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Heterogeneous preferences and consumer willingness to pay for vitamin D fortification of eggs

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Abstract

Food reformulation can contribute to achieve public health objectives by facilitating access to healthy and sustainable food choices to consumers. Vitamin D is an important micronutrient that contributes to calcium absorption and bone health. Low vitamin D levels may lead to having a higher risk of poor bone and muscle for human health. In this manuscript we investigated, for the first time, United Kingdom consumer willingness to pay (WTP), and heterogeneity preferences for vitamin D fortification of eggs. We used a choice experiment (CE) involving several hypothetical egg products (i.e., pack of 10 eggs) that vary across three attributes levels such as production method (i.e., Cage, Barn, Free-range, and Organic), vitamin (i.e., no information or by reporting on the pack the claim “Vitamin D added”), and price (i.e., £0.80/pack, £1.90/pack, £3.00/pack, and £4.10/pack). Results suggest that, although on average consumers prefer low-price eggs produced using the free-range production method and the information about vitamin D fortification does not affect their valuation, there is a significant preference heterogeneity in consumer

Abbreviations: 25(OH)D3, 25-hydroxyvitamin D3; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; CAIC, Consistent Akaike Information; CE, choice experiment; DCMs, Discrete Choice Models; EM, expectation–maximization; FAO, Food and Agriculture Organisation; GHG, greenhouse gas; LCL, Latent Class Logit; MIXL, Mixed Logit model; mWTP, marginal willingness to pay; OLS, ordinary least square; UV, ultraviolet; WHO, World Health Organisation; WTP, willingness to pay; WTPi, individual WTP.

preferences associated with animal welfare, environment, health, and price attributes. Particularly, there is a significant preference heterogeneity towards the purchasing of eggs produced using the barn production method. Furthermore, we found that consumer preferences for vitamin D fortification of eggs is affected by consumer's age and the price of eggs. These findings provide useful insights into the psychology of consumer acceptance and attitudes that can be used in communicating the nature of the fortified vitamin D eggs to the public. They also have important implications for future labeling policies and marketing strategies of egg industry.

KEYWORDS
consumer, eggs, heterogeneity, United Kingdom, vitamin D fortification, willingness to pay

JEL CLASSIFICATION
Q13, D12

1 | INTRODUCTION

Food reformulation can be described as the change in the composition of foods and beverages to obtain healthier food products by limiting or adding (fortification) certain nutrients in the diet (Drewnowski et al., 2022). Food reformulation, such as, for example, reducing the salt, fat, energy content in food products, and increasing important micronutrients of food products, can contribute to improving food product quality, and consequently consumer health (Leroy et al., 2016). In this way, food reformulation is considered to be a way to contribute to public health through eating healthier diets. Diet-related risks such as overweight, under-nutrition, cardiovascular diseases, type 2 diabetes, and lack of key nutrients are found across the world leading to loss of lives (Gressier et al., 2020; Leroy et al., 2016). However, policy agendas promoting the transformation of food systems also require that healthy diets are produced sustainably (e.g., International institutions such as the Food and Agriculture Organisation [FAO] and the World Health Organisation [WHO] of the United Nations promote sustainable healthy diets; FAO and WHO, 2019). In this regard, ultimately, the role of national governments, public health agencies, and food industry is crucial for designing and implementing policies aiming at achieving sustainable healthy diets at the national level. Thus, establishing clear target reference values in combination with the use of approaches such as food reformulation and/or reviewing portion sizes without drawing away consumer demand can facilitate consumer access to healthy and sustainable food choices and a positive long-term dietary behavior change (Buttriss, 2013; Drewnowski et al., 2022; Gressier et al., 2020). This manuscript investigates consumers' acceptance for eggs with the addition of a micronutrient (Vitamin D).

Vitamin D is a micronutrient that contributes to calcium absorption and bone health (Public Health England, 2016). Furthermore, low vitamin D levels may lead to a higher risk of poor bone and muscle health, as well as cardiovascular disease, osteoporosis, common cancers, and diabetes (Guo et al., 2017), which also has economic implications for healthcare systems (Hannemann et al., 2018). Vitamin D insufficiency or deficiency is estimated to affect 40% of the European population (Cashman & Kiely, 2016). According to the National Diet and Nutrition Survey there are approximately one in five people within the British population who have low vitamin D levels (Bates et al., 2019). Humans usually obtain vitamin D by exposing our skin to UV radiation (Cashman & Kiely, 2016). Apart from obtaining vitamin D from exposure to sunlight, vitamin D can be obtained through the diet, but only a few foods are naturally rich in vitamin D including eggs (Cashman & Kiely, 2016). Specifically, eggs, apart from being a good and cheap source of protein and minerals, contain both vitamin D_3 (D_3) and 25-hydroxyvitamin D_3 (25(OH) D3), the latter providing five times the relative biological activity of vitamin D (Browning & Cowieson, 2014). To guarantee an adequate dietary intake of vitamin D by the general population, the use of vitamin D supplements or vitamin D-fortified foods is required (Guo et al., 2018; Hayes & Cashman, 2017). However, intake of vitamin D supplements is generally low, and it is unlikely to be an effective strategy to increase vitamin D intake at a population (Hayes & Cashman, 2017). One possible way to increase the intake of vitamin D level is by adding vitamin D to the feed of hens, which will result in higher levels of Vitamin D content in the eggs (Browning & Cowieson, 2014; Mattila et al., 2004, 2011), and with no detrimental effects to the birds health (Mattila et al., 2004). Another possible way to increase vitamin D in egg yolks is through exposing eggs to ultraviolet (UV) light (Kühn et al., 2015).

After a decrease in egg consumption during the second half of the twentieth century due to a mix of circumstances (e.g., changing lifestyles, salmonella scare in 1989), during the last decades, there has been an increase in consumer's demand for animal welfare products (Bennett, 1997; Fearne & Lavelle, 1996), sustainable food production, and better human health which have affected the egg industry (Asioli et al., 2020; Rondoni et al., 2020). However, it is important for egg producers and policymakers who may be considering implementing interventions to increase the intake of vitamin D via vitamin D-enriched eggs to understand consumer acceptance of such new products and whether different groups of consumers having different preferences exist. Gaining understanding on how many different groups of consumers may be according to relevant information (e.g., consumer's socio-demographic characteristics, attitudes, habits) can help to develop and better target marketing and policy strategies. Previous studies have found consumer segmentation with regard to egg consumption (Fearne & Lavelle, 1996; Yoo, 2020). Specifically, Fearne and Lavelle (1996) found a polarization of egg consumers with a group of consumers caring for bird welfare and another group of consumers focused on functional properties, and value for money. Yoo (2020) found three groups of consumers: price-sensitive and quality-optimizing, opportunist consumers, and health-conscious buyers. Moreover, in a recent review, Rondoni et al. (2020) found that there is an increasing consumer valuation for alternative production systems to cage-based systems (e.g., barn, free range systems), which may pose a risk for avian flu outbreaks (Koch & Elbers, 2006), and environmental issues, such as greenhouse gas emissions.

Collecting information about consumers' preferences for eggs with added vitamin D is important to inform egg industry to successfully develop and better target the market of this new product. To the best knowledge of the authors, only a few studies have been conducted to investigate consumers' acceptance, preferences, willingness to pay (WTP), and heterogeneity for vitamin D added to feed of the hens that may result in higher vitamin D content in the eggs. To illustrate, Hayes et al. (2015) found that consumer's acceptance of enriched vitamin D eggs, using sensory analysis, was not altered by the level of vitamin D added to hen diets. Currently, research is being conducted to investigate consumer attitudes towards enriched eggs to identify commercial opportunities for enriched eggs (Clark et al., 2021). Regarding consumer's WTP for enriched vitamin D, Panzone et al. (2022) found that both provision of generic information on the effects of low-level vitamin D and personalized information are associated with consumer WTP increases for vitamin D enrichment.

To fill this void, we investigated, for the first time, United Kingdom consumers' preferences, WTP, and heterogeneity for vitamin D fortification of a typical pack of 10 eggs. Specifically, the main objectives of this manuscript are to (i) investigate consumer preferences and WTP towards eggs enriched with vitamin D; (ii) identify different consumers' segments; and (iii) explore the determinants that affect consumer WTP for vitamin D fortification eggs. We performed a choice experiment (CE) involving hypothetical eggs that vary across three attributes such as production method (i.e., Cage, Barn, Free-range, and Organic), vitamin (i.e., no information, or by reporting on the pack the claim "Vitamin D added"), and price (i.e., £0.80/pack, £1.90/pack, £3.00/pack, and £4.10/pack).

The remainder of this manuscript is organized as follows. First, we describe the methodological approach we have implemented, including experimental design, and data. Second, we present the econometric analysis used. Third, we describe the results we have obtained from our analysis. Fourth, we discuss the results, and provide several policy and industry implications as well as some limitations of the study. Finally, we will provide some conclusions together with several future research avenues.

2 | MATERIALS AND METHODS

2.1 | Choice experiment design

In the CE, three attributes, including "production method," "vitamin," and "price" (Table 1), were used to describe the different types of eggs and collect information on consumer preferences associated with animal welfare, sustainability, health, and price attributes. First, we included "production method" to test consumers' preferences and WTP for eggs produced using different production methods since it is one of the most important drivers for consumers when purchasing eggs (Rondoni et al., 2020). Specifically, four levels of production methods were specified: "Cage," "Barn," "Free-range," or "Organic" because there are the types of production methods available in the United Kingdom market (Defra, 2022). These attributes help to capture consumer ethical preferences associated with egg production, such as animal welfare, and environmental concerns. Second, we included the information about vitamin D because as the main aim of the study we would like to test consumers' preferences and WTP for eggs with information about the addition of vitamin D in the feed of the hens[1] (Browning & Cowieson, 2014; Mattila et al., 2004, 2011) which result in higher content of vitamin D in the eggs. Therefore, two levels for vitamin were specified by the phrase "Vitamin D added" or no information about this was reported. Lastly,

TABLE 1 Attributes and levels.

Attributes	Levels
Production method	Cage
	Barn
	Free range
	Organic
Vitamin	No information reported
	"Vitamin D added"
Price	£0.80/pack
	£1.90/pack
	£3.00/pack
	£4.10/pack

[1]Participants were informed that if hens are fed with Vitamin D, consumers would be getting more Vitamin D from an egg than from eggs where hens have not been fed with Vitamin D. They were also informed that in the choice cards they would find egg packs where Vitamin D is added by feeding hens with vitamin D and egg packs where vitamin D is not added to the feeding of hens.

four price levels were specified based on the current market prices for a typical pack of 10 eggs in stores in the United Kingdom (i.e., £0.80/pack, £1.90/pack, £3.00/pack, and £4.10/pack).[2]

The selected attributes and their levels were then used to generate a D-efficient design. The design resulted in the creation of 24 choice sets, which were then divided into three blocks of eight choice tasks each to prevent respondents' fatigue. Each choice task was composed of two product alternatives (options A and B), and an "opt-out" option (option C) (see an example in Supporting Information: Appendix A). The eight choice tasks within each block were presented in a random order to each participant.

The CE was introduced to the respondents with the explanation and description of the attributes and levels. Before the choice tasks, respondents were asked to read a cheap talk (CT) script in an attempt to mitigate possible hypothetical bias that typically affects WTP estimates in stated preference studies (Cummings & Taylor, 1999) (see Supporting Information: Appendix B for the CT script). Upon completion of the eight choice tasks, the respondents were then asked to fill out a questionnaire to collect several consumers' characteristics. Specifically, we included questions related to food habits, socio-demographics (i.e., gender, age, education, and income), and attitudinal factors, including the General Health Interest (GHI) questionnaire (Roininen et al., 1999), and the personality traits scale (Lachman & Weaver, 1997). The latter is composed of 30 items which form six personality dimensions (latent constructs) (i.e., Agency, Agreeableness, Openness to experience, Neuroticism, Extraversion, and Conscientiousness) measured using the 4-point scales ranging from 1 (Not at all) to 4 (A lot) (Lachman & Weaver, 1997).

2.2 | Data

The data used in this study are drawn from an online survey involving 370 consumers in the United Kingdom using the online platform Qualtrics LLC conducted in Spring 2019.[3] Participants were recruited by Qualtrics using sampling quotas in terms of age and gender in line with United Kingdom census. Only consumers who were at least 18 years old and who are responsible for food shopping in household always or sometimes were included in the study. The sociodemographic characteristics of the sample are presented in Table 2. According to the most recent census (Office for National Statistics, 2019), given the quota sampling the consumer sample was similar in terms of gender, while for age participants were lower represented for the age groups between 33 and 47 years and higher than 62 years, while they were overrepresented for the group of participants between 48 and 62 years.

3 | ECONOMETRIC ANALYSIS

We conducted data analysis in five steps. First, to estimate consumer's WTP for eggs we used the Discrete Choice Models (DCMs) that are typically applied to analyze choice data (Hensher et al., 2015). Consistent with Lancaster Theory (Lancaster, 1966), DCMs assume that the total utility consumers derive from a product can be segregated into marginal utilities given by attributes of a product. Specifically, DCMs are based on modeling "utility," that is the net benefit a subject obtains from selecting a specific product in a choice situation, as a function of the attributes which are embedded to the product under consideration (Hensher et al., 2015). We use the Mixed Logit model (MIXL) with specification of the utility function in WTP space which provides estimates directly in WTP terms (i.e., currencies, £). As such, the specification of the utility (U) function in our study can be defined as follows:

$$U_{njt} = \alpha_n(ASC - PRICE_{njt} + \theta_{n1}BARN_{njt} + \theta_{n2}FREE_{njt} + \theta_{n3}ORGANIC_{njt} + \theta_{n4}VITAMIN_{njt}) + \in_{njt}, \quad (1)$$

[2]The prices for a pack of 10 eggs were based on prices recorded in different United Kingdom stores, including grocery stores, farmers' markets, specialty stores, organic stores, and supercentres.

[3]We obtained the informed consent by all the participants of the study. Our study was approved by an Institutional Ethical Clearance.

TABLE 2 Sociodemographics characteristics of the consumers (sample).

Socio-demographics	Sample (*N* = 370)	United Kingdom population[a]
Gender		
Male	190 (51.35%)	49.41%
Female	180 (48.65%)	50.59%
Age (years)		
18–32	95 (25.68%)	24.22%
33–47	62 (16.76%)	24.15%
48–62	143 (38.65%)	25.21%
63 years and more	74 (18.92%)	26.42%
Education		
Primary school	3 (0.82%)	/
Secondary school	135 (36.78%)	
College qualification (e.g., Diploma)	100 (27.25%)	
University degree (e.g., BA, BSc, Masters, PhD, PGCE)	129 (35.15%)	
Other	3 (0.82%)	
Annual household income before taxes		
Less than £10,000	37 (10.60%)	/
£10,000 to £19,999	76 (21.78%)	
£20,000 to £29,999	68 (19.48%)	
£30,000 to £39,999	60 (17.19%)	
£40,000 to £49,999	48 (13.75%)	
£50,000 to £59,999	20 (5.73%)	
£60,000 to £69,999	16 (4.58%)	
£70,000 to £79,999	11 (3.15%)	
£80,000 to £89,999	5 (1.43%)	
£90,000 to £99,999	5 (1.43)	
£100,000 or more	3 (0.46%)	
I do not want to declare/I do not know	21 (5.68%)	

[a]Office for National Statistics (2019).

where n refers to individual, j denotes each of the three alternatives available in the choice set, t is the number of choice occasions, and α_n is the price scale parameter that is assumed to be random, and to follow a log-normal distribution. The *ASC* is the alternative constant indicating the selection of the opt-out option. The price ($PRICE_{njt}$) attribute is represented by four price levels for a typical pack of 10 eggs (i.e., £0.80/pack, £1.90/pack, £3.00/pack, and £4.10/pack). $BARN_{njt}$ is a dummy variable representing if eggs have been produced using the barn or cage method, taking the value of 0 if it is the "cage" or 1 if it is "barn." $FREE_{njt}$ is a dummy variable representing if eggs have been produced using the free-range or cage method, taking the value of 0 if it is the "cage" or 1 if it is "free-range." $ORGANIC_{njt}$ is a dummy variable representing if eggs have been produced using the organic or cage method, taking the value of 0 if it is the "cage" or 1 if it is "organic." $VITAMIN_{njt}$ is a dummy variable for information about vitamin D taking the value of 0 if no information is reported and 1 if the phrase "Vitamin D added" is reported on the pack. $\theta n1$, $\theta n2$, $\theta n3$, and $\theta n4$ are the coefficients of the estimated mWTP values for BARN, FREE, ORGANIC, and VITAMIN, respectively. Finally, $\in_{njt}$ is an unobserved random term that is distributed following an extreme value type I (Gumbel) distribution, independent and identically distributed (i.i.d.) over alternatives. The parameters corresponding to the three non-price attributes were modeled as random parameters assumed to follow a normal distribution, while the opt-out parameter was modeled as a fixed parameter.

Second, we investigated the interactions effects between VITAMIN, being the main focus of this study, and the other attributes (i.e., BARN, FREE, ORGANIC, and PRICE) to detect possible effects using the specification of the utility (U) function defined as follows:

$$\begin{aligned} U_{njt} = \alpha_n(ASC - PRICE_{njt} &+ \theta_{n1}BARN_{njt} + \theta_{n2}FREE_{njt} + \theta_{n3}ORGANIC_{njt} + \theta_{n4}VITAMIN_{njt} \\ &+ \theta_{n5}VITAMIN_{jt} \times BARN_n + \theta_{n6}VITAMIN_{jt} \times FREE_n + \theta_{n7}VITAMIN_{jt} \times ORGANIC_n \\ &+ \theta_{n8}VITAMIN_{jt} \times PRICE_n + \in_{njt} \end{aligned} \tag{2}$$

$\theta n5$, $\theta n6$, $\theta n7$, and $\theta n8$ are the coefficients of the estimated mWTP values for the interactions VITAMIN × BARN, VITAMIN × FREE, VITAMIN × ORGANIC, and VITAMIN × PRICE, respectively. The interaction effects are obtained by multiplying the columns in the dataset for the corresponding main effects.

The MIXL models in WTP space were estimated using the Stata module *mixlogitwtp*. We run different MIXL models using different number of draws both with correlated and not correlated variables. Based on logL, AIC, and BIC parameters, the best model was 300 Halton draws with no correlated variables that were used in the simulations.

Third, we investigated consumer heterogeneity by calculating the distribution of the individual-level coefficients (i.e., mWTP) for BARN, FREE, ORGANIC, and VITAMIN using the Kernel Density Estimates distribution across individuals using the command *kdensity* in Stata.

Fourth, further to identify consumer segments, the Latent Class Logit (LCL) model was used which assumes constant model parameters within each group and captures consumer heterogeneity assuming a mixing distribution for the groups (Greene & Hensher, 2003). The LCL model assumes that the consumer group can be split into subgroups with a constant β vector in each group (Greene & Hensher, 2003). The choice probability that an individual of class s chooses alternative j from a particular set constituted of J_t alternatives, is expressed as

$$P_{j/s} = \frac{\exp(\beta_s' X_{jt})}{\sum_{i=1}^{J_t} \exp(\beta_s' X_{it})}, \tag{3}$$

where $s = 1, \ldots S$ represents the number of classes, and β'_s is the fixed (constant) parameter vector associated with class s. To establish the likelihood, these choice probabilities have to be multiplied over the choice sets, and finally combined over all individuals. To estimate the LCL model we used the expectation–maximization (EM) algorithm, which allows for a good numerical stability and good performance in terms of runtime (Bhat, 1997; Train, 2008). The LCL model was estimated using the modules *lclogit2*, *lclogitml2*, *lclogitwtp2*, and *lclogitpr2* (Hong IL, 2020) on Stata. We then assigned consumers to groups based on the highest posterior probabilities.

Finally, we performed a post-regression analysis to investigate the potential sources of heterogeneity, such as individual consumer characteristics, for consumer WTP for VITAMIN being the main aim of the study. Thus, we used the ordinary least square (OLS) regression model where the dependent variable being the elicited individual WTP (i.e., WTPi) for VITAMIN which were extracted from the MIXL model by using the command *mixlbeta* in Stata. The independent variables were the potential sources of heterogeneity such as age, gender, income, education, frequency of eggs purchasing and consumption, health attitudes, and personality traits. Accordingly, the OLS model can be specified as follows:

$$\begin{aligned} VITAMIN_i = \beta_0 &+ \beta_1 AGE_i + \beta_2 GENDER_i + \beta_3 INCOME_i + \beta_4 EDUCATION_i + \beta_5 EGGPUR_i + \beta_6 EGGCON_i \\ &+ \beta_7 GHI_i + \beta_8 AGENCY_i + \beta_9 AGREE_i + \beta_{10} OPEN_i + \beta_{11} NEURO_i + \beta_{12} EXTRA_i + \beta_{13} CONSCI_i + \varepsilon, \end{aligned} \tag{4}$$

where VITAMIN is the dependent variable, i indicates the participants, β_0 is the intercept of the model, β_{1-13} are the regression coefficients of the explanatory variables, AGE represents the age of the consumer, GENDER represents the gender of the consumer taking the value of 0 for male, and 1 for female, INCOME is the annual household income before taxes measured taking the value from 1 (Less than £10,000) to 11 (£100,000 or more), EDUCATION is the education level of consumer measured by taking the value from 1 (primary school) to 6 (Postgraduate University Degree), EGGPUR is frequency of eggs purchasing taking the value from 1 (less than once a month) to 6 (Daily), EGGCON is the frequency of eggs consumption taking the value from 1 (less than one egg per week) to 5 (more than 15 eggs per week), GHI represents the consumer health attitudes taking the value from 1 (strongly disagree) to 7 (strongly agree), and personality traits, such as AGENCY (i.e., Agency), AGREE (i.e., Agreeableness), OPEN (i.e., Openness to experience), NEURO (i.e., Neuroticism), EXTRA (i.e., Extraversion), and CONSCI (i.e., Conscientiousness) taking the value from 1 (Not at all) to 4 (A lot). Given the different scales used to measure the variables standardization of the variables was applied before the analysis. Then, the OLS regression model was estimated using the module *regress* run in Stata.

All the models were estimated using Stata 16.1 software (Stata-Corp LP).

4 | RESULTS

4.1 | Description of consumer habits and attitudes

Table 3 presents consumer eggs purchasing and eating habits. We can notice that almost all participants purchase eggs, and most of them consumers purchase eggs once a month or once a week. Furthermore, more than half of the participants eat between 1 and 5 eggs per week.

TABLE 3 Consumers habits.

Habits	*N* = 370
Purchase eggs	
Yes	341 (92.16%)
No	29 (7.84%)
Eggs purchase frequency:	
Less than once a month	15 (4.40%)
Once a month	102 (29.91%)
Once a week	184 (53.96%)
2–3 times a week	33 (9.68%)
4–6 times a week	5 (1.47%)
Daily	2 (0.59%)
Number of eggs consumed per week:	
Less than 1 egg per week	3 (0.88%)
1–5 egg per week	202 (59.24%)
6–10 eggs per week	92 (26.98%)
10–15 eggs per week	37 (10.85%)
More than 15 eggs per week	7 (2.05%)

Table 4 shows that participants show high interest toward the healthiness of food products (GHI). Furthermore, in terms of personality traits, consumers show high values in terms of agency, neuroticism, lower in conscientiousness, and agreeableness.

4.2 | WTP estimates: main effects and interactions

The results from the estimation of the MIXL models using Equations (1) and (2) in WTP space for both the main effects and interactions are exhibited in Table 5, respectively. Specifically, we reported the estimates (mWTP) for the main effects (BARN, FREE, ORGANIC, VITAMIN, opt-out), interactions effects (VITAMIN × BARN, VITAMIN × FREE, VITAMIN × ORGANIC, VITAMIN × PRICE), and significances for the attributes (*p* value).

Overall, the mean estimate for the opt-out option is negative and significant, suggesting that consumers tended to prefer one of the two product alternatives as opposed to the opt-out option. Results show that, on average, the production method is the attribute that mostly affects consumer WTP for eggs. This means that ethical aspects such as animal welfare and environmental concerns are the attributes which mostly drive consumer choices on egg consumption with vitamin D added being relatively less important. Indeed, consumers prefer production methods that raise animal welfare such as barn and free-range and environmental standards such as organic and barn methods compared to a cage-based system. Specifically, eggs produced using the free-range production method is the mostly valued attribute by consumers followed by organic and barn methods. In addition, consumers do not show preference for eggs labeled or not with the claim "Vitamin D added." Hence, on average, consumers

TABLE 4 Consumer attitudes.

Attitudes	(*N* = 370), mean (SD), Cronbach alpha
General Health Interest (GHI)	4.27 (0.99), 0.84
The healthiness of food has little impact on my food choices	3.83 (1.48)
I am very particular about the healthiness of food I eat	4.35 (1.40)
I eat what I like and I do not worry much about the healthiness of food	4.04 (1.57)
It is important for me that my diet is low in fat	4.40 (1.42)
I always follow a healthy and balanced diet	4.52 (1.39)
It is important for me that my daily diet contains a lot of vitamins and minerals	4.79 (1.23)
The healthiness of snacks makes no difference to me	3.86 (1.54)
I do not avoid foods, even if they may raise my cholesterol	4.12 (1.54)
Personality	
Agency	2.80 (0.61), 0.62
Agreeableness	1.93 (0.64), 0.86
Openness to experience	2.25 (0.52), 0.69
Neuroticism	2.77 (0.71), 0.75
Extraversion	2.37 (0.64), 0.76
Conscientiousness	1.83 (0.59), 0.66

Abbreviation: SD, standard deviation.

TABLE 5 Estimated mWTP space from MIXL models: main effects and interactions.

Attribute	Main effects ($N = 370$) mWTP (£/pack) (SE)	SD	Main effects and Interactions ($N = 370$) mWTP (£/pack) (SE)	SD
Barn	0.54*** (0.13)	1.82*** (0.16)	0.42* (0.23)	2.09*** (0.22)
Free range	1.49*** (0.12)	1.30*** (0.12)	1.76*** (0.18)	1.59*** (0.16)
Organic	1.08*** (0.12)	0.94*** (0.11)	1.57*** (0.22)	1.24*** (0.16)
Vitamin	−0.12 (0.08)	1.02*** (0.09)	0.93*** (0.32)	1.35*** (0.15)
Price	0.36*** (0.09)	0.98*** (0.14)	0.21** (0.10)	0.90*** (0.12)
Optout	−1.91*** (0.08)	/	−1.79*** (0.15)	/
Barn × Vitamin	/	/	0.07 (0.28)	/
Free-range × Vitamin	/	/	−0.21 (0.27)	/
Organic × Vitamin	/	/	−0.56** (0.25)	/
Price × Vitamin	/	/	−0.35*** (0.11)	/
Model fit statistics				
N. obs.	8880		8880	
Wald chi^2	2055.98		1590.66	
Prob > chi^2	0.00		0.00	
logL	−2445.39		−2431.38	
df	11		15	
AIC	4912.77		4892.76	
BIC	4990.78		4999.13	

Abbreviations: AIC, Akaike's information criterion; BIC, Bayesian information criterion; df, degree of freedom; logL, log likelihood function; mWTP, marginal willingness to pay; N. obs, number of observations; SD, standard deviation; SE, standard error; Wald chi^2, Wald test.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

value ethical aspects, such as animal welfare and environment above health. Interestingly, standard deviations (SDs) are significant for all the attributes investigated signaling potential consumer heterogeneity.

Furthermore, we can notice two significant interactions effects for VITAMIN: consumers who prefer organic eggs tend to dislike more eggs labeled with the claim "Vitamin D added" indicating that there is a trade-off between organic and health attributes while consumers who prefer low price eggs value more eggs labeled with the claim "Vitamin D added."

4.3 | WTP estimates: distribution of individual mWTP values

Given the significant magnitudes of the standard deviations (SDs) of the main effects identified in Section 4.2, we calculated the distribution of mWTP values across individuals (kernel density estimates) (Figure 1). Not only did the mean values for each mWTP differ, but some mWTP distributions were more diffuse than others. Specifically, individual mWTP was much more concentrated for the attributes organic and vitamin, while the distributions for barn and FREE are more diffuse. Specifically, there seems to be some large consumer segments for BARN attribute while for the other attributes there seem to be only one large segment.

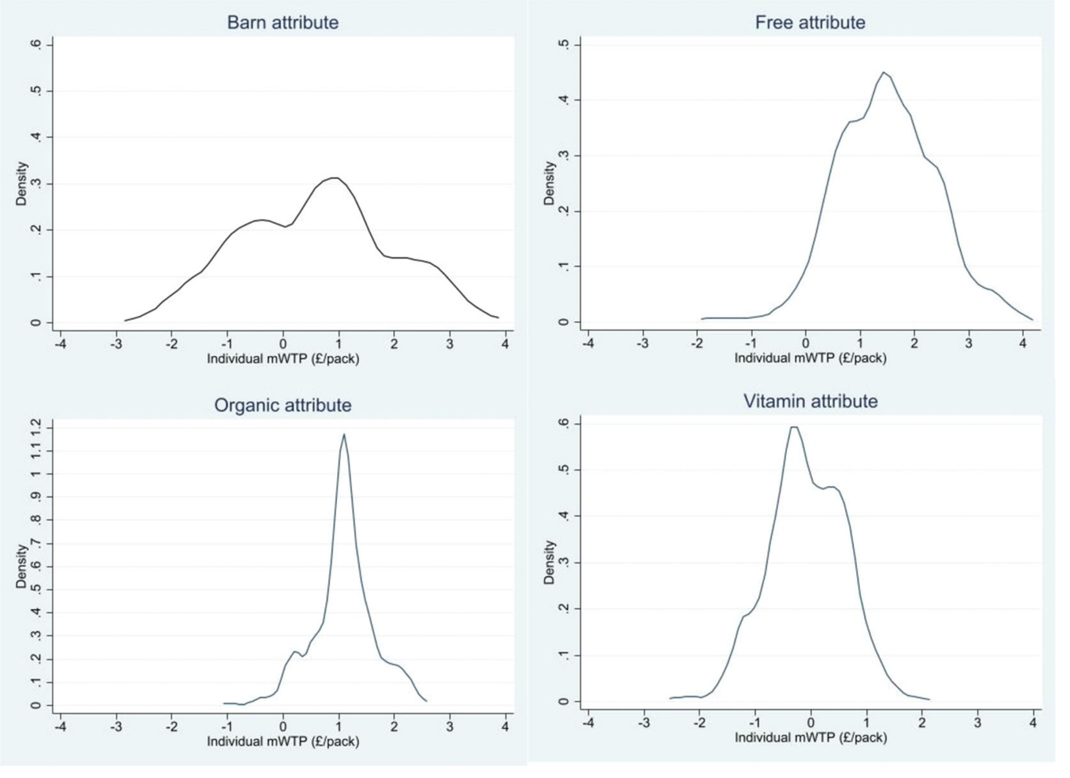

FIGURE 1 Distributions of mWTP across individuals for the attributes: BARN, FREE, ORGANIC, and vitamin.

4.4 | Estimation results from LCL model with design attributes' main effects

We estimated the regression coefficients, and the mWTP for each design attributes of the LCL model for the different consumers' groups. We run different LCL models using different number of groups (2–7[4]). Although the 7-group solution fit best the data based on the Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC), and Consistent Akaike Information (CAIC) scores (see for details, Hong IL, 2020) we present the three-groups solution as it provide more meaningful and interpretable results.[5] We can always find groups within consumer data, but it is important to group consumers in a way that is meaningful (Chapman & McDonnell Feit, 2019). The results of the LCL model with the three-groups solution are reported in Tables 6 and 7, respectively, for the regression coefficients, and the mWTP shows two large groups of similar size and one smaller. Specifically, in Table 6, the regression coefficients of "barn," "free," "organic," "vitamin," "price," and optout are reported, including the standard errors and the significance for the design attributes for each of the consumer groups. Group 1 (129 consumers, "Ethically & environmentally oriented") involves consumers who have preference for eggs produced with methods that increase animal welfare, using the organic production method, indifferent to enhancing eggs with Vitamin D, and of low price. Group 2 (132 consumers, "Ethically focused, environmental & healthy oriented") includes

[4]We also tried the classes 8–10, but convergences were not achieved.

[5]BIC: 2 classes: 4928.03; 3 classes: 4663.90; 4 classes: 4539.46; 5 classes: 4470.00; 6 classes: 4423.66; 7 classes: 4339.76. AIC: 2 classes: 4877.15; 3 classes: 4585.63; 4 classes: 4433.79; 5 classes: 4336.94; 6 classes: 4263.20; 7 classes: 4151.92.CAIC: 2 classes: 4941.03; 3 classes: 4683.90; 4 classes: 4566.46; 5 classes: 4504.00; 6 classes: 4464.66; 7 classes: 4387.76. As can been noticed, based on BIC, AIC and CAIC the best model fit would have been seventh-group solution, but it provides results with noisy which are less meaningful, interpretable and useful for industry and policymakers.

TABLE 6 Estimated regression coefficients from Latent Class Logit (LCL) model.

Attribute	Group 1 "Ethically & environmentally oriented" (*N* = 129) Coefficient (SE)	Group 2 "Ethically focused, environmental & healthy oriented" (*N* = 132) Coefficient (SE)	Group 3 "Ethically & environmentally focused, but unhealthy" (*N* = 109) Coefficient (SE)
Barn	0.96*** (0.15)	0.97*** (0.31)	0.77*** (0.26)
Free range	1.62*** (0.17)	2.05*** (0.33)	2.18*** (0.22)
Organic	1.46*** (0.16)	0.80*** (0.27)	2.00*** (0.23)
Vitamin D	−0.01 (0.11)	0.49*** (0.16)	−0.92*** (0.17)
Price	−0.30*** (0.07)	−2.51*** (0.22)	−0.45*** (0.08)
Optout	−2.45*** (0.37)	−4.87*** (0.48)	0.66*** (0.24)
Model fit statistics			
AIC	4585.63		
CAIC	4683.90		
BIC	4663.90		

Abbreviations: AIC, Akaike's information criterion; BIC, Bayesian information criterion; C-AIC: Consistent Akaike Information Criterion; SE: standard error.
***, **, * significance respectively at 1%, 5%, 10% level.

TABLE 7 Estimated marginal Willingness to pay (mWTP) from Latent Class Logit (LCL) model.

Attribute	Group 1 "Ethically & environmentally oriented" (*N = 129*) WTP: £/pack SE	Group 2 "Ethically focused, environmental & healthy oriented" (*N = 132*) WTP: £/pack SE	Group 3 "Ethically & environmentally focused, but unhealthy" (*N = 109*) WTP: £/pack SE
Barn	3.21*** (0.95)	0.39*** (0.12)	1.71*** (0.62)
Free range	5.44*** (1.44)	0.82*** (0.11)	4.86*** (0.99)
Organic	4.89*** (1.37)	0.32*** (0.11)	4.45*** (0.98)
Vitamin D	−0.05 (0.36)	0.20*** (0.07)	−2.06*** (0.58)

Abbreviations: SE, standard error, WTP: willingness to pay.
*** significance at 1% level.

consumers who strongly prefer more eggs produced with methods that increase animal welfare, prefer using the organic production method, and labeled with the claim "Vitamin D added." This group shows relative strong sensitivity to low-price eggs. Finally, group 3 (109 consumers, "Ethically & environmentally focused, but unhealthy") involves consumers who strongly prefer more eggs produced using methods that increase animal welfare, strongly prefer the use of the organic production method, but dislike eggs labeled with "Vitamin D added," and prefer low-price eggs.

Table 7 presents the consumer mWTP for each of the consumer groups.

TABLE 8 Effect of consumer sociodemographics, habits, and attitudes on consumer WTP for VITAMIN.

Variable	Sample (N = 370) Coefficient (SE)	p Value
Intercept	0.04 (0.05)	0.50
Age	−0.22 (0.07)	0.00
Gender	−0.01 (0.06)	0.82
Income	−0.02 (0.06)	0.70
Education	0.03 (0.06)	0.65
Frequency buying eggs	−0.02 (0.07)	0.77
Frequency eating eggs	0.05 (0.07)	0.42
GHI	−0.07 (0.06)	0.22
Agency	−0.02 (0.07)	0.79
Agreeableness	−0.09 (0.07)	0.21
Openness	−0.04 (0.089	0.66
Neuroticism	0.09 (0.07)	0.20
Extraversion	0.03 (0.08)	0.68
Conscientiousness	−0.05 (0.07)	0.48
Model fit statistics		
Number of obs	321	
Prob > F	0.08	
R^2	0.06	
Adj R^2	0.02	

Note: General Health Interest.

Abbreviations: N. obs, number of observations; SE, standard error.

4.5 | Post-regression analysis

The results from the estimation of the OLS model using Equation (4) are shown in Table 8. Overall, younger consumers have preference for eggs labeled with the claim “Vitamin D added” while other sociodemographic characteristics, eggs habits, health attitudes, and personality traits do not affect consumer preference for eggs labeled with the claim “Vitamin D added.”

5 | DISCUSSION AND CONCLUSIONS

We investigated, for the first time, United Kingdom consumer WTP, and heterogeneity preferences for vitamin D fortification of eggs. Several relevant findings for social planning and firms can be highlighted from the consumer valuation of attributes related to animal welfare, environmental sustainability (i.e., production method), and health.

First, there is no clear-cut situation where all consumers share the same preferences nor share preferences that are completely in line with current international and national policy aims, such as shaping food systems for both sustainable and healthy diets (WHO, 2019). On the contrary, there is significant heterogeneity in consumers' preferences regarding animal welfare, environmental, and health issues around egg consumption. This variety of egg preference patterns creates challenges for social planning wanting to alter consumption patterns, and potential opportunities for firms that may tailor different products for different type of consumers.

Second, focusing on average consumer preferences, consumers prefer eggs produced with methods that raise animal welfare and deal with environmental concerns, such as free-range, barn, and organic methods. Specifically, we found that overall consumers prefer free-range over organic, barn, and cage eggs. This may be related to consumers believing that free-range eggs taste better than caged eggs as previously found for United Kingdom consumers (Pettersson et al., 2016). Our results are in line with previous research for consumers in European, North and South American countries (Lemos Teixeira et al., 2018; Norwood & Lusk, 2011; Ochs et al., 2019), which show consumers are willing to pay a premium price for eggs produced using free-range, and organic production methods. However, as pointed out above, we found that there is heterogeneity in consumer preferences regarding production methods with some consumers valuing alternative methods to cage production systems while other groups of consumers focus on own health benefits, and not on animal welfare.

Third, we found that on average consumers do not show preference for eggs labeled or not with the claim "Vitamin D added," but there is significance heterogeneity depending on eggs attributes. Specifically, a trade-off between organic and health concerns was found among consumers, which consumers who prefer organic eggs tend to dislike more eggs labeled with the claim "Vitamin D added." On average consumers are WTP £1.57 more for an organic eggs pack than for a cage egg pack, but would be WTP £1.01 if the eggs pack had Vitamin D added. A similar trade-off between organic and health attributes was also found in the case of the carbon label and organic (Edenbrandt & Lagerkvist, 2021). As suggested by Edenbrandt and Lagerkvist (2021) this indicates that there is decreasing marginal utility from additional sustainability labels. In our case, there may be a decreasing marginal utility from combining sustainability and health labels. From a social planning perspective, this indicates that labeling may need to be presented combined rather than as separate attributes, which poses other challenges such as, for example, how to combine health and environmental impact information into one single indicator. We also found that consumers who prefer low-priced eggs value more eggs labeled with the claim "Vitamin D added."

Fourth, we found that younger consumers have preference for eggs labeled with the claim "Vitamin D added." Regarding consumers' preferences on vitamin D-fortified eggs, there is heterogeneity of preferences. This means that the use of vitamin D fortification of eggs for tackling the problem of low vitamin D levels among population and its associated health issues (e.g., a higher risk of poor bone and muscle health-related problems) is limited. Hence, despite research showing that feeding hens can lead to a higher concentration of vitamin D in eggs and could reduce low levels of vitamin D among population, our results show that the benefits of vitamin D-enriched eggs are limited. We found that not all consumers value vitamin D fortification of eggs and therefore there will be groups of consumers who will be unlikely to purchase vitamin D-fortified eggs and benefit from it. From a social planning perspective, more reticent consumer groups to purchase vitamin D-enriched eggs would need further incentives, such as price reductions. For instance, taking that a pack of 10 eggs costs £2.45, consumers belonging to group 3 ("Ethically & environmentally focused, but unhealthy") would need the pack of 10 eggs to cost £1.53 on average to consider its purchase. We also found that consumers belonging to group 1 (Ethically & environmentally oriented) to be insensitive to the Vitamin D attribute. This indicates that there are consumers who prioritize (i.e., have strong preferences for) ethical and environmental aspects to health aspects which are considered irrelevant, and therefore policies aiming at increasing vitamin D egg consumption may be unnecessary for these groups of consumers if environmental and ethical considerations are satisfied. Hence, although the use of a set of policies to incentivise the consumption of eggs enriched with vitamin D, including provision of information (e.g., through labeling), the use of personalized messages, price reduction on their own or combined could be also used for all consumers, its success is not guaranteed for consumers belonging to group 3 (Ethically and environmentally focused but unhealthy). Measures beyond labeling may not be needed for consumers in groups 1 (Ethically and environmentally oriented) and 2 (Ethically focused, environmental & healthy oriented) since enriching eggs with vitamin D is irrelevant in their eggs choice (group 1 consumers) or it is already a preferred option (group 2 consumers). Panzone et al. (2022) found that both personalized messages, and in combination with general health claims increase individual's WTP. Our questionnaire includes a generic (non-personalized) explanation on the CE attributes where we add the following health claim "Vitamin D is a micronutrient that contributes to calcium absorption and bone health" similar to the one used by Panzone et al. (2022) that an enriched egg "…helps maintain normal bones and teeth." Thus, our results complement and support the findings by Panzone et al. (2022). Panzone et al. (2022) found that in the absence of any information about the benefits of enriched Vitamin D eggs, consumers are not interested in this product. Based on our results we advocate for the specific/targeted provision of general and personal health claims/information to those individuals in need of intake of Vitamin D who would be most sensitive to such information, based on the consumer's WTP for enriched Vitamin D heterogeneity found. According to our findings, the provision of health information/claims on enriched Vitamin D eggs can be particularly effective aiming at younger groups of the population, a finding in line with Panzone et al. (2022). We found that there are segments of the population which will not be interested in purchasing enriched Vitamin D eggs and therefore these groups of the population should not be the target of campaigns around intake Vitamin D using enriched eggs. Hence, strategies to increase Vitamin D intake by population may focus on segments of the population where campaigns can be most effective. Therefore, based on our results, campaigns could be designed to target consumers, particularly young consumers, who tend to prefer more the organic system production method and those consumers who have a preference for production methods that increase animal welfare. From a social point of view (i.e., public health), the incorporation of awareness campaigns by governments that include general health claims associated with the consumption of enriched Vitamin D eggs could partly contribute to increase Vitamin D intake by groups in the population. From a private point of view (i.e., retailers, egg producers), the use of health messages in egg packs labels such as "Vitamin D added for a better bones and teeth" may help to increase the chance of selling enriched Vitamin D eggs. In both cases, the targeting of young audiences (e.g., through social media channels) would be a good strategy to increase Vitamin D among the population.

From a firms' perspective the identification of different groups of consumers offers opportunities for product differentiation on aspects regarding environment, health, and animal welfare developing novel products that use different combinations of these attributes including the product reformulation such as for example, enriched Vitamin D eggs in combination with free-range or organic production method.

Further research is needed to test the robustness of our findings in other countries, and maybe with other food products given the need to increase the vitamin D intake in the population. Future studies should further explore consumers' WTP for vitamin D-fortified eggs using different information benefits about vitamin D intake to test which type of information is mostly effective. In addition, it is suggested the investigation of consumers' WTP by using non-hypothetical experiments like real choice experiments (Alfnes & Rickertsen, 2011), experimental auctions (Lusk & Shogren, 2007), or multiple price list (Asioli et al., 2021) experiments combined with sensory evaluations of vitamin D-fortified eggs (Asioli et al., 2017) to provide more realistic information in real market scenario (e.g., stores). Also, future research could investigate the association between the different type of consumers, and how they may be nudged to increase their intake of vitamin D in case they need it.

It is also worth highlighting that vitamin-enriched eggs is a type of food reformulation which adds a new product to the market, and does not to replace all eggs (Gressier et al., 2020). Therefore, consumers need to transit from their status quo to the new product, which presents a challenge. Alternatively, food reformulations where a product replaces the old product (i.e., all eggs are vitamin D enriched) could have a larger impact on tackling low vitamin D levels and related health issues in the population, but this approach would have implications for the industry and consumers willing to have more choices.

This manuscript has several limitations. First, regarding the personality traits scale the Cronbach's alpha values for agency and conscientiousness are slightly below the rule of thumb 0.7 for a good fit. Second, although we added the CT script as standard practice to reduce the hypothetical bias in CE, we do not have information able to verify the consumer understanding of the CT script which might have affected the WTP estimations. Third, it has been found that attribute framing may influence consumer's attitudes and intentions with respect to food products

(Dolgopolova et al., 2022). In particular, stronger responses from consumers of food products are obtained with the use of gain frames than with the use of loss frames (Dolgopolova et al., 2022). Regarding health and food consumption, the potential effect of framing of health risks associated with food consumption has been acknowledged (Harkness & Areal, 2018; Sckokai et al., 2014). In our case, adding vitamin D was positively framed as follows "If hens are fed with Vitamin D you would be getting more Vitamin D from an egg than if hens not fed with Vitamin D" (see Supporting Information: Appendix C). Hence, it is possible that if this was framed differently (e.g., "If hens are not fed with Vitamin D you would be getting less Vitamin D from an egg not fed with Vitamin D than hens fed with Vitamin D") consumers might have been less likely to select choices where Vitamin D was present and consequently lower estimates for WTP for vitamin D-enriched eggs. Fourth, although consumers were told that vitamin D-enriched eggs meant hens being fed with vitamin D, consumers may perceive that organic labeled eggs contain higher vitamin D either through (a) a halo effect where organic food is perceived as healthier with no basis in reality; and (b) through knowing research that suggest higher vitamin D content in organic labeled eggs (Guo et al., 2017; Matt et al., 2009). Either way, during the CE these consumers could potentially be focusing more on the "organic" attribute disregarding the information on vitamin D. These consumers would be placing a relative high value to the organic attribute compared to a case where consumers do not perceive that organic-labeled eggs contain higher vitamin D. Regarding the valuation of the vitamin D attribute, these consumers could place a relative low value to it (if no attention is paid to this attribute).

In conclusion, our findings show that consumers' preference for vitamin D-fortified eggs depends on the attributes of eggs like organic production method and the price of eggs as well as by consumer age. Our results provide insights into consumers' psychology that can be useful for effectively communicating the potential benefits of vitamin D-fortified eggs to the public.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

We obtained informed consent from all the participants of the study. Our study was approved by the University of Reading Ethical Clearance Committee.

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PEER REVIEW

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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