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

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## 1 Introduction

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

21 The ~~benefits of~~ **need to move towards** healthy and sustainable diets may be accepted  
22 within academic, policy and advisory bodies, **but** ~~However~~, awareness of the calorie  
23 content and carbon footprint **of many foods is** ~~of may be~~ less well understood amongst  
24 the general public, particularly amongst certain demographic groups, **hampering the**

1  
2  
3 25 **move towards health and sustainable dietary practices** (Carels, Konrad and Harper,  
4  
5 26 2007; Harper and Hallsworth, 2012; Kretsch *et al.*, 1999). For carbon footprint  
6  
7 estimations, Research suggests that the public particularly struggle to correctly  
8  
9 estimate **carbon footprint** values for animal origin products such as meat or dairy. As  
10  
11 animal products have higher carbon footprints compared with other food groups such  
12  
13 as grains or vegetables (Berlin, 2002; Foster *et al.*, 2007), this lack of awareness may  
14  
15 hamper behaviour change towards more sustainable diets. As outlined by the COM-B  
16  
17 model of behaviour change, capability, opportunity, and motivation are all required to  
18  
19 make a change in consumer behaviour (Mitchie, Stralen and West, 2011). In the  
20  
21 context of moving consumers toward healthier and more sustainable diets, as  
22  
23 consumers lack knowledge (capability) about the calorie content (Carels *et al.*, 2007;  
24  
25 Harper and Hallsworth, 2012; Kretsch *et al.*, 1999), and carbon footprint of foods  
26  
27 (Berlin, 2002; Foster *et al.*, 2007) Consequently, consumers may be unable to move  
28  
29 toward a healthier and more sustainable diet due to their lack of knowledge  
30  
31 (capability). Thus, exploring consumer perceptions about energy content and carbon  
32  
33 footprint of foods, and understanding the relevant knowledge gaps, is important to the  
34  
35 development of effective interventions.  
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43 As healthy and sustainable diets must be thought of in terms of the whole food system,  
44  
45 the welfare of animals **also** needs to be considered when investigating consumer food  
46  
47 choices and perceptions (Lindgren *et al.*, 2018). Animal welfare relates to how well the  
48  
49 animals are treated, the quality of the space in which they are kept and how humanely  
50  
51 they are slaughtered (Legislation.gov.uk, 2006). The UN SDGs include animal welfare  
52  
53 as a global goal of sustainable agricultural policy (Buller *et al.*, 2018). **Previous**  
54  
55 **research indicates that** consumers expect chicken that has been raised in higher  
56  
57 animal welfare standards to be tastier, have a lower carbon footprint, be safer to eat  
58  
59  
60

1  
2  
3 50 and report higher purchase intention than when a chicken has been raised in lower  
4  
5 51 welfare standards (Armstrong and Reynolds, 2020). However, alternative findings  
6  
7 52 suggest that consumers do not often consider animal welfare **at all** when making  
8  
9 53 purchase or consumption decisions, ~~with the exception of~~ **except for when purchasing**  
10  
11 54 **free-range** eggs (Lagerkvist and Hess, 2010), which could be due to **higher welfare,**  
12  
13 55 free-range eggs being considered as 'better quality, more nutritious, and safer' (Bray  
14  
15 56 and Ankeny 2017). Highlighting the lack of consideration for animal welfare when  
16  
17 57 making purchasing decisions, **other** research found that providing details about animal  
18  
19 58 welfare standards for products such as meat only leads to small changes in purchase  
20  
21 59 intention (Hoogland, de Boer and Boerseman, 2007).

22  
23  
24  
25  
26  
27 60 Food safety is **another** a—major concern when taking a whole food system approach  
28  
29 61 to ensuring healthy and sustainable diets. Recent estimates suggesting that **unsafe,**  
30  
31 62 contaminated foods cause more than 200 acute and chronic diseases (FAO and WHO,  
32  
33 63 2019), 600 million cases of foodborne disease and over 420,000 deaths (WHO, 2018).  
34  
35 64 Unsafe foods have also been attributed to a global loss of over 33 million years of  
36  
37 65 healthy life, impacting economic and individual well-being (WHO, 2018). Whilst many  
38  
39 66 foodborne diseases are associated with pathogens such as bacteria or parasites,  
40  
41 67 some foodborne conditions are attributed to chemicals, such as pesticides, or  
42  
43 68 metalloids such as arsenic (Oberoi, Barchowsky and Wu, 2014). Previous research  
44  
45 69 suggests that consumers perceive chicken, and other meat products to be higher risk  
46  
47 70 than non-meat products (Food Standards Scotland, 2018). However, as grains,  
48  
49 71 vegetables, fruit and fish can pose food safety risks, for example in terms of naturally  
50  
51 72 occurring arsenic which may cause cancer, these products need to also be considered  
52  
53 73 **when developing recommendations for dietary change** (Oberoi *et al.*, 2014). This is  
54  
55 74 especially timely since the move towards a more plant-based diet may lead to

1  
2  
3 75 increased exposure to pesticides and heavy metals, or to pathogens if foods are eaten  
4  
5 76 raw, as well as increased exposure to mycotoxins from nuts (Oberoi *et al.*, 2014).  
6  
7  
8 77 Exploring public awareness and understanding of the safety levels of different foods  
9  
10 78 is important as we promote the transition to a more sustainable and healthy diet.

11  
12  
13 79 As highlighted, understanding consumer perceptions and estimations concerning  
14  
15 80 healthy and sustainable diets is important. Previous research has relied on survey  
16  
17 81 methods with either pilot or small sample sizes (e.g. N=42, N=<226) often restricted  
18  
19 82 by access to a limited number of participants, due to factors such as experimental set-  
20  
21 83 up and budget (Panzone, Lemke and Petersen, 2016; Shi *et al.*, 2016). Citizen science  
22  
23 84 projects invite members of the public to take part in scientific investigations by  
24  
25 85 contributing data, processing data or both (Silvertown, 2009). As citizen science  
26  
27 86 recruits volunteers to help with data collection, research can be completed quickly, at  
28  
29 87 a lower cost and with wider participation than with other methods (Conrad and Hilchey,  
30  
31 88 2011). Therefore, citizen science could be used to better understand current  
32  
33 89 perceptions of carbon footprint, energy content, food safety and animal welfare in the  
34  
35 90 general population (Zooniverse, 2019). However, it has been posited that recruitment  
36  
37 91 methods for citizen science research can affect the quality and volume of the data  
38  
39 92 obtained and thus the conclusions that are drawn from the data (Ponto, 2015;  
40  
41 93 Worthington *et al.*, 2012), so assessing the suitability of different recruitment methods  
42  
43 94 is critical.

44  
45  
46 95 The current study develops understanding gained from previous exploratory pilot  
47  
48 96 research to explore consumer perceptions of the energy and GHG emissions of foods  
49  
50 97 and animal welfare and food safety for foods (Armstrong *et al.*, 2020). and The study  
51  
52 98 also builds on literature assessing methods for recruitment of citizen scientists (West  
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99 and Pateman, 2016; Worthington *et al.*, 2012). This study provides a novel comparison  
100 of three recruitment methods in the exploration of consumer perceptions. Participants  
101 were recruited through social media via Facebook and Twitter adverts and were  
102 redirected to the citizen science platform, Zooniverse, to explore consumer perception  
103 of the Calorie Content, Carbon Footprint, Food Safety, and Animal Welfare of 29  
104 different foods. Zooniverse is an online platform that 'enables everyone to take part in  
105 real cutting edge research in many fields across the sciences, humanities, and more'  
106 (Smith, Lynn and Lintott , 2013; Zooniverse, 2019). A comparison of the data collected  
107 was made between participants recruited via Twitter and Facebook, and respondents  
108 to a previous survey conducted on Qualtrics, which used a representative UK sample,  
109 to identify differences in citizen perceptions.

## 110 **Methods**

### 111 Recruitment

112 For this exploratory study, recruitment of citizen scientists occurred via Qualtrics, and  
113 social media platforms Facebook and Twitter. Paid adverts were used to aid  
114 recruitment on Facebook and Twitter, with a budget of £1000 and parameters set for  
115 a UK adult population. The adverts were run over two weeks in spring 2020. The  
116 adverts included links to the Zooniverse. The Zooniverse citizen science platform was  
117 selected as it is the largest citizen science hosting platform on the internet with over  
118 900,000 volunteers registered, and upwards of 90+ citizen science projects running at  
119 any one time (Smith *et al.*, 2013).

120 Citizens took part voluntarily in a survey on the Zooniverse and did not receive  
121 payment. On Facebook, the adverts achieved 10,889 clicks (11 engagements) and a  
122 total of 358 ratings, and on Twitter, the survey received 4845 clicks (85 engagements)

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2  
3 123 and a total of 2184 ratings. To compare the data gathered through social media  
4  
5 124 recruitment with those gathered by a traditional survey approach, a separate cohort of  
6  
7  
8 125 respondents were recruited via Qualtrics. The Qualtrics sample included 398 people,  
9  
10 126 representing the diversity of the UK population. The respondents were compiled using  
11  
12 127 overall demographic quotas based on census percentages for representation: age,  
13  
14 128 gender, ethnicity, household income, and census region.

### 17 18 129 Procedure

20  
21 130 For the Zooniverse survey, each citizen scientist was randomly allocated to one of four  
22  
23 131 workflows (per IP address or Zooniverse ID). Workflows were a series of questions,  
24  
25 132 designed to counterbalance responses, reflecting the randomisation process used by  
26  
27 133 Qualtrics. Participants could retire at any point during the survey. The presentation  
28  
29 134 order of the food images was randomised. Exact questions and additional text  
30  
31 135 information provided to citizens can be found in the supplementary materials.  
32  
33 136 Zooniverse uses a glossary of specific terms. In this paper, the term 'classification'  
34  
35 137 denotes a single unit of analysis on a project by a respondent, whilst the term 'subject'  
36  
37 138 refers to a single data object such as an image. (For a detailed glossary of Zooniverse  
38  
39 139 terms, see Simpson, Page, and De Roure, 2014).

### 42 43 44 45 140 Survey design

46  
47  
48 141 Topic 1 (Energy Density or Carbon Footprint) x Topic 2 (Food Safety or Animal  
49  
50 142 Welfare) of 29 foods (apple, bacon, banana, beef, beans, bread, cabbage, carrot,  
51  
52 143 cauliflower, cereal, chicken, chickpeas, egg, fish, full fat cheese, lamb, low fat cheese,  
53  
54 144 milk, mushroom, onion, orange, pasta, peas, pork, potato, Quorn, rice, strawberries,  
55  
56 145 tomato). A photograph of each food was selected from the Intake24 image bank and  
57  
58 146 was shown in the workflow with a text description and portion weight (grams)

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3 147 information (Intake24, 2018). Citizens were shown an image of each food and asked  
4  
5 148 to estimate calorie content (0-930 Kcal), carbon footprint (0-8180). The values gave a  
6  
7 149 tolerance one third higher than the highest calorie content or carbon footprint of the  
8  
9 150 foods included. Ratings for food safety were on a ten point scale, with (0 (Low risk) -  
10 151 10 (High risk)) and (0 (Low welfare) - 10 (High welfare)) respectively. Previous  
11  
12 152 research using Zooniverse has explored methodological aspects of data collection and  
13  
14 153 found that the slider tool was the most appropriate measure in terms of accuracy and  
15  
16 154 validity compared to text box and multiple-choice alternatives, and thus the slider  
17  
18 155 option was used in this citizen science study (Armstrong, Bridge, Oakden, Reynolds,  
19  
20 156 Wang, Kause, et al., 2020).

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27 157 \*[INSERT TABLE 1 HERE]\*  
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### 30 158 **Data analysis**

31  
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33 159 Energy content data (Kcal/100g product) used in the analysis were those reported in  
34  
35 160 the National Diet and Nutrition Survey databank and from the NHS calorie checker  
36  
37 161 platform (NDNS, 2019; NHS, 2018). The carbon footprint values (kgCO<sub>2</sub>e /100g  
38  
39 162 product) were based on published data (Poore and Nemecek, 2018). The values  
40  
41 163 represent the average emissions released during the production of primary food  
42  
43 164 commodities to the point of the regional distribution centre in the UK (see Table 1 for  
44  
45 165 a summary of the energy content and CO<sub>2</sub>e values).

46  
47  
48 166 In total, 48,168 ratings (Twitter n=2184, Facebook n=358, Qualtrics n=45,626) were  
49  
50 167 submitted. Across the three recruitment platforms, 12,648 energy content (Kcal)  
51  
52 168 classifications were recorded (Qualtrics n=11,877, Facebook n=78, Twitter n=693).  
53  
54 169 Perceptions of the energy content of the foods were compared against validated  
55  
56 170 figures (NDNS, 2019; NHS, 2018). A +/-10% range of the figures were classified as

1  
2  
3 171 correct, to allow for the accuracy tolerance of food labels and variations in energy  
4  
5 172 content of foods regionally (>930 kcal).  
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8  
9 173 12,817 classifications were recorded for carbon footprint perceptions (Jumpertz *et al.*,  
10  
11 174 2013; McCane and Widdowson, 2015). As with calorie estimations, carbon footprint  
12  
13 175 estimations were compared against values calculated from previously validated  
14  
15 176 figures (Poore and Nemecek, 2018). For comparisons, a +/-10% range of the figures  
16  
17 177 were classified as correct (0-815 g of gCO<sub>2</sub>e x 10<sup>1</sup>).  
18  
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20  
21 178 For food safety, 12,164 classifications were recorded (Qualtrics n=11,910, Facebook  
22  
23 179 n=34, Twitter n=220), whilst for animal welfare (0 (Low welfare) - 10 (High welfare),  
24  
25 180 10,072 classifications across the three recruitment platforms (Qualtrics n=9,930,  
26  
27 181 Facebook n=11, Twitter n=131) were recorded.  
28  
29

30  
31 182 Using SPSS statistics software, the Kruskal Wallis H test and subsequent pairwise  
32  
33 183 comparisons (Bonferroni corrections applied) were used to explore the impact of  
34  
35 184 recruitment method, on citizen estimates of carbon footprint, energy content, animal  
36  
37 185 welfare and food safety. This test was chosen because the sample sizes are so  
38  
39 186 variable.  
40  
41

## 42 43 44 187 **Results**

### 45 46 47 188 Energy content perception 48 49

50  
51 189 Overall, citizens were more likely to overestimate the calorie content of foods  
52  
53 190 (n=1,1403, 88.9%) than correctly estimate (n=235, 1.8%) or underestimate (n=1,178,  
54  
55 191 9.2%). However, this effect was not observed when the recruitment method was  
56  
57 192 considered. Citizens recruited from Facebook were more likely to underestimate  
58  
59 193 calorie content (n=40, 51%), whilst citizens recruited from Qualtrics and Twitter were

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3 194 more likely to overestimate calorie content (n=7,663, 65% and n=350, 51%  
4  
5 195 respectively). As a small number of citizens were recruited using social media  
6  
7 196 platforms the conclusions drawn need to be interpreted with caution, those from  
8  
9 197 Facebook were more likely to correctly estimate calorie content (n=4, 0.05%) than  
10  
11 198 those recruited from Twitter (n=34, 0.05%) or Qualtrics (n=438, 0.03%).  
12  
13  
14

15 199 The impact of food type on the estimates of energy content was compared to the range  
16  
17 200 of validated values. The energy content of cereal products was more likely to be  
18  
19 201 underestimated than overestimated or estimated within range. For example, with  
20  
21 202 pasta, 71.5% of estimations underestimated energy content whilst under a quarter  
22  
23 203 (24.4%) were overestimated and just 4% were within range. In contrast, energy  
24  
25 204 content for fruit and vegetables was likely to be overestimated. For example, 93.5% of  
26  
27 205 energy estimates for carrots were overestimations, whilst just 5.7% underestimated  
28  
29 206 calorie content and only 1 estimation was within range. Similarly, for peas, 72.2% of  
30  
31 207 estimations were over the accepted range, whilst 24.8% were underestimates and just  
32  
33 208 2.8% were within range. Calorie content of dairy products were frequently  
34  
35 209 overestimated with 95% of estimation of milk, and 62% of estimations for full fat  
36  
37 210 cheese being overestimated. The accuracy of meat product calorie estimations varied.  
38  
39 211 The energy content of bacon and chicken were mostly overestimated, (64% and  
40  
41 212 56.1% respectively). However, the perceived energy content of beef and pork were  
42  
43 213 more likely to be underestimated (53.4% and 77.2% respectively).  
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#### 50 51 214 Carbon footprint perception 52 53

54 215 Across recruitment methods, citizens were most likely to overestimate the carbon  
55  
56 216 footprint of foods (n=11,403, 88.9%). Citizens recruited via social media (Twitter and  
57  
58 217 Facebook) made no correct estimations, with all estimations being above the correct  
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3 218 range. Whilst most citizens recruited via Qualtrics overestimated carbon footprint  
4  
5 219 across foods (n=10,496, 88%), some underestimated (n=1,178, 9%) and an even  
6  
7 220 smaller minority correctly estimated within range (n=235, 1.9%). Due to the small  
8  
9 221 sample numbers on social media, no statistical tests could be conducted to explore  
10  
11 222 differences between recruitment methods.  
12  
13  
14

15 223 The impact of food type on the carbon footprint estimates was explored, first by food  
16  
17 224 groups. When looked at descriptively, carbon footprint estimations for plant-based  
18  
19 225 foods were lower ( $1,388.6 \pm 1,319.6$ ) than estimations for dairy ( $1881.9 \pm 1567.6$ ) or  
20  
21 226 meat or fish products ( $2,569.5 \pm 1,888.3$ ). A Kolmogorov-Smirnov test indicates that the  
22  
23 227 carbon footprint estimations do not follow a normal distribution ( $D(12,817) = .137, p <$   
24  
25 228  $.001$ ) and so statistical differences could not be explored.  
26  
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30 229 Estimations were then compared to the range of validated carbon footprint values.  
31  
32 230 Citizens were most likely to overestimate carbon footprints of grain-based foods, with  
33  
34 231 89% of estimations for pasta and 73.2% of estimations for rice over the accepted  
35  
36 232 range. Overestimations of carbon footprints were also most likely across dairy  
37  
38 233 products, with 96% of ratings for milk, and 88% for full fat cheese above the 10%  
39  
40 234 margin of error. Similarly, overestimations were most frequent for white meats, with  
41  
42 235 93% of estimates were over the accepted range for chicken. In contrast, carbon  
43  
44 236 footprints of red meat were more likely to be underestimated, with 60% of perceptions  
45  
46 237 for beef and 57.2% for lamb, under the accepted range for their respective carbon  
47  
48 238 footprint values.  
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### 53 54 239 Food safety perception

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57 240 12,164 valid classifications of food safety ratings (0 (Low risk) - 10 (High risk)) were  
58  
59 241 recorded across the three recruitment platforms. Across all classifications, 71.4%  
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2  
3 242 (n=8,696) were rated as low risk, 23.5% (n=2867) whilst just 4.9% (n=601) were rated  
4  
5 243 as high risk. Between recruitment platforms, overall food safety ratings were  
6  
7 244 statistically different ( $H(2)=20.21$ ,  $p=.001$ ), with safety perceptions highest amongst  
8  
9 245 citizens recruited from Facebook and lowest amongst those from Twitter (mean rank  
10  
11 246 food safety: Twitter: 5,053.91, Qualtrics: 6,100.52, Facebook: 6,424.41). When  
12  
13 247 pairwise comparisons were conducted, statistically significant differences were  
14  
15 248 apparent between food safety perceptions from citizens on Twitter - Qualtrics ( $p<.001$ ).  
16  
17 249 When food safety perceptions were explored by food type, a significant difference in  
18  
19 250 food safety perceptions were found between plant based foods, dairy products and  
20  
21 251 meat or fish ( $\chi^2(4) = 1,434$ ,  $p <.001$ ), with plant based foods rated as lower risk than  
22  
23 252 dairy, meat or fish products.

### 29 253 Animal welfare perception

31  
32  
33 254 Perceptions of animal welfare (0 (low welfare) - 10 (high welfare)) were statistically  
34  
35 255 different between those recruited from Qualtrics, Twitter and Facebook ( $H(2)=13.12$ ,  
36  
37 256  $p<.001$ ). Perceptions of animal welfare across all foods were lowest amongst citizens  
38  
39 257 recruited from Facebook, and highest amongst citizens from Twitter (Mean rank  
40  
41 258 animal welfare: Facebook=4,815, Qualtrics=5,025, Twitter=5,921). Pairwise  
42  
43 259 comparisons indicated that Twitter respondents had higher perceptions of animal  
44  
45 260 welfare than Qualtrics respondents ( $H(1)=-895.48$ ,  $p<.001$ ).

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50 261 When explored by food groups (dairy or meat and fish) there was no statistically  
51  
52 262 significant difference in terms of welfare estimations (see Figure 1). When explored by  
53  
54 263 individual food items chicken was the only food that showed a statistically significant  
55  
56 264 difference in welfare ratings between recruitment methods ( $H(1)=8.13$ ,  $p=.004$ ) with  
57  
58 265 Twitter citizens reporting higher welfare (mean ranks: Qualtrics: 198.58, Twitter: 388).  
59  
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2  
3 266 However, this is based on only 3 ratings from Twitter so should be interpreted with  
4  
5 267 caution. No ratings for chicken were received from Facebook. Just over a third of  
6  
7 268 citizens reported that dairy (n=510, 35.1%) and meat/ fish (n=981, 35.3%) products  
8  
9 269 are low welfare, whilst just over a quarter of citizens reported that dairy (n=415, 28.5%)  
10  
11 270 and meat/fish (n=741, 26.6%) products are high welfare. When explored across  
12  
13 271 individual foods, perceptions of animal welfare were similar, with approximately a third  
14  
15 272 of citizens perceiving each food item to have low, medium or high welfare (range of  
16  
17 273 30.4% to 37.3%). One outlier was white fish, with more citizens perceiving this product  
18  
19 274 to have lower animal welfare (n=139, 40.2%).  
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25 275 \*[INSERT FIGURE 1 HERE]\*  
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27

#### 28 276 Impact of recruitment method 29

30  
31 277 Recruitment method had a significant impact on perceptions of carbon footprint  
32  
33 278 (H(2)=2,391.3, p=.001), calorie estimation (H(2)=139.9, p=.001), food safety  
34  
35 279 (H(2)=20.21, p=.001) and animal welfare perceptions (H(2)=13.12, p<.001). Citizens  
36  
37 280 recruited from Facebook perceived animal welfare to be higher across all food groups  
38  
39 281 than those from Twitter and Facebook (mean rank animal welfare: Facebook= 4,815,  
40  
41 282 Qualtrics= 5,025, Twitter= 5,921). Those recruited from Facebook and Twitter had the  
42  
43 283 lowest carbon footprint estimations (mean rank carbon footprint: Facebook: 618.5,  
44  
45 284 Twitter: 618.5, Qualtrics: 6849.9). The Twitter recruitment sample had lower calorie  
46  
47 285 estimations than those given by citizens recruited via Qualtrics (mean rank calories:  
48  
49 286 Twitter: 5473.5, Qualtrics: 6426.0). For food safety, again, citizens recruited from  
50  
51 287 Twitter had lower perceptions than Qualtrics (mean ranks: Twitter: 5053.91, Qualtrics:  
52  
53 288 6100.9). The Facebook sample was too small to be included in the comparative  
54  
55 289 analysis for calorie and food safety estimations.  
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## 290 Discussion

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

307 Across all three recruitment platforms, citizens were unable to accurately estimate the  
308 energy content of foods ( $\pm 10\%$ ), which supports previous research (Brown *et al.*, 2016;  
309 Carels *et al.*, 2007). When energy estimations from the present study were looked at  
310 per food type, citizens underestimated the calorie content of cereal-based products  
311 such as rice and pasta and red meats like beef, whilst they overestimated the calorie  
312 content of dairy products, fruit and vegetables and white meats such as chicken. This  
313 finding contrasts with previous research which suggests that consumers

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3 314 systematically underestimate the calories of healthy/weight loss foods such as  
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5 315 vegetables or yogurt, but overestimate calorie content of unhealthy/weight gain foods,  
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7 316 such as red meat, sweets and French fries (Carels *et al.*, 2007).  
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11 317 As with energy estimations, citizens were unable to estimate the carbon footprint of  
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13 318 foods. Previous research has highlighted the vagueness of the term 'carbon footprint'  
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15 319 and the difficulties in making a full life-cycle calculation for foods, and these factors  
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17 320 could explain, at least in part, the poor estimations seen in this study (Wiedmann and  
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19 321 Minx, 2008). When individual foods were considered, the carbon footprint of red meats  
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21 322 (beef and lamb) was underestimated, which supports previous research (Camilleri *et*  
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23 323 *al.*, 2019; Shi *et al.*, 2016).  
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28 324 When estimations were considered by food type, carbon footprint estimations for plant-  
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30 325 based foods were statistically significantly lower than estimations for dairy or meat or  
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32 326 fish products. This finding supports the notion of the hierarchy of carbon footprint  
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34 327 values and suggests that although citizens may not possess numerical accuracy, they  
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36 328 do have an understanding that some foods have a higher carbon footprint than others  
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38 329 (Choi and Pak, 2006). Capability (knowledge), opportunity and motivation (Mitchie *et*  
39  
40 330 *al.*, 2011) are required for consumers to effectively move toward a healthier more  
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42 331 sustainable diet. We have demonstrated that consumers lack sufficient knowledge  
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44 332 about the energy content and carbon footprint of foods, important information to enable  
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46 333 transition to healthier and more sustainable diets. In addition, we have demonstrated  
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48 334 that the lack of knowledge differs between consumer groups which were recruited from  
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50 335 different platforms. Consumers increasingly demonstrate concern (motivation) about  
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52 336 the sustainability of foods, yet these motivations do not translate to the purchase of  
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54 337 sustainable foods (Barcellos *et al.*, 2011; Bray, Johns and Kilburn *et al.*, 2011).  
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3 338 Consequently, we suggest that the lack of knowledge about which foods are healthy  
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5 339 and sustainable acts as a barrier in the move toward healthy and sustainable diets.  
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8 340 We propose that providing consumers with more information about the energy content  
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10 341 and carbon footprint of foods could assist with the uptake of more sustainable diets.  
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12 342 This finding could support the development of a labelling scheme for foods that allows  
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14 343 comparisons of carbon footprints to be made among food products, as has been  
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17 344 suggested in previous research (Hartikainen *et al.*, 2014).

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20 345 Supporting previous research, citizens perceived plant-based foods to be lower risk  
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22 346 than dairy, meat or fish products (Food Standards Scotland, 2018). Meat and meat-  
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24 347 related products, poultry, eggs and egg-related products are most frequently involved  
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27 348 in outbreaks of foodborne diseases (Rocourt *et al.*, 2003), however other foods also  
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29 349 pose risks to health. For example, ingestion of raw/undercooked vegetables and poor  
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31 350 hygienic practices, such as not inadequate hand washing, can contribute to outbreaks  
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33 351 of foodborne diseases (Patil *et al.*, 2004). The drive towards a more plant-based diet,  
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35 352 highlights the need to re-evaluate educational campaigns relating to food safety to  
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38 353 ensure interventions are appropriate to the foods prevalent in the food supply chain  
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40 354 and the existing knowledge of food safety amongst consumers (Hillers *et al.*, 2003).  
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42 355 This is particularly important considering the push towards a more plant-based diet  
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44 356 and the recent emergence of infectious diseases of food origins (Andersen *et al.*, 2020;  
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47 357 FoodSaftey.gov, 2019).

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51 358 The recruitment method had a significant impact on food safety ratings and on calorie  
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53 359 and carbon footprint estimations, with those recruited from Twitter having lower calorie  
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55 360 estimations than those recruited via Qualtrics, and citizens recruited from Facebook  
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57 361 and Twitter having lower carbon footprint estimations than citizens from Qualtrics.  
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3 362 Whilst demographic data is unavailable for the citizens recruited from Facebook and  
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5 363 Twitter, the users of social media are not considered to be representative of the  
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7 364 general population as they are more likely to be younger (for example, 41.3% of  
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9 365 Facebook users in the UK are between 18-34) (Johnson, 2020), and better educated  
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11 366 than non-users (Mellon and Prosser, 2017). These potential differences in population  
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13 367 characteristics between the representative sample from Qualtrics and the citizens from  
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15 368 social media could account for the significant differences in estimations found in this  
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17 369 study. In support, previous research has found that the accuracy of calorie and carbon  
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19 370 footprint estimations can depend on demographic characteristics, such as gender  
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21 371 (Carels *et al.*, 2007), age, ethnicity (Block *et al.*, 2013) and body weight (Brown *et al.*,  
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23 372 2016). Therefore, such differences need to be considered when deciding on how  
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25 373 participants are recruited for research in this field.  
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32 374 Animal welfare refers to the physical and mental well-being of non-human animals  
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34 375 (Carenzi and Verga, 2009). In this study, perceptions of animal welfare were  
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36 376 statistically different between those recruited from Qualtrics, Twitter and Facebook,  
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38 377 with perceptions of welfare highest amongst citizens recruited from Facebook, and  
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40 378 lowest amongst citizens from Twitter. When explored by food groups (dairy or meat  
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42 379 and fish) there was no statistically significant difference in terms of welfare estimations.  
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44 380 A difference was found in welfare estimations for chicken between Twitter and  
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46 381 Qualtrics, however, this was based on only 3 ratings from Twitter and therefore must  
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48 382 be interpreted with caution.  
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53 383 The welfare estimations in this study were varied. This could be explained by the lack  
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55 384 of a single welfare metric **that** could be used by consumers to make assessments, or  
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57 385 the complexity of animal welfare as a concept, since accurate estimations would need  
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3 386 to consider the life quality of the animal, the life duration and the number of animals  
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5 387 affected for providing a unit of product (Scherer *et al.*, 2018), amongst other factors  
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8 388 (Farm Animal Welfare Council, 1993). Furthermore, the varied animal welfare  
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10 389 perceptions could be explained by the differences that exist between individuals based  
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12 390 on their location of residence (World Animal Protection, 2014) since there are different  
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14 391 farming practices, and personal food preferences, for instance, those following a  
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16 392 vegan diet may have ethical objections to using animals for food and thus may  
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19 393 perceive animal welfare poorly across all animal products.  
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### 22 394 **Strengths and limitations**

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26 395 This study provides insight into citizen understanding of the calorie content, carbon  
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28 396 footprint, safety and animal welfare implications of many commonly eaten foods.  
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30 397 Citizens were unable to correctly estimate calorie content or carbon footprints of foods,  
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32 398 which indicates that educational interventions are needed before sustainable  
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34 399 purchase decisions can be enhanced to reduce the environmental impact of food  
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36 400 purchases and consumption. However, citizens do have some understanding of the  
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38 401 hierarchy of carbon footprints across foods, which could be used as a starting point  
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40 402 for interventions. The current research also suggests that citizens have an  
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42 403 appreciation of food safety, rating animal products as riskier than plant-based foods.  
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44 404 However, as some plant-based foods do carry some risks, for example, fruit and  
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46 405 vegetables have been found to carry bacterial pathogens (Grant *et al.*, 2008),  
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48 406 educational interventions about food safety may be of use (Bennett *et al.*, 2015).  
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50 407 Importantly, as was the key aim of this study, the paper demonstrates that whilst  
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52 408 Zooniverse and social media can be used to gather insights in nutrition research and  
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3 409 may enable larger populations to take part in research, recruitment methods must be  
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5 410 considered since responses appear varied across platforms.  
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9 411 The study is not without limitations. Attrition through each survey was explored by  
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11 412 recruitment method and responses decreased across all surveys but was greatest in  
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13 413 the Zooniverse surveys and lowest in the Qualtrics survey. This decline in responses  
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15 414 across surveys resulted in a limited number of ratings for some questions, and thus  
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17 415 limited the analysis that could be applied and the conclusions that could be drawn.  
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19 416 Similar attrition may occur in other similar studies, and therefore should be factored in  
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21 417 when survey instruments and analyses plans are being devised. Moreover, it is  
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23 418 important to consider the functionality differences between the survey platforms,  
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25 419 Zooniverse and Qualtrics. No demographic data can be gathered through Zooniverse  
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27 420 due to the community guidelines of the platform. It would have been good to collect  
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29 421 demographic information to enable a better understanding of the knowledge levels of  
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31 422 different consumer groups and thus develop effective information campaigns. Google  
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33 423 Analytics (GA) could be explored as a method to obtain demographic data, as  
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35 424 suggested previously (Spiers *et al.*, 2019). Secondly, the design of Zooniverse is not  
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37 425 well controlled, citizens can complete as many or as few classifications as they wish  
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39 426 and can drop out of studies at any time. Due to this, it is not possible to pre-determine  
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41 427 how many citizens complete a study which not only makes pre-registration difficult, but  
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43 428 it also makes the planning of analyses hard. Finally, although images and weights of  
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45 429 each food were shown in all the survey instruments, no information about the origin of  
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47 430 the food, cooking method or growing conditions were provided, which may have  
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49 431 impacted on carbon footprint, food safety and animal welfare estimations.  
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### 433 **Citizen science implications**

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

### 442 **Conclusion**

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

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3 457 **Conflict of interest statement**  
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6 458 Dr Grant Miller is affiliated with Zooniverse which is a project at the University of  
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8  
9 459 Oxford. He advised on the development of the experiment, use of the Zooniverse tool,  
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11 460 and deployment of the research on Zooniverse, he was in no way involved with the  
12  
13 461 other two experiments and did not influence the analysis of the data or the results that  
14  
15 462 were presented.  
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## Tables

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

Food	Carbon footprint in range [gCO <sub>2</sub> e 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

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

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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)

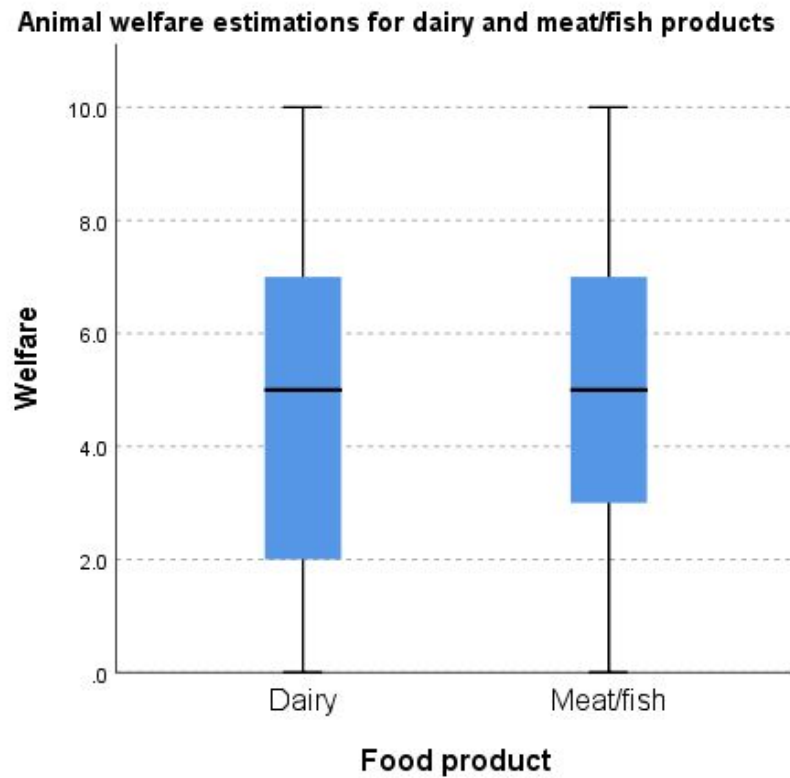
Table 3. Frequency of Food Safety estimates for each recruitment method

		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)

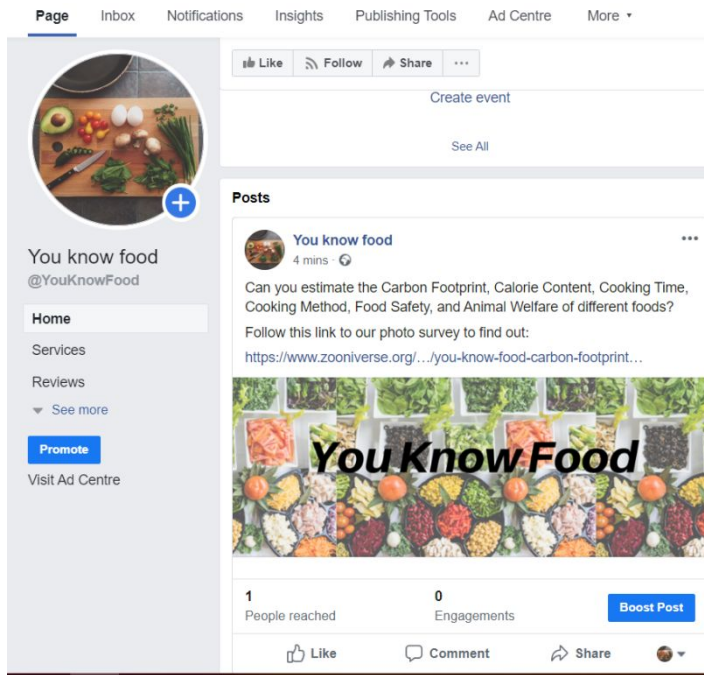
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## Figures

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



# Appendix



Appendix 1. Facebook post for recruitment

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