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# Avoidable food losses and associated production-phase greenhouse gas emissions arising from application of cosmetic standards to fresh fruit and vegetables in Europe and the UK

Stephen D Porter<sup>\*a</sup>, David S Reay<sup>a</sup>, Elizabeth Bomberg<sup>b</sup>, Peter Higgins<sup>c</sup>

## ABSTRACT

The use of aesthetics for classifying and accepting fresh food for sale and consumption is built into food quality standards and regulations of the European Union. The food distribution sector in Europe and the UK is oligopolistic in nature; a small number of supermarket chains control a large market share. The influence of these ‘multiples’ enables them to impose additional proprietary ‘quality’ criteria. Produce that doesn’t meet these standards may be lost from the food supply chain, never seeing a supermarket shelf – it may not get past the supplier, or even leave the farm. Here, for the first time, we estimate the quantity of food loss and waste of fresh fruit and vegetables arising from cosmetic standards in Europe and UK, and its associated greenhouse gas (GHG) emissions. We find few direct measurements of such losses, resulting in large uncertainties for key commodities. In the context of these uncertainties, we estimate avoidable FLW from on-farm cosmetic grade-outs of up to 4,500 kt yr<sup>-1</sup> in the UK and 51,500 kt yr<sup>-1</sup> in the European Economic Area (EEA). Our estimates suggest over a third of total farm production is lost for aesthetic reasons, which equates to as much as 970 kt CO<sub>2</sub>e (UK) and 22,500 kt CO<sub>2</sub>e (EEA) of embedded production-phase GHG emissions annually. Examining the issue from the perspective of markets, suppliers, and consumers we establish there is an over-emphasis on superficial qualities (i.e. cosmetic appearance) of fresh produce, which leads to its unnecessary loss and waste. Using an illustrative case study, we provide potential avenues to mitigate these losses and the associated GHG emissions.

## HIGHLIGHTS (3-5 bullets, max 85 characters per bullet)

- Application of cosmetic standards has resulted in substantial avoidable food losses
- Many actors across the agri-food chain enforce these standards upon farmers
- The embedded emissions of lost sub-optimal food in the EEA is as much as 22.5 Mt CO<sub>2</sub>e yr<sup>-1</sup>
- Quantity of avoidable on-farm losses remains uncertain due to a lack of coverage
- We propose several avenues to mitigate on-farm food loss and its embedded emissions

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39 **KEYWORDS (up to 6)**

40 climate change mitigation; food supply chain; cosmetic standards; fresh fruit and  
41 vegetables; embedded emissions; food loss and waste

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48

## 49 1. Introduction

50 Food loss and waste (FLW) is one of the great scourges of our time. In excess of 10% of  
51 global population is chronically hungry (FAO et al., 2017, p. 5), yet we lose or waste about  
52 a third of all food meant for human consumption at some point in the food supply chain  
53 (FSC) (Gustavsson et al., 2011). Producing food accounts for 10-12% of global  
54 greenhouse gas (GHG) emissions, primarily nitrous oxide (N<sub>2</sub>O) from crop production  
55 and methane (CH<sub>4</sub>) from meat and dairy production (Smith et al., 2014, pp. 822–824).  
56 Food waste alone may account for up to 16% of environmental impact of the agri-food  
57 chain (Scherhauer et al., 2018). In addition to global food security and nutrition  
58 challenges, producing food that does not serve its purpose of feeding the populace has  
59 potentially avoidable climate-cost emissions embedded within it.

60 There are many drivers of FLW, from the technological to the social (Canali et al., 2016).  
61 Amongst them in the agricultural production phase are ‘aesthetic imperfection’ and  
62 ‘overplanting’ of produce (Parfitt et al., 2010; Teuber and Jensen, 2016, p. 34). These two  
63 drivers are linked – farmers must meet their contractual obligations to deliver specified  
64 tonnage of produce that meets particular standards (Beretta et al., 2013; Halloran et al.,  
65 2014). A proportion of yield is expected not to meet cosmetic criteria and thus may not  
66 easily be sold, and possibly not even harvested (Garrone et al., 2014). Cosmetic  
67 requirements are an important component of ‘quality’ standards for fresh fruit and  
68 vegetables (FFV) – a greater number of prescribed elements apply to the appearance of  
69 FFV than to nutritional or food-safety characteristics (Porter et al., 2018). Produce  
70 deemed of too low a quality to enter the food supply chain may take several different non-  
71 food routes. It is typically ploughed back into fields, composted, landfilled, used as animal  
72 feed, or as anaerobic digestion feedstock (Beretta et al., 2013; Jeannequin et al., 2015;  
73 Redlingshöfer et al., 2017).

74 Reporting of on-farm FLW data by producers is not required by EU regulations – prior to  
75 harvest it is not considered to be food (European Parliament and Council, 2002, Art. 2).  
76 Discourse on food waste at the production stage has typically focused on accidental loss,  
77 such as from natural hazards and disease (Gille, 2012). In contrast, there is a dearth of  
78 studies quantifying avoidable food loss due to cosmetic standards and its embedded  
79 greenhouse gas emissions. Estimates at this life cycle stage are usually based upon a small  
80 number of studies carried out on just a few crops and applied to entire regions  
81 (Gustavsson et al., 2011), although others are more locally focused (Franke et al., 2016;  
82 Hartikainen et al., 2018). Some studies omit losses in the production phase entirely due  
83 to uncertainties (Monier et al., 2010). The few reported losses from failure to meet  
84 cosmetic criteria are wide and quite uncertain. The limited evidence of on-farm food  
85 losses due to aesthetics suggests upwards of 40% of harvested FFV produce can be lost  
86 from the food supply chain at this stage alone (Bloom, 2011, p. 96; Davis et al., 2011, p.  
87 19; Stuart, 2009, p. 102). Recently, a more focused investigation in Germany and the  
88 Netherlands, utilising farmer self-assessed losses due to cosmetics, confirmed anecdotal  
89 evidence that wastage varies greatly by product, with ‘typical’ levels of about 20% (de  
90 Hooge et al., 2018).

91 Here, we extend the discourse by viewing food loss and its embedded GHG emissions  
92 through the lens of aesthetics. Cosmetics-centred ‘quality’ criteria derived from physical  
93 characteristics of attractiveness alone are imposed on many food producers by down-  
94 stream actors (such as regulators, retailers, and consumers). These criteria may stem  
95 from in-built consumer preferences, with other actors reacting in response (EU FUSIONS,

96 2014). Produce that is excluded from the food supply chain (FSC) through not meeting  
97 such aesthetic ‘standards’ can be regarded as avoidable waste. Likewise, greenhouse gas  
98 emissions associated with the production of this wasted food can be deemed avoidable,  
99 with changes in aesthetic classifications having the potential for emissions mitigation.

100 In the following, we provide what we believe to be the first estimation of production-  
101 phase embedded emissions of fresh fruit and vegetables lost from the food supply chain  
102 due to application of cosmetic standards. We then argue a complex and interactive system  
103 exists that encourages food waste and is perpetuated by all actors in the typical agri-food  
104 chain. As we will show, these actors include governments (via regulations of minimum  
105 ‘quality standards’), supermarket multiples (via the power to impose private voluntary  
106 standards), and consumers (via learned expectations). Finally, we supplement this  
107 analysis and argument with a case study of an atypical farming operation within the  
108 Central Belt of Scotland to illustrate potential pathways to prevent cosmetic standard-  
109 driven FLW.

## 110 **2. Estimations of EEA and UK grade-out losses and embedded** 111 **emissions**

### 112 **2.1 Methods**

113 The geographic areas of focus are the European Economic Area (EEA) and the UK. The  
114 EEA is comprised of the EU Member States as well as Iceland, Norway, and Switzerland.  
115 These three countries are all members of the EU’s ‘single market’, and are thus bound by  
116 the same regulations on food produce as EU Member States. Only EEA and UK FFV crops  
117 with at least one published on-farm cosmetic grade-out loss factor (*LF*) and  
118 corresponding cradle-to-farm-gate emission factor (*EF*) are included in this analysis. The  
119 factors are taken from the underlying sources referred to by Porter et al. (2016), plus  
120 additional, more recent, sources from peer-reviewed literature and reputable grey-  
121 literature sources. The keywords “carbon footprint” and “life cycle analysis” together  
122 with “UK” and “Europe” were used to search the Scopus, ScienceDirect and Web of  
123 Science databases for peer-reviewed emissions factors published since 2016. Citation  
124 tracking was subsequently used to identify potential grey literature using the same  
125 filtering criteria. In addition, the official French database of agriculture emissions,  
126 ADEME, (2017), was included. The resulting literature was further filtered to include only  
127 those with emissions factor data in CO<sub>2</sub> for the production stage, or had sufficient detail  
128 included to make this conversion, for fresh fruit and vegetables. Full details of sources  
129 and values for both *LF* and *EF* variables are contained within Supplementary Information  
130 Tables 1 and 2.

131 The estimates we used for regional EEA on-farm grade-out FFV loss factors (*LFs*) and  
132 their production-phase embedded emission factors (*EFs*) are crop-specific from any EEA  
133 country. In the UK, all but two crops have a country-specific *LF*; for pears and cabbages,  
134 the respective EEA factors are used as proxies. *LFs* may be reported as a range or as a  
135 single estimate; *EFs* are typically reported as a single point estimate. The absolute  
136 minimum and maximum estimates are identified for each crop’s *LF* and *EF* for the EEA  
137 and also within the UK sub-set. We also make a central estimate of the *LF* for each crop  
138 by averaging the mid-points of ranges and the single estimates. Alternatively, the central  
139 estimate of the *EFs* is an average of all reported estimates for each crop within the EEA  
140 as a whole and also for the UK specifically. We present these as ‘min’, ‘max’, and ‘central’

141 in Section 2.2. Data for FFV production for the year 2016 was sourced from the eurostat  
 142 (n.d.) database. Non-food use data was obtained from the United Nation's Food and  
 143 Agriculture Organization's (FAO) Food Balance Sheet database (FAOSTAT, n.d.); see  
 144 Table 1.

145 We estimate the mass of on-farm cosmetic grade-out losses with the model shown in Eq  
 146 1. We use the Eurostat database for FFV crop production in the EEA as a whole and the  
 147 UK specifically. Most FFV crops have a single entry for *Harvested Production*; this value is  
 148 used. However, tomatoes, apples, and pears, have two entries for *Harvested Production*.  
 149 For these three crops, we use the quantity indicated as 'for fresh consumption' in the  
 150 Eurostat database; cosmetic criteria are not applied to that proportion of these crops  
 151 intended 'for processing' from the outset. FFV graded-out on-farm does not enter the food  
 152 chain and therefore is not included in *Harvested Production* data (Redlingshöfer et al.,  
 153 2017). We adjust for this in the denominator term of Eq 1.

154 Eq 1

$$155 \quad Loss_s = \sum \left( \frac{Harvested\ Production_{j,k} * AF_{j,k} * LF_{j,k,s}}{1 - LF_{j,k,s}} \right)$$

156 Where: *Loss* is the total food loss in scenario *s* from on-farm cosmetic grade-outs (in kt);  
 157 *Harvested Production* is the mass (in kt) of food crop *j* in country *k*, (where *k* is either the  
 158 UK or EEA); *AF* is the allocation factor of crop *j* in region *k* (Eq 2); *LF* is the loss factor (in  
 159 %) for crop *j*, in country *k*, under scenario *s* (minimum, maximum, average).

160 Some portion of a crop may be intended for seed or other use, but not recorded in  
 161 Eurostat as such. To adjust for the non-food uses, we create a weighted-average allocation  
 162 factor (*AF*) for each FFV crop. We use annual FAO data for the most recent five-year  
 163 period available (2009-2013), as shown in Eq 2. The only FFV crop affected is potatoes –  
 164 where the *AF* is calculated as 0.86 for the EEA and 0.88 for the UK. That is, 14% and 12%  
 165 of the respective recorded harvests for the EEA and UK is not intended for human  
 166 consumption and thus do not have cosmetic standards applied to them.

167 Eq 2

$$168 \quad AF_k = 1 - \left( \frac{Seed_k + Other\ Uses_k}{Production_k} \right)$$

169 Where, for crop *j* in region *k* (the EEA or UK) for the period 2009-2013: *AF* is proportion  
 170 of the FFV crop not intended for consumption by humans; *Production* is the amount of  
 171 crop (in kt); *Seed* is the amount directly used to propagate a future harvest (in kt); and  
 172 *Other Uses* is the amount intended for any other non-food purposes (in kt).

173 Finally, we estimate the production-phase embedded emissions (*Em*) using the  
 174 'minimum', 'maximum', and 'average' peer-reviewed crop and region-specific cradle-to-  
 175 farm-gate emission factors (*EFs*) detailed previously. These factors are applied to the  
 176 three grade-out *Loss* estimates ('minimum', 'maximum', and 'average') from Eq 1 for each  
 177 FFV crop in the EEA and UK (Eq 3). The result is a 3x3 scenario matrix of total EEA and  
 178 UK, and specific FFV crop *Em* estimates.

179 Eq 3

$$180 \quad Em_{j,k,s} = \sum Loss_{j,k,s} * EF_{j,k,s}$$

181 Where: *Em* is the quantity (in kt CO<sub>2</sub>e) of GHG emissions of crop *j* in country *k* for scenario  
 182 *s*; *Loss* (in kt) is food loss for crop *j* in region *k* from Eq 1, and; *EF* is the emission factor  
 183 (in kt CO<sub>2</sub>e kt<sup>-1</sup>) for crop *j* in country *k* for scenario *s*. Summary data is provided in Table  
 184 1.

185 Table 1. Summary of data used to estimate range of on-farm cosmetic grade-outs of FFV. *Harvested Production* for  
 186 potatoes is adjusted for its allocation factor from Eq 2. Fully referenced tables for Loss Factors and Emissions Factors  
 187 are provided in Supplementary Information (Tables S11 and S12).  
 188

Crop	Region	Harvested Production (kt)	Loss Factor (%)			Emissions Factor (kt CO <sub>2</sub> e kt <sup>-1</sup> )		
			Min	Central	Max	Min	Central	Max
Apple	UK	208	5	15	25	0.11	0.21	0.32
	Europe	9,309	1	10	25	0.03	0.17	0.43
Broccoli + Cauliflower	UK	152	3	12	20	0.29	1.12	1.94
	Europe	2,341	3	12	20	0.29	1.26	2.22
Cabbage	UK	231	8	22	40	0.22	0.22	0.22
	Europe	3,821	8	22	40	0.22	0.35	0.48
Carrot	UK	724	24	31	50	0.05	0.20	0.35
	Europe	5,663	10	23	50	0.02	0.17	0.50
Lettuce	UK	107	5	26	50	1.00	1.39	1.78
	Europe	2,285	5	24	50	0.26	1.01	1.78
Onion	UK	390	9	15	20	0.07	0.22	0.37
	Europe	6,623	8	17	33	0.04	0.23	0.48
Pear	UK	24	10	11	12	0.32	0.32	0.32
	Europe	2,231	10	11	12	0.20	0.32	0.43
Potato	UK	4,888	3	19	40	0.17	0.22	0.26
	Europe	48,729	3	14	40	0.09	0.19	0.51
Strawberry	UK	118	1	12	35	0.80	0.94	1.27
	Europe	1,311	1	10	35	0.30	0.78	1.27
Tomato	UK	97	7	7	7	2.07	4.34	9.40
	Europe	6,969	1	3	7	0.11	1.59	9.40

189

## 190 2.2 Results

### 191 2.2.1 Cosmetic losses

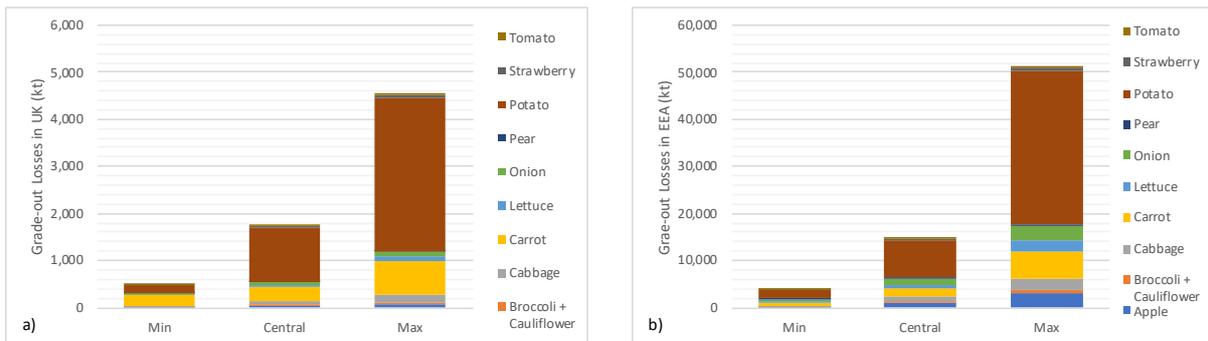
192 The Eurostat-recorded harvest quantity for FFV in the EEA and UK in 2016 is 89,300 kt  
 193 and 6900 kt, respectively. Estimated on-farm grade-out losses of FFV in the EEA range  
 194 from 3700 kt to 51,500 kt and from 470 kt to 4500 kt for the UK in 2016 (see  
 195 Supplementary Information). Thus, the range of losses for cosmetic reasons is 4 – 58%  
 196 and 7 – 65% of recorded *Harvested Production* in the EEA and UK, with an ‘central’  
 197 estimate of 17% and 25%. As indicated in Section 2.1, *Harvested Production* from the

198 Eurostat database does not include grade-out losses. Adding the losses back gives total  
 199 actual FFV farm production intended for human consumption of 93,000 – 141,000 kt for  
 200 the EEA, and 7400 – 11,500 kt for the UK. The estimated range of on-farm cosmetic grade-  
 201 out losses relative to total farm production in the EEA and UK is 4 – 37% and 6 – 39%,  
 202 respectively, with a ‘central’ value of 14% for the EEA and 20% for the UK.

203 In the UK, cosmetic grade-out losses are dominated by potatoes and carrots (Figure 1a).  
 204 This is a function of their importance as an agricultural crop – potatoes were 70% of the  
 205 UK FFV harvest by mass in 2016, whilst carrots were 10%. They also have higher  
 206 minimum, maximum, and central cosmetic grade-out *LFs* relative to other crops.  
 207 Together, these two crops account for 81 – 88% of grade-out losses by mass. This is  
 208 equivalent to 380 – 4000 kt of losses, with a ‘central’ value of 1500 kt. Onions and  
 209 cabbage, the third and fourth most important crop group for UK farming (just under 10%  
 210 combined total), deliver just 6 – 13% of grade-out losses (250 – 880 kt, ‘central’ estimate  
 211 of 390 kt).

212 Total grade-out losses for FFV within the EEA are estimated to range from 3700 kt to  
 213 51,500 kt. Similar to the UK, potatoes dominate cosmetic-related losses in the EEA,  
 214 accounting for 41 – 63% of all grade-outs by mass (1500 – 32,500 kt, ‘central’ estimate of  
 215 7900 kt) from 55% of recorded production volume. Carrots, onions, and brassicas, are  
 216 key hotspots of grade-out losses in the remaining 45% of the harvest (Figure 1b).  
 217 Together, these latter three crop groups account for FFV losses of 1600 kt – 12,100 kt  
 218 (‘central’ value of 4400 kt), equivalent to 23 – 44% of EEA on-farm grade-out losses. (See  
 219 Supplementary Information for details.)

220  
 221



222  
 223 Figure 1. Grade-out losses (in kt) in 2016 in; a) the UK, and b) the EEA of the different FFV crops, applying the minimum,  
 224 maximum, and ‘central’ *LF* estimates to recorded *Harvested Production* in Table 1 (i.e. the output of Eq 1).

225 **2.2.2 Embedded emissions of cosmetic losses**

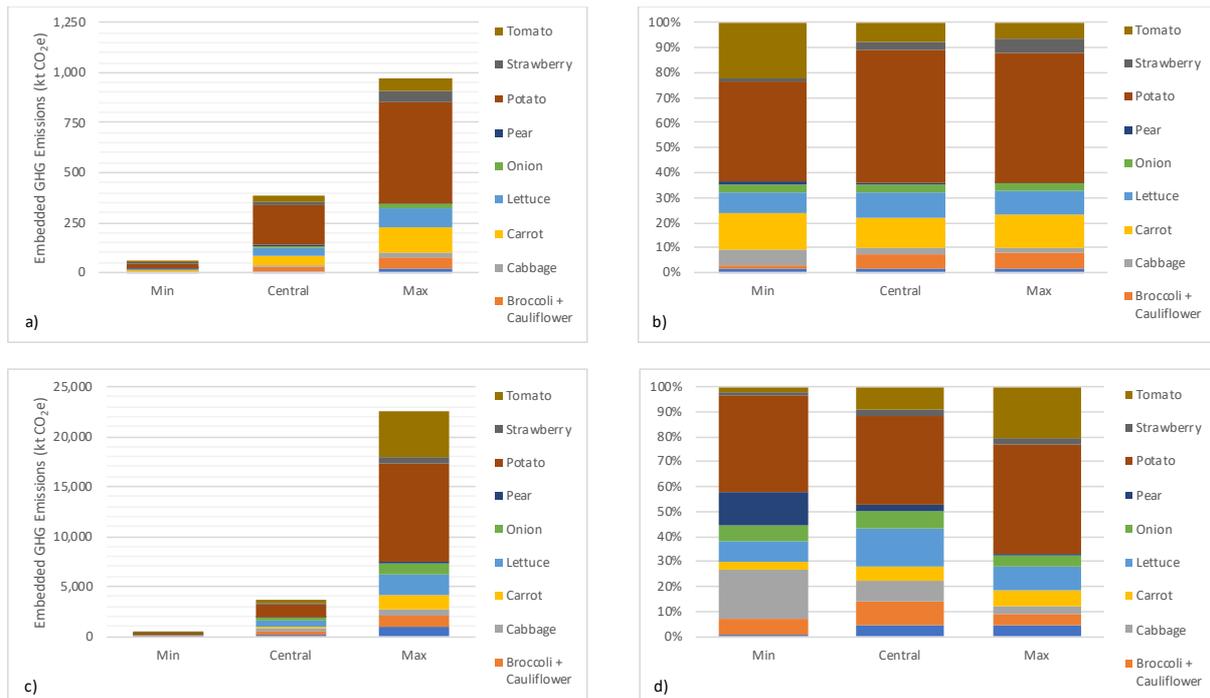
226 Applying three *EF* values (minimum, maximum, and ‘central’ estimates) for each *Loss*  
 227 scenario generates nine ‘scenarios’ of embedded production-phase GHG emissions. The  
 228 absolute and proportional emissions of three scenarios for FFV in the UK and EEA are  
 229 shown in Figure 2. They are the output of Eq 3 using the Min-Min, Central-Central, and  
 230 Max-Max combination of *Loss* from Eq 1 and *EF* values from Table 1. Relative importance  
 231 of crops and their production-phase emissions is evident when comparing the UK with  
 232 the EEA at large. Total embedded production-phase GHG emissions of food loss due to  
 233 cosmetic criteria in the UK range from about 60 kt CO<sub>2e</sub> in a ‘minimum’ scenario to 970  
 234 kt CO<sub>2e</sub> in a ‘maximum’ scenario, with a ‘central’ estimate of 380 kt CO<sub>2e</sub>. At the EEA level,  
 235 total production-phase embedded GHG emissions range from about 340 kt CO<sub>2e</sub> to almost

236 22,500 kt CO<sub>2</sub>e, with an ‘central’ estimate of about 3600 kt CO<sub>2</sub>e (details of all scenarios  
 237 are in Table SI 4). To put these latter figures in context, they are up to roughly 5% of the  
 238 426,000 kt CO<sub>2</sub>e of GHG emissions attributed to the European agriculture sector in 2015  
 239 (Eurostat, 2017).

240 In the UK, the highest levels of embedded emissions from grade-out losses are from  
 241 potatoes, carrots, and brassicas; together they account for 55 – 77% of the total. Potatoes  
 242 have a relatively narrow range of UK-specific *EF* estimates (0.17 – 0.26 t CO<sub>2</sub>e t<sup>-1</sup>),  
 243 typically at or near the lowest factor value for FFV crops. Even so, because of the high  
 244 production volume and grade-out losses of potatoes, this crop is apportioned the highest  
 245 level of embedded emissions. Our estimates of these emissions for the UK potato crop  
 246 range from 25 to 510 kt CO<sub>2</sub>e, with a central estimate of 200 kt CO<sub>2</sub>e (or 19 – 67% of the  
 247 total for the UK). Embedded emissions in grade-out losses of carrots and brassicas range  
 248 from 14 – 210 kt CO<sub>2</sub>e, or 10 – 36% of the UK total. The range of absolute and  
 249 proportionate emissions of carrots and brassicas reflects the higher level of uncertainty  
 250 in the *EF* literature of these crops relative to others, particularly potatoes.

251 Trends at the EEA region level are similar to those for the UK specifically. Potatoes are  
 252 also the most important in terms of magnitude of embedded GHG emissions in all nine  
 253 scenarios for the EEA. This one crop accounts for roughly one- to two-thirds of these  
 254 emissions (or, 130 – 9900 kt CO<sub>2</sub>e) with a ‘central’ scenario estimate of 36% (1300 kt  
 255 CO<sub>2</sub>e). Brassicas and root vegetables (carrots and onions) together account for 19 – 35%  
 256 of embedded emissions (‘central’ of 30%), or 120 – 4200 kt CO<sub>2</sub>e (‘central’ estimate of  
 257 1100 kt CO<sub>2</sub>e; see Supplementary Information for detailed breakdown by FFV crop).

258



259

260 Figure 2. Production-phase embedded GHG emissions of grade-out losses by FFV (in kt CO<sub>2</sub>e) and as a proportion of  
 261 total FFV by scenario for the UK (a, b) and the EEA (c, d). The three scenarios correspond to application of the Minimum,  
 262 Central, and Maximum estimates of both the *LF* and *EF* variables from Table 2 (i.e. the Min scenario represents Min *LF*  
 263 and Min *EF*). Details of all nine scenarios examined are contained within Table SI 4.

### 264 2.2.3 Limitations

265 There is considerable uncertainty in these results, demonstrated by the range of our  
266 estimates for absolute FFV losses at farm-level and their respective embedded emissions.  
267 We have assumed that studies on these loss factors conducted on a particular crop in one  
268 country within the EEA are relevant to the same crop in another country. There is a very  
269 limited amount of data currently available on FFV loss factors at farm level. A further  
270 significant assumption in our results is that all grade-out food losses have left the agri-  
271 food chain for destinations such as composting or ploughing-in and are therefore  
272 considered waste whose embedded emissions should be accounted for. There is no  
273 discernible consensus on what proportion of cosmetic losses of FFV would have another  
274 food-related use (such as animal feed, or used in further food processing). Porter et al.  
275 (2018) reports that within the EU under the current Common Agriculture Policy,  
276 approximately two-thirds of safe, edible FFV withdrawn from market after harvest is  
277 destroyed. de Hooge et al. (2018) states ploughing in, animal feed, and anaerobic  
278 digestion were the most common destinations, and that few of their interviewees  
279 mentioned selling a lower class product was a viable option. Redlingshöfer et al. (2017)  
280 indicates reuse plays a moderate role, but estimates a destruction rate greater than 80%  
281 for even the crop most commonly redirected to animal feed (i.e. potatoes). Terry et al.  
282 (2013, 2011) indicate the destination of grade-outs depends heavily on the crop, with  
283 ploughing-in the common destination for lettuce, tomato, and strawberry, whereas  
284 potato typically goes to animal feed or compost. Jeannequin et al. (2015) and Meyer et al.  
285 (2017) argue that field-graded produce, whether picked by hand or mechanised, is simply  
286 ploughed-in, but post-harvest graded produce is more likely to be redirected to another  
287 food use.

288 Embedded emissions calculations rely estimates of UK- and Europe-specific emissions  
289 factors for fruit and vegetable published between 2000 and 2018. Coverage of food  
290 commodities in this literature was variable and sometimes seemingly dated (the oldest  
291 source is from 2006). For example, UK cabbage and pear have one *EF* estimate each (from  
292 2009) whereas there are more than a dozen from 1998-2018 for EEA tomatoes (see Table  
293 SI 2). A review of the LCA literature by Clune et al., (2017) highlighted the considerable  
294 variability in such estimates across food group and showed activity in this area dropping  
295 considerably by 2015 relative to the seven years prior. This is consistent with the results  
296 of our own literature review – little data, and with considerable variation. It also  
297 demonstrates continued, more localised research on greenhouse gas emissions of food  
298 across its full life cycle is warranted by the wider community.

## 299 3. An over-emphasis on superficial qualities (i.e. cosmetic 300 appearance) of fresh produce

301 In the following we present arguments for why FFV loss and waste from aesthetic  
302 standards – as estimated in the previous section – may occur.

### 303 3.1 Waste encouraged by current marketing standards & regulations

304 Food safety and food quality are treated separately within EU Regulations, with safety  
305 paramount. Article 14(1) of the General Requirements of Food Law states “food shall not  
306 be placed on the market if it is unsafe” (European Parliament and Council, 2002).  
307 However, it may be that food safety laws are overly strict, thus creating unnecessary

308 inefficiency in the food supply chain (Aschemann-Witzel, 2016). As a result, only fresh  
309 produce that is deemed safe for human consumption is subject to ‘quality’ standards.  
310 Fresh produce has natural variability in terms of size, colour, and shape; cosmetic  
311 appearance is not uniform. The EU’s Common Market Organisation (CMO) regulations  
312 specify particular requirements for different types of fresh produce to grade them (in  
313 ascending order) as Class II, Class I, or Extra Class (European Commission, 2011, Annex  
314 I, Part B). EU Member States may permit unclassified fresh produce to be sold in retail  
315 outlets provided it is clearly labelled as ‘for home processing’ or similar (Defra, 2017).  
316 This regulation implies fresh produce that does not meet arbitrary cosmetic  
317 requirements is not fit for consumption in its natural form.

318 These EU-level marketing standards codify a common set of minimum acceptable criteria  
319 across EU Member States which, together with the EU CAP reforms of 2013, are intended  
320 to improve the competitiveness of international trade of agricultural produce of those  
321 States (DG-AGRI, 2013). For example, it is easier to pack and ship produce of standard,  
322 versus varying, proportions. The relative efficiency of the stages between the farm-gate  
323 and the consumer would appear to support this preference. Loss rates for fruit and  
324 vegetables in Europe at the handling and storage, processing, and distribution stages  
325 range from 2-7%, between a tenth and a third of the 20% estimated pre-farm-gate loss  
326 rate (Porter et al. 2016, Table SI 1).

### 327 **3.2 Waste currently endorsed (and ‘gold-plated’) by retailers**

328 The evidence that sub-optimal (‘imperfect’/‘ugly’) produce won’t sell is inconclusive. De  
329 Hooge et al. (2017) provides support for the claim. Their choice modelling survey  
330 reported a clear preference to ‘optimal’ foods whether in the home or supermarket. Much  
331 variability remains unexplained, but that ‘beauty is good’ seemed to apply to foodstuffs.  
332 At least in an artificial, online environment a price discount was required to equalise  
333 optimal and sub-optimal choice preference. In contrast, Aschemann-Witzel et al. (2017)  
334 states that ‘quality’ is linked primarily to characteristics such as taste, nutritional quality,  
335 and food safety. As we stated in Section 3.1, EU CMO marketing standards only specifically  
336 consider the latter. Whilst urban consumers in developing and developed countries (i.e.  
337 China and Denmark) may share a preference for ‘perfect’ produce (Loebnitz et al., 2015;  
338 Loebnitz and Grunert, 2015), only ‘extremely abnormal’ cosmetic appearance affects  
339 willingness to purchase in the former (Loebnitz et al., 2015). Within developed countries,  
340 a pro-environmental self-identity may also positively influence willingness to purchase  
341 ‘wonky’ veg (Loebnitz et al., 2015). The range of these findings suggests beliefs of what  
342 consumers will accept is too narrow, resulting in unnecessary food loss at the production  
343 phase by prohibiting ‘ugly’ produce from entering food supply chain.

344 The application of retailer’s private standards at the farm level influences production and  
345 distribution practices. Selective harvesting is an integral component of fresh fruit and  
346 vegetable production, with pickers trained to take only the produce that will meet  
347 retailer’s standards for sale (Gunders, 2012, p. 8). Potential edible-quality yield may be  
348 greater than that actually harvested, but the extra costs from picking fruit that doesn’t  
349 meet expected aesthetic standards and will thus be rejected at the next stage in the agri-  
350 food chain would drive down economic yield. For the proportion that would not meet  
351 standards and thus be left in the field, creative marketing/processing/distribution of  
352 such produce could reduce avoidable on-farm loss, potentially increasing farm income  
353 and food availability (Stuart, 2009, p. 102). For example, processing ‘misshapen’ carrots

354 into 'baby' carrots can eliminate virtually all food waste associated with this vegetable  
355 (Peterson, 2008). Additionally, some charities and volunteer organisations, such as the  
356 St. Andrews Society in the U.S. and Feedback in Europe, engage with the farming  
357 community to collect produce that would be rejected by supermarkets for re-distribution  
358 (Feedback, 2018; SoSA, 2018). The prices obtained, and thus economic margins, of such  
359 out-graded produce may be lower than that of the highest classification (Roels and van  
360 Gijseghem, 2017), but provided they at least cover the cost of harvest, then it is  
361 worthwhile for the farmer to do so. If not, then the rational economic decision is to 'walk-  
362 by' such produce – leave it in the field and plough it under as preparation for the next  
363 cycle.

364 It is not in the farmer's interest to have 'quality' standards based upon appearance that  
365 results in produce not being harvested and sold if such produce is safe to eat. Such  
366 standards differentiate produce of the same variety, with higher classifications achieving  
367 a higher selling price in normal conditions, but can result in substantial levels of on-farm  
368 loss pre- and post-harvest (Garnett, 2006, p. 63). Gunders (2012, p. 8) provides several  
369 individual examples of losses for different produce (cucumbers, citrus, tomatoes, stone  
370 fruit) regularly reaching or exceeding 50% in a season.

371 Labelling of fresh produce is another manifestation of private standards and the  
372 demonstrates the power of supermarkets in defining a message. The use of devices that  
373 permit a 'flexible best-before date' have been successful in reducing loss between  
374 processor and distributor (Dobon et al., 2011). However, consumers commonly  
375 misinterpret 'quality' labels, such as "best before" and "sell-by", as indicative of safety,  
376 leading to avoidable waste as food is discarded whilst still safely edible (Lebersorger and  
377 Schneider, 2014). Dynamic pricing – reducing the price of produce approaching its 'best  
378 before' – can increase purchase activity by the consumer and reduce supermarket waste  
379 (Aschemann-Witzel et al., 2016). The potential downside to such a marketing strategy is  
380 increased food waste by households if consumption patterns are not adjusted (Brook  
381 Lyndhurst and WRAP, 2012). Better 'food knowledge' on behalf of the consumer –  
382 knowledge that is built up over time through exposure to food and its uses (which is being  
383 lost in developed countries as we are ever more removed from the food chain) – could  
384 result in greater acceptability of a greater range of cosmetic appearance.

### 385 **3.3 Waste perpetuated by the structural power of large supermarkets**

386 The food supply chain in many EU countries has undergone such consolidation that it can  
387 be considered an oligopoly. For example, at the end of 2017, the five largest chain food  
388 retailers ('multiples') had over 75% of the market share in each of the UK, France, and  
389 Ireland (KANTAR WorldPanel, 2018). This concentration is a marked change from the  
390 early post-WWII years, where multiples in the UK had a market share of 30% (Harvey,  
391 2007, p. 55). Whilst the number of institutional buyers has fallen through this  
392 consolidation, the supply-side of the relationship has not undergone a similar  
393 transformation. The relative imbalance in scarcity – there is far more competition for  
394 sellers – leads to greater power being held by the retailers as buyers (Cox and Chicksand,  
395 2007, p. 83).

396 In addition to horizontal market consolidation of food retailing, some multiples have also  
397 consolidated vertically, taking a controlling interest in upstream production (Simons and  
398 Skydmore, 2017). Supermarkets exert their buyer power by imposing 'voluntary private  
399 standards' of cosmetic specifications for fresh produce (Henson & Humphrey, 2010). The

400 power exerted by the structure of the market – many suppliers for few retailers – acts as  
401 extra-governmental regulatory reach by the supermarket multiples. Private rules may be  
402 used to enhance or maintain a retailer’s reputation as well as managing suppliers  
403 (Fulponi, 2006). They are codified within business relationships of the more powerful  
404 party and often form part of contractual terms and conditions (Rindt and Mouzas, 2015).  
405 This power structure limits producers’ ability to influence the imposition of ‘quality  
406 standards’ (Gille, 2012). Such standards lead to avoidable food loss at the farm-level  
407 (Devin and Richards, 2016).

408 The oligopolistic nature of many developed countries’ agri-food chains effectively make  
409 supplier compliance of ‘private’ standards mandatory (Davey and Richards, 2013). The  
410 more asymmetric the relationship between multiples and their suppliers, the more likely  
411 the dominant party will be able to exercise power over the weaker. Within the agri-food  
412 chain, this has manifested itself in the proliferation of ‘private standards’ by the  
413 supermarkets (Rindt and Mouzas, 2015). These private rules ‘normalise’ and auto-  
414 reinforce what is otherwise an imbalanced relationship, shifting risk onto the weaker  
415 party (i.e. the supplier) via an ‘intervention-enforcement-sanctioning’ feedback loop  
416 (Rindt and Mouzas, 2015). The consolidation of supermarket multiples within the agri-  
417 food chain has led to a virtual vertical integration with fewer suppliers and a  
418 strengthening of power of those multiples (Hingley, 2005). By coming together as a  
419 cohesive group acting in concert (promoted as ‘producer organisations’ by the EU in  
420 recognition of supplier-retailer imbalance as a potential driver of food waste (European  
421 Court Auditors, 2016, p. 52); suppliers could shift the power relationship towards a  
422 balance with retailers (Maglaras et al., 2015).

### 423 **3.4 Waste perpetuated by the consumer’s learned experience**

424 What produce should ‘typically’ look like guides purchase intentions – consumers are  
425 more likely to purchase something that is familiar and recognisable (Gigerenzer and  
426 Gaissmaier, 2011). Consumers use simple learned heuristics of visual appearance to  
427 make food selection rather than the time-consuming process of comparing large amounts  
428 of data (Schulte-Mecklenbeck et al., 2013). Consumers’ lack of experience of abnormally  
429 shaped food leads them to view such produce as more risky and less natural than produce  
430 that conforms to supermarket standards (Loebnitz and Grunert, 2018). Although  
431 moderate differentiation/incongruity of produce may increase the attention paid to that  
432 product by a consumer (e.g. a new variety of familiar produce), there is a counteracting  
433 social risk of being linked with food whose appearance is atypical (Campbell and  
434 Goodstein, 2001). Visual perception and setting influences consumers’ expectation of  
435 taste experience; they are less willing to purchase cosmetically ‘sub-optimal’ fruit than  
436 consume it in the home (Symmank et al., 2018). Consumers appear to apply a ‘beauty  
437 mystique’ – a sociological concept to judgement where goodness is beauty and beauty is  
438 goodness (Synnott, 1989) – to fresh produce. Being exposed to broader parameters of  
439 ‘normal’ during the learning phase could lead to an acceptance of ‘sub-optimal’ food.

440 Heuristics are well-entrenched, though may interact with each other. Knowledge of  
441 origins of food (e.g. organic or not) and acceptance of abnormally-shaped food may be  
442 inversely related (Loebnitz and Grunert, 2018). The ‘blender effect’ of Szocs and Lefebvre  
443 (2016) – greater ‘processing’ is required in the home to achieve acceptable palatability -  
444 may reduce likelihood of purchase. Labelling of visually sub-optimal produce that  
445 reinforces its taste may have more influence on the purchase decision of ‘ugly’ food than

446 price discounts relative to optimal produce (Helmert et al., 2017). Loss aversion – e.g.  
447 avoiding throwing away ‘good money’ by binning uneaten produce – is a powerful  
448 modifier of behaviour (Moseley and Stoker, 2013). Unintentional or unconscious  
449 decisions may result in actions by consumer waste activity not otherwise aligned with  
450 their attitudes, referred to as the ‘squander sequence’ by Block et al. (2016). Wasteful  
451 behaviour or attitudes may not be universally held, even within a given culture. Over 65s  
452 in the UK exhibit behaviours that typically lead to less food waste relative to younger  
453 consumers. For the last generation to have experienced government food rationing  
454 ‘wastefulness’ in general is ‘just wrong’ (Quested et al., 2013). Consumers are key to  
455 sustainable food choices, and those choices can influence upstream efficiency, leading to  
456 more or less food loss and waste along the food supply chain.

## 457 **4. Learning opportunities case study**

458 In this section, we use a case study as a small-scale illustration of what may be possible,  
459 in a UK context, to address food loss and waste of ‘ugly’ produce from the endemic drivers  
460 discussed in Section 3 previously. Specifically, we are concerned with avoidable food loss  
461 at the farm-level as a function of aesthetics, a key aspect of quality within the food  
462 industry and regulatory bodies. Care was taken in choosing a case atypical to the *status*  
463 *quo* UK agri-food supply chain. Conclusions drawn may not be generalisable to other  
464 fresh produce or farming operations, particularly for farms and distribution that are  
465 much larger in scale and with more complex supply chains. As a single case study, it  
466 should be viewed as explorative rather than definitive; a potential precursor to inform  
467 larger scale investigations. However, whilst the case’s operations may not be fully  
468 applicable to industrial food producers, removing the real or perceived need to abide by  
469 cosmetic standards unrelated to food safety could see significant cuts to food losses. This  
470 section is intended to spark discussion and review of policy, custom, and behaviour to  
471 improve efficiency across the food system.

### 472 **4.1 Illustrative atypical case study: Description of case and data collection methods**

473 A medium-sized farm (c. 500 acres) in the Central Belt of Scotland was selected as the  
474 case study, with strawberry production as the unit of interest. The farm has been run  
475 under a perpetual lease by the same family for three generations, with the current  
476 generation in place for over 15 years. The farm uses standard production techniques for  
477 Scotland, such as raised coir-beds within covered poly-tunnels. This protects the crop,  
478 increases the length of the growing season, and eases the effort to harvest.

479 The case-study farm’s changes to its business model allows an examination of each of the  
480 four drivers cosmetics-related loss identified in the previous section. Losses from other  
481 food supply stages inherent in more complex supply chains – specifically storage,  
482 handling, process, and transport to distribution centres – are excluded here for  
483 comparability. The farm had previously operated within a typical environment of  
484 supplying to supermarket multiples. Dissatisfaction on multiple levels led the owner to  
485 completely change to an atypical model. For the past 10 years, the food supply chain of  
486 this case study is the shortest possible – direct from farmer to final consumer. There are  
487 no other agents in the chain (i.e. no packers, distributors, retail supermarket multiples,  
488 or other ‘middlemen’). The farm thus has complete control over what it sells to  
489 consumers, and when, including the level of grade-outs due solely to aesthetic reasons.

490 A mix of qualitative and quantitative data collection methods were employed. These  
 491 included extensive interviews conducted over several months with the farm’s owner and  
 492 general manager, and direct measurements of produce. As part of the case-study, we  
 493 sought to generate a rough estimate of avoidable aesthetics-related losses in UK-wide  
 494 strawberry production and their embedded production-phase GHG emissions (Eq 4). We  
 495 use the term ‘avoidable loss’ as there are no health-based reasons for the fruit to not enter  
 496 the supply chain; it remains safely edible. Supermarket multiples in the UK are now  
 497 selling some proportion of non-Class I (i.e. ‘sub-optimal’) fruit and vegetables as ‘ugly’,  
 498 ‘imperfect’, or ‘wonky’ – a relatively recent occurrence within the UK. This is taken into  
 499 account in our estimates of avoidable loss in Table 2 as the variable *Suboptimal<sub>Supermarket</sub>*.  
 500 Based upon our interviews, the typical supply chain has no other economic use for out-  
 501 graded fruit (i.e. that proportion of fruit not meeting Class I criteria); it is composted on-  
 502 site by the producer, thereby being lost to the FSC.

503 The percentage of *Suboptimal<sub>Farm</sub>* fruit was estimated from strawberry produce offered  
 504 for sale at the case-study farm. On six days over the course of a 15-day period in the  
 505 latter half of June 2017 (peak season), we collected a random sample of 10% of punnets  
 506 for sale in the farm shop. Under the guidance of the farm owner, we applied EU quality  
 507 standards to categorise each berry in the sampled punnets into Class I and non-Class I,  
 508 which we then weighed separately. As a proxy for variable *Suboptimal<sub>Supermarket</sub>*, we took  
 509 direct measurements of shelf linear feet allocated to Class I and Class II strawberries by  
 510 a national supermarket chain on the same days as we collected the farm samples.  
 511 *Harvest<sub>total</sub>* is the five-year average of the UK strawberry harvest for 2012-16 (Defra,  
 512 2016). Finally, we applied the UK-specific *EF* for strawberries from  
 513 Table 1 to estimate embedded production-phase GHG emissions of the avoidable loss  
 514 (*Em<sub>Avoidable</sub>*).

516 Eq 4

$$517 \quad Em_{Avoidable} = \left( (Suboptimal_{Farm} - Suboptimal_{Supermarket}) * Harvest_{total} \right) * EF$$

518

## 519 4.2 Overcoming waste encouraged by market standards/regulations

520 The case-study farming business uses a more holistic definition of quality than EU  
 521 marketing standards or retail multiples whilst retaining a quality-control/quality-  
 522 assurance effort. By selling direct to consumers, the specific EU-level marketing  
 523 standards on the appearance of the fruit for grading into official Classes needn’t be  
 524 applied. Therefore, the farm shop has greater flexibility to decide what is suitable for sale  
 525 to its customers. However, interviews with the farm owner and manager indicate that  
 526 those fruit selected for the farm shop are the best quality available on the plants each day.

527 *“Would you be happy paying for and eating that strawberry yourself? We*  
 528 *don't mind if there's some misshapen fruit that goes in there or anything*  
 529 *like that. Basically, if you're happy to eat it yourself then it's a Class I fruit*  
 530 *for us.” (Owner)*

531 Fruit for the farm shop is sold at a price premium relative to supermarkets as ‘picked  
 532 fresh’ yet avoidable waste on the case study farm is practically zero. This is due to  
 533 flexibility in decisions of what fruit is sold and how, by not being beholden to EU

534 classifications. The case study farm has invested in infrastructure such as an industrial  
535 kitchen and farm café to be able to use what fresh produce is left unsold at the end of the  
536 day in the farm shop. It is processed on-site into other products, such as jams, or  
537 otherwise used in the café. Fruit that is unsafe for consumption – the unavoidable losses  
538 – is composted on-site. This proportion was estimated by the farm owner at less than 1%  
539 of annual harvest yield, though is not systematically recorded.

#### 540 **4.3 Avoiding waste encouraged by retailers' cosmetic standards**

541 The case-study farm is both producer and retailer – produce grown on site is sold only on  
542 site. The have full control over what and how produce is presented to customers of the  
543 farm shop, which differs from EU or the more strict supermarket classification standards.  
544 For example, whilst colouration is an aspect of visual appearance taken into  
545 consideration during the selection decision of fruit for the farm shop, size and shape are  
546 not. This approach is in direct contrast to industry 'quality' standards.

547 *"Our spec, it's very loose. It's very rare that I go in and reject any fruit. The*  
548 *basic requirement is that it's picked that day, and that it looks appealing*  
549 *to eat". (Owner)*

550 The mean proportion of 'ugly', or non-Class I, fruit from farm shop punnet samples was  
551 19%, with a median of 23%, and ranged from 0 to 27%, dependent upon sample. There  
552 was one outlier with a measure of zero non-Class I fruit. If this single data-point were  
553 excluded – it is more than two standard deviations from the nearest – the minimum  
554 proportion of 'uglies' rises to 14%, the mean matches the median at 23%, and standard  
555 error contracts to 1.9% from 3.8%. The average proportion of retail space allocated to  
556 non-Class I strawberries in the supermarket sample was 12%, just over half the  
557 proportion measured from the case study farm (Table 2). This suggests actual FLW at  
558 farms supplying the large retail multiples may be about 10%, similar to the value in Table  
559 2 of 12%.

560 Annual UK strawberry production in the five years to 2016 averaged 102,000 t (Defra,  
561 2016), of which roughly a quarter (25,300 t) was produced in Scotland (Scottish  
562 Government, 2017). Scaling up the difference in non-Class I fruit sold via supermarkets  
563 and that produced by our case study farm to the whole of the UK, we estimate  
564 approximately 10,000 t of strawberries may be lost from the FSC due to aesthetic  
565 standards. This estimated loss has the equivalent of 8000 t CO<sub>2</sub>e of embedded emissions.  
566 It must be noted that these estimates are very preliminary, and are presented as only  
567 potentially indicative of the avoidable loss due to cosmetics. Broader and deeper  
568 investigation of the full supply chain for strawberries and other produce in the UK is  
569 needed.

570

	Sub-optimal Fruit (%)	
	Case-study Farm	Supermarket
Mean	23	12
Median	23	10
Standard Error	1.9	3.4
Maximum	27	24
Minimum	14	6

572 Table 2. Proportion of 'ugly' fruit sold through different distribution channels. The case-study farm values in this table  
573 exclude a single outlier of 0%. Including that data point into the set reduces the mean to 19% and increases the  
574 standard error to 3.8%. There were no outliers in the supermarket data.

#### 575 4.4 Reducing waste encouraged by the structural power of supermarkets

576 Our case study interviewees clearly communicated the lack of power they had with  
577 respect to selling their produce to retail multiples under the previous business model.  
578 From their perspective, the supermarkets 'held all the cards'. At times the participants  
579 discarded entire harvests by ploughing under, or even not harvested at all, where the cost  
580 of harvesting was more than the price being offered by supermarkets for the produce.  
581 Costs to grow the produce would still be incurred, but further losses to harvest and 'sell'  
582 it would be avoided – a practice they felt was anathema to farming.

583 Farmers are expected to honour production contracts or risk being dropped. If short of  
584 produce, a farmer must source it wherever possible and absorb the cost of doing so.  
585 Selling direct to customer puts at least some of that power back into the hands of the  
586 farmer – they have full decision-making power over what they offer for sale to the  
587 customer. It is not necessary to strictly comply with the EU marketing standards. At the  
588 same time, selling direct also exposes the farmer to different risks; they take full  
589 responsibility for marketing their produce. Selling produce that lacks value for money  
590 could quickly have a negative feedback effect, particularly if it is already selling at a  
591 premium to a similar supermarket offering.

592 *"I've got 100% control over what we do. If I make a good job of marketing*  
593 *and get customers in to buy the products, then I get a high return. If I make*  
594 *a bad job, then I get a low return. To me that's what gets me up in the*  
595 *morning; it's having control over your own destiny, which you don't have*  
596 *if you're doing it the other ways." (Owner)*

## 597 5. Conclusion

598 We have argued there are likely to be several drivers of avoidable loss of 'ugly' food,  
599 involving multiple actors within the food supply chain. These include: regulations that  
600 incorporate purely cosmetic elements at national and supranational levels; private  
601 'voluntary' grading criteria by retail multiples; power differential between farmer and  
602 retailer; and, learned expectations of consumers. Via our atypical case study, we suggest  
603 it may be possible for some actors to overcome these drivers, generating multiple  
604 benefits. Less discard of safe, edible food for aesthetic reasons could help reduce food  
605 insecurity. Less avoidable food loss would also lower the climate cost and increase  
606 agriculture's GHG-efficiency, in terms of embedded GHG emissions, by needing to  
607 produce less food. An efficient food supply chain, where food loss and waste are

608 minimised within and between the various stages, could increase food availability  
609 without the need for producing more.

610 The use of fresh fruit and vegetable produce that would otherwise be lost or wasted  
611 requires alternative routes that are available to farmers, and provide a sufficient price to  
612 make it economical to do anything other than plough-in or walk-by an out-of-  
613 specification harvest. Entrepreneurs have launched new businesses aimed at both  
614 consumers and producers, with the aim of using more of food that is produced (e.g. Olio,  
615 Imperfect Produce, FoodCloud, etc.). A law passed unanimously by both French  
616 legislative Houses in late 2015 aims to empower all actors within the food supply chain  
617 to eliminate avoidable food waste, emphasising efforts to maintain its use as food for  
618 human consumption (French Senate, 2015). In contrast to France, a food waste reduction  
619 private member's bill, also targeting supermarkets, first tabled in the UK Parliament in  
620 late 2015 remains mired at the first stage of the process (McCarthy, 2016). Positively  
621 however, all major supermarkets in the UK publicly support the voluntary Courtauld  
622 2025 Commitment of 20% reduction of food waste by 2025 (WRAP n.d.). Further, some  
623 supermarkets have seen this as a marketing opportunity, with new branding for fruit and  
624 vegetables that would have previously fallen short of their aesthetic/quality criteria (e.g.  
625 Asda's 'Wonky Veg' and Tesco's 'Perfectly Imperfect'). This could reduce avoidable food  
626 loss at source, generating benefits for the climate through reduced emissions from waste.  
627 Other co-benefits, such as less food poverty, and greater stability of farm income, may  
628 also be obtained.

629 A changing political climate within the UK also looms large on the horizon for the  
630 agriculture industry. The details and domestic policy implications of the UK's expected  
631 exit in 2019 from the European Union (or 'Brexit') remain unknown. Brexit may offer the  
632 UK the opportunity to develop and apply policy options for domestically-consumed FFV  
633 that current EU regulations may not permit, such as banning the use of cosmetic  
634 characteristics as factors in determining 'quality'. However it is far from certain the UK  
635 government would adopt such a policy, especially if they choose to keep open the  
636 prospects of trade with EU countries. Moreover the UK government has not taken other  
637 measures available to it as an EU member (or where membership should not inhibit  
638 action), such as: educational initiatives to increase knowledge and familiarity of food  
639 produce; and, revisit labelling of foods to provide consumers with clear information they  
640 can use in their decision-making process. The potential impact of policy on food loss  
641 warrants further research, building upon that begun by the EU FUSIONS project (EU  
642 FUSIONS, 2015).

643 Much research continues to be focused at the consumer end of the food supply chain in  
644 Europe (e.g.: De Laurentiis et al. (2018) on quantification; Gaiani et al. (2018) on  
645 attitudes; von Kameke and Fischer (2018) on behaviour change; Aschemann-Witzel et al.  
646 (2017a) on success factors). However, there remain considerable levels of uncertainty in  
647 many aspects of estimating food loss and waste in early FSC stages and its embedded  
648 climate impact. Here, we have attempted to provide some measure of additional clarity  
649 on such wastage. Our specific perspective has been one of viewing avoidable loss as a  
650 function of arbitrary quality standards. The case study we used focused only upon one  
651 crop – strawberries – grown and sold in the UK. The estimates presented with respect to  
652 the UK strawberry industry are very rough, based on this small-scale pilot, and are meant  
653 to be illustrative of possible climate cost due to application of cosmetic standards to fresh  
654 produce. Without generalising from a single specific case, our conclusion is there are very

655 likely to be substantial avoidable losses, yet also a great deal of uncertainty of the  
656 quantity. Larger-scale investigations to generate a more robust quantification of food loss  
657 at the farm stage, from all drivers, is necessary. A clearer picture of the scale and nature  
658 of the issue is also needed, recognising that different food crops in different geographic  
659 and social contexts may have different issues.

660

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664

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