Authors: Bridge, Gemma; Armstrong, Beth; Reynolds, Christian; Wang, Changqiong; Schmidt, Ximena; Kause, Astrid; Ffoulkes, Charles; Krawczyk, Coleman; Miller, Grant; Serjeant, Stephen; Oakden, Libby

Engaging citizens in sustainability research: Comparing survey recruitment and responses between Facebook, Twitter and Qualtrics

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Introduction

Malnutrition in all its forms and the degradation of environmental and natural resources are two ~~of the key~~ challenges that we currently face; ~~and~~ neither ~~is~~ showing any sign of improvement (FAO, 2019). Food is an essential factor in both challenges; poor diets, low in fibre and high in sugar, salt and fats, are contributing to the global burden of diet-related chronic disease (DRCD), (GBD 2017 Diet Collaborators, 2019). ~~whilst~~ The way we produce and consume food is also taking a toll on the environment and our ~~the~~ natural resources (McLaughlin and Kinzelbach, 2015). ~~To address both~~ In acknowledgement of the combined challenges of malnutrition and degradation of the environment, the United Nations (UN) Decade of Action on Nutrition 2016 – 2025 highlighted the importance of food system transformation to promote healthy and sustainable diets to achieve the DRCD targets in line with commitments stated at the Food and Agriculture Organisation (FAO) and World Health Organization (WHO) Second International Conference on Nutrition (ICN2), (FAO, 2014) and the Sustainable Development Goals (SDGs) (FAO and WHO, 2019). ~~Thus, a~~As the current global food system ~~has a negative impact on~~ harms both the environment and human health, we must move consumers towards the consumption of sustainable and healthy diets that can reduce global greenhouse gas emissions (GHG emissions) and reduce DRCD's such as diabetes, obesity and heart disease (Clark, 2019; Hyland *et al.*, 2017).

The ~~benefits of~~ need to move towards healthy and sustainable diets may be accepted within academic, policy and advisory bodies, but ~~However,~~ awareness of the calorie content and carbon footprint of many foods is ~~of may be~~ less well understood amongst the general public, particularly amongst certain demographic groups, hampering the move towards health and sustainable dietary practices (Carels, Konrad and Harper, 2007; Harper and Hallsworth, 2012; Kretsch *et al.*, 1999). ~~For carbon footprint estimations,~~ Research suggests that the public particularly struggle to correctly estimate carbon footprint values for animal origin products such as meat or dairy. As animal products have higher carbon footprints compared with other food groups such as grains or vegetables (Berlin, 2002; Foster *et al.*, 2007), this lack of awareness may hamper behaviour change towards more sustainable diets. As outlined by the COM-B model of behaviour change, capability, opportunity, and motivation are all required to make a change in consumer behaviour (Mitchie, Stralen and West, 2011). In the context of moving consumers toward healthier and more sustainable diets, as consumers lack knowledge (capability) about the calorie content (Carels et al., 2007; Harper and Hallsworth, 2012; Kretsch et al., 1999), and carbon footprint of foods (Berlin, 2002; Foster et al., 2007) ~~Consequently,~~ consumers may be unable to move toward a healthier and more sustainable ~~diet due to their lack of knowledge (capability)~~. Thus, exploring consumer perceptions about energy content and carbon footprint of foods, and understanding the relevant knowledge gaps, is important to the development of effective interventions.

As healthy and sustainable diets must be thought of in terms of the whole food system, the welfare of animals also needs to be considered when investigating consumer food choices and perceptions (Lindgren *et al.*, 2018). Animal welfare relates to how well the animals are treated, the quality of the space in which they are kept and how humanely they are slaughtered (Legislation.gov.uk, 2006). The UN SDGs include animal welfare as a global goal of sustainable agricultural policy (Buller *et al.*, 2018). Previous research indicates that consumers expect chicken that has been raised in higher animal welfare standards to be tastier, have a lower carbon footprint, be safer to eat and report higher purchase intention than when a chicken has been raised in lower welfare standards (Armstrong and Reynolds, 2020). However, alternative findings suggest that consumers do not often consider animal welfare at all when making purchase or consumption decisions, ~~with the exception of~~ except for when purchasing ~~free-range~~ eggs (Lagerkvist and Hess, 2010), which could be due to higher welfare, free-range eggs being considered as 'better quality, more nutritious, and safer' (Bray and Ankeny 2017). Highlighting the lack of consideration for animal welfare when making purchasing decisions, other research found that providing details about animal welfare standards for products such as meat only leads to small changes in purchase intention ~~(~~Hoogland, de Boer and Boerseman, 2007).

Food safety is another ~~a~~ major concern when taking a whole food system approach to ensuring healthy and sustainable diets. Recent estimates suggest~~ing~~ that unsafe, contaminated foods cause more than 200 acute and chronic diseases (FAO and WHO, 2019), 600 million cases of foodborne disease and over 420,000 deaths (WHO, 2018). Unsafe foods have also been attributed to a global loss of over 33 million years of healthy life, impacting economic and individual well-being (WHO, 2018). Whilst many foodborne diseases are associated with pathogens such as bacteria or parasites, some foodborne conditions are attributed to chemicals, such as pesticides, or metalloids such as arsenic (Oberoi, Barchowsky and Wu, 2014). Previous research suggests that consumers perceive chicken, and other meat products to be higher risk than non-meat products (Food Standards Scotland, 2018). However, as grains, vegetables, fruit and fish can pose food safety risks, for example in terms of naturally occurring arsenic which may cause cancer, these products need to also be considered when developing recommendations for dietary change (Oberoi *et al.*, 2014). This is especially timely since the move towards a more plant-based diet may lead to increased exposure to pesticides and heavy metals, or to pathogens if foods are eaten raw, as well as increased exposure to mycotoxins from nuts (Oberoi *et al.*, 2014). Exploring public awareness and understanding of the safety levels of different foods is important as we promote the transition to a more sustainable and healthy diet.

As highlighted, understanding consumer perceptions and estimations concerning healthy and sustainable diets is important. Previous research has relied on survey methods with either pilot or small sample sizes (e.g. N=42, N=<226) often restricted by access to a limited number of participants, due to factors such as experimental set-up and budget (Panzone, Lemke and Petersen, 2016; Shi *et al.*, 2016). Citizen science projects invite members of the public to take part in scientific investigations by contributing data, processing data or both (Silvertown, 2009). As citizen science recruits volunteers to help with data collection, research can be completed quickly, at a lower cost and with wider participation than with other methods (Conrad and Hilchey, 2011). Therefore, citizen science could be used to better understand current perceptions of carbon footprint, energy content, food safety and animal welfare in the general population (Zooniverse, 2019). However, it has been posited that recruitment methods for citizen science research can affect the quality and volume of the data obtained and thus the conclusions that are drawn from the data (Ponto, 2015; Worthington *et al.*, 2012), so assessing the suitability of different recruitment methods is critical.

The current study develops understanding gained from previous exploratory pilot research to explore consumer perceptions of the energy and GHG emissions of foods and animal welfare and food safety for foods (Armstrong *et al.*, 2020). ~~and~~ The study also builds on literature assessing methods for recruitment of citizen scientists (West and Pateman, 2016; Worthington *et al.*, 2012). This study provides a novel comparison of three recruitment methods in the exploration of consumer perceptions. Participants were recruited through social media via Facebook and Twitter adverts and were redirected to the citizen science platform, Zooniverse, to explore consumer perception of the Calorie Content, Carbon Footprint, Food Safety, and Animal Welfare of 29 different foods. Zooniverse is an online platform that 'enables everyone to take part in real cutting edge research in many fields across the sciences, humanities, and more' (Smith, Lynn and Lintott , 2013; Zooniverse, 2019). A comparison of the data collected was made between participants recruited via Twitter and Facebook, and respondents to a previous survey conducted on Qualtrics, which used a representative UK sample, to identify differences in citizen perceptions.

Methods

Recruitment

For this exploratory study, recruitment of citizen scientists occurred via Qualtrics, and social media platforms Facebook and Twitter. Paid adverts were used to aid recruitment on Facebook and Twitter, with a budget of £1000 and parameters set for a UK adult population. The adverts were run over two weeks in spring 2020. The adverts included links to the Zooniverse. The Zooniverse citizen science platform was selected as it is the largest citizen science hosting platform on the internet with over 900,000 volunteers registered, and upwards of 90+ citizen science projects running at any one time (Smith et al., 2013).

Citizens took part voluntarily in a survey on the Zooniverse and did not receive payment. On Facebook, the adverts achieved 10,889 clicks (11 engagements) and a total of 358 ratings, and on Twitter, the survey received 4845 clicks (85 engagements) and a total of 2184 ratings. To compare the data gathered through social media recruitment with those gathered by a traditional survey approach, a separate cohort of respondents were recruited via Qualtrics. The Qualtrics sample included 398 people, representing the diversity of the UK population. The respondents were compiled using overall demographic quotas based on census percentages for representation: age, gender, ethnicity, household income, and census region.

Procedure

For the Zooniverse survey, each citizen scientist was randomly allocated to one of four workflows (per IP address or Zooniverse ID). Workflows were a series of questions, designed to counterbalance responses, reflecting the randomisation process used by Qualtrics. Participants could retire at any point during the survey. The presentation order of the food images was randomised. Exact questions and additional text information provided to citizens can be found in the supplementary materials. Zooniverse uses a glossary of specific terms. In this paper, the term ‘classification’ denotes a single unit of analysis on a project by a respondent, whilst the term ‘subject’ refers to a single data object such as an image. (For a detailed glossary of Zooniverse terms, see Simpson, Page, and De Roure, 2014).

Survey design

Topic 1 (Energy Density or Carbon Footprint) x Topic 2 (Food Safety or Animal Welfare) of 29 foods (apple, bacon, banana, beef, beans, bread, cabbage, carrot, cauliflower, cereal, chicken, chickpeas, egg, fish, full fat cheese, lamb, low fat cheese, milk, mushroom, onion, orange, pasta, peas, pork, potato, Quorn, rice, strawberries, tomato). A photograph of each food was selected from the Intake24 image bank and was shown in the workflow with a text description and portion weight (grams) information (Intake24, 2018). Citizens were shown an image of each food and asked to estimate calorie content (0-930 Kcal), carbon footprint (0-8180). The values gave a tolerance one third higher than the highest calorie content or carbon footprint of the foods included. Ratings for food safety were on a ten point scale, with (0 (Low risk) - 10 (High risk)) and (0 (Low welfare) - 10 (High welfare)) respectively. Previous research using Zooniverse has explored methodological aspects of data collection and found that the slider tool was the most appropriate measure in terms of accuracy and validity compared to text box and multiple-choice alternatives, and thus the slider option was used in this citizen science study (Armstrong, Bridge, Oakden, Reynolds, Wang, Kause, et al., 2020).

[INSERT TABLE 1 HERE]

Data analysis

Energy content data (Kcal/100g product) used in the analysis were those reported in the National Diet and Nutrition Survey databank and from the NHS calorie checker platform (NDNS, 2019; NHS, 2018). The carbon footprint values (kgCO2e /100g product) were based on published data (Poore and Nemecek, 2018). The values represent the average emissions released during the production of primary food commodities to the point of the regional distribution centre in the UK (see Table 1 for a summary of the energy content and CO2e values).

In total, 48,168 ratings (Twitter n=2184, Facebook n=358, Qualtrics n=45,626) were submitted. Across the three recruitment platforms, 12,648 energy content (Kcal) classifications were recorded (Qualtrics n=11,877, Facebook n=78, Twitter n=693). Perceptions of the energy content of the foods were compared against validated figures (NDNS, 2019; NHS, 2018). A +/-10% range of the figures were classified as correct, to allow for the accuracy tolerance of food labels and variations in energy content of foods regionally (>930 kcal).

12,817 classifications were recorded for carbon footprint perceptions (Jumpertz *et al.*, 2013; McCane and Widdowson, 2015). As with calorie estimations, carbon footprint estimations were compared against values calculated from previously validated figures (Poore and Nemecek, 2018). For comparisons, a +/-10% range of the figures were classified as correct (0-815 g of gCO2e x 10^1).

For food safety, 12,164 classifications were recorded (Qualtrics n=11,910, Facebook n=34, Twitter n=220), whilst for animal welfare (0 (Low welfare) - 10 (High welfare), 10,072 classifications across the three recruitment platforms (Qualtrics n=9,930, Facebook n=11, Twitter n=131) were recorded.

Using SPSS statistics software, the Kruskal Wallis H test and subsequent pairwise comparisons (Bonferroni corrections applied) were used to explore the impact of recruitment method, on citizen estimates of carbon footprint, energy content, animal welfare and food safety. This test was chosen because the sample sizes are so variable.

Results

Energy content perception

Overall, citizens were more likely to overestimate the calorie content of foods (n=1,1403, 88.9%) than correctly estimate (n=235, 1.8%) or underestimate (n=1,178, 9.2%). However, this effect was not observed when the recruitment method was considered. Citizens recruited from Facebook were more likely to underestimate calorie content (n=40, 51%), whilst citizens recruited from Qualtrics and Twitter were more likely to overestimate calorie content (n=7,663, 65% and n=350, 51% respectively). As a small number of citizens were recruited using social media platforms the conclusions drawn need to be interpreted with caution, those from Facebook were more likely to correctly estimate calorie content (n=4, 0.05%) than those recruited from Twitter (n=34, 0.05%) or Qualtrics (n=438, 0.03%).

The impact of food type on the estimates of energy content was compared to the range of validated values. The energy content of cereal products was more likely to be underestimated than overestimated or estimated within range. For example, with pasta, 71.5% of estimations underestimated energy content whilst under a quarter (24.4%) were overestimated and just 4% were within range. In contrast, energy content for fruit and vegetables was likely to be overestimated. For example, 93.5% of energy estimates for carrots were overestimations, whilst just 5.7% underestimated calorie content and only 1 estimation was within range. Similarly, for peas, 72.2% of estimations were over the accepted range, whilst 24.8% were underestimates and just 2.8% were within range. Calorie content of dairy products were frequently overestimated with 95% of estimation of milk, and 62% of estimations for full fat cheese being overestimated. The accuracy of meat product calorie estimations varied. The energy content of bacon and chicken were mostly overestimated, (64% and 56.1% respectively). However, the perceived energy content of beef and pork were more likely to be underestimated (53.4% and 77.2% respectively).

<u>Carbon footprint perception</u>

Across recruitment methods, citizens were most likely to overestimate the carbon footprint of foods (n=11,403, 88.9%). Citizens recruited via social media (Twitter and Facebook) made no correct estimations, with all estimations being above the correct range. Whilst most citizens recruited via Qualtrics overestimated carbon footprint across foods (n=10,496, 88%), some underestimated (n=1,178, 9%) and an even smaller minority correctly estimated within range (n=235, 1.9%). Due to the small sample numbers on social media, no statistical tests could be conducted to explore differences between recruitment methods.

The impact of food type on the carbon footprint estimates was explored, first by food groups. When looked at descriptively, carbon footprint estimations for plant-based foods were lower (1,388.6±1,319.6) than estimations for dairy (1881.9±1567.6) or meat or fish products (2,569.5±1,888.3). A Kolmogorov-Smirnov test indicates that the carbon footprint estimations do not follow a normal distribution ($D(12,817) = .137$, $p < .001$) and so statistical differences could not be explored.

Estimations were then compared to the range of validated carbon footprint values. Citizens were most likely to overestimate carbon footprints of grain-based foods, with 89% of estimations for pasta and 73.2% of estimations for rice over the accepted range. Overestimations of carbon footprints were also most likely across dairy products, with 96% of ratings for milk, and 88% for full fat cheese above the 10% margin of error. Similarly, overestimations were most frequent for white meats, with 93% of estimates were over the accepted range for chicken. In contrast, carbon footprints of red meat were more likely to be underestimated, with 60% of perceptions for beef and 57.2% for lamb, under the accepted range for their respective carbon footprint values.

<u>Food safety perception</u>

12,164 valid classifications of food safety ratings (0 (Low risk) - 10 (High risk)) were recorded across the three recruitment platforms. Across all classifications, 71.4%

(n=8,696) were rated as low risk, 23.5% (n=2867) whilst just 4.9% (n=601) were rated as high risk. Between recruitment platforms, overall food safety ratings were statistically different (H(2)=20.21, p=.001), with safety perceptions highest amongst citizens recruited from Facebook and lowest amongst those from Twitter (mean rank food safety: Twitter: 5,053.91, Qualtrics: 6,100.52, Facebook: 6,424.41). When pairwise comparisons were conducted, statistically significant differences were apparent between food safety perceptions from citizens on Twitter - Qualtrics (p<.001). When food safety perceptions were explored by food type, a significant difference in food safety perceptions were found between plant based foods, dairy products and meat or fish ($\chi 2(4)$ = 1,434, p <.001), with plant based foods rated as lower risk than dairy, meat or fish products.

<u>Animal welfare perception</u>

Perceptions of animal welfare (0 (low welfare) - 10 (high welfare)) were statistically different between those recruited from Qualtrics, Twitter and Facebook (H(2)=13.12, p<.001). Perceptions of animal welfare across all foods were lowest amongst citizens recruited from Facebook, and highest amongst citizens from Twitter (Mean rank animal welfare: Facebook=4,815, Qualtrics=5,025, Twitter=5,921). Pairwise comparisons indicated that Twitter respondents had higher perceptions of animal welfare than Qualtrics respondents (H(1)=-895.48, p<.001).

When explored by food groups (dairy or meat and fish) there was no statistically significant difference in terms of welfare estimations (see Figure 1). When explored by individual food items chicken was the only food that showed a statistically significant difference in welfare ratings between recruitment methods (H(1)=8.13, p=.004) with Twitter citizens reporting higher welfare (mean ranks: Qualtrics: 198.58, Twitter: 388).

However, this is based on only 3 ratings from Twitter so should be interpreted with caution. No ratings for chicken were received from Facebook. Just over a third of citizens reported that dairy (n=510, 35.1%) and meat/ fish (n=981, 35.3%) products are low welfare, whilst just over a quarter of citizens reported that dairy (n=415, 28.5%) and meat/fish (n=741, 26.6%) products are high welfare. When explored across individual foods, perceptions of animal welfare were similar, with approximately a third of citizens perceiving each food item to have low, medium or high welfare (range of 30.4% to 37.3%). One outlier was white fish, with more citizens perceiving this product to have lower animal welfare (n=139, 40.2%).

[INSERT FIGURE 1 HERE]

<u>Impact of recruitment method</u>

Recruitment method had a significant impact on perceptions of carbon footprint (H(2)=2,391.3, p=.001), calorie estimation (H2(2)=139.9, p=.001), food safety (H(2)=20.21, p=.001) and animal welfare perceptions (H(2)=13.12, p<.001). Citizens recruited from Facebook perceived animal welfare to be higher across all food groups than those from Twitter and Facebook (mean rank animal welfare: Facebook= 4,815, Qualtrics= 5,025, Twitter= 5,921). Those recruited from Facebook and Twitter had the lowest carbon footprint estimations (mean rank carbon footprint: Facebook: 618.5, Twitter: 618.5, Qualtrics: 6849.9). The Twitter recruitment sample had lower calorie estimations than those given by citizens recruited via Qualtrics (mean rank calories: Twitter: 5473.5, Qualtrics: 6426.0). For food safety, again, citizens recruited from Twitter had lower perceptions than Qualtrics (mean ranks: Twitter: 5053.91, Qualtrics: 6100.9). The Facebook sample was too small to be included in the comparative analysis for calorie and food safety estimations.

Discussion

The current study was exploratory in design and aimed to assess perceptions of the calorie content, carbon footprint, food safety, and animal welfare of 29 different foods, comparing perceptions between citizen scientists recruited through Facebook and Twitter and respondents to a survey on Qualtrics. The study provides novel insights into the impact which different recruitment platforms can have on observed data. ~~In addition, w~~We demonstrate that citizens are unable to accurately estimate the calorie content or carbon footprint of many everyday foods, supporting previous research (Armstrong *et al.*, 2020). We observe that citizens rate plant-based foods as lower risk, in terms of food safety, than dairy, meat or fish products, which again reflects previous research (Food Standards Scotland, 2018). Whilst this study demonstrates that Zooniverse is a valuable platform to conduct research in nutrition and sustainability since many classifications were collected, we have demonstrated that Facebook and Twitter may not be suitable platforms for the recruitment of citizen scientists. Not only was the number of individuals recruited via social media low, but their estimations were not reflective of the representative sample from Qualtrics, suggesting variations in population characteristics across the three platforms.

Across all three recruitment platforms, citizens were unable to accurately estimate the energy content of foods (±10%), which supports previous research (Brown *et al.*, 2016; Carels *et al.*, 2007). When energy estimations from the present study were looked at per food type, citizens underestimated the calorie content of cereal-based products such as rice and pasta and red meats like beef, whilst they overestimated the calorie content of dairy products, fruit and vegetables and white meats such as chicken. This finding contrasts with previous research which suggests that consumers systematically underestimate the calories of healthy/weight loss foods such as vegetables or yogurt, but overestimate calorie content of unhealthy/weight gain foods, such as red meat, sweets and French fries (Carels *et al.*, 2007).

As with energy estimations, citizens were unable to estimate the carbon footprint of foods. Previous research has highlighted the vagueness of the term ’carbon footprint’ and the difficulties in making a full life-cycle calculation for foods, and these factors could explain, at least in part, the poor estimations seen in this study (Wiedmann and Minx, 2008). When individual foods were considered, the carbon footprint of red meats (beef and lamb) was underestimated, which supports previous research (Camilleri *et al.*, 2019; Shi *et al.*, 2016).

When estimations were considered by food type, carbon footprint estimations for plant-based foods were statistically significantly lower than estimations for dairy or meat or fish products. This finding supports the notion of the hierarchy of carbon footprint values and suggests that although citizens may not possess numerical accuracy, they do have an understanding that some foods have a higher carbon footprint than others (Choi and Pak, 2006). Capability (knowledge), opportunity and motivation (Mitchie et al., 2011) are required for consumers to effectively move toward a healthier more sustainable diet. We have demonstrated that consumers lack sufficient knowledge about the energy content and carbon footprint of foods, important information to enable transition to healthier and more sustainable diets. In addition, we have demonstrated that the lack of knowledge differs between consumer groups which were recruited from different platforms. Consumers increasingly demonstrate concern (motivation) about the sustainability of foods, yet these motivations do not translate to the purchase of sustainable foods (Barcellos et al., 2011; Bray, Johns and Kilburn et al., 2011).

Consequently, we suggest that the lack of knowledge about which foods are healthy and sustainable acts as a barrier in the move toward healthy and sustainable diets. We propose that providing consumers with more information about the energy content and carbon footprint of foods could assist with the uptake of more sustainable diets. This finding could support the development of a labelling scheme for foods that allows comparisons of carbon footprints to be made among food products, as has been suggested in previous research (Hartikainen *et al.*, 2014).

Supporting previous research, citizens perceived plant-based foods to be lower risk than dairy, meat or fish products (Food Standards Scotland, 2018). Meat and meat-related products, poultry, eggs and egg-related products are most frequently involved in outbreaks of foodborne diseases (Rocourt *et al.*, 2003), however other foods also pose risks to health. For example, ingestion of raw/undercooked vegetables and poor hygienic practices, such as not inadequate hand washing, can contribute to outbreaks of foodborne diseases (Patil *et al.*, 2004). The drive towards a more plant-based diet, highlights the need to re-evaluate educational campaigns relating to food safety to ensure interventions are appropriate to the foods prevalent in the food supply chain and the existing knowledge of food safety amongst consumers (Hillers *et al.*, 2003). This is particularly important considering the push towards a more plant-based diet and the recent emergence of infectious diseases of food origins (Andersen *et al.*, 2020; FoodSaftey.gov, 2019).

The recruitment method had a significant impact on food safety ratings and on calorie and carbon footprint estimations, with those recruited from Twitter having lower calorie estimations than those recruited via Qualtrics, and citizens recruited from Facebook and Twitter having lower carbon footprint estimations than citizens from Qualtrics.

Whilst demographic data is unavailable for the citizens recruited from Facebook and Twitter, the users of social media are not considered to be representative of the general population as they are more likely to be younger (for example, 41.3% of Facebook users in the UK are between 18-34) (Johnson, 2020), and better educated than non-users (Mellon and Prosser, 2017). These potential differences in population characteristics between the representative sample from Qualtrics and the citizens from social media could account for the significant differences in estimations found in this study. In support, previous research has found that the accuracy of calorie and carbon footprint estimations can depend on demographic characteristics, such as gender (Carels *et al.*, 2007), age, ethnicity (Block *et al.*, 2013) and body weight (Brown *et al.*, 2016). Therefore, such differences need to be considered when deciding on how participants are recruited for research in this field.

Animal welfare refers to the physical and mental well-being of non-human animals (Carenzi and Verga, 2009). In this study, perceptions of animal welfare were statistically different between those recruited from Qualtrics, Twitter and Facebook, with perceptions of welfare highest amongst citizens recruited from Facebook, and lowest amongst citizens from Twitter. When explored by food groups (dairy or meat and fish) there was no statistically significant difference in terms of welfare estimations. A difference was found in welfare estimations for chicken between Twitter and Qualtrics, however, this was based on only 3 ratings from Twitter and therefore must be interpreted with caution.

The welfare estimations in this study were varied. This could be explained by the lack of a single welfare metric that could be used by consumers to make assessments, or the complexity of animal welfare as a concept, since accurate estimations would need to consider the life quality of the animal, the life duration and the number of animals affected for providing a unit of product (Scherer *et al.*, 2018), amongst other factors (Farm Animal Welfare Council, 1993). Furthermore, the varied animal welfare perceptions could be explained by the differences that exist between individuals based on their location of residence (World Animal Protection, 2014) since there are different farming practices, and personal food preferences, for instance, those following a vegan diet may have ethical objections to using animals for food and thus may perceive animal welfare poorly across all animal products.

Strengths and limitations

This study provides insight into citizen understanding of the calorie content, carbon footprint, safety and animal welfare implications of many commonly eaten foods. Citizens were unable to correctly estimate calorie content or carbon footprints of foods, which indicates that educational interventions are needed before sustainable purchase decisions can be enhanced to reduce the environmental impact of food purchases and consumption. However, citizens do have some understanding of the hierarchy of carbon footprints across foods, which could be used as a starting point for interventions. The current research also suggests that citizens have an appreciation of food safety, rating animal products as riskier than plant-based foods. However, as some plant-based foods do carry some risks, for example, fruit and vegetables have been found to carry bacterial pathogens (Grant *et al.*, 2008), educational interventions about food safety may be of use (Bennett *et al.*, 2015). Importantly, as was the key aim of this study, the paper demonstrates that whilst Zooniverse and social media can be used to gather insights in nutrition research and may enable larger populations to take part in research, recruitment methods must be considered since responses appear varied across platforms.

The study is not without limitations. Attrition through each survey was explored by recruitment method and responses decreased across all surveys but was greatest in the Zooniverse surveys and lowest in the Qualtrics survey. This decline in responses across surveys resulted in a limited number of ratings for some questions, and thus limited the analysis that could be applied and the conclusions that could be drawn. Similar attrition may occur in other similar studies, and therefore should be factored in when survey instruments and analyses plans are being devised. Moreover, it is important to consider the functionality differences between the survey platforms, Zooniverse and Qualtrics. No demographic data can be gathered through Zooniverse due to the community guidelines of the platform. It would have been good to collect demographic information to enable a better understanding of the knowledge levels of different consumer groups and thus develop effective information campaigns. Google Analytics (GA) could be explored as a method to obtain demographic data, as suggested previously (Spiers *et al.*, 2019). Secondly, the design of Zooniverse is not well controlled, citizens can complete as many or as few classifications as they wish and can drop out of studies at any time. Due to this, it is not possible to pre-determine how many citizens complete a study which not only makes pre-registration difficult, but it also makes the planning of analyses hard. Finally, although images and weights of each food were shown in all the survey instruments, no information about the origin of the food, cooking method or growing conditions were provided, which may have impacted on carbon footprint, food safety and animal welfare estimations.

Citizen science implications

In addition to developing a robust tool, it is important to consider the recruitment method in citizen science studies. There is a tension between designing and recruitment to surveys used in citizen science projects for broad community engagement, versus optimizing the survey for scientific and analytical efficiency. This needs to be considered when developing studies using citizen science methods. Moreover, depending on what the citizen science survey aims to investigate, and which demographic groups are to be included, social media platforms could offer a cost effective and efficient way of recruiting citizens to projects.

Conclusion

This study has revealed that whilst Zooniverse has the potential to be used as a measure of citizen perceptions of carbon footprint, energy content, food safety and animal welfare of foods, as a recruitment method, it is not without limitation and these limitations need to be carefully considered when designing a research study. Whilst citizens appear to understand the hierarchy of carbon footprint values and calorie contents, they do not have an accurate understanding of numerical values. Although poor understanding of calorie content and carbon footprints of food amongst consumers could act as a barrier to reducing DRCD's and GHG emissions, it also represents a promising area for simple interventions such as well-designed visual calorie or carbon labels, based on the hierarchy of carbon footprints or energy content. The study suggests that food safety is somewhat understood, but that citizens may not appreciate the possible health risks associated with plant-based foods, such as bacterial pathogens. This represents an important area for educational interventions considering the current push towards more plant-based diets.

Conflict of interest statement

Dr Grant Miller is affiliated with Zooniverse which is a project at the University of Oxford. He advised on the development of the experiment, use of the Zooniverse tool, and deployment of the research on Zooniverse, he was in no way involved with the other two experiments and did not influence the analysis of the data or the results that were presented.

References

Andersen, K.G., Rambaut, A., Lipkin, W.I., Holmes, E.C. and Garry, R.F. (2020), "The proximal origin of SARS-CoV-2", *Nature Medicine*, Nature Publishing Group, Vol. 26 No. 4, pp. 450–452.

Armstrong, B., Bridge, G., Oakden, L., Reynolds, C., Wang, C., Panzone, L.A., Rivera, X.S., *et al.* (2020), "Piloting Citizen Science Methods to Measure Perceptions of Carbon Footprint and Energy Content of Food", *Frontiers in Sustainable Food Systems*, Frontiers, Vol. 4, available at:https://doi.org/10.3389/fsufs.2020.00120.

Armstrong B and Reynolds C. China and the USA, a higher perceived risk for UK consumers in a post COVID-19 food system: the impact of country of origin and ethical information on consumer perceptions of food [version 1; peer review: 1 approved]. Emerald Open Res 2020, 2:35 https://doi.org/10.35241/emeraldopenres.13711.1

Barcellos, M.D. de, Krystallis, A., Saab, M.S. de M., Kügler, J.O. and Grunert, K.G. (2011), "Investigating the gap between citizens' sustainability attitudes and food purchasing behaviour: empirical evidence from Brazilian pork consumers", *International Journal of Consumer Studies*, Vol. 35 No. 4, pp. 391–402.

Bennett, S.D., Littrell, K.W., Hill, T.A., Mahovic, M. and Behravesh, C.B. (2015), "Multistate foodborne disease outbreaks associated with raw tomatoes, United States, 1990–2010: a recurring public health problem", *Epidemiology & Infection*, Cambridge University Press, Vol. 143 No. 7, pp. 1352–1359.

Berlin, J. (2002), “Environmental life cycle assessment (LCA) of Swedish semi-hard cheese”, *International Dairy Journal*, Vol. 12 No. 11, pp. 939–953.

Block, J.P., Condon, S.K., Kleinman, K., Mullen, J., Linakis, S., Rifas-Shiman, S. and Gillman, M.W. (2013), “Consumers’ estimation of calorie content at fast food restaurants: cross sectional observational study”, *BMJ*, British Medical Journal Publishing Group, Vol. 346, available at:https://doi.org/10.1136/bmj.f2907.

Bray and Ankeny, R.A. (2017), “Happy chickens lay tastier eggs: Motivations for buying free-range eggs in Australia”, *Anthrozoös*, Taylor & Francis, United Kingdom, Vol. 30 No. 2, pp. 213–226.

Bray, J., Johns, N. and Kilburn, D. (2011), “An Exploratory Study into the Factors Impeding Ethical Consumption”, *Journal of Business Ethics*, Vol. 98 No. 4, pp. 597–608.

Brown, R.E., Canning, K.L., Fung, M., Jiandani, D., Riddell, M.C., Macpherson, A.K. and Kuk, J.L. (2016), “Calorie Estimation in Adults Differing in Body Weight Class and Weight Loss Status”, *Medicine and Science in Sports and Exercise*, Vol. 48 No. 3, pp. 521–526.

Buller, H., Blokhuis, H., Jensen, P. and Keeling, L. (2018), “Towards Farm Animal Welfare and Sustainability”, *Animals: An Open Access Journal from MDPI*, Vol. 8 No. 6, available at:https://doi.org/10.3390/ani8060081.

Camilleri, A.R., Larrick, R.P., Hossain, S. and Patino-Echeverri, D. (2019), “Consumers underestimate the emissions associated with food but are aided by labels”, *Nature Climate Change*, Nature Publishing Group, Vol. 9 No. 1, pp. 53–58.

Carels, R.A., Konrad, K. and Harper, J. (2007), “Individual differences in food perceptions and calorie estimation: an examination of dieting status, weight, and gender”, *Appetite*, Vol. 49 No. 2, pp. 450–458.

Carenzi, C. and Verga, M. (2009), “Animal welfare: review of the scientific concept and definition”, *Italian Journal of Animal Science*, Taylor & Francis, Vol. 8 No. sup1, pp. 21–30.

Choi, B.C.K. and Pak, A.W.P. (2006), “Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness”, *Clinical and Investigative Medicine. Medecine Clinique Et Experimentale*, Vol. 29 No. 6, pp. 351–364.

Clark, M. (2019), “Chapter 13 - Healthy diets as a climate change mitigation strategy”, in Sabaté, J. (Ed.), *Environmental Nutrition*, Academic Press, pp. 243–261.

Conrad, C.C. and Hilchey, K.G. (2011), “A review of citizen science and community-based environmental monitoring: issues and opportunities”, *Environmental Monitoring and Assessment*, Vol. 176 No. 1–4, pp. 273–291.

FAO. (2014), “ICN2 Second International Conference on Nutrition”, *Food and Agriculture Organization of the United Nations*, available at: http://www.fao.org/about/meetings/icn2/en/ (accessed 7 June 2020).

FAO. (2019), *The State of Food Security and Nutrition in the World: Safeguarding against Economic Slowdowns and Downturns.*, Food and Agriculture Organization of the United Nations, p. 239.

FAO and WHO. (2019), *SUSTAINABLE HEALTHY DIETS: Guiding Principles.*, FOOD & AGRICULTURE ORG, Place of publication not identified.

Farm Animal Welfare Council. (1993), *Report on Priorities for Animal Welfare Research and Development*, FAWC, Surbiton, Surrey, available at: https://edepot.wur.nl/134980.

Food Standards Scotland. (2018), *Consumer Forums Outcomes: Perceptions of Food Safety Risk*, Food Standards Scotland, Aberdeen, Scotland, available at: https://www.foodstandards.gov.scot/downloads/Consumer_forums_-_perception_of_food_safety_risks_-_fss_and_kantar_report.pdf.

FoodSaftey.gov. (2019), “Bacteria and Viruses”, *FoodSafety.Gov*, Text, , 12 April, available at: https://www.foodsafety.gov/food-poisoning/bacteria-and-viruses (accessed 7 June 2020).

Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A. and Mylan, J. (2007), *The Environmental Impacts of Food Production and Consumption*, Department for

538 Environment, Food and Rural Affairs, London, available at: https://www.eldis.org/document/A24330.

540 GBD 2017 Diet Collaborators. (2019), "Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017", *The Lancet*, Vol. 393 No. 10194, pp. 1958–1972.

543 Grant, J., Wendelboe, A.M., Wendel, A., Jepson, B., Torres, P., Smelser, C. and Rolfs, R.T. (2008), "Spinach-associated Escherichia coli O157:H7 Outbreak, Utah and New Mexico, 2006", *Emerging Infectious Diseases*, Vol. 14 No. 10, pp. 1633–1636.

546 Harper, H. and Hallsworth, M. (2012), *How Under-Reporting Can Explain the Apparent Fall in Calorie Intake*, The Behavioural Insights Team, p. 43.

548 Hartikainen, H., Roininen, T., Katajajuuri, J.-M. and Pulkkinen, H. (2014), "Finnish consumer perceptions of carbon footprints and carbon labelling of food products", *Journal of Cleaner Production*, Vol. 73, pp. 285–293.

551 Hillers, V., Medeiros, L., Kendall, P., Chen, G. and DiMascola, S. (2003), "Consumer food-handling behaviors associated with prevention of 13 foodborne illnesses.", *Journal of Food Protection*, Vol. 66 No. 10, pp. 1893–1899.

554 Hoogland, C.T., de Boer, J. and Boersema, J.J. (2007), "Food and sustainability: do consumers recognize, understand and value on-package information on production standards?", *Appetite*, Vol. 49 No. 1, pp. 47–57.

557 Hyland, J., Henchion, M., McCarthy, M. and McCarthy, S.N. (2017), "The role of meat in strategies to achieve a sustainable diet lower in greenhouse gas emissions: A review", *Meat Science*, Vol. 132, pp. 189–195.

560 Intake24. (2018), "Intake24 | System features", *Intake24*, available at: https://intake24.co.uk/info/features (accessed 7 June 2020).

562 Johnson, J. (2020), "United Kingdom: Facebook users by age and gender 2020", *Statista*, available at: https://www.statista.com/statistics/1030057/facebook-users-united-kingdom-age-gender/ (accessed 7 June 2020).

Jumpertz, R., Venti, C.A., Le, D.S., Michaels, J., Parrington, S., Krakoff, J. and Votruba, S. (2013), “Food label accuracy of common snack foods”, *Obesity (Silver Spring, Md.)*, Vol. 21 No. 1, pp. 164–169.

Kretsch, M.J., Fong, A.K. and Green, M.W. (1999), “Behavioral and body size correlates of energy intake underreporting by obese and normal-weight women”, *Journal of the American Dietetic Association*, Vol. 99 No. 3, pp. 300–306; quiz 307–308.

Lagerkvist, C.J. and Hess, S. (2010), *A Meta-Analysis of Consumer Willingness to Pay for Farm Animal Welfare*.

Legislation.gov.uk. (2006), *Animal Welfare Act 2006.*, available at: http://www.legislation.gov.uk/ukpga/2006/45/section/9 (accessed 17 December 2020).

Lindgren, E., Harris, F., Dangour, A.D., Gasparatos, A., Hiramatsu, M., Javadi, F., Loken, B., *et al.* (2018), “Sustainable food systems—a health perspective”, *Sustainability Science*, Vol. 13 No. 6, pp. 1505–1517.

McCane and Widdowson. (2015), *Composition of Foods Integrated Dataset (CoFID)*, Public Health England, available at: https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid (accessed 7 June 2020).

McLaughlin, D. and Kinzelbach, W. (2015), “Food security and sustainable resource management”, *Water Resources Research*, Vol. 51 No. 7, pp. 4966–4985.

Mellon, J. and Prosser, C. (2017), “Twitter and Facebook are not representative of the general population: Political attitudes and demographics of British social media users”, *Research & Politics*, SAGE Publications Ltd, Vol. 4 No. 3, p. 2053168017720008.

NDNS. (2019), *National Diet and Nutrition Survey. Years 1 to 9 of the Rolling Programme (2008/2009 – 2016/2017): Time Trend and Income Analyses*, NDNS, PHE and FSA, p. 56.

NHS. (2018), “Calorie checker”, *Nhs.Uk*, available at: https://www.nhs.uk/live-well/healthy-weight/calorie-checker/ (accessed 7 June 2020).

Oberoi, S., Barchowsky, A. and Wu, F. (2014), “The Global Burden of Disease for Skin, Lung, and Bladder Cancer Caused By Arsenic in Food”, *Cancer Epidemiology and Prevention Biomarkers*, American Association for Cancer Research, Vol. 23 No. 7, pp. 1187–1194.

Panzone, L., Lemke, F. and Petersen, H.L. (2016), “Biases in consumers’ assessment of environmental damage in food chains and how investments in reputation can help”, *Technological Forecasting and Social Change*, Elsevier, Vol. 111 No. C, pp. 327–337.

Patil, S.R., Morales, R., Cates, S., Anderson, D. and Kendall, D. (2004), “An Application of Meta-Analysis in Food Safety Consumer Research To Evaluate Consumer Behaviors and Practices”, *Journal of Food Protection*, Allen Press, Vol. 67 No. 11, pp. 2587–2595.

Ponto, J. (2015), “Understanding and Evaluating Survey Research”, *Journal of the Advanced Practitioner in Oncology*, Vol. 6 No. 2, pp. 168–171.

Poore, J. and Nemecek, T. (2018), “Reducing food’s environmental impacts through producers and consumers”, *Science*, American Association for the Advancement of Science, Vol. 360 No. 6392, pp. 987–992.

Rocourt, J., Moy, G., Vierk, K. and Schlundt, J. (2003), *The Present State of Foodborne Disease in OECD Countries*, World Health Organization, Geneva, Switzerland.

Scherer, L., Tomasik, B., Rueda, O. and Pfister, S. (2018), “Framework for integrating animal welfare into life cycle sustainability assessment”, *The International Journal of Life Cycle Assessment*, Vol. 23 No. 7, pp. 1476–1490.

Shi, J., Siegrist, M., Bumann, N. and Visschers, V.H.M. (2016), “Consumers’ climate-impact estimations of different food products”, *Journal of Cleaner Production*, Elsevier Ltd, available at: https://agris.fao.org/agris-search/search.do?recordID=US201700135611 (accessed 7 June 2020).

Silvertown. (2009), “A new dawn for citizen science”, *Trends in Ecology & Evolution*, Trends Ecol Evol, Vol. 24 No. 9, pp. 461–471.

Simpson, R., Page, K.R. and De Roure, D. (2014), “Zooniverse: observing the world’s largest citizen science platform”, *Proceedings of the 23rd International Conference on World Wide Web*, Association for Computing Machinery, Seoul, Korea, pp. 1049–1054.

Smith, A., Lynn, S. and Lintott, C. (2013), “An Introduction to the Zooniverse”, *The First AAAI Conference on Human Computation and Crowdsourcing (HCOMP-2013)*, presented at the HCOMP, Palm Springs, California, p. 1.

Spiers, H., Swanson, A., Fortson, L., Simmons, B., Trouille, L., Blickhan, S. and Lintott, C. (2019), “Everyone counts? Design considerations in online citizen science”, *Journal of Science Communication*, Vol. 18 No. 01, available at:https://doi.org/10.22323/2.18010204.

West, S. and Pateman, R. (2016), “Recruiting and Retaining Participants in Citizen Science: What Can Be Learned from the Volunteering Literature?”, *Citizen Science: Theory and Practice*, Ubiquity Press, Vol. 1 No. 2, p. 15.

WHO. (2018), “Estimating the burden of foodborne diseases”, *World Health Organization*, available at: https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases (accessed 7 June 2020).

Wiedmann, T. and Minx, J. (2008), “A Definition of Carbon Footprint”, *Economics Research Trends*, Nova Science Publishers, Hauppauge, NY, USA, pp. 1–11.

World Animal Protection. (2014), “Indicators | World Animal Protection”, *World Animal Protection*, available at: https://api.worldanimalprotection.org/indicators (accessed 7 June 2020).

Worthington, J.P., Silvertown, J., Cook, L., Cameron, R., Dodd, M., Greenwood, R.M., McConway, K., *et al.* (2012), “Evolution MegaLab: a case study in citizen science methods”, *Methods in Ecology and Evolution*, Vol. 3 No. 2, pp. 303–309.

Zooniverse. (2019), “Zooniverse”, available at: https://www.zooniverse.org/ (accessed 7 June 2020).

Tables

Table 1. In range values of Carbon Footprint and Energy Content values for each food

Food	Carbon footprint in range [gCO2e x 10]	Energy content in range (Kcal)
Pasta (238g)	257-314	309-377
Rice (258g)	617-754	308-377
Bread (100g)	45-55	194-237
Cereal (52g)	51-62	166-203
Potato (213g)	38-46	141-173
Carrot (82g)	16-19	14-18
Tomato (92g)	38-46	9-12
Peas (75g)	40-49	47-57
Cabbage (92g)	26-32	13-16
Cauliflower (128g)	40-49	32-36
Mushrooms (62g)	15-18	8-10
Onions (59g)	9-11	18-22
Apples (141g)	45-55	52-63
Citrus (263g)	74-90	76-93
Banana (137g)	97-119	62-76
Strawberry (105g)	61-75	23-29
Milk (68g)	85-103	26-32
Cheese (full fat) (52g)	414-506	167-204
Cheese (low fat) (52g)	414-506	145-177
Eggs (121g)	369-451	82-100
Bacon (61g)	321-392	155-190
Beef (140g)	3619-4424	274-334
Lamb (139g)	3491-4267	260-318
Pork (238g)	1253-1531	409-500
Chicken	415-507	177-216
Fish (134g)	420-514	90-110

Chickpeas tinned (95g)	57-70	109-133
Baked beans (233g)	130-158	173-211
Quorn (105g)	113-138	98-120

Table 2. Accuracy of Carbon Footprint and Energy Content estimates for each recruitment method

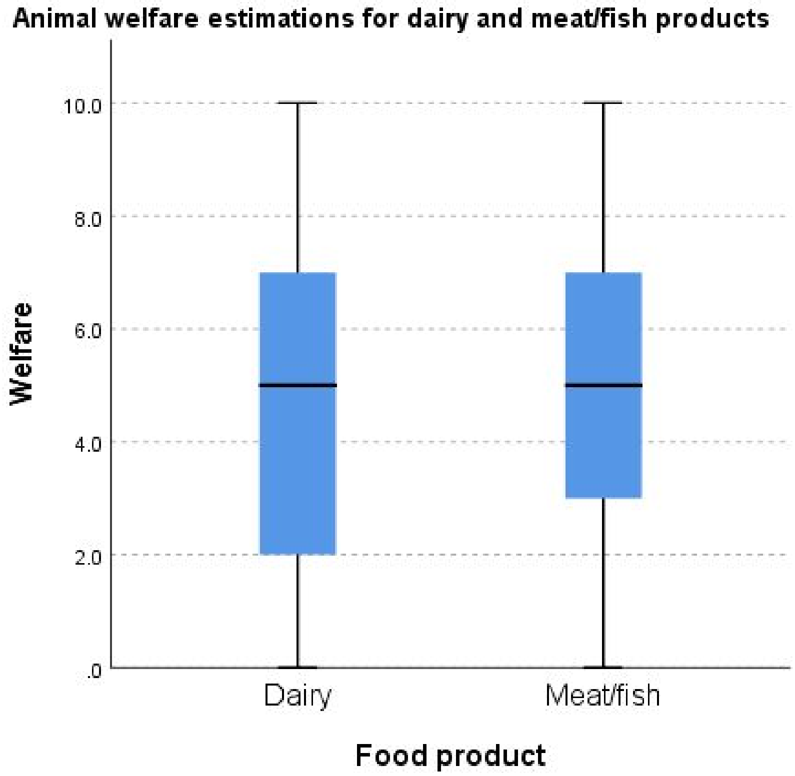
		Carbon footprint (%)			Energy content (%)		
		Below	**In range**	**Above**	**Below**	**In range**	**Above**
Recruitment method	**Qualtrics**	1178 (9.9)	235 (2)	10496 (88.1)	3735 (31.6)	438 (3.7)	7663 (64.7)
	Twitter	0	0	728 (100)	4076 (32.4)	8047 (63.9)	476 (3.8)
	Facebook	0	0	179 (100)	40 (51.3)	4 (5.1)	34 (43.6)

Table 3. Frequency of Food Safety estimates for each recruitment method

		Food safety (%)		
		Low risk *[ratings: 0-3]*	**Medium risk** *[4-7]*	**High risk** *[8-10]*
Recruitment method	**Qualtrics**	8508 (71.4)	2821 (23.7)	581 (4.9)
	Twitter	160 (72.7)	42 (19.1)	18 (8.2)
	Facebook	28 (82.4)	4 (11.8)	2 (5.9)

Figures

Figure 1. Animal welfare estimations by dairy and meat or fish products



Appendix

Appendix 1. Facebook post for recruitment

Appendix 2. Animal welfare perceptions by food

			Animal welfare perceptions by food												Total
			Other	Milk	Full Fat cheese	Low Fat cheese	Eggs	Bacon	Beef	Lamb	Pork	Chicken	White Fish	Oily Fish	
Welfare	Low welfare (0-3)	Count	2217	113	127	110	130	110	100	114	122	119	139	114	3515
		% within all foods	34.9%	34.1%	37.2%	33.7%	39.4%	31.5%	30.4%	33.4%	35.6%	35.3%	40.2%	33.4%	34.9%
	Medium welfare (4-6)	Count	1793	103	106	107	94	123	111	104	115	116	115	111	2998
		% within all foods	28.2%	31.1%	31.1%	32.8%	28.5%	35.2%	33.7%	30.5%	33.5%	34.4%	33.2%	32.6%	29.8%
	High welfare (7-10)	Count	2348	115	108	109	106	116	118	123	106	102	92	116	3559
		% within all foods	36.9%	34.7%	31.7%	33.4%	32.1%	33.2%	35.9%	36.1%	30.9%	30.3%	26.6%	34.0%	35.3%
Total		Count	6358	331	341	326	330	349	329	341	343	337	346	341	10072
		% within all foods	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%