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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**

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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
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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
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33 footprint of foods, and understanding the relevant knowledge gaps, is important to the
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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
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47 choices and perceptions (Lindgren *et al.*, 2018). Animal welfare relates to how well the
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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
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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).

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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

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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).
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7 77 Exploring public awareness and understanding of the safety levels of different foods
8
9 78 is important as we promote the transition to a more sustainable and healthy diet.

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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
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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
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43 94 is critical.

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51 95 The current study develops understanding gained from previous exploratory pilot
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53 96 research to explore consumer perceptions of the energy and GHG emissions of foods
54
55 97 and animal welfare and food safety for foods (Armstrong *et al.*, 2020). and The study
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57 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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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
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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

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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

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48 141 Topic 1 (Energy Density or Carbon Footprint) x Topic 2 (Food Safety or Animal
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50 142 Welfare) of 29 foods (apple, bacon, banana, beef, beans, bread, cabbage, carrot,
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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,
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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,
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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**

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33 159 Energy content data (Kcal/100g product) used in the analysis were those reported in
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35 160 the National Diet and Nutrition Survey databank and from the NHS calorie checker
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37 161 platform (NDNS, 2019; NHS, 2018). The carbon footprint values (kgCO₂e /100g
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39 162 product) were based on published data (Poore and Nemecek, 2018). The values
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41 163 represent the average emissions released during the production of primary food
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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 CO₂e values).

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50 166 In total, 48,168 ratings (Twitter n=2184, Facebook n=358, Qualtrics n=45,626) were
51
52 167 submitted. Across the three recruitment platforms, 12,648 energy content (Kcal)
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54 168 classifications were recorded (Qualtrics n=11,877, Facebook n=78, Twitter n=693).
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56 169 Perceptions of the energy content of the foods were compared against validated
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58 170 figures (NDNS, 2019; NHS, 2018). A +/-10% range of the figures were classified as

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3 171 correct, to allow for the accuracy tolerance of food labels and variations in energy
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5 172 content of foods regionally (>930 kcal).
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9 173 12,817 classifications were recorded for carbon footprint perceptions (Jumpertz *et al.*,
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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 gCO₂e x 10¹).
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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),
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25 180 10,072 classifications across the three recruitment platforms (Qualtrics n=9,930,
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27 181 Facebook n=11, Twitter n=131) were recorded.
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31 182 Using SPSS statistics software, the Kruskal Wallis H test and subsequent pairwise
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33 183 comparisons (Bonferroni corrections applied) were used to explore the impact of
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35 184 recruitment method, on citizen estimates of carbon footprint, energy content, animal
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37 185 welfare and food safety. This test was chosen because the sample sizes are so
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39 186 variable.
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42 43 44 187 **Results**

45 46 47 188 Energy content perception 48 49

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51 189 Overall, citizens were more likely to overestimate the calorie content of foods
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53 190 (n=1,1403, 88.9%) than correctly estimate (n=235, 1.8%) or underestimate (n=1,178,
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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
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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
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11 198 those recruited from Twitter (n=34, 0.05%) or Qualtrics (n=438, 0.03%).
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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
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19 201 underestimated than overestimated or estimated within range. For example, with
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21 202 pasta, 71.5% of estimations underestimated energy content whilst under a quarter
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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
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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
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41 212 56.1% respectively). However, the perceived energy content of beef and pork were
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43 213 more likely to be underestimated (53.4% and 77.2% respectively).
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50 51 214 Carbon footprint perception 52

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54 215 Across recruitment methods, citizens were most likely to overestimate the carbon
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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
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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.
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15 223 The impact of food type on the carbon footprint estimates was explored, first by food
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17 224 groups. When looked at descriptively, carbon footprint estimations for plant-based
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19 225 foods were lower ($1,388.6 \pm 1,319.6$) than estimations for dairy (1881.9 ± 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.
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30 229 Estimations were then compared to the range of validated carbon footprint values.
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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
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42 235 93% of estimates were over the accepted range for chicken. In contrast, carbon
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44 236 footprints of red meat were more likely to be underestimated, with 60% of perceptions
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46 237 for beef and 57.2% for lamb, under the accepted range for their respective carbon
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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
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59 241 recorded across the three recruitment platforms. Across all classifications, 71.4%
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3 242 (n=8,696) were rated as low risk, 23.5% (n=2867) whilst just 4.9% (n=601) were rated
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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
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13 247 pairwise comparisons were conducted, statistically significant differences were
14
15 248 apparent between food safety perceptions from citizens on Twitter - Qualtrics ($p<.001$).
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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
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21 251 meat or fish ($\chi^2(4) = 1,434$, $p <.001$), with plant based foods rated as lower risk than
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23 252 dairy, meat or fish products.

29 253 Animal welfare perception

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32
33 254 Perceptions of animal welfare (0 (low welfare) - 10 (high welfare)) were statistically
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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
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43 259 comparisons indicated that Twitter respondents had higher perceptions of animal
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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
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52 262 significant difference in terms of welfare estimations (see Figure 1). When explored by
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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
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58 265 Twitter citizens reporting higher welfare (mean ranks: Qualtrics: 198.58, Twitter: 388).
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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
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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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28 276 Impact of recruitment method 29

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31 277 Recruitment method had a significant impact on perceptions of carbon footprint
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33 278 (H(2)=2,391.3, p=.001), calorie estimation (H(2)=139.9, p=.001), food safety
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35 279 (H(2)=20.21, p=.001) and animal welfare perceptions (H(2)=13.12, p<.001). Citizens
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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
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43 283 lowest carbon footprint estimations (mean rank carbon footprint: Facebook: 618.5,
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45 284 Twitter: 618.5, Qualtrics: 6849.9). The Twitter recruitment sample had lower calorie
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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
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51 287 Twitter had lower perceptions than Qualtrics (mean ranks: Twitter: 5053.91, Qualtrics:
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53 288 6100.9). The Facebook sample was too small to be included in the comparative
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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
16
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*
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40 330 *al.*, 2011) are required for consumers to effectively move toward a healthier more
41
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
45
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
49
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
27
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 ₂ 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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Chickpeas tinned (95g)	57-70	109-133
Baked beans (233g)	130-158	173-211
Quorn (105g)	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)

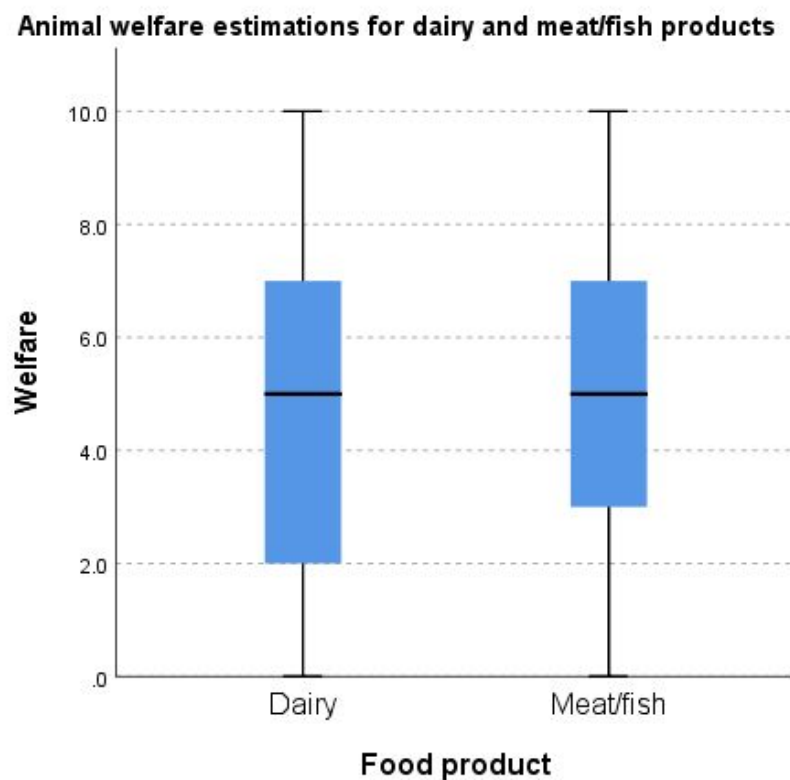
Table 3. Frequency of Food Safety estimates for each recruitment method

		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)

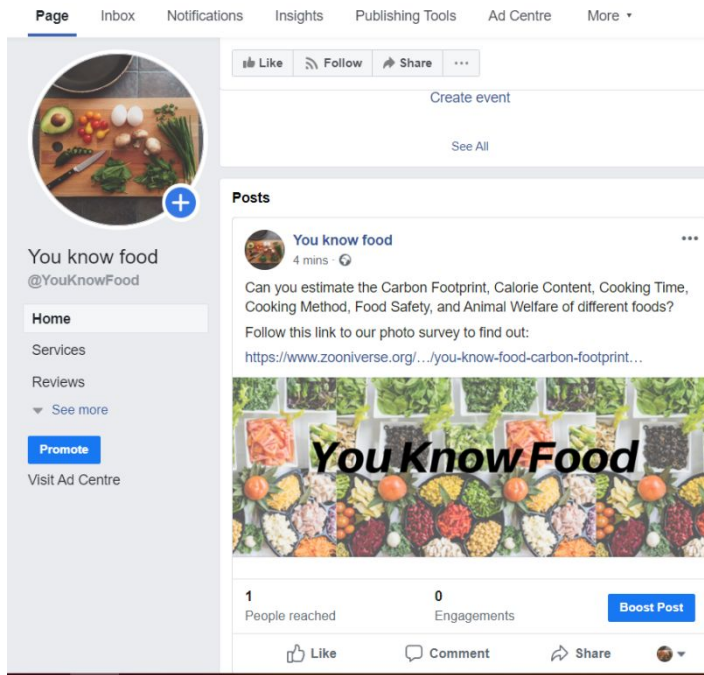
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Figures

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



Appendix



Appendix 1. Facebook post for recruitment

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