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Consumer adoption of blockchain food traceability: Effects of innovation-adoption characteristics, expertise in food traceability and blockchain technology, and segmentation

Author Details *(please list these in the order they should appear in the published article)*

Author 1 Name: Ou Wang
Department: Waikato Management School
University/Institution: University of Waikato
Town/City: Hamilton
State (US only):
Country: New Zealand

Author 2 Name: Frank Scrimgeour
Department: Waikato Management School
University/Institution: University of Waikato
Town/City: Hamilton
State (US only):
Country: New Zealand

NOTE: affiliations should appear as the following: Department (if applicable); Institution; City; State (US only); Country. No further information or detail should be included

Corresponding author: Ou Wang
Corresponding Author's Email: ou.wang@waikato.ac.nz

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Consumer adoption of blockchain food traceability: Effects of innovation-adoption characteristics, expertise in food traceability and blockchain technology, and segmentation

Structured Abstract:

Purpose

This study explores the influence of the following factors on consumer adoption of blockchain food traceability (BFT): innovation-adoption characteristics, segmentation, expertise in food traceability, expertise in blockchain technology, food categorical preferences and perceived important features of BFT.

Design/methodology/approach

The data was collected via an online questionnaire with 1,401 participants in New Zealand. Exploratory factor analysis, structural equation modelling and segmentation analysis were undertaken.

Findings

Consumer adoption of blockchain food traceability was significantly influenced by two innovation-adoption characteristics – perceived incentives and perceived complexity, as well as their expertise in food traceability. Two consumer segments were identified: Conservatives (48%) and Pioneers (52%). Significant differences were found between these two segments in terms of gender, age, education, occupation, residential area and ethnicity. Consumers are more willing to use BFT for purchasing fresh, imported, staple and normal foods than for processed, domestic and upscale foods. Their perceived important specific features of BFT are product origin, food safety information, quality control, food safety information, hygienic condition and scarcity management.

Originality/value

This study contributes knowledge to address the current knowledge gap regarding consumer adoption of blockchain food traceability by using a large sample set. It is also the first study to recognise consumer segments for BFT; to provide information about consumers' important socio-demographic characteristics, food categorical preferences and perceived important features towards BFT; and to explore the influences of consumers' innovation-adoption characteristics, expertise in food traceability and expertise in blockchain technology on their adoption of blockchain food traceability.

Abstract

Keywords

Consumer; blockchain; food traceability; innovation-adoption characteristics.

1. Introduction

Rising consumer demand for safety-assured food products has intensified consumers' desire to know where their food comes from, including its components and processing history (Akram et al., 2020; Sander et al., 2018). The COVID-19 epidemic has hastened this trend due to the food security and safety issues impacts on food industry labour (Attwood and Hajat, 2020; Galanakis, 2020). A credible traceability system must be able to trace and track food and ingredients through all stages of production, processing and distribution within a supply chain (Van Rijswijk and Frewer, 2008). However, traditional food traceability systems (e.g. alphanumerical codes, barcodes, RFID tags) are problematic: (1) they only consider distribution and warehousing steps; (2) they do not consider if the information shared by supply chain members can be trusted; and (3) they are monopolistic, asymmetric and opaque information systems (Badia-Melis et al., 2015; Tian, 2016). These problems result in further challenges, such as fraud, corruption, tampering and falsification of information (Tian, 2016).

In a blockchain-based system, information is supervised by every chain participant, rather than an information centre, thus creating decentralised, collectively maintained and reliable databases (Kamble et al., 2020; Saurabh and Dey, 2021; Tian, 2016). A blockchain-based food traceability system could therefore increase the transparency of a food chain, strengthen information credibility, realise real-time tracking of food products and enhance the assurance of safety along the food chain (Tian, 2016).

Research on blockchain food traceability (BFT) is still embryonic with few academic research papers. Most existing studies on the topic are either conceptual or reviews. Few empirical studies include consumer analysis of blockchain technology in association with food traceability. The limited findings show that consumers are unfamiliar with BFT globally, and their attitudes, trust, perceived behaviour control, perceived security and privacy and received extra information about BFT have significantly influenced their adoption of the technology (Cao et al., 2021; Dionysis et al., 2022; Garaus and Treiblmaier, 2021; Kumar et al., 2022; Mazzù et al., 2021; Rainero and Modarelli, 2021; Sander et al., 2018; Shew et al., 2022). There remains a lack of understanding of consumers' perceptions, choice motives, psychological factors, segmentation, categorical preferences, innovation-adoption characteristics (IACs) and behaviours regarding BFT. There is no literature providing empirical evidence to support actions and polices to enhance BFT adoption.

The results of this study will contribute to filling the knowledge gaps concerning consumer adoption of BFT. First, the study presents the theoretical background and research framework shaping the analysis of the influence of the following factors on consumer adoption of BFT: IACs, segmentation, expertise in food traceability (FT), expertise in blockchain technology (BT), food categorical preferences and perceived important features of BFT. Next, the framework is empirically assessed by using exploratory factor analysis, structural equational modelling and segmentation analysis. Last but not the least, the study discusses the academic and practical implications derived from this preliminary and more comprehensive picture of BFT from the perspective of consumers.

2. Theoretical background and research objectives

Figure 1 shows the research framework, which contextualises the research approaches used in this study. The following subsections introduce the theoretical and empirical background of this research framework.

>>>>>>>>> Insert Figure 1

2.1. Innovation-adoption characteristics

Hansen (2005) developed a conceptual model with five IAC factors that drive consumers' adoption of innovative products and services: perceived subjective norms (i.e. peer pressure on personal adoption of the innovative products/services); perceived compatibility of the innovative products/services with personal lifestyle and values; perceived complexity of using the innovative products/services; perceived risk regarding the innovative products/services; and perceived relative advantage (i.e. perceived superiority of the innovative products/services over relevant old products/services).

However, there is a lack of empirical studies to test if this theoretical five factorial IAC model fits well with real consumer samples regarding the adoption of innovative products and services. A few recent empirical studies have recognised this original model does not fit well with the real consumer samples regarding the adoption of e-commerce food shopping by using factor analysis (Wang and Scrimgeour, 2022; Wang and Somogyi, 2018). These studies have also found a more suitable IAC model for real consumers. This adjusted model has a three-factorial construct for IAC including perceived risk, perceived complexity and perceived incentives (i.e. perceived incentives what drove consumers to adopt the innovative products/services, including original factors- perceived subjective norm, perceived relative advantage and perceived compatibility) (Wang and Scrimgeour, 2022; Wang and Somogyi, 2018). Hence, the current study will use factor analysis to explore if an adjusted IAC model can be utilised to identify the adoption of BFT from real consumer samples.

Prior studies have confirmed the significant effects of one or several IAC factors on consumer adoption of innovative products/services such as business-to-consumer food shopping, online-to-offline food delivery services and autonomous vehicles (Alaimo et al., 2020; Roh and Park, 2019; Wang and Scrimgeour, 2022; Wang and Somogyi, 2018; Yuen et al., 2020). BFT is an innovative and new service to normal consumers. There is still a lack of studies exploring the effects of IACs on consumer adoption of BFT. Hence, this study builds on the prior work by focusing on an unexplored area: the impact of IACs on consumer adoption of BFT. Two hypotheses (H) were developed as follows:

H1a. Consumers' IACs have significant effects on their attitudes towards BFT.

H1b. Consumers' IACs have significant effects on their purchase intentions towards BFT.

2.2. Expertise in blockchain technology and food traceability

Consumers' expertise is distinguished from their previous product/service-related experiences (Alba and Hutchinson, 1987). Previous studies indicate that consumer expertise pertaining to a product/service has a significant effect on their current or future choice of it (including food traceability systems) (Hu et al., 2021; Lanseng and Sivertsen, 2019; Wang et al., 2017).

Given BFT is an innovative product/service based on two categories of existed technologies – food traceability and blockchain technology, consumer expertise in these two technologies may affect the adoption of BFT. The current study thus explores the lack of understanding of the impact of consumers' FT and BT on their adoption of BFT. The current study thus explores the impacts of consumers' FT and BT on their adoption of BFT. Four hypotheses were developed as follows:

H2a. Consumers' FT have significant effects on their attitudes towards BFT.

H2b. Consumers' FT have significant effects on their purchase intentions towards BFT.

H3a. Consumers' BT have significant effects on their attitudes towards BFT.

H3b. Consumers' BT have significant effects on their purchase intentions towards BFT.

2.3. Consumer adoption

Consumer adoption of a product/service is based on a two-stage procedure including their attitudes and consumption behaviours (purchase intention or real purchase) (Bredahl, 2001;

Cho et al., 2019; Wang and Scrimgeour, 2022; Wang and Somogyi, 2018). Attitudes are consumers' general evaluation (positive or negative) towards a product/service (Bredahl, 2001; Cho et al., 2019; Wang and Somogyi, 2018; Wang and Scrimgeour, 2022).

Previous studies indicate that consumer attitudes have a strongly positive impact on purchase intention/real purchase of a product/service, and are a significant mediator between the purchase intention/real purchase and other significant factors related to the adoption of the product/service (e.g. IACs) (Bartsch et al., 2016; Lim et al., 2017; Wang and Scrimgeour, 2022; Wang and Somogyi, 2018). Hence, this study explores the effect of consumer attitudes on their purchase intention towards BFT and the mediation effects of consumer attitudes between BFT purchase intention and their IACs and FT and BT. Four hypotheses are developed as follows:

H4. Consumers' attitudes towards BFT have significant effects on their purchase intentions towards BFT.

H5a. Consumers' attitudes towards BFT have significant mediation effects between their IACs and purchase intentions towards BFT.

H5b. Consumers' attitudes towards BFT have significant mediation effects between their FT and purchase intentions towards BFT.

H5c. Consumers' attitudes towards BFT have significant mediation effects between their BT and purchase intentions towards BFT.

2.4. Consumer segmentation and profiling

Segmentation analysis is increasingly being conducted in consumer and marketing studies, providing a deeper look at consumer segments and their profiling characteristics (e.g. socio-demographics) towards a product/service (Pallant et al., 2020; Wang & Scrimgeour, 2022), but as far as we know, there has been no empirical study of consumer segmentation and BFT. This study will thus contribute knowledge to filling this gap, by exploring and profiling consumer segments related to BFT.

In this study, segmentation variables include those IACs, FT and BT that have significant effects on consumer adoption of BFT and consumers attitudes and purchase intentions towards BFT. The identified segments will be profiled using consumers' socio-demographic characteristics.

2.5. Categorical preferences

Scholars have explored consumers categorical preferences when purchasing specific food products by using innovative services (e.g. e-commerce food shopping) (Wang & Somogyi, 2018; Wang et al., 2020). Consumers have obviously categorical preferences for different innovative food shopping services (e.g. consumers prefer snack for business-to-consumer food shopping, and restaurant meals for online-to-offline food shopping to other specific food categories) (Wang & Somogyi, 2018; Wang et al., 2020). However, as far as we know, there is not academic empirical study to explore consumers' categorical preferences for FT and BFT. As such, this study will fill this knowledge gap and explore consumer categorical preferences for BFT based on their purchase intentions towards eighteen food categories.

2.6. Perceived importance for specific features

A few studies have examined consumers' perceived importance of specific features of FT. These studies recognised most and least important features attached to FT by consumers such as origin, quality control, verifying label information, while attaching less importance to food traceability in allocating liability, manufacturing process information, product sustainability, food scarcity management, manufacturing process information, quality information, fight food counterfeiting and specific information for 'at risk' people (Liu et al., 2018; Myae et al., 2011; Rodriguez-Salvador & Dopico, 2020). However, to our knowledge, there are no relevant

empirical consumer studies of BFT adoption. Hence, this study will explore consumers' perceived importance of fifteen specific features relevant to BFT adoption.

3. Methods and materials

3.1. Participants and procedure

The data for this study was collected using an online survey in New Zealand. The questionnaire was developed in English. Before the survey, participants were asked to read a description about FT and BFT summarised from previous studies (Kamble et al., 2020; Saurabh and Dey, 2021; Tian, 2016).

A pre-test was conducted with 30 New Zealand residents in February 2021. The language expression and measurement design of the questionnaire were adapted based on the pre-test results and participants' feedback. The final questionnaire was distributed among New Zealand–based registered members of the consumer sample panel owned by an internationally reputed research agency from March to April 2021. A total of 1,401 participants completed the survey, and were representative in distribution for age, gender, residential area and ethnicity in New Zealand (population older than 18). Table 1 presents the socio-demographic characteristics of the total sample, including residential area, marital status, age, household size, annual household income, education, occupation, gender and ethnicity.

>>>>>>>>>> Insert Table 1

3.2. Measures

Table 2 indicates the measures and items involved in this study. Participants' IACs towards BFT were measured by fourteen items within the original five factorial constructs conceptualised by Hansen (2005). The measurement items were adjusted into the text expressions suitable for BFT based on a literature review related to (consumer behaviour towards) food traceability, blockchain technology and BFT (Asfarian et al., 2020; Kim and Woo, 2016; Mao et al., 2018; Nie and Luo, 2019; Yeh et al., 2019; Yuan, Wang et al., 2020; Zhao et al., 2019). A seven-point Likert agreement scale was employed, with response categories from 1 = totally disagree to 7 = totally agree (Wang and Scrimgeour, 2022; Wang and Somogyi, 2018).

Participants' FT and BT were measured by three items each, also using the seven-point Likert agreement scale mentioned above. The measures were developed from a previous study by Yuan et al. (2020) that explored consumers' FT.

Participants' attitudes towards BFT were measured using three items with seven-point semantic differential scales of bipolar adjectives from 1= unhappy/terrible/bad to 7= happy/ delightful/good. This design has frequently been used in previous studies to examine consumers' attitudes towards a product/service (e.g. Wang and Scrimgeour, 2022; Wang and Somogyi, 2018).

Participants' purchase intentions towards BFT were measured by three items with the seven-point Likert agreement scale. The measurement items were developed from previous studies that examined consumers' purchase intentions towards BFT and food traceability (Kim and Woo, 2016; Nie and Luo, 2019; Yeh et al., 2019; Yuan et al., 2020). Further, participants' purchase intentions towards eighteen food categories with BFT were measured by a single item with the seven-point Likert agreement scale. The food categories were developed from a previous study by Wang and Somogyi (2018) that examined consumers' online purchase intentions towards specific food categories.

Participants were asked to evaluate the importance of fifteen features for BFT on the seven-point Likert agreement scale and the measurement design developed from Wang et al. (2017), which explored consumers' perceived importance for beer consumption attributes with

questions such as: '*It is important that the blockchain-based food traceability system can be used [the fifteen important features]*'. The fifteen items were adjusted from previous studies that examined consumers' perceived important features of food traceability (Liu et al., 2018; Myae et al., 2011; Rodriguez-Salvador and Dopico, 2020).

>>>>>>>>> Insert Table 2

3.3. Data analysis

Data were analysed using the IBM SPSS 27 and AMOS 27 software package. Figure 2 indicates the data analysis procedure utilsed in this study. First, exploratory factor analysis (with a maximum likelihood estimation method with varimax rotation) was conducted to explore the suitable factorial construct for consumers' IACs towards BFT (Jones et al., 2002). Second, a structural equation model (SEM) was built to associate consumers' IACs, FT and BT with their attitudes and purchase intentions towards BFT. Path analysis was conducted to identify the significant IACs, FT and BT influencing consumer attitudes and purchase intentions towards BFT (Collier, 2020). A bootstrap sample of 5,000 was used to examine the mediation effect of attitudes on the relationships between the IACs/FT/BT and purchase intention towards BFT (Collier, 2020). Third, two-step hierarchical cluster analysis was conducted to identify consumer segments using the significant IACs, FT and BT for BFT adoption and the BFT attitudes and purchase intentions as segmentation variables (Zhang and Zhao, 2019). Chi-square tests and independent sample T-tests were employed to identify the significant differences between the segments in socio-demographic characteristics (Verbeke and Viaene, 1999). Fourth, descriptive analysis (with mean values) were conducted to recognise the most and least important features of BFT and favourite specific food categories with BFT (Myae et al., 2011; Rodriguez-Salvador and Dopico, 2020; Wang and Somogyi, 2018).

>>>>>>>>> Insert Figure 2

4. Results

4.1. Exploratory factory analysis

Table 3 presents the results of the exploratory factor analysis of an adjusted IAC factorial construct for BFT. A new two factor construct was identified. The values of the standardised factor loading for most of the items were within the acceptable limit – higher than 0.5 (Haszard et al., 2013). Internal reliability of the two new IAC factors was acceptable, with all Cronbach's α values higher than 0.7 (Pieniak et al., 2009).

>>>>>>>>>> Insert Table 3

The items for *subjective norm*, *perceived compatibility* and *perceived relative advantage* in the original IAC factorial construct loaded on a new factor in the adjusted factorial construct. The three items for *perceived relative advantage* also cross-loaded on a single factor. Previous studies on consumers' IACs for e-commerce food shopping identified an IAC factor, *perceived incentive*, that included the original IAC factors *subjective norm, perceived relative advantage* and *perceived compatibility* (Wang and Scrimgeour, 2022; Wang and Somogyi, 2018). As such, we finally combined the items of *subjective norm, perceived compatibility* and *perceived relative advantage* into a new factor we called '*perceived incentive*' for BFT. One item of the original *perceived compatibility* factor (PCT2) was removed from further analyses due to a low value of the standardised factor loading (less than 0.5).

One original *perceived risk* item (PR3) loaded on a new factor with all three items from the original *perceived complexity* factor. This factor was labelled '*perceived complexity*' as

item PR3 ('*with low understanding of the technology among ordinary consumers, it is difficult for blockchain-based traceability systems to become popular in the real market*') semantically dealt with the similar topic related to the complexity of BFT.

The other two items of the original *perceived risk* factor (PR1 and PR2) did not load well on any factor found in the exploratory factor analysis, with very low values for standardised factor loading (less than 0.4) for all the factors. Therefore, these two items were removed from further analyses.

4.2. Structural equation modelling

Figure 3 presents an SEM that associates consumers' IACs, FT and BT with their attitudes and purchase intentions towards BFT, including six latent variables and twenty-three observed variables. The observed variables for the latent variables FT, BT and attitudes and purchase intentions towards BFT had good internal reliability, with high Cronbach α values: 0.879 for the attitudes toward BFT, 0.815 for the purchase intentions towards BFT, 0.783 for BT and 0.835 for FT. There was no severe multi-collinearity among the independent variables in the later path analysis, as correlation coefficients were below 0.8, as shown in Table 3 (Pieniak et al., 2009).

>>>>>>>>> Insert Figure 3

Path analysis performed well based on the SEM, as the values for the goodness-of-fit indices were within acceptance limits: lower than 0.08 for RMSEA and higher than 0.9 for CFI (Pieniak et al., 2009). The SEM was modified by correlating the error variables among the three observed variables – PRA1, PRA2 and PRA3. This was done because the values for modification indices were much higher than the other modifications suggested by the path analysis outputs, and the three measurement items for the observed variables from the original IAC factor *perceived relative advantage* and referred to similar issues – that is, the relative advantages related to BFT (Collier, 2020; Wang et al., 2015; Wu, 2009).

>>>>>>>>>>>> Insert Table 4

Table 4 summarises the findings from the path analysis. Consumers' FT and *perceived incentive* were significantly and positively linked to their *attitudes* and *purchase intentions towards BFT*. While consumers' *perceived complexity* was significantly and negatively linked to their *attitudes towards BFT*. Therefore, H1a and H1b are partially supported. H2a and H2b are supported. In other words, those consumers who had more prior experience with food traceability and perceived more incentives for BFT would have more positive attitudes and stronger purchase intention for food shopping with BFT. Those consumers who considered BFT as being relatively complicated would have negative attitudes towards food shopping with it. Further, consumers' BT had no significant effects on either their attitudes or purchase intention towards BFT. As such, H3a and H3b are not supported.

Consumers' attitudes had a significantly positive impact on their purchase intention towards BFT. H4 is supported. However, as shown in Table 4, it was not significant for the mediation effects of attitudes on the relationships between IACs/FT/BT and purchase intention towards BFT. H5a, H5b and H5c are not supported. In other words, those IACs/FT/BT that had significant effects on BFT attitudes would have no significant indirect effects on BFT purchase intention through attitudes.

4.3. Segmentation analysis

The two-step hierarchical cluster analysis resulted in a two-segment solution using five segmentation variables including the significant independent variables for the O2O-FDS adoption in the path analysis (*perceived incentive, perceived complexity* and FT), as well as the two BFT adoption variables (*attitudes* and *purchase intentions towards BFT*). Because of the high scale reliabilities mentioned above, the five segmentation variables were obtained on the basis of the mean values of their observed variables (Wang and Scrimgeour, 2022). Table 5 shows the size and mean value per segmentation variable for the total sample. Segment 1 accounted for 52% of the total sample. Segment 2 contained 48% of the total sample. Segment 1 had much higher mean values for *perceived incentive*, FT, attitudes and purchase intention towards BFT than Segment 2. Segment 1 had a lower mean value for *perceived complexity* than Segment 2. Further, all segmentation variables in Segment 1 scored on the positive answer anchor (higher than 4), while the segmentation variables FT, attitudes and purchase intentions towards BFT in Segment 2 scored on the negative answer anchor (lower than 4). In other words, consumers in Segment 1 were more likely to agree that BFT would bring benefits and fit with the daily lives of their peers and themselves. They had positive attitudes and strong purchase intentions towards food shopping with BFT. They were more experienced in food traceability and were less likely to consider BFT as a complicated technology and services than participants in Segment 2. As such, this segment was named *Pioneers*.

By contrast, consumers in Segment 2 had negative attitudes and weak purchase intention for food shopping with BFT. They were less likely to agree that BFT would bring benefits and fit with the daily lives of their peers and themselves. They were extremely lacking in experience in food traceability and were more likely to consider BFT as a complicated technology and service than their peers in Segment 1. Therefore, this segment was labelled *Conservatives*.

>>>>>>>>>>>> Insert Table 5

As shown in Table 5, chi-square tests and independent sample T-tests indicated significant differences between the two segments in socio-demographic characteristics including gender, age, education, occupation, residential area and ethnicity. The *Pioneers* segment was characterised by a higher percent of participants of younger age, high educational level, a high- or medium-level position (e.g. managing employee and salaried employee), male, of Chinese and Indian ethnicity and living in a big city (e.g. Auckland) than the *Conservatives* segment. By contrast, the *Conservatives* segment was typified by a higher percent of participants who were older in age, had a low educational level, a low-level position (e.g. unemployed, retired, farmer, housewife/houseman or on leave), female, of NZ European ethnicity and living in a small city or region (e.g. Whangarei, Wanganui, Tasman, Taranaki, Southland, Palmerston North, Northland, Nelson, Napier, Hawkes Bay, Manawatu, Marlborough and Gisborne) than the *Pioneers* segment.

4.4. Descriptive analysis

As shown in Figure 4, the mean values of perceived importance of fifteen specific features for BFT ranged from 5.28 to 5.70. The highest mean values were found for the features '*To know the origin of the food product*', '*To know if the food product has been maintained within quality control specifications*' and '*To make sure that the food product is safe and risk free*', '*To make sure that the food product has been prepared, transported and stored in hygienic conditions*', '*To manage a food scare and to identify and recall products in bad condition*' and '*To make sure that the food product is safe and risk free*' (mean values above 5.65). The lowest mean values were found for the features '*To fight food counterfeiting*', '*To know the information*

about every stage of the food manufacturing process', '*To know if it is a sustainable food product*', '*To allocate liability in case the food product has deteriorated or is in a bad condition*' and '*To provide confidence when selecting healthy foods*' (mean values below 5.5).

>>>>>>>>>>>> Insert Figure 4

As shown in Figure 5, the mean values for the BFT purchase intentions towards the eighteen food categories ranged from 4.67 to 5.51. The highest mean values were found for imported food, fresh meats, dairy products, fresh vegetables and fresh fruits (mean values above 5.4). The lowest mean values were found for alcoholic drinks, soft drinks and snacks (mean values below or closed to 5). In general, fresh foods (e.g. fresh meat, fresh vegetable, eggs, fresh fruits and fresh seafood), dairy product, imported food, staple food and normal food ranked in the first half of the food categorical list in both the two segments. Processed food (e.g. processed meat, processed vegetable, processed fruits, processed seafood, snacks, soft drinks and alcoholic drinks), domestic food and upscale food ranked in the second half of the food categorical list. In other words, consumers were more willing to use BFT when purchasing fresh food, imported food, staple food and normal food than for processed food, domestic food and upscale food.

>>>>>>>>>>>> Insert Figure 5

5. Discussion

Regarding consumers' IACs, this study obtained an adjusted two-factorial construct for BFT (including *perceived incentive* and *perceived complexity*), to replace the original five-factorial construct developed by Hansen (2005). The findings are similar to those found in previous studies regarding the IAC factorial construct for business-to-consumer food shopping and online-to-offline food delivery services, with three of the original IACs – *subjective norm*, *perceived relative advantage* and *perceived compatibility* – combined into the new factor *perceived incentive* (Wang & Scrimgeour, 2022; Wang & Somogyi, 2018).

Regarding the two IACs for BFT, *perceived incentive* has a significantly positive influence on both consumers' attitudes and purchase intentions for food shopping with BFT. This is partly in line with the findings from recent studies. Garaus & Treiblmaier (2021) indicated that consumers' awareness of blockchain benefits (*perceived relative advantage*) would have significantly positive influences on their adoption of BFT. While Dionysis et al. (2022) did not identify the significant influence of *subjective norm* on consumer adoption of BFT.

Perceived complexity has a significantly negative influence on consumers' attitudes towards BFT. This is reasonable, because BFT is only a conceptual product to consumers and they have no real consumption experience with it, so *perceived complexity* is a significant barrier for them in adopting this innovative technology and service. This is in line with previous findings that *perceived ease of use or complexity* has a significantly negative influence on consumer adoption of BFT (Kumar et al., 2022; Sander et al., 2018). Further, our study is the first to indicate that *perceived complexity* has either no significant direct influence or indirect influence through attitudes on consumers' purchase intentions towards BFT.

Nie & Luo (2019) have pointed out that *perceived risk* has a significantly negative influence on consumers' purchase intention towards BFT. However, our study does not recognise the factor *perceived risk* in the adjusted IAC factorial construct for BFT. Consumers have no real consumption experience with BFT and therefore are not familiar with the specific risks related to the use of BFT described in the measurement items. This might lead to low

reliability in the measures for *perceived risk* and the items do not load well on the factors in the IAC factorial construct for BFT in this study.

This study explored the influence of consumers' FT and BT on their adoption of BFT. Interestingly, although the major innovation of BFT compared to traditional FT systems is to decentralise databases of food traceability using BT, consumers' BT has no significant influence on their adoption of BFT. By contrast, consumers' FT has a significantly positive influence on both their attitudes and purchase intentions for shopping food with BFT. Shew et al. (2021) also had similar findings: consumers place little or no additional value in blockchain technology–specific labels for food purchases compared to traditional food traceability labels authorised by government departments without any technological claims.

This study identified two consumer segments: *Pioneers* and *Conservatives*. Consumers in the *Pioneers* segment have much more positive general attitudes, perceived incentives and stronger purchase intentions towards BFT, are more experienced in FT and are less likely to consider BFT as complicated compared to their counterparts in the *Conservatives* segment. The BFT *Pioneers* are more likely to be male, young, of high educational level, have a high- or medium-level position and live in a big city than BFT *Conservatives*. This is in line with previous findings that young people, males, people with a high level of occupation and education and/or people lived in big cities are more likely to become pioneers in accepting food innovation (e.g. e-commerce food shopping and cultured meat) (Barrena et al., 2015; Bryant & Barnett, 2018; Wang & Scrimgeour, 2022; Wang & Somogyi, 2018). The BFT *Pioneers* segment also contains a higher percentage of consumers of Chinese and Indian ethnicity than the BFT *Conservatives* segment. This might be caused by the Asian demographic in New Zealand having a higher educational level on average, than other ethnicities in the country (Meehan et al., 2019).

Regarding the specific features of BFT that are perceived as important, consumers attach more importance to product origin, food safety information, quality control, food safety information, hygienic condition and scarcity management. While they attach less importance to fighting food counterfeiting, manufacturing process information, product sustainability allocating liability and healthy food selection. Our findings are partly in line with previous findings regarding consumers' perceived important features of food traceability. Rodriguez-Salvador and Dopico (2020) suggested that consumers attach more importance to food traceability in terms of product origin, quality control and verifying label information, while attaching less importance to food traceability in allocating liability, manufacturing process information and product sustainability. Myae et al. (2011) pointed out that consumers attach more importance to food scarcity management, manufacturing process information, quality information, fight food counterfeiting and specific information for 'at risk' people.

According to the food categorical preferences for BFT, consumers are more willing to use BFT for purchasing fresh, imported, staple and normal foods than for processed, domestic and upscale foods. This corresponds with the reality and tendency of food consumption indicated by previous studies. Consumers are increasingly worried about the safety of imported food, particularly during the COVID-19 pandemic (Armstrong & Reynolds, 2020; Ben Hassen et al., 2020). Fresh food products are more difficult to transport, store and trace than processed and bulky food products, which have more widely established safety and quality control standards and systems (Golan et al., 2004; Unnevehr, 2000). Consumers eat staple and normal foods every day: much more frequently than the luxury and upscale foods that they often consume on special occasions (Hastorf, 2003; Wargenau & Che, 2006). Consumers may therefore care more about the safety and quality of and have a stronger willingness to trace (using BFT) fresh, imported, staple and normal foods than processed, domestic and upscale foods.

6. Conclusion

This study contributes to filling an important research gap in the understanding of consumer adoption of BFT using a large sample representative for New Zealand. As far as we know, this is the first study to identify consumer segments for BFT; to provide information about consumers' important socio-demographic characteristics, food categorical preferences and perceived important features towards BFT; and to explore the influences of consumers' IACs, FT and BT on their adoption of BFT. These findings are exploratory in nature but do provide foundational methods and insights that should inform ongoing research into the adoption of BFT.

The findings have vital managerial and policy implications. They highlight the need for consumer education regarding BFT. Further, this education needs to be focused on the different segments. These results will help stakeholders in the food industry to develop effective promotion strategies and policies for BFT, allowing stakeholders to clearly identify different consumer segments for BFT based on socio-demographic profiles: *Conservatives* (e.g. a low level of education and occupation, female, older and living in small cites) and *Pioneers* (e.g. a high level of education and occupation, male, younger and living in big cities). Consumer education that positively impact the "Conservatives" will need to be different to that which meets the needs of "Pioneers". BFT promotion strategies and policies designed specifically for the different consumer segments based on their different IACs, food categorical preferences and perceived important features of BFT have the potential to enhance the rate of BFT adoption. In addition, citizens should also be more broadly educated regarding food traceability, rather than blockchain technology, as governments and companies seek to socialise the benefits of BFT.

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Table 1 Socio-demographics of the sample in this study

Total sample (n=1401)			
Gender		**Household size**	
Male	47.7%	1	15.8%
Female	52.3%	2	35.8%
Age		3	18.9%
Mean value	45.42	4	16.7%
18- 30	25.1%	≥5	11.8%
31- 40	18.0%	**Education**	
41- 50	18.2%	Secondary school or below	27.3%
51- 60	15.3%	Trade training or equivalent	26.1%
61- 70	13.6%	Bachelor degree or equivalent	34.0%
⩾70	9.8%	Master degree, equivalent or above	12.6%
Household income		**Occupation**	
0- $50,000	31.7%	Managing employee	6.1%
$50,001- $100,000	33.3%	Salaried employee	32.8%
≥ $100,000	35.0%	Student	5.9%
Marital status		Worker	13.4%
Married	45.8%	Self-employed	10.7%
No, but has a partner	22.3%	Other (Unemployed, Retired, Farmer, Housewife/houseman or On leave)	31.1%
Single	31.8%		
Residential area		**Ethnicity**	
Auckland	32.8%	NZ European	62.5%
Wellington	13.3%	Maori	7.8%
Waikato	11.2%	Pacific Island	2.6%
Canterbury	7.3%	European	5.8%
Bay of Plenty	8.3%	Chinese	4.5%
Otago	5.8%	Indian	5.0%
Other regions (Whangarei, Wanganui, Tasman, Taranaki, Southland, Palmerston North, Northland, Nelson, Napier, Hawkes Bay, Manawatu, Marlborough, Gisborne etc.)	21.3%	Other ethnicities (Sri Lankan, South American, South African, Middle East, Filipino, Korean, Japanese etc.)	11.8%

Note: $= New Zealand dollars

Table 2 Measurement items in the study

Code	Factor and measurement items
	(Innovation-adoption characteristics)
SN	**Subjective norm**
SN1	My family members probably think that it is a good idea to track food information using blockchain-based traceability systems.
SN2	My friends and acquaintances probably think that tracking food information through blockchain-based traceability systems is a good idea.
PCL	**Perceived complexity**
PCL1	It will be complex to use the blockchain-based food traceability system.
PCL2	The blockchain-based food traceability system is hard to understand.
PCL3	It will be difficult to learn how to use the blockchain-based food traceability system.
PCT	**Perceived compatibility**
PCT1	Tracking food information by using blockchain-based traceability systems is attractive to me.
PCT2	In general, tracking food information using blockchain-based traceability systems is problem free.
PCT3	The blockchain-based food traceability system will be very useful in my life.
PRA	**Perceived relative advantage**
PRA1	The blockchain-based traceability system is favorable as it can eliminate fraud and false information in the food supply chain.
PRA2	Blockchain-based traceable food products are safety- and quality-assured.
PRA3	The blockchain-based food traceability system can help people to obtain trustworthy information about food products.
PR	**Perceived risk**
PR1	Using blockchain-based traceability systems will increase food production costs that may be passed on to consumers.
PR2	A risk with the high level of information transparency of blockchain-based food traceability systems is leaking my privacy.
PR3	With low understanding of the technology among ordinary consumers, it is difficult for blockchain-based traceability systems to become popular in the real market.
FT	**Expertise towards food traceability**
FT1	I understand standards related to traceable food.
FT2	I have a lot of experience in purchasing traceable food.
FT3	I am an expert in the purchase of traceable food.
BT	**Expertise towards blockchain technology**
BT1	I understand the rationale of blockchain technology.
BT2	I know more about blockchain technology than my friends.
BT3	I have more experience than my friends in purchasing or using blockchain-based products e.g. Bitcoin or other blockchain coins.
A	**Attitudes towards blockchain food traceability** (When I think about blockchain-based food traceability system, I feel …)
A1	Unhappy/Happy
A2	Terrible/Delightful
A3	Bad/Good
PI	**Purchase intentions towards blockchain food traceability**
PI1	I will use blockchain-based food traceability tools in the future.
PI2	I am willing to buy blockchain-based traceable food products.
PI3	I will recommend blockchain-based food traceability tools to my friends.

Table 2 Continued

Factor and measurement items
Perceived important aspects for blockchain food traceability
(It is important that the blockchain-based food traceability system can be used…)
To know the origin of the food product.
To know the quality of the food product.
To make sure that the food product is safe and risk free.
To make sure that the food product has been prepared, transported and stored in hygienic conditions.
To know if the food product has been maintained within quality control specifications.
To know if it is a sustainable food product.
To allocate liability in case the food product has deteriorated or is in a bad condition.
To know the information about every stage of the food manufacturing process.
To know all the ingredients of the food product.
To manage a food scare and to identify and recall products in bad condition.
To verify the information that appears on the food label.
To ensure authenticity of food products.
To fight food counterfeiting.
To provide confidence when selecting healthy foods.
To provide specific information for "at risk" individuals e.g. with weakened immune system.
Purchase intentions towards using blockchain food traceability systems for specific food categories (I am willing to buy blockchain-based traceable…)
Fresh meats
Processed meat products (e.g. canned meat, smoked meat, dried meat, sausage etc.)
Eggs
Dairy products
Fresh vegetables
Processed vegetable products (e.g. dried and picked vegetables etc.)
Fresh fruits
Processed fruit products (e.g. dried and canned fruits etc.)
Staple food (e.g. rice and flour products etc.)
Fresh seafood
Processed seafood (e.g. canned seafood, smoked seafood, dried seafood etc.)
Soft drink
Alcoholic drink
Snack
Domestic food
Imported food
Normal food
Upscale food

Table 3. Outputs of the exploratory factor analysis and the correlation matrix of the independent variables in the path analysis based on the SEM (n=1401)

Factor and item	Standardized factor loading	Cronbach's α
Perceived incentive	**Code: IN**	0.861
PCT1	0.745	
SN1	0.721	
SN2	0.704	
PCT3	0.692	
PRA1	0.615	
PRA2	0.566	
PRA3	0.554	
Perceived complexity		0.775
PCL3	0.733	
PCL2	0.681	
PR3	0.521	
PCL1	0.514	

Factor	1	2	3	4
1. BT	1			
2. FT	0.716	1		
3. PCT	-0.141	-0.040	1	
4. IN	-0.449	0.310	-0.260	1

Note: For the codes of measurement items, please see Table 2 and Table 3; Goodness-of-fit Test ($\chi 2=466.676$, $p=0.000$).

Table 4 Standardized regression weights of the path analysis the Bootstrap test for indirect effects based on the SEM:

Factor	Path	Factor	Total sample (n=1401)
Expertise towards blockchain technology	→	Attitude	ns
Expertise towards food traceability	→	Attitude	0.068*
Perceived complexity	→	Attitude	-0.089***
Perceived incentive	→	Attitude	0.819***
Expertise towards blockchain technology	→	Purchase intention	ns
Expertise towards food traceability	→	Purchase intention	0.135***
Perceived complexity	→	Purchase intention	ns
Perceived incentive	→	Purchase intention	0.820***
Attitude	→	Purchase intention	0.094*

Bootstrap test for indirect effects	Total sample (n=1401)
Expertise towards blockchain technology → Attitude → Purchase intention	ns
Expertise towards food traceability → Attitude → Purchase intention	ns
Perceived complexity → Attitude → Purchase intention	ns
Perceived incentive → Attitude → Purchase intention	ns

*Note: ***= p<0.001, *= p<0.05, ns = no significant; Goodness-of-fit indices: RMSEA=0.077, CFI=0.902, Chi-square=1995.001, Degrees of freedom=213, p=0.0000.*

Table 5 Outputs of the segmentation and profiling analyses

	Segment 1	Segment 2
Segmentation variable	Pioneers	Conservatives
Share of the total sample (n=1401)	52%	48%
Expertise towards food traceability***	4.09	2.86
Perceived complexity***	4.50	4.87
Perceived incentive***	5.54	4.21
Attitude***	5.32	3.93
Purchase intention***	5.51	3.89
Gender* **		
Male	51.4%	43.7%
Female	48.6%	56.3%
Marital status		
Married	47.9%	43.5%
No, but has a partner	22.4%	22.3%
Single	29.7%	34.2%
Age*		
Mean value	44.35	46.58
Household Income		
0- $50,000	29.9%	33.6%
$50,001- $100,000	32.6%	34.0%
≥ $100,000	37.5%	32.4%
Education* **		
Secondary school or below	23.1%	31.8%
Trade training or equivalent	25.0%	27.3%
Bachelor degree or equivalent	37.8%	30.0%
Master degree, equivalent or above	14.1%	10.8%
Household size		
1	14.8%	16.9%
2	34.1%	37.7%
3	20.2%	17.5%
4	17.6%	15.8%
≥5	13.3%	12.0%
Occupation* **		
Managing employee	8.0%	4.2%
Salaried employee	35.9%	29.6%
Student	6.3%	5.3%
Worker	12.4%	14.6%
Self-employed	10.9%	10.5%
Other	26.6%	35.8%
Residential area **		
Auckland	36.7%	28.7%
Wellington & Canterbury & Waikato	31.0%	32.5%
Otago & Bay of Plenty	14.3%	13.8%
Other regions	18.0%	25.0%
Ethnicity* **		
NZ European	58.8%	66.6%
Maori	8.4%	7.1%
Pacific Island	3.0%	2.2%
European	5.9%	5.6%
Chinese	5.8%	3.1%
Indian	7.4%	2.4%
Other ethnicities	10.7%	12.9%

*Note: ***= p<0.001, **= p<0.01, *= p<0.05 (Chi-square tests or Independent sample T-tests); $= New Zealand dollars.*

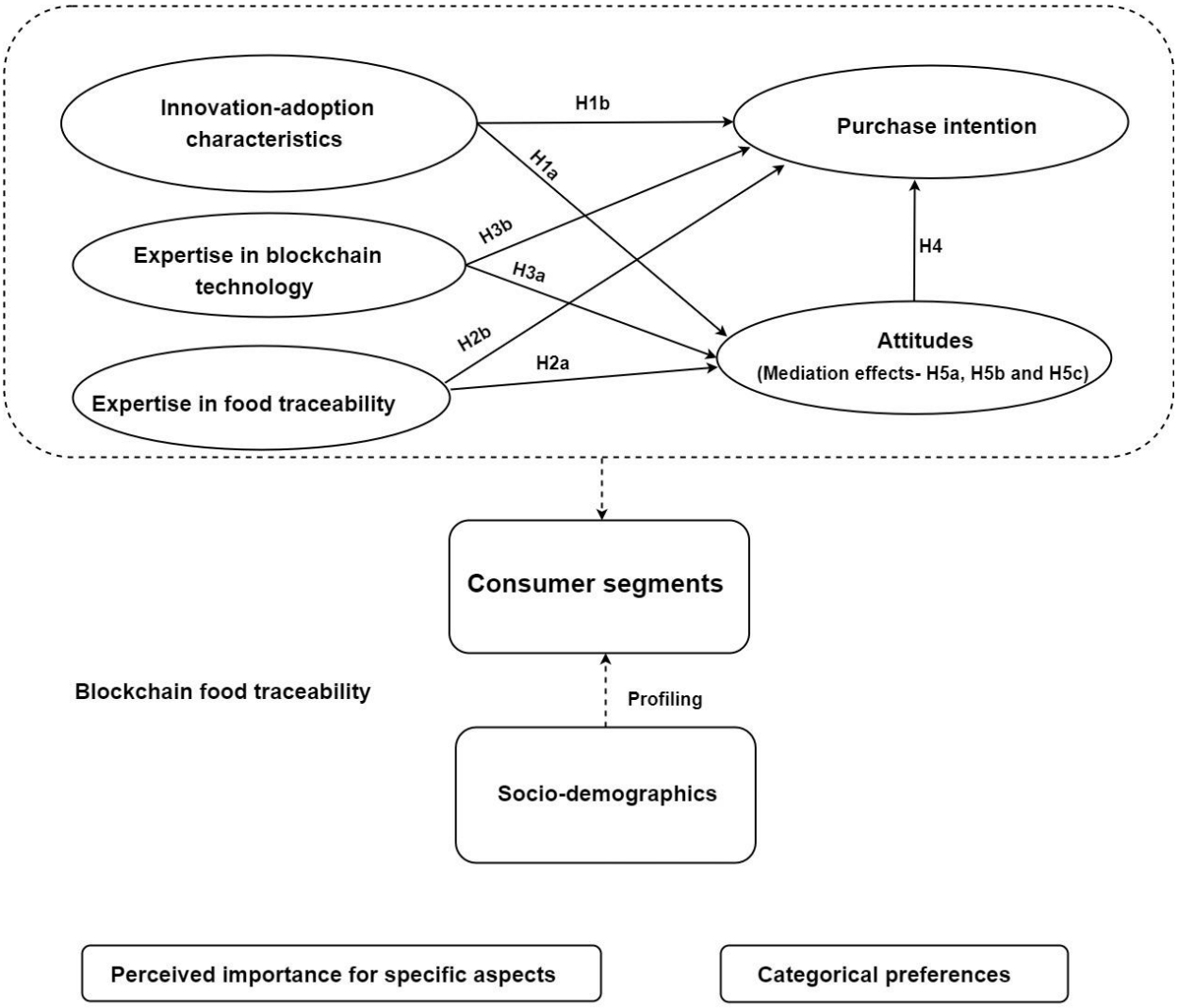

Figure 1 Research framework of the study

Figure 2 Procedure of data analysis

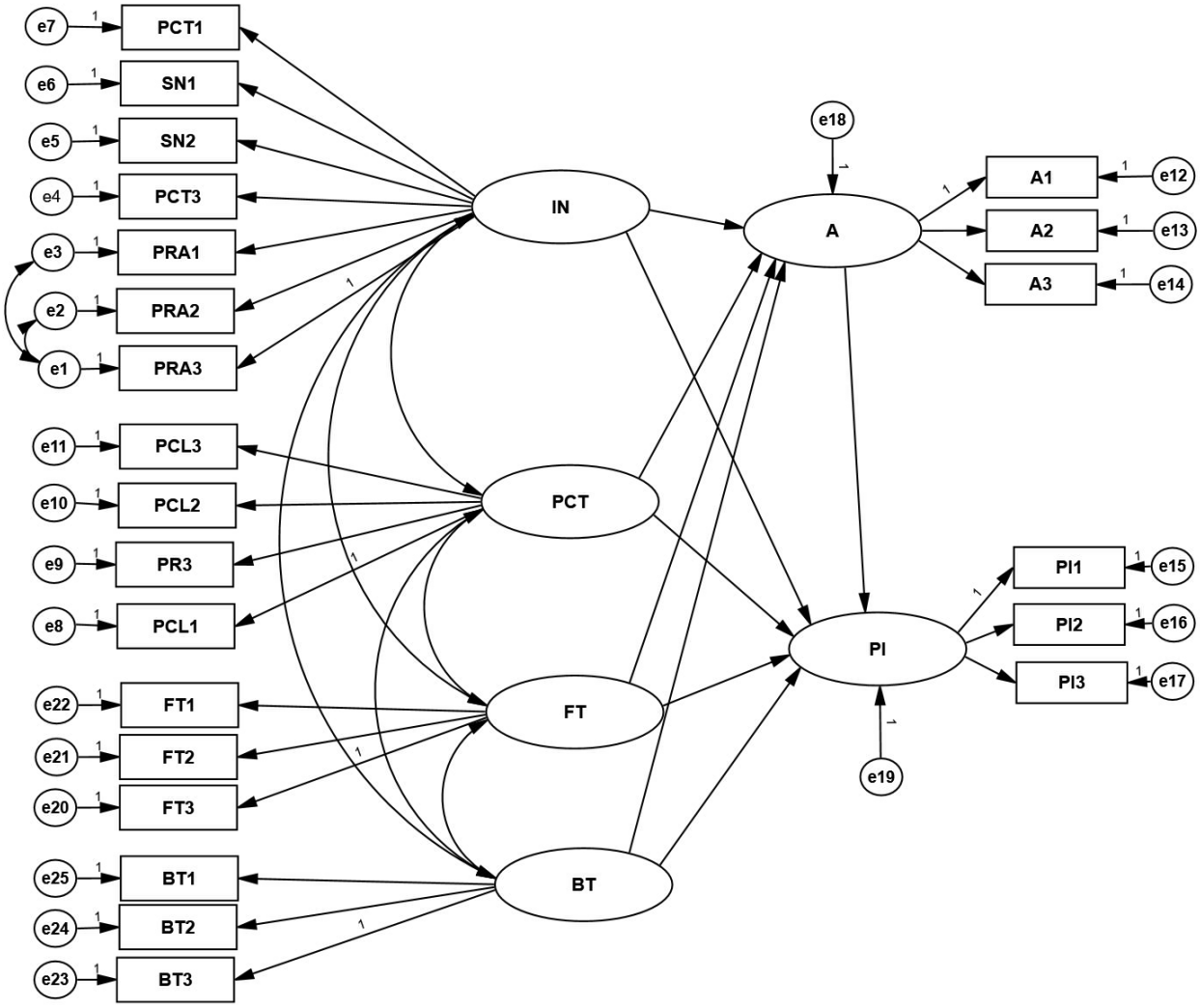

Figure 3 Structural equation model in the study

Note: For the codes of variables, please refer to Table 2 and Table 3; e1-e25: error variables.

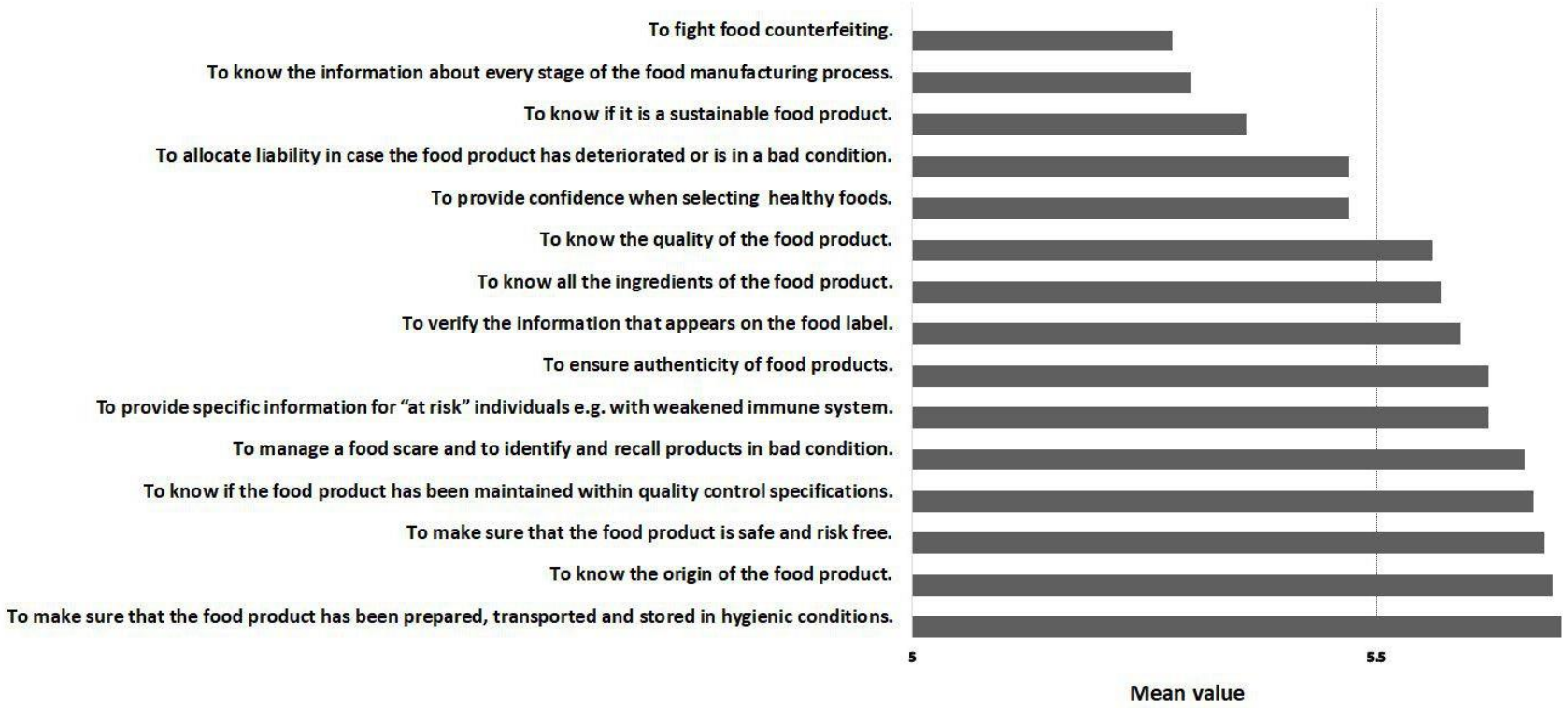

Figure 4 Mean values of perceived important features of blockchain food traceability

Note: Sample size (n=1022), Missing values (n=379).

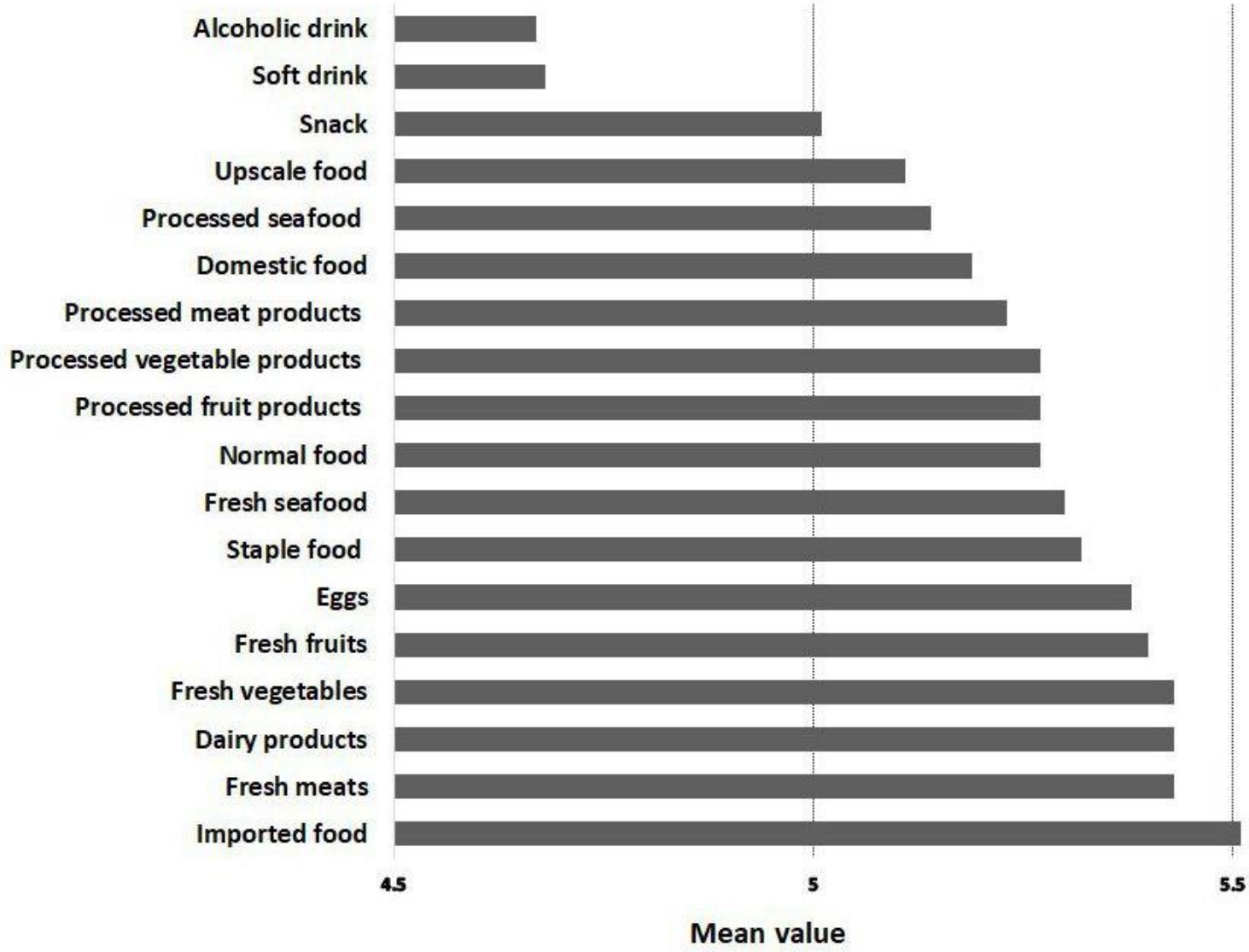

Figure 5 Mean values of purchase intentions towards using blockchain food traceability systems for specific food categories
Note: Sample size (n=1022), Missing values (n=379).