption of meat, the factors influencing consumers' behaviour have to be identified, and this can be a complex process (Scalco *et al.*, 2017; Barcellos *et al.*, 2016). Some studies indicated cost and health as the most relevant attributes in the push to reduce or replace beef consumption (Mylan, 2018; Neff *et al.*, 2018; Hartman and Siegrist, 2017). Social pressure is another issue worth considering (de Boer *et al.*, 2017), but attitudes seem to represent a significant contributor to dietary shifting (Burnier *et al.*, 2019; Macdiarmid *et al.*, 2015). Studies show that the reduction of meat demand or its

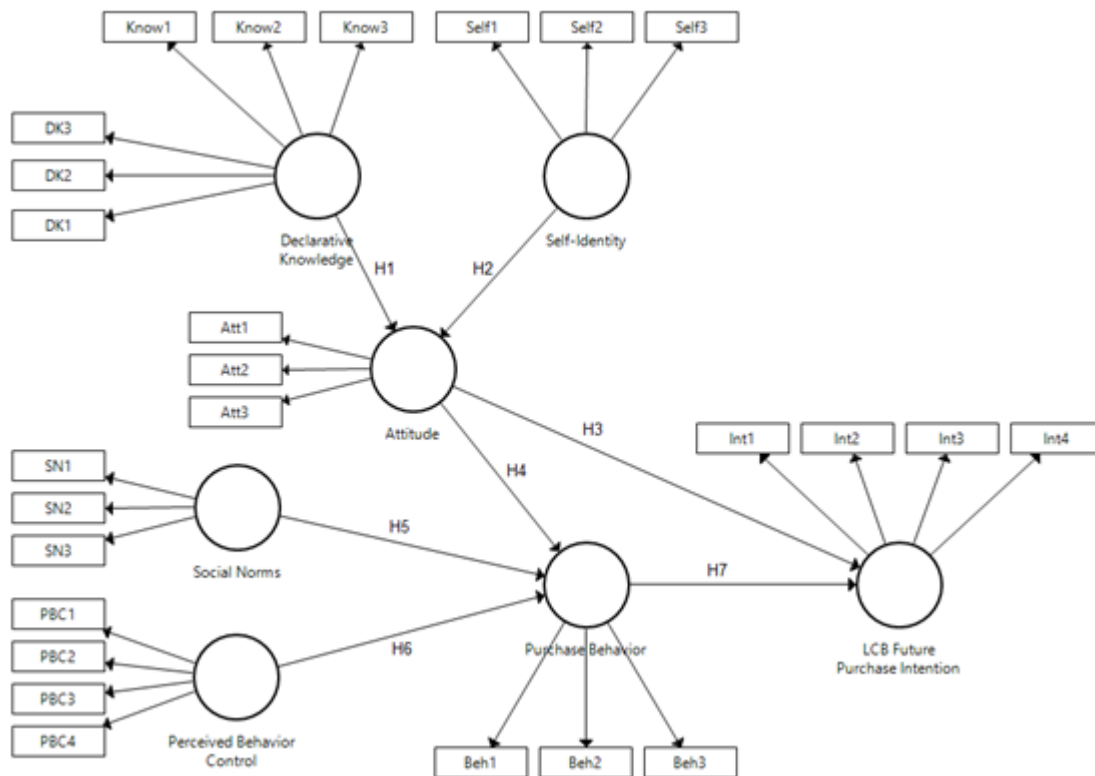
replacement with another source of protein, such as plant-based protein, insects, or artificial meat, is low (Çoker and Van der Linden, 2020; Hartmann and Siegrist, 2017).

To address this issue, this study aims to provide insight into the factors influencing British consumers' intentions to purchase low-carbon beef (LCB) products. The data was collected in June 2020, with 500 respondents answering a 26-question survey that was designed based on the Theory of Planned Behaviour (TPB), which was extended by adding two variables, environmental knowledge and self-identity that influence consumers' attitudes. Structural equation modelling (SEM) was used to test the conceptual model estimated by partial least square (PLS software). The results provide guidance to policy makers and the beef industry about demand aspects that may drive market and policy change towards a more resource efficient sector.

Concept and hypotheses

Several studies focused on TPB applications to investigate sustainable consumption behaviours (Gunarathne *et al.*, 2020; Wong *et al.*, 2020). To test influences on consumers' LCB purchasing intentions, we extend the TPB model to consider knowledge and self-identity as predictors of a person's beliefs towards their attitudes. We built the conceptual model based on hypotheses drawn from a review of recent literature on consumers' environmentally friendly behaviour and pro-environmental purchasing intentions. The schematic representation of the extended TPB model used in the present study is shown in Figure 1.

Figure 1. Conceptual model



The hypotheses tested are presented as follows:

H1: Consumers are more likely to have environmentally friendly attitudes if they have higher declarative knowledge.

Kaiser and Fuhrer (2003) introduced a typology of knowledge relevant to ecological behaviours, which includes declarative knowledge (DK) - information people gather about environmental systems, such as knowledge of the side effects of GHGs being in the atmosphere - procedural knowledge (PK) – awareness of the means to achieving ecological goals - and effectiveness knowledge (EK) – awareness of how effective one’s personal effort is towards resulting ecological benefits (Kaiser and Fuhrer, 2003). According to previous studies, the more DK consumers have, the greater its influence on their pro-nature attitudes (Nguyen *et al.*, 2019). The work of Frisk and Larson (2011) states that information alone

cannot change how individuals behave towards environmental consciousness, although it is an important part of transforming such behaviour and the lack of it may form a barrier to behaviour change (Monroe, 2003). To have environmentally friendly attitudes, one's beliefs must be pro-nature, and, in order to support nature, one must avoid that which harms the environment, which, in the case of our study, refers to consumers' awareness of the share of greenhouse gases (GHG) emissions contributed by the beef sector. Most studies have shown that consumers do not relate GHGs to meat eating (Siegrist and Hartmann, 2019), and, according to De Groeve and Bleys (2017), scepticism remains common among meat eaters, even after they had access to specific information regarding its damage to the environment. Most studies on environmental behaviours (Siegrist and Hartmann, 2019; Wang and Wu, 2016; Pagiaslis and Krontalis, 2014) state that the more knowledgeable consumers are about the consequences of climate change, the more concerned they are. In line with these findings, Weibel *et al.* (2019) consider a significant correlation between DK and both environmental behaviour and consumers' awareness.

Although access to information by itself may not lead directly to substantial change in consumers' preferences, it may improve knowledge and, therefore, awareness of one's carbon footprint, potentially strengthening consumers' intentions to buy environmentally friendly products (Stöckigt *et al.*, 2018; Kumar *et al.*, 2017).

H2: Consumers are more likely to have environmentally friendly attitudes if they identify themselves as someone who is concerned with the outcomes of their behaviour.

Pro-environmental self-identity corresponds to people seeing themselves as concerned with the environmental impact of their purchases. They know their consumption patterns may contribute to climate change and global warming, and awareness of the carbon footprint of their purchases may influence behaviour (Onel, 2016). How people define themselves can impact their intentions to protect the environment (Sparks *et al.*, 1992). Thøgersen's

(1996) study suggests that environmental concerns are a function of beliefs about what is right or wrong and, as such, are a matter of one's individuality and principles. Graham and Abrahamse's (2017) research was based on two premises. The first is that people do not connect meat consumption to environmental impact (MacDiarmid *et al.*, 2015); the second is that self-enhancement and self-transcendence are values strongly related with meat eaters. The former does not show environmental concerns, whilst the latter involves strong beliefs related to altruistic purposes like protection of animal welfare or the nature. Hayley *et al.* (2015) show similar results, where self-transcendence values were highly associated with red meat reduction. There is a conceptualisation of environmental identity where a person sees themselves as interdependent with the whole ecosystem, which integrates humans, fauna, and flora on the same level. The concept of an environmental self-identity refers to an individual seeing themselves as someone who intends to behave in a pro-environmental way (Carfora *et al.*, 2017; Werff *et al.*, 2013). The evidence from earlier studies provides the understanding that self-identity affects behaviours (Ates, 2020). Individuals being concerned with nature and considering themselves as part of it, valuing self, other people, or biosphere, tend to have more pro-environmental attitudes (Schultz, 2001). Based on this, Hypothesis 2 was proposed in order to test the correlation between declarative knowledge concerning the environmental impact of meat and consumers' attitudes.

H3: Respondents with stronger attitudes towards the global environment and low carbon footprint are more likely to intend to purchase LCB.

Previous studies (Whybrow and McDiarmid, 2018; Lentz *et al.*, 2018) have presented attitudes as a strong influence on purchasing intentions, as having a positive attitude towards the environment may lead to a greater demand for products with a smaller environmental impact. Similarly, Pagiaslis and Krontalis (2014) suggest that environmental concerns,

knowledge, and beliefs have direct and indirect effects on the intention to behave in a more environmentally friendly way.

Pro-environmental purchase intentions depend on consumers' awareness of their ecological footprint and willingness to reduce this impact, among other factors. Awareness of green products may build attitudes and lead to green purchasing intentions (Sreen *et al.*, 2018; Wang and Wu, 2016). The positive effect that attitude has on green product purchasing has been tested with survey data in a TPB framework (Burnier *et al.*, 2020; Song *et al.*, 2017). In light of this evidence, Hypothesis 3 was developed to test the relationship between attitudes and purchasing intentions.

H4: Consumers are more likely to buy LCB products if they have stronger environmental attitudes.

Attitudes towards behaviour are formed by behaviour beliefs, and a person's beliefs are stronger when substantiated by information (Ajzen, 2001). Behavioural studies based on the TPB framework state that consumers with stronger environmental awareness and attitudes are more likely to purchase environmentally friendly meat (Stampa *et al.*, 2020; Lentz *et al.*, 2018). More specifically, the more aware people are about the negative effect that beef has on climate, the more likely they are to buy sustainable beef (Burnier *et al.*, 2019). Çoker and Van der Linden (2020) found that attitudes were the strongest predictor of environmentally friendly meat consumption, among TPB constructs.

Environmentally friendly purchasing is a behaviour that has been slowly rising since information about global warming and climate change has spread the notion that natural resources are in peril. Even though specific knowledge such as how many kilograms of methane emissions are associated to each pound of beef, or the use of water in the sector is not common among consumers, their general environmental attitudes have improved (Ardoin *et al.*, 2020; Sanchez-Sabate *et al.*, 2019). Therefore, we assume that there is a positive

relationship between environmental attitudes and environmental behaviour. Consumers will make low carbon purchases if they are aware that changing their consumption patterns to reduce or replace intensively produced beef and thus lower their carbon footprint will benefit the global environment.

H5: Consumers are more likely to perform environmental behaviours if they are concerned about social norms.

Subjective norms refer to consumers' perception of social normative impetus (Ajzen, 2015), which includes people they care about or other significant groups, which may put pressure on individuals. Because humans are social beings and need to be a part of and accepted by certain groups, individuals might be influenced to behave according to these groups' expectations. Therefore, subjective norm embeds the social pressure that a person feels to exercise a particular behaviour (Ajzen, 1985). Social norms (SNs) vary from group to group; Šedová *et al.* (2016) results were very clear about that, where students of environmental studies are influenced by the norms of the groups to which they belong. Feeling pressured by their peers who are concerned with the carbon footprint of their consumption choices, people may change their own behaviour (Biel and Thøgersen, 2007; Vermeir and Verbeke, 2006). The latter study finds that social problems end up involving more social concerns, and, eventually, more individuals will internalise this consciousness. Recent studies have found social norms influence green behaviours, such as eating less meat and buying more sustainably as a behaviour common to family members, partners and friends (Nguyen *et al.*, 2021; Šedová *et al.*, 2016). This is enhanced by increasing pressure and influence from media and policy.

H6: Consumers are more likely to purchase LCB if they have higher PBC regarding environmentally friendly consumption.

Perceived behavioural control (PBC) is the perceived control over performance behaviour (Ajzen, 1991), can be understood as one's perception of the ease or difficulty of performing a behaviour, and may comprise both the ability and availability to perform a given behaviour (Ajzen, 2002). This may embed constraints such as time and money (Šedová *et al.*, 2016). Nguyen *et al.* (2019) indicated that price was arguably the most relevant barrier to the purchase of eco-friendly products. The findings of Maichum *et al.* (2016) highlight the importance of PCB and its effect on green purchasing intentions. Heeren *et al.* (2016) found PBC to be the most important variable among all those correlated to pro-environmental behaviour.

H7: Consumers who already purchase environmentally friendly products are more likely to (intend to) continue purchasing LCB.

Recent studies show that green consumption behaviours such as purchasing green products indicate an intention to continue behaving sustainably (Kautish *et al.*, 2019; (Sreen *et al.*, 2018). Trivedi *et al.* (2015) study on willingness to pay for environmentally friendly products posits that consumers with pro-environmental behaviour are more likely to buy sustainable products than the less environmentally active individuals. Past behaviour predicts intentions and future behaviour, and positive experiences lead to stronger intentions to repeat them (Albarracin and Wyer Jr, 2000), thus, current green products purchasing behaviour predicts the intention to perform this behaviour (Costa *et al.*, 2021; Wang and Wu, 2016; Agyeman, 2014), with Song *et al.* (2017) study highlighting past experience as a strong influence on consumers' intentions towards purchasing traceable beef. Similarly, findings from a survey conducted with Vietnamese respondents, investigating their intentions towards organic meat consumption support the assumption that sustainable behaviours are positively related to green purchasing intentions (Nguyen *et al.*, 2021). Path dependence studies found that low-carbon products purchasing intentions are predicted by past and current pro-environmental behaviours, some of

which may have become habitual (Sreen *et al.*, 2018; Peschel *et al.*, 2016). Ajzen's (1991) TPB framework postulates that intention precedes behaviour, which, in this case, represents a purchase planned to be carried out in the future. Thus, not only intention may lead to future behaviour, but, as path dependence theory postulates, past and current behaviour may influence intention.

Method and data

To test the conceptual model and research hypotheses, structural equation modelling (SEM) was used, an approach commonly applied in studies focused on the impact of determining factors on consumer behaviour (Thompson *et al.*, 2020; Bashir *et al.*, 2018; Wang and Wu, 2016). The model is estimated with partial least square method and statistical package SmartPLS. Responses with missing values were excluded from the sample used for model estimation. Model fit was assessed using the relevant range of goodness-of-fit indicators, including Standardized Root Mean Square Residuals (SRMR), Square Euclidean Distance (d-ULS), Geodesic distance (dG), and Normed Fit Index (NFI) (Kline, 2016). Model validity was assessed in a two-step procedure, measurement and structural models. Model selection was performed through a nested model approach, in which the number of constructs and indicators remained constant, and the number of estimated relationships was changed iteratively.

The questionnaire, designed based on a review of the literature and expert opinion, was tested in a pilot with one hundred respondents (early June 2020). No subsequent revision was required, and the questionnaire was then used in the survey run by a marketing company, Dynata (June 2020). The online survey was completed by 500 British respondents. Respondents were given details of the aims, dissemination, anonymity linked to this research, and asked to give their consent to participate in the research. The sample included only

respondents fully or partially responsible for the grocery shopping in the household. The respondents were asked about their diet (vegan ‘I do not eat any animal products’, vegetarian ‘I do not eat meat or fish’, pescatarian ‘I do not eat meat, but I do eat fish’, flexitarian ‘I eat vegetarian but also occasionally meat or fish’, meat eater/omnivore ‘I eat meat and fish’; respondents who did not select the latter were screened out. Although flexitarians (11% of respondents) are more likely to have a vegetarian lifestyle (Rosenfeld *et al.*, 2020; Padilha *et al.*, 2022), they still consume and shop meat, and thus they were also included in the sample. Additionally, respondents were asked if they consumed beef mince in the last 3 months, and those who did not were screened out.

Sample quotas were applied; these include region (79% from England, 11% Scotland, 5% Wales and 4% Northern Ireland), gender (female respondents 60%, male respondents 40%), age (18 – 24 years old, 12% respondents, 25 – 34, 15.5%; 35 – 44, 19.5%; 45 – 54, 15%; 55 – 64, 13%; 65 – 74, 10%; over 74 years old, 9% respondents), employment status (employed, 60% respondents; self-employed, 9%; retired, 9%; stay-at-home parent, 8%; student, 8%; unemployed, 6% respondents). Other socio-demographic characteristics included income of respondents, beef purchasing frequency, and purchasing purpose patterns e.g., for casual dinners (33% of respondents) or for entertaining (25% of respondents).

The questionnaire statements used in this analysis formed ordinal variables measured on a five-point Likert scale ranging from “strongly disagree” (1) to “strongly agree” (5), a common measurement scale for variables associated to behaviours, beliefs, and perceptions of a social phenomenon (Bashir *et al.*, 2018). Latent variables and their respective indicators were built according to the respective literature as presented in Table 1.

Table 1. Latent variables and indicators

Latent variables and indicators (questionnaire statements)

Declarative Knowledge

Know1: The contribution of greenhouse gas emissions from beef production to global warming is a significant share of the agricultural footprint

Know2: Meat production has a higher carbon footprint compared to crop production

Know3: The whole beef supply chain from cattle production through beef processing to retail and consumption has a significant carbon footprint

DK1: there is scientific evidence that responsible consumption patterns have a direct contribution to the reduction of global warming

DK2: There is sufficient information available on e.g., traditional, social and the new media about the climate change impact of beef production and consumption

DK3: There is clear information available on e.g., traditional, social and the new media about the ways to reduce the climate change impact of beef production and consumption

Source: Nguyen *et al.*, (2019); Siegrist and Hartmann (2019); Wang and Wu. (2016); Pagiaslis and Krontalis (2014); Frisk and Larson, (2011); Kaiser and Fuhrer, (2003); Monroe (2003);

Self-identity

Self1: I think of myself as someone who is concerned with food safety

Self2: I think of myself as someone who is concerned with the health and consequences of what I eat

Self3: I think of myself as someone who is concerned with the environmental footprint of my consumption patterns

Source: Graham and Abrahamse (2017); Carfora *et al.* (2017); Onel (2016); Hayley *et al.* (2015); Werff *et al.*, (2013); Schultz (2001)

Attitudes

Att1: I eat beef and thus am aware of my carbon footprint

Att2: Changing my consumption of beef to beef products labelled to have a lower carbon footprint will contribute to improving the global environment

Att3: Reducing my consumption of beef will reduce my carbon footprint and thus have an actual impact on the global environment

Source: Ajzen (2001); Lentz *et al.* (2018); Stampa *et al.* (2020); Çoker and Van der Linden (2020); Sanchez-Sabate *et al.* (2019); Ardoin *et al.* (2020); Burnier *et al.* (2019)

Social Norms

SN1: People who are important to me think that beef consumption has a higher carbon footprint than consumption of other types of meat

SN2: People who are important to me would approve of me buying low carbon beef products

SN3: People who are important to me would approve of me reducing my beef consumption

Source: Ajzen (1985, 2015); Šedová *et al.* (2016); Vermeir and Verbeke (2006); Biel and Thøgersen (2007).

Perceived Behaviour Control

PBC1: It would be financially difficult for me to change to more environmentally friendly consumption patterns e.g. buying low carbon beef

PBC2: I am not always aware of or have the time to search for beef products labelled low carbon*

PBC3: The shops where I usually buy beef products do not always display environmentally friendly alternatives

PBC4: If budget constrained, people should eat low carbon beef less frequently than cheaper beef regularly

*PBC2 was removed before the final model iteration as detailed in the Results section.

Source: Šedová *et al.* (2016); Maichum *et al.* (2016); Heeren *et al.* (2016); Moser (2015); Zhou *et al.* (2013)

Purchase Behaviour

B.1: I buy low carbon beef products for specific events such as entertaining

B.2: I buy environmentally friendly beef products with some regularity for casual dining

B.3: I always check the labelling to ensure I buy low carbon beef whenever I can

Source: Kautish *et al.* (2019); Sreen *et al.* (2018); Peschel *et al.* (2016); Trivedi *et al.* (2015)

LCB Future Purchase Intention

IB.1 I intend to reduce my beef consumption gradually during the next future

IB.2 I intend to shift to eating more environmentally friendly beef gradually during the next future

IB.3 I am willing to change the places I shop for others selling more environmentally friendly beef products

IB. 4 I tend to buy more frequently other types of meats with lower carbon footprint than beef

Source: Whybrow and McDiarmid, 2018; Lentz *et al.*, 2018; Sreen *et al.*, 2018; Wang and Wu, 2016; Pagiaslis and Krontalis (2014)

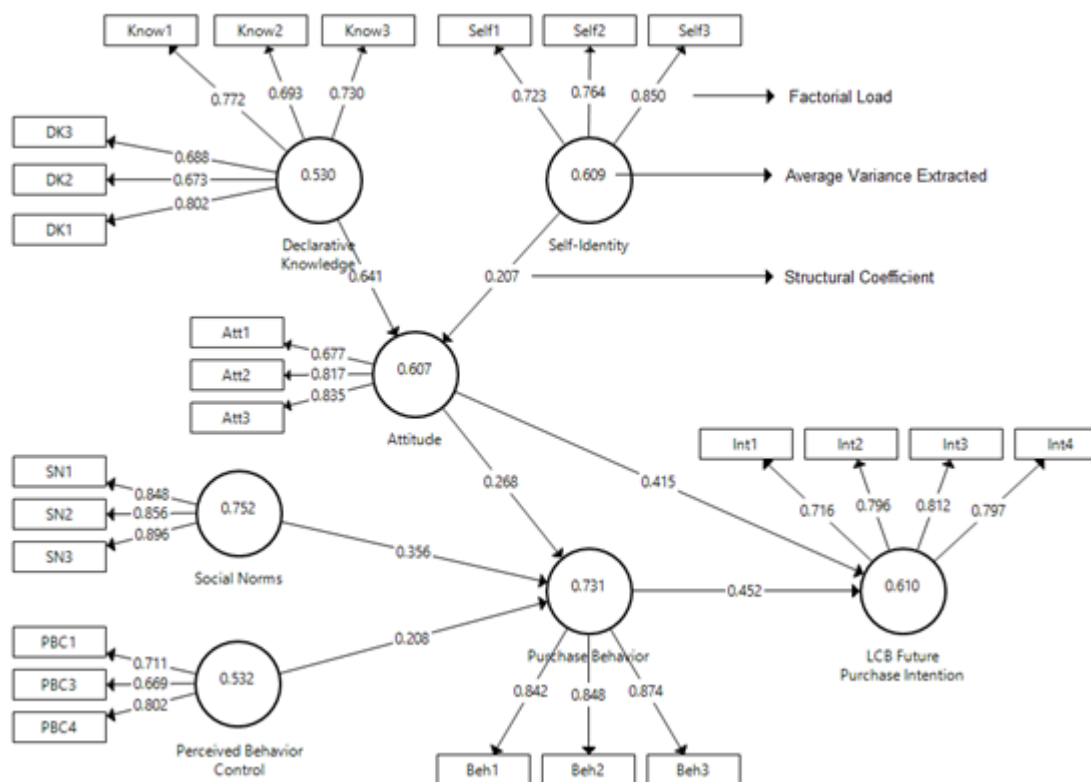
Descriptive analysis of the answers show that a majority of respondents (74%) see themselves as being concerned with food safety at some level, and a small majority (53%) see themselves as being concerned with the environmental footprint of their consumption pattern. Other descriptive statistics include frequencies on respondents' awareness or time availability to search for beef products that are labelled as being low carbon (65% of respondents); and availability of environmentally friendly alternatives of beef products in respondents' regular shops (54%). This is significant information as consumers' purchasing intentions may be (in)directly predicted by own knowledge (58% of respondents agree with the statement "I eat beef thus am aware of my carbon footprint") but limited by external factors (ease of identifying these products in the shops).

As regards the regularity with which consumers buy environmentally friendly products for casual meals, a minority of respondents choose environmentally friendly options (31% neither agree nor disagree with the statement, 27% disagree, and 33% agree). Similarly, a minority of respondents (24%) state buying low-carbon beef products for specific events / entertaining. More respondents state willingness to change regular shops in pursuit of more environmentally friendly products (45%) than not (26%). Almost half (47%) of respondents state intentions to change beef eating patterns to more sustainable options in the near future. A quarter of the respondents state checking for low carbon emission labels when buying beef products, while two fifths state they buy other types of meats with low carbon footprint more often than beef. This may mean that consumers' footprint may decrease if clearly labelled low carbon meat was more largely available. This supports Chekima *et al.* (2016) findings that labels are instrumental in facilitating the purchase of green products.

Results

The model stabilised after six iterations, following the necessary exclusion of the PBC2 indicator of the Perceived Behaviour Control latent variable due to the factor loading below 0.6 and affecting the average variance extracted ($\lambda = 0.249$). The structural model had acceptable goodness of fit values (SRMR = 0.073, d-ULS = 1.735, d-G = 0.467, NFI = 0.855) (Henseler, Hubona, Ray, 2016), with SRMR value below the threshold of 0.08 and NFI value above the recommended value of 0.8 (Henseler, Ringle, Sarstedt, 2016).

Figure 2. Structural equation model (consistency and validity assessment of the measurement model)



Source: Estimated using SmartPLS[®] v. 3.3.7 (Ringle, Wende, Becker, 2015)

The internal consistency of the measurement model was analysed using Cronbach's alpha and composite reliability ($0.7 < \theta < 0.95$), and its convergent validity through the average

variance extracted ($AVE > 0.5$) (Figure 1). Table 1 presents satisfactory consistency and validity levels (Hair *et al.*, 2009).

Table 1. Consistency and validity assessment of the measurement model

variables	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Attitude (Att)	0.772	0.822	0.607
Declarative Knowledge (Know)	0.822	0.871	0.530
LCB Future Purchase Intention (Int)	0.786	0.862	0.610
Purchase Behaviour (Beh)	0.816	0.891	0.731
Purchase Behaviour Control (PBC)	0.768	0.772	0.532
Self-identity (Self)	0.701	0.823	0.609
Social Norms (SN)	0.835	0.901	0.752

Source: Estimation using SmartPLS[®] v. 3.3.7 (Ringle, Wende, Becker, 2015)

The discriminant validity was measured by two approaches: Fornell-Larcker (1981) and Heterotrait-Monotrait Ratio (HTMT) according to Henseler *et al.* (2015). Both criteria were met, i.e., the positive square root of AVE for each latent variable was higher than the highest correlation with any other latent variable (Pearson's), and the upper limit values of HTMT were lower than 1.0 at 95% reliability when estimated using the Bootstrapping method on 5,000 subsamples (Netemeyer, Bearder, Sharma, 2003) (Table 2).

Table 2. Evaluation of the structural model (1)

variables	Pearson's Correlation Matrix
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	$\sqrt{\text{AVE}}$	Att	Know	Int	Beh	PBC	Self	SN
Att	0.779	1.000						
Know	0.728	0.639	1.000					
Int	0.781	0.676	0.654	1.000				
Beh	0.855	0.576	0.620	0.691	1.000			
PBC	0.729	0.529	0.552	0.537	0.523	1.000		
Self	0.781	0.512	0.476	0.550	0.426	0.307	1.000	
SN	0.867	0.559	0.570	0.616	0.607	0.486	0.344	1.000
Upper Limit (HTMT) ^{97.5%}								
Know		0.857						
Int		0.808	0.872					
Beh		0.875	0.835	0.919				
PBC		0.965	0.894	0.882	0.849			
Self		0.814	0.682	0.784	0.611	0.582		
SN		0.834	0.769	0.826	0.802	0.798	0.505	

Source: Estimation using SmartPLS[®] v. 3.3.7 (Ringle, Wende, Becker, 2015)

The relationship between the exogenous and endogenous variables rejects collinearity assumption as Variance Inflation Factor $VIF < 5$ (Thompson *et al.*, 2017). As for f^2 values, the relationships vary from medium effect ($0.075 < f^2 < 0.225$) to large effect ($f^2 > 0.225$), with acceptable values for $R^2 > 0.19$ and $Q^2 > 0.25$ (Lopes *et al.*, 2020) (Table 3).

Table 3. Evaluation of the structural model (2)

Endogenous variables

Exogenous variables	VIF			f ² (p – value)		
	Att	Int	Beh	Att	Int	Beh
Att		1.498	1.665		0.282 (0.000)	0.083 (0.013)
Know	1.292			0.757 (0.000)		
Beh		1.498			0.335 (0.000)	
PBC			1.499			0.056 (0.019)
Self	1.292			0.109 (0.008)		
SN			1.568			0.155 (0.000)
R ² (p – value)				0.580 (0.000)	0.593 (0.000)	0.479 (0.000)
Q ²				0.345	0.355	0.344

Source: Estimation using SmartPLS[®] v. 3.3.7 (Ringle, Wende, Becker, 2015)

Table 4 and Figure 3 present the estimation of the conceptual model (Figure 1), namely the structural coefficients of the relationships between exogenous and endogenous variables, all significant and thus validating the hypotheses, with the mediation effect of Purchase Behaviour, also significant.

Table 4. Structural coefficients and the mediation effect

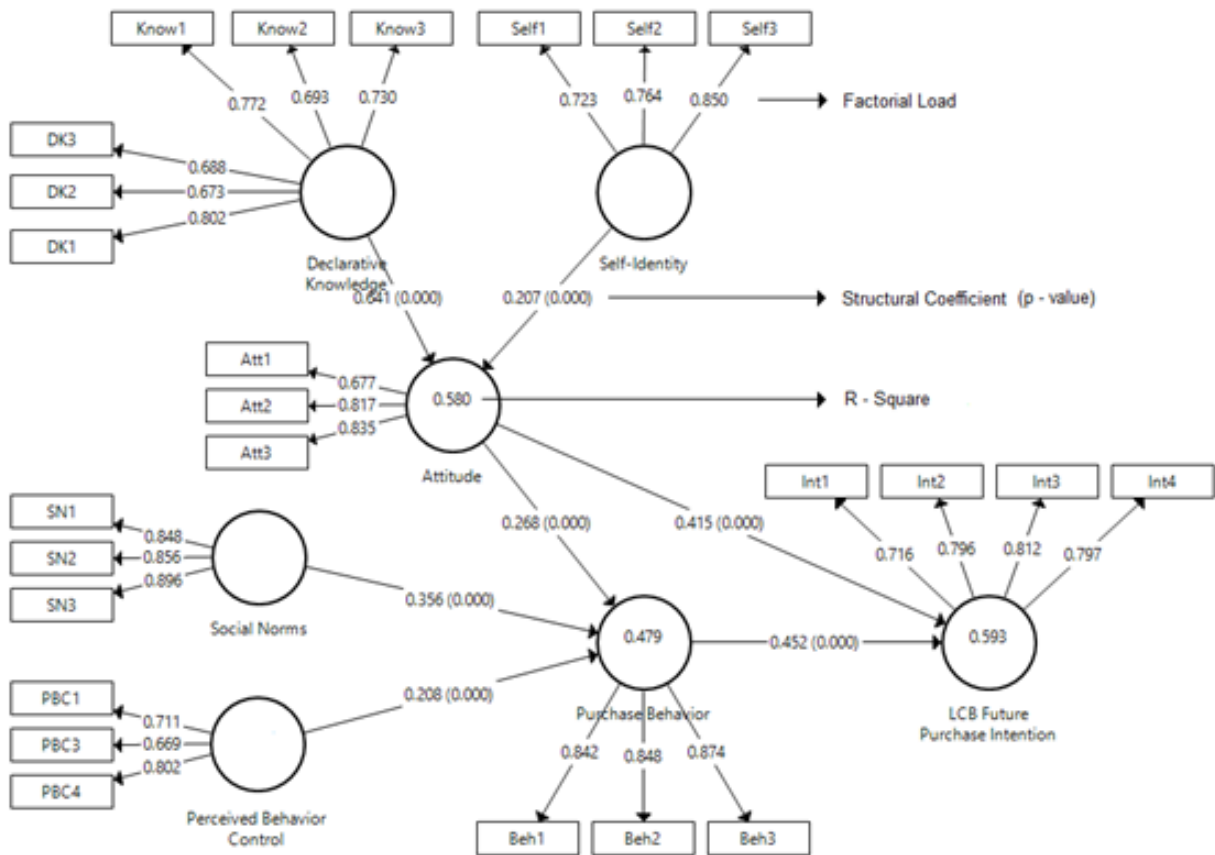
Hypotheses	Relationship			β	Standard deviation	T-	
	Exogenous	→	Endogenous			statistic ($ \beta/SD $)	p-value
H ₁	Know	→	Att	0.64	0.035	18.319	0.000
H ₂	Self	→	Att	0.21	0.038	5.473	0.000
H ₃	Att	→	Int	0.42	0.040	10.501	0.000

H ₄	Att	→	Beh	0.27	0.049	5.479	0.000
H ₅	SN	→	Beh	0.36	0.044	8.157	0.000
H ₆	PBC	→	Beh	0.21	0.042	4.959	0.000
H ₇	Beh	→	Int	0.45	0.039	11.726	0.000
	Exogeno	Mediat	Endogeno				
	us	or	us				
H ₈	Att	→ Beh	→ Int	0.12	0.023	5.297	0.000
H ₉	SN	→ Beh	→ Int	0.16	0.026	6.264	0.000
H ₁₀	PBC	→ Beh	→ Int	0.09	0.022	4.301	0.000

Source: Estimation using SmartPLS[®] v. 3.3.7 (Ringle, Wende, Becker, 2015)

TPB variables - Attitude, Social Norms and Perceived Behavioural Control - have positive effects in the mediation of Intention. Attitude has a stronger direct effect on Intention than its indirect effect mediated by Behaviour (the latter lower than Social Norms' effect).

Figure 3. Structural equation model (structural coefficients and variance explained)



Source: Estimated using SmartPLS® v. 3.3.7 (Ringle, Wende, Becker, 2015)

Discussion

The non-TPB constructs, declarative knowledge and self-identity, added as predictors of attitudes, have a positive effect on the latter, thus validating hypotheses H1 and H2, namely that consumers who are aware of the environmental footprint of beef production and identify themselves as someone discerning as regards the multiple aspects of consumption including environmental impact, are more likely to hold pro-nature attitudes. The literature has demonstrated that attitude formation and change may be influenced by a range of cognitive and motivational processes (Ajzen and Fishbein, 1977). What we know about information influencing perception and attitude is based upon empirical studies that investigate how they are correlated (Wongprawmas *et al.*, 2022; Costa *et al.*, 2021). In a study with students who were given information about the potential environmental threat from livestock production,

Jalil *et al.* (2020) state that, after this intervention, the demand for meat on the campus diminished, while that for alternative protein increased. Even though self-identity scored a smaller influence on pro-environmental attitude when compared to the effect of declarative knowledge, this is still a positive influence and supports findings of previous studies (Ates, 2020) highlighting the role of personal norms as predictors of pro-environmental attitudes and behaviour. Other studies correlating various types of ecological knowledge and pro-environment behaviour reached similar results. Tobler *et al.* (2012) state that having information about the consequences of climate change directly increases people's concern about it; those who were aware of the outcomes of global warming tend to worry more than those who do not have such knowledge, and therefore may act in a way to prevent such impact.

Pro-environmental attitudes have statistically significant positive effects on both LCB purchasing behaviour and intention, thus confirming hypothesis H3 and H4. This supports Ajzen's TPB theory (1991) and is consistent with the findings of several studies such as Paul *et al.* (2016), Song *et al.* (2017), Burnier *et al.* (2019), and Kumar (2021) who found pro-environmental attitudes (among other factors such as awareness) to be an important influence on green purchasing intentions. Other studies focused on consumer attitudes and green purchase intentions (such as Zaremohzzabieh *et al.*, 2021) found that extended versions of the TPB model may improve its predictive power.

Social norms have a statistically significant positive effect on LCB purchasing behaviour, thus validating hypothesis H5, which stipulates that one's peers' attitudes towards green consumption may influence one's LCB purchasing behaviour.

Hypothesis H6 was also validated as perceived behavioural control has a significant effect on LCB purchasing behaviour, and indirectly on intention, albeit the lowest influence compared

with attitude and social norms. This may suggest that, while budget constraints may limit consumers' choices towards low carbon beef, this is not the main behavioural influence. Nguyen *et al.* (2021) study 'I'll eat meat because that's what we do' found that national norms and national social identification may have an important role in predicting meat eating; for example, hotdogs in the USA, Sunday roast in the UK or meat pies in Australia. Many studies based on the TPB theory linking meat consumption and consumers' awareness of its environmental impact show that people do not always make the connection between meat and pollution. However, this is not always the case as, for example, Pohjolainen *et al.* (2016) run a large scale survey of Finnish consumers and found they form a wide typological range with a small majority of consumers 'unsure', and more than two fifths 'conscious' in their perceptions of the environmental burden of meat, which may suggest the need for carefully tailored political actions to guide meat consumption. Burnier *et al.* (2019) also suggest policies towards sustainable education to incentivise pro-environment behaviour, which they found, must be reinforced through a change in attitudes and social norms. Hypothesis H7 was also confirmed as current behaviour significantly predicts intention, which supports path dependence studies (Costa *et al.*, 2021). Studies on consumers' willingness to reduce meat consumption in favour of alternative proteins, such as Onwezen *et al.* (2021), found low acceptance levels. This suggests that dietary patterns are difficult to change and a shift from regular to low carbon beef may be more palatable, which is why the findings of our study may assist policymakers and industry in enabling factors of behavioural change within the context of climate change targets of net zero policies. Our findings show knowledge to have the strongest influence on attitudes, and indeed the strongest among all individual direct effects in the model, and attitude the second strongest

effect on both LCB purchasing behaviour and intention, thus policies supporting education and access to information may be an effective way to lead to behavioural change.

Limitations apply as in any study based on cross section, state preferences surveys.

Conclusions

Human consumption patterns have evolved slowly to account for global priorities on environment and health, and shocks such as the Covid-19 pandemic may further speed up this trend. Increasing awareness of food safety, welfare and environmental ethics may lead to a change in consumers' perceptions and attitudes, which may reflect in their consumption habits. Some changes, such as incorporating self-stable foods into diets, are relevant in the protein sector (Malafaia *et al.*, 2021), however beef continues to be one of the most consumed sources of animal protein in the world (Fitch Solutions, 2020). However slow, and whatever factors determine it, a change in demand is reflected in the supply and thus, predicting it is a key aspect of the market. The global cattle and beef sector needs to adapt to the market orientation suggesting an increasing shift to product quality coupled with quantity, which may include adjustments throughout the chain, e.g., less additives in feed and meat processing, higher welfare principles in primary production and lower waste and carbon footprint along the chain, improved supply chain traceability (Magnier *et al.*, 2016). These trends are being observed by policymakers and investors, and incentive mechanisms may include, alongside e.g., subsidies, regulation or improved access to (bio)technology and information, measures such as attributing higher levels of environmental, social and corporate governance risk to agribusinesses, which may be implemented to ensure the sector complies with increasing environmental requirements (Malafaia *et al.*, 2021).

To meet the progressively sophisticated demand, the global beef supply chain has increased uptake of sustainable technologies that balance productivity and GHGs mitigation, often in

integrated systems whose capacity to remove CO₂ from the sector is not always accurately taken into account by commonly used metrics (Malafaia et al., 2021). There is a need to more carefully balance consumers' perceptions about the negative externalities of the beef sector, to a certain extent reflected into their consumption behaviour, and the ability and willingness of the beef sector to lower its carbon footprint while maintaining economic sustainability. Well coordinated incentive mechanisms targeting sustainable behaviours of both consumers and producers need to be put in place to reduce market imperfections. Contributing to the debate, our findings indicate that social norms and knowledge influence attitudes and potentially behaviour, which may imply the need to increase access to information through well targeted education campaigns. Knowledge alone will unlikely lead to behavioural change, however coordinated educational efforts between scientists, industries and communities may facilitate more effective impacts (Ardoin *et al.*, 2020). Our findings point towards the conflicting influence of perceived behavioural control, which has the lowest impact on behaviour, albeit still explaining a share of its variance. This influence refers to both financial constraints and availability of beef products clearly labelled low carbon. Policy and industry should collaborate in designing mechanisms to incentivise an optimal redistribution of the cost low carbon beef along the supply chain from producers to consumers, so that more producers can remain financially sustainable while complying with increased environmental requirements, and more consumers can afford to lower their consumption footprint until/unless ready to shift to alternative sources of protein.

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