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Every little helps: exploring meat and animal product consumption in the Tesco 1.0 dataset

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Abstract

The production and consumption of meat and animal products have been associated with an array of ethical, health, and environmental issues. While social scientists have increasingly focused on meat reduction and the promotion of meat alternatives in recent years, and have identified a number of regional, seasonal, and sociodemographic variations in consumption, empirical work is often based on self-reported data. To build a greater understanding of actual dietary habits, we seek to provide analysis based on real food purchase data by aggregating data from different sources. To this end, we explore the consumption of meat and animal products in the Tesco 1.0 dataset, an Open Access dataset representing 420 million food item purchases made by 1.6 million loyalty card users at 411 Tesco stores across Greater London in 2015. The data is aggregated most granularly at the level of monthly purchase of 11 broad food categories in 4833 lower super output areas (LSOA—the smallest geographic area). We represented the consumption of meat and animal products graphically for each month of the year and for each of 33 London boroughs. In general, we found that the spring and summer months had the highest consumption of meat and animal products, including poultry, and this decreased in autumn. We also combined the Tesco 1.0 dataset with datasets from the London Datastore (a free and open data-sharing portal that provides over a thousand datasets to understand the city and develop solutions to its problems), and identified several demographic factors as predictors for the meat consumption. Contrary to our hypothesis, areas with older, lower education, and more conservative populations had a lower proportion of meat consumed. In line with our hypotheses, a lower proportion of meat consumed could be observed in areas with higher population density, better health, and more Hindus. The purpose of this paper is to add to knowledge on regional, seasonal, and sociodemographic variations in animal product consumption, as well as provide a valuable overview of animal product consumption using a novel data source that comprises actual purchase data rather than self-reported consumption.

Keywords Meat consumption, Meat reduction, Consumer behaviour, Animal products, Dairy, Eggs, Retail data

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Background

In this manuscript, we highlight global issues with animal agriculture, give a brief overview of meat reduction research and its limitations, and explore some trends in meat reduction observed in the existing literature. We then present the objectives of this study, and introduce the dataset we will be analysing to contribute to this research.

Issues with animal farming

Modern animal agriculture is at the root of several dire global problems. First, the environmental outcomes are broadly negative, with problems including climate change, deforestation, and overconsumption of freshwater all attributable to some degree to intensive animal agriculture (Clark et al. 12; Eshel et al. 14; Theurl et al. 53). For example, animal agriculture is one key contributor to global human-induced GHG emissions, emitting approximately 8.1 gigatons (Gt) carbon dioxide equivalents (CO2eq) (FAO 15), corresponding to 14.5% of global anthropogenic GHG emissions in 2013 (Gerber et al. 18). According to the World Bank report, animal agriculture is also responsible for a large share of Amazon deforestation; Compared with 1970, 91% "of the increment of the cleared area has been converted to cattle ranching" (Margulis 35, p. 9). Additionally, animal products account for 42% of food-related water consumption, while providing just 18% of calories (Grosso et al. 21; Poore and Nemecek 2018).

Second, animal agriculture poses a threat to public health, exacerbating antibiotic resistance while constituting one of the most common source of foodborne illness and zoonotic disease (Aiyar and Pingali 2; Canica et al. 11; Fosse et al. 17).

Third, despite clear scientific evidence that animals are conscious and can feel pain, the vast majority of farmed animals worldwide are on factory farms (Griffin and Speck 20; Reese-Anthis 44). Therefore, there is considerable cause to reduce meat consumption for the good of other people, animals, and the planet.

Beyond these reasons, there are well-documented negative personal health outcomes associated with the consumption of animal products. High consumption of red and processed meat has been found to be associated with high risks for a several diseases such as ischaemic heart disease and diabetes (Bechthold et al. 5; Bouvard et al. 6; Papier et al. 42; Zhao et al. 57). Conversely, balanced vegetarian and vegan diets have lower incidences of these issues and can be nutritionally healthy for all stages of life (Craig 2009; Melina et al. 2016).

To sum up, there are 'selfish' health-related motivations as well as altruistic ethical and environmental motivations for meat avoidance.

Meat avoidance & meat reduction research

Given the importance of these issues, research on meat reduction has gained traction in recent years. Veganism ranked as the most popular diet, followed by vegetarianism in Google Trends in 14 and 23 countries, respectively. They were searched 19.54 and 15.09 times more than the benchmark—Mediterranean diet—correspondingly (Kamiński et al. 31).

We generally observe that health benefits are the most widely-cited amongst meat-reducers, while ethical motivations are most common amongst strict meat-avoiders, including vegetarians and vegans (Bryant 9; Humane League Labs 26). Previous studies have reported that consumers are generally unaware of the environmental impacts of meat production (Hartmann and Siegrist 22; Sanchez-Sabate and Sabaté, 49). However, there appears to be evidence that the environmental benefits of vegetarianism have become more widely regarded by UK meat-eaters in recent years (Bryant 9). This could explain why longitudinal data suggests that the rate of veganism is rising in the UK, more than doubling between 2019 and 2021 (Finder 16). However, paradoxically, data suggests that meat consumption is going up, not down (Ritchie et al. 2017).

This points to a frequent criticism of research in meat reduction: the lack of reliability in self-reported data. Self-reported intentions commonly go unfulfilled (the so-called 'intention-behavior gap', see Hassan et al. 23), and even self-reported current or past behaviors may not be accurate. Survey respondents may give inaccurate or unthoughtful answers through lack of attention or misunderstanding the question, and other answers may be subject to social desirability bias, especially in a moralized context such as animal activism (Bryman 10; Humane League Labs 27). In a systematic review of research on reducing meat consumption, Mathur et al. (37) specifically identify the need to base future research on direct behavioral outcomes rather than self-reported behavior or intentions, in addition to long follow-ups. Therefore, there is value in exploring data sources that contain not self-reported survey responses but actual food purchases. Additional value can be found in tracking observations over time.

Demographic, seasonal, and regional trends in meat reduction

Some research points to possible seasonal, regional, and demographic trends in meat consumption, which would be useful for meat reduction advocates to identify in order to target interventions (James et al. 29). The evidence is strongest for sociodemographic predictors of meat consumption: Hayley et al. (24) found that females tend to value universalism, which is associated with lower meat consumption, whereas males tend to value power and conformity, which are associated with higher meat consumption. Ruby (48) highlighted that surveys almost ubiquitously point to a higher proportion of vegetarians being female. Rothgerber (47) showed that males tended to use more direct pro-meat justifications than females and argued that these were rooted in conceptions of masculinity. Similarly, Mohr and Schlich (38) found that women had a higher propensity for sustainable food consumption, as did well-educated and middle-aged people. While Haddad and Tanzman (2003), have argued that people 50 or above may be 2–4 times more likely to over-report vegetarianism, this age trend is also reflected in the findings of Neff et al. (41), who found that self-reported meat reduction was most common among the 45–59 age group and those with lower incomes (ostensibly due to health and cost concerns, respectively).

Findings also show that people with higher income levels view vegetarianism and veganism more positively (Bryant 8). Other research has suggested that there is no clear link between meat reduction and demographics correlated with income such as the father's occupation (Beardsworth and Bryman 4). Another study found that people who adopt right wing authoritarianism consume more meat (Dhont and Hodson 13). Interestingly, both vegetarians and consumers of meat substitutes, compared to meat consumers, show a trend towards higher education levels, higher SES, and more urbanised residential areas (Hoek et al. 25). Religion may also play a crucial role in meat consumption: while only a few Christians are discouraged from meat eating by their religious views, many Jains, Buddhists and many Hindus are (Szűcs et al. 52). Finally, as discussed above, there are a variety of health problems associated with overconsumption of meat.

In terms of trends over time, Stewart et al. (51) observed a general decline in UK meat consumption over the 10 year period to 2019. There is also some evidence of a seasonal effect: Mutondo and Henneberry (40) observed that US consumption of beef was significantly lower in Q4 (autumn) compared to Q2 (spring), purportedly due to an increase in poultry consumption around the holiday season, while pork consumption was significantly higher, purportedly due to increased consumption of hot breakfasts during the winter months. Somewhat similarly, Matheson and Philpott (36) reported a significant increase in pork and beef consumption, but a significant decrease in lamb consumption in London in Q4.

Regionally, Matheson and Philpott (36) also note that UK regions further north of London tended to have a stronger preference for beef over lamb, although this data is, of course, very dated. More recently, James et al. (29) showed significant variations in the weekly per-person expenditure on pork products, with Londoners spending far less than those living in surrounding areas. For example, they found that London cosmopolitans show low expenditure for red and processed meat categories of beef, bacon and ham, pork, sausages, and other preserved and processed meats. In contrast, people from the countryside show high expenditure on these products. For example, London cosmopolitans spent 1.28% of their food budget on sausages compared to 1.45% on behalf of people from the countryside. Specifically, people living in London (13.3%) and the south of England (10.7%) were more likely to be vegetarian, followed by East Anglia and the Midlands (11.9%—combined, British Market Research Bureau 7). Although dated, these findings fall in line with the formerly discussed findings about urban people's (and specifically Londoners') tendency to eat less meat.

To conclude, while there is substantial evidence for demographic factors influencing meat consumption, there is also some evidence for seasonal, and regional trends in meat consumption. Based on the literature, there is some evidence for lower meat consumption amongst females, younger people, higher income people, more educated people, more urban populations, healthier populations, less conservative people, and adherents to certain religions such as Hinduism and Buddhism. Furthermore, there appear to be specific trends in meat consumption across the year with poultry consumption increasing in autumn.

Objectives

Given the importance of understanding meat avoidance and meat reduction, this paper seeks to further explore trends in the consumption of meat and animal products using an open-source dataset of real food purchases. It is hoped that this will add to the evidence on seasonal, regional, and sociodemographic variation in the consumption of meat and animal products, whilst also demonstrating a potentially valuable resource for meat reduction researchers. To this end, we aim to provide an overall picture of meat purchasing in London in 2015.

Based on the general patterns related to meat consumption above, we also formed the following specific hypotheses:

1. Seasonally, we will observe:
    a. An increase in the total mass of poultry sales in Q4 compared to other seasons.
2. Geographically, we will observe that meat makes up a higher proportion of the total mass of food sold in areas with:
    a. A higher proportion of males
    b. A higher average age
    c. A lower average income
    d. A lower average level of education
    e. A lower population density

f. A lower health level
g. A more conservative political record
h. A lower proportion of Buddhists
i. A lower proportion of Hindus

While there is some evidence for other seasonal variations in consumption of specific meats (e.g. beef, pork, lamb), the present dataset only denotes 'red meat' and 'poultry', and does not classify items more precisely by species. Similarly, there is evidence that meat consumption was falling in the UK during this time (Stewart et al. 51), but seasonal trends likely mean that this overall decrease would not be reflected in one year of monthly data.

Methods

The Tesco 1.0 Dataset (Aiello et al. 1) is a large open access dataset of food purchases at the UK's largest supermarket, Tesco. The dataset is a record of 420 million food item purchased by 1.6 million loyalty card holders at 411 Tesco stores across Greater London during 2015. The data is aggregated to purchases within geographical areas with four levels of granularity available from Borough (n = 33, average population = 262,634) to lower super output area (LSOA, n = 4833, average population = 1793) which preserves anonymity. For each area, the number of transactions and nutritional properties of the typical food item bought is reported. Unlike other retail datasets such as Nielsen's Retail Scanner Data which reports data on an annual basis, the Tesco 1.0 Dataset reports purchases for each month, allowing for finer trend analysis. Among other variables, the datasets contain the percentage of the total weight of food sold in each area/month belonging to each of 11 categories: dairy, eggs, fats and oils, fish, fruit and vegetables, grains, red meat, poultry, readymade, sauces, and sweets. Accordingly, the data paints a picture of the rough composition of diets according to these categories in each area/month (see Table 1).

First, we explored the Tesco 1.0 datasets to report some basic descriptive statistics, including consumption of each food category in each London Borough, and in each month of the year. This paints a picture of geographical and seasonal trends in meat and animal product consumption in London. We represent the data by graphs and tables using plots depicting product purchases vs. time and product purchases vs. season.

Second, we combined the Tesco 1.0 dataset with an Open Access 'LSOA Atlas' dataset from the London Datastore (http://data.london.gov.uk). The LSOA Atlas dataset we used provides a summary of demographic data for each lower super output area in Greater London using the current LSOA boundaries (2011). In particular, we made use of the data on religion, education, health, and income. Data on the proportion of males, age, and population density was used from the Tesco 1.0 dataset. By combining the Tesco 1.0 dataset with the LSOA Atlas, our goal was to explore the relationships between food purchases and sociodemographic factors. We used a multiple linear regression where sociodemographic factors were entered as independent variables, and used to predict consumption of meat products. Furthermore, as the authors of the original Tesco 1.0 dataset suggest excluding regions where fewer than 10% of residents are Tesco shoppers to increase representativeness of the sample, we opted here to include only regions in the analyses where more than 10% of residents are Tesco clubcard owners. The representativeness of the sample was measured through the ration between the number of residents and the number of clubcard owners in each area.

Some variables were computed, including the education and health variables. This data was given as the percentage of individuals with each of 5 levels of education ("No qualifications", "Level 1 qualifications", "Level 2 qualifications", "Level 3 qualifications", "Level 4 qualifications and above", taken from London datastore) and 3 levels of health ("Bad or very bad health", "Fair health", or "Very good or good health", taken from London datastore). We computed an overall 'education' and 'health' variable for each area, which was the weighted sum of these percentages with higher weight given to higher levels of education and health. The education variable takes a value between 0–5 where 5 corresponds to the highest average level of education (all education scores $\in$ 1.21–3.80, $\bar{x} = 2.43$, $\sigma = 0.51$). The health variable takes a value between 1–3 where 3 indicates the best health state, as self-reported (subjective health) in the London Datastore dataset (all health scores $\in$ 2.55–2.96, $\bar{x} = 2.79$, $\sigma = 0.06$).

Table 1 Information about the granularity of relevant data in Tesco 1.0

Geographical	Time	Product details
33 boroughs	Monthly	% of value in each category
638 wards	Full year	% of weight in each category
983 medium super output area (MSOAs)		Animal products: red meat, poultry, fish, dairy, eggs
4833 lower super output area (LSOAs)		Unknown/mixed: fats and oils, sauces, sweets, readymade
		Plant products: fruits and vegetables, grains

We also computed the consumption of meat (red meat + poultry + fish), animal products (meat + dairy + eggs) and plant foods (fruits and vegetables + grains). These are given as percentages of total consumption; we further computed total consumption by multiplying these values by the variables 'weight' (the weight of the average product in grams) and 'num_transactions' (the total number of products purchased). Several categories, including readymade, sweets, fats and oils, and sauces were ambiguous as to whether they contained animal products, and were therefore counted as neither.

For the seasonal analysis, the months were grouped into 4 seasons: winter (January, February, and March), spring (April, May, and June), summer (July, August, and September), and autumn (October, November, and December). We grouped months into seasons based on their proximity to the astronomical seasons (i.e. the winter solstice is on December 21). This had the added benefit of grouping consecutive months together, rather than treating December 2015 as consecutive to January 2015. We then used a series of One-Way ANOVAs to test for significant differences in the total amount of different animal products consumed in each season.

As shown above, the total amount of food sold differed substantially from month-to-month. This introduces a potential source of bias for different outcome measures. If we choose to measure the total amount of food sold in kg, we might falsely identify some seasons as higher or lower animal product consumption when variations are actually due to differences in food sales overall (e.g. lowest sales in August, when many Londoners will go on vacation during the school holidays). On the other hand, if we choose to measure the percentage of total food which is animal products, we may falsely identify lower animal product consumption in overall busier months (e.g. average meat consumption in December, but very high consumption of other foods including sweets due to Christmas).

Therefore, to form a holistic assessment of animal product by season, we analysed consumption of red meat, poultry, fish, dairy, and eggs in terms of both grams per capita per day, and percentage of total food by weight.

For the geographical analysis, we not only did a descriptive analysis, but also ran two multiple linear regressions to investigate the association between various demographic factors for 4833 LSOA areas and consumption of meat and animal products. The percentage of food by weight in the categories of red meat, poultry, and fish for each area were used as dependent variables. Independent variables were demographic measures taken from the London Datastore LSOA Atlas including mean household income, percentage of males, average age, education, population density, percentage of council seats in the Borough won by Conservative candidates in 2014, 2014 local election turnout, and the percentage belonging to religious groups (Christian, Buddhist, Hindu, Jewish, Muslim, Sikh, Other religion, No religion).

Results

Seasonal trends in animal product consumption

Our first analysis provides descriptive data of the percentage of the total weight of food sold belonging to five animal product categories: red meat, poultry, fish, dairy, and eggs. Since the total amount of food purchased differs significantly by month, we present both the percentage of food in each category (Fig. 1) and the amount in thousands of kilograms (Fig. 2).

As shown in Fig. 1, July and August had the highest percentage of food by weight coming from meat (13.6%) and July had the highest percentage of food coming from all animal products (23.6%). December had the lowest percentage of food by weight coming from meat (11.9%) and animal products (20.0%). Plant foods were the highest percentage of food sales in April (58.7%) and lowest in August (56.3%). Mean percentages and standard deviations for every food group are shown in Table 2.

In terms of absolute sales (Fig. 2), May saw the highest food sales overall (13.17 thousand kgs), including the highest sales of meat (1.71 thousand kgs), animal products (2.98 thousand kgs), and plant products (7.63 thousand kgs). August saw the lowest food sales overall (11.48 thousand kgs) whereas November saw the lowest

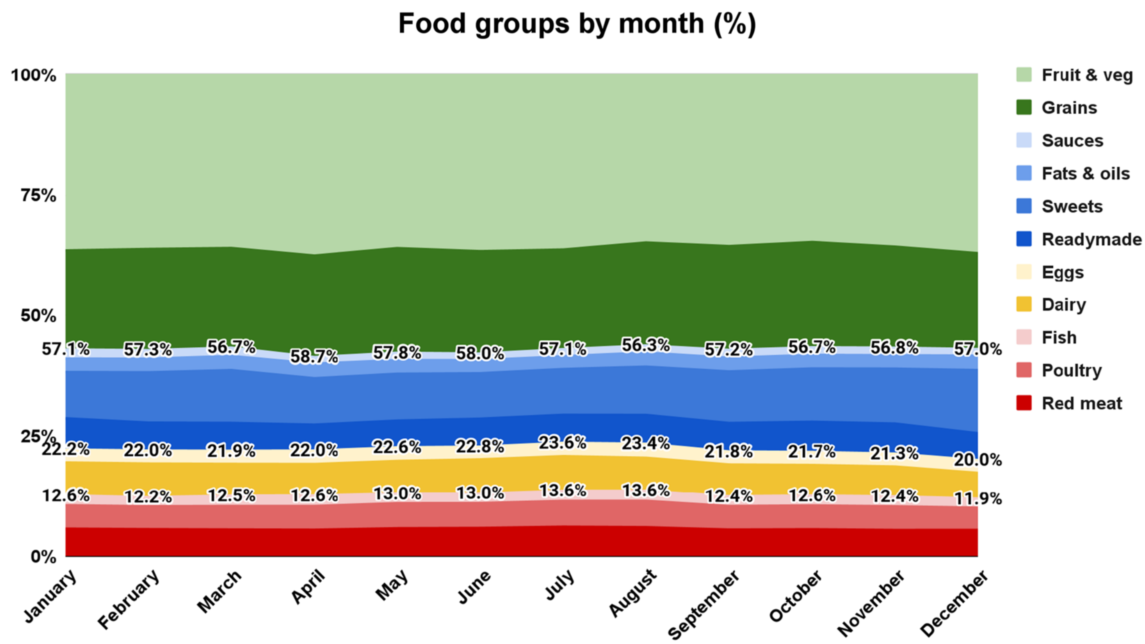


Fig. 1 The percentage of food by weight belonging to each food group by month. Labels show the total percentages for meat, animal products, and plant products

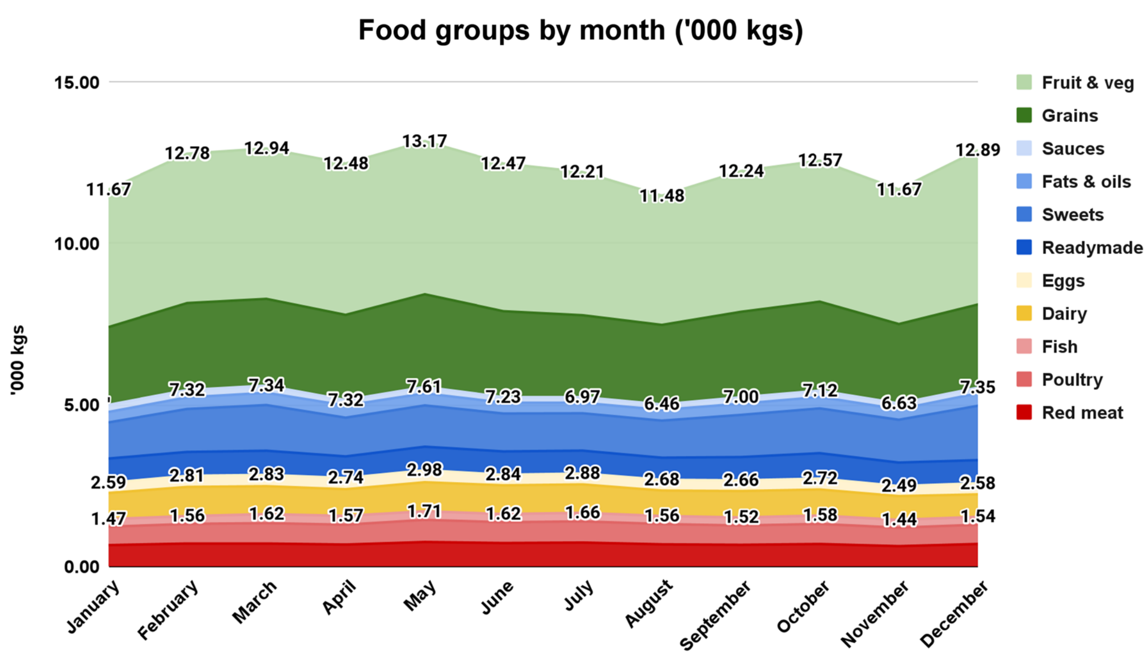
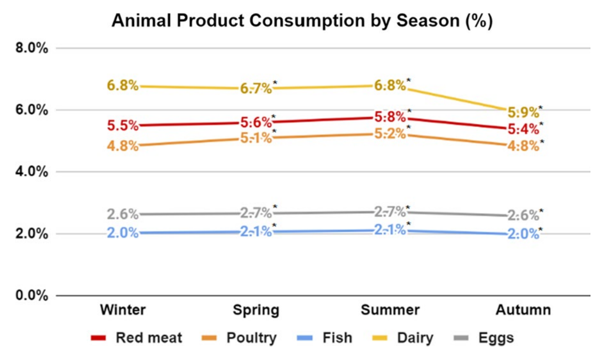


Fig. 2 The total weight of food sold in each food group by month. Labels show the total in 000 s kgs for meat, animal products, plant products, and total food

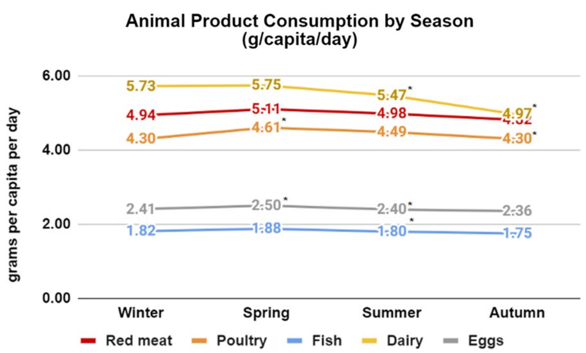
Table 2 Monthly consumption data (all values are percentages)

%	Winter						Spring						Summer						Autumn					
	January		February		March		April		May		June		July		August		September		October		November		December	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Dairy	6.9	0.7	7.1	0.7	6.7	0.7	6.6	0.8	6.8	0.8	7.1	0.8	7.2	0.8	6.8	0.8	6.7	0.8	6.4	0.7	6.3	0.7	5.4	0.6
Eggs	2.7	0.3	2.7	0.3	2.7	0.4	2.8	0.4	2.8	0.3	2.6	0.4	2.8	0.4	2.9	0.4	2.7	0.4	2.7	0.4	2.7	0.3	2.7	0.3
Fats & oils	2.8	0.3	2.8	0.3	2.9	0.3	3.0	0.4	2.8	0.3	2.7	0.3	2.7	0.3	2.9	0.3	2.8	0.3	2.8	0.3	2.8	0.3	3.0	0.3
Fish	2.1	0.2	1.9	0.2	2.2	0.3	2.2	0.3	2.0	0.3	2.0	0.3	2.2	0.3	2.2	0.3	2.0	0.3	2.1	0.3	2.1	0.3	1.9	0.3
Fruit & veg	36.5	1.7	36.2	1.7	36.0	2.0	37.6	2.0	36.0	1.9	36.6	2.1	36.3	2.0	34.9	1.9	35.6	2.1	34.7	2.1	35.7	2.2	37.1	2.3
Grains	20.6	2.0	21.1	2.2	20.7	2.4	21.1	2.6	21.8	2.7	21.3	2.9	20.8	2.1	21.4	2.3	21.6	2.8	21.9	3.1	21.0	2.5	20.0	2.2
Red meat	5.7	0.6	5.5	0.6	5.5	0.6	5.4	0.6	5.7	0.6	5.8	0.6	6.1	0.6	6.0	0.6	5.5	0.6	5.5	0.6	5.4	0.6	5.4	0.6
Poultry	4.9	0.4	4.8	0.4	4.9	0.5	4.9	0.5	5.2	0.5	5.2	0.5	5.4	0.5	5.5	0.6	4.9	0.5	5.0	0.5	4.9	0.6	4.6	0.5
Readymade	6.5	1.0	5.8	0.9	5.8	0.9	5.4	0.8	5.5	0.8	5.8	0.8	5.8	0.9	6.0	1.0	5.9	1.0	6.3	1.0	6.2	1.1	5.6	1.0
Sauces	1.9	0.1	1.8	0.2	1.7	0.1	1.4	0.1	1.5	0.2	1.4	0.1	1.5	0.1	1.5	0.1	1.6	0.2	1.6	0.2	1.6	0.2	1.4	0.1
Sweets	9.6	0.8	10.4	0.9	10.9	1.1	9.6	1.0	9.7	0.9	9.4	0.9	9.5	0.9	10.0	0.9	10.7	1.3	11.0	1.1	11.4	1.3	13.1	1.9

consumption of meat (1.44 thousand kgs) and animal products (2.49 thousand kgs).



Values marked with an asterisk are significantly different from the previous season at p = 0.05.



Values marked with an asterisk are significantly different from the previous season at p = 0.05.

As shown, there is significant seasonal variation with respect to the percentage of food coming from different animal products as measured both by grams per capita per day, and percentage of total food sold.

When measured as the percentage of total food sold, the ANOVA analysis indicated significant differences for every pair of consecutive seasons. In terms of the seasonal patterns, we see a consistent pattern emerge for all meat products on this measure, and eggs. Red meat, poultry, fish, and eggs by percentage of total food by weight all increase significantly from winter to spring, and again from spring to summer, before decreasing significantly in autumn. Dairy follows a similar pattern, but is higher in the winter, decreasing into spring before peaking in summer and decreasing significantly in autumn.

When measured by grams per capita per day, fewer consecutive seasons are flagged as significantly different overall. Red meat is not significantly different in any two consecutive seasons (though it was significantly higher in the spring than the autumn). Poultry consumption increased significantly between winter and spring, and then decreased significantly between summer and autumn. Notably, this leads us to reject H1a, that poultry sales would be significantly higher in Q4—instead, this was the lowest season for poultry sales, next to Q1. Fish consumption peaked in spring, and then decreased significantly between spring and summer. Dairy consumption decreased significantly from spring to summer, and again from summer to winter. Egg consumption increased significantly from winter to spring, then decreased significantly from spring to summer.

Notably, the analysis by percentage of total food reflects the highest consumption of all animal products in the summer, whereas all animal products peak in the spring when measured by grams per capita per day. This reflects the lower overall quantity of food sold in summer compared to other seasons (see July, August, September, in Fig. 2). Overall, the spring and summer months saw the highest consumption of meat and animal products, including poultry which actually decreased in Q4, counter to our hypothesis.

Geographical variation in animal product consumption

Figure 3 shows the proportion of food from each category for each London borough. On the low end, the Borough of Harrow's groceries by weight were 19.4% animal products, and just 10.6% from meat. Other low-animal-product boroughs included the lowest meat-eating Borough of Newham (19.5% animal products, 10.2% meat) and Sutton (19.5% animal products, 10.9% meat). On the high end, animal products made up 24.7% of groceries by weight in the Borough of Kensington and Chelsea, and meat made up 13.3%. Other high-animal-product-consumption boroughs were Hammersmith and Fulham (24.0% animal products, 13.7% meat) and the highest meat-eating Borough of Lambeth (24.0% animal products, 14.5% meat).

The results of the linear regression on the association between various demographic factors and meat consumption are shown in Table 3. Green rows indicate a significant association with less meat consumption; red rows indicate a significant association with more meat consumption.

Several significant predictors of higher meat consumption in an area were identified, some of which confirmed our hypotheses, but some which were directly counter to our hypotheses. The hypothesized and observed results are summarised in Table 4.

As shown, six out of nine hypotheses related to demographic predictors of meat consumption were rejected. Contrary to our expectations, there was an inverse statistical effect for the influence of age, education level and conservative political views on meat consumption. Areas with older populations, lower education populations, and more conservative political records had a lower proportion of meat consumed. In addition, no statistical significance could be found for the influence of the proportion of males and income on meat consumption.

On the other hand, there was a statistically significant effect for population density and health on meat consumption. In alignment with our expectations, a lower proportion of meat consumed could be observed in areas with higher population density and better health. With regard to the religion variables, we did observe a lower proportion of meat sold in areas with more Hindus, but observed that the opposite was true for areas with more Buddhists.

Discussion

This paper explored the Tesco 1.0 Dataset for trends relevant to meat and animal product consumption. By aggregating retail data at the area, month and broad food category level, the Tesco 1.0 Dataset provides a perspective on meat and animal product consumption that is not based on self-reported intentions or behaviours. It thus addresses a key gap in existing research on reducing animal product consumption (Mathur et al. 37).

With regard to the evidence on seasonal variation in the consumption of meat and animal products, we found that—counter to our hypothesis—poultry consumption decreased rather than increased in autumn. In fact, there was an increase in poultry consumption between winter and spring, and then a decrease between summer and autumn. However, the results make sense when that the spring and summer months saw the highest consumption of meat products. With the most dominant livestock type being poultry (Ritchie and Roser 45), it is likely that poultry consumption is highly correlated with an individual's general meat consumption of a person.

With regard to the evidence on sociodemographic variation in the consumption of meat, the statistical analysis in this study could only partly support the hypotheses.

While most research shows that vegetarians are likely to be younger (Bryant 8), the statistical regression identified older average age as a predictor of lower meat consumption. This may be explained by older people tending to eat less overall (Morley 39; Pilgrim et al. 43). It may also be a case of meat-reducers (as opposed to strict vegetarians) being more likely to be older or middle-aged (Mohr and Slich 38; Neff et al. 41). Thus higher average age may still be compatible with lower average meat consumption despite a lower rate of strict vegetarianism. Although some have argued that older or middle-aged

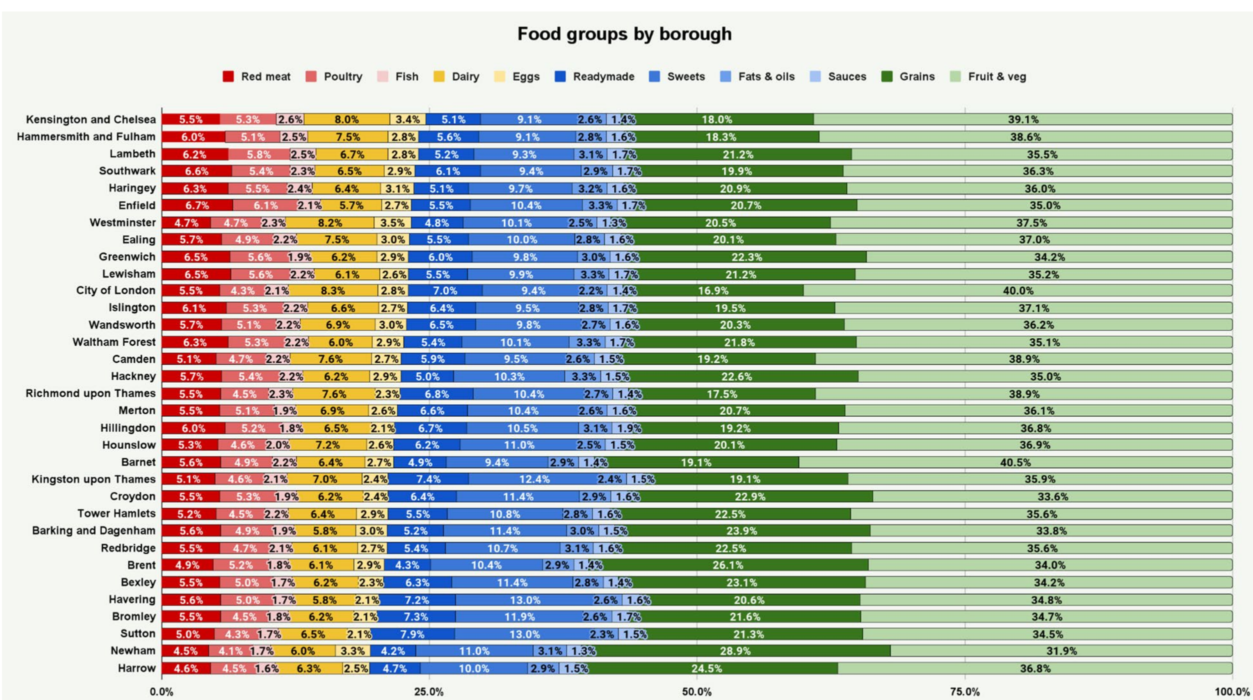


Fig. 3 The percentage of food by weight belonging to each food group by Borough

Table 3 Multiple linear regressions showing demographic factors correlated with meat consumption

	F(16,3851)= 154.455, p<.001, R^2=0.391, Adj R^2=0.388		
	ß (S.E.)	*Std. ß*	*p*
Constant	0.357	-	-
% Male	0.005 (0.012)	0.005	0.702
Average age	-0.001 (<0.001)	-0.120	<0.001***
Mean household income	<0.001 (<0.001)	-0.043	0.120
Education	0.003 (0.001)	0.063	0.042*
Population density (people/km^2)	-<0.001 (<0.001)	-0.066	<0.001***
Health	-0.044 (0.010)	-0.118	<0.001***
% seats in Borough won by Conservatives (2014)	<0.001 (<0.001)	-0.130	<0.001***
2014 election turnout	-0.001 (<0.001)	-0.135	<0.001***
% Christian	<0.001 (<0.001)	-0.114	0.060
% Buddhist	0.002 (<0.001)	0.057	<0.001***
% Hindu	-0.001 (<0.001)	-0.446	<0.001***
% Jewish	-0.001 (<0.001)	-0.284	<0.001***
% Muslim	-0.001 (<0.001)	-0.558	<0.001***
% Sikh	-0.001 (<0.001)	-0.166	<0.001***
% Other religion	-0.001 (<0.001)	-0.023	0.156
% No religion	-0.001 (<0.001)	-0.273	<0.001***

A single asterisk (*) signifies that the p-value is less than 0.05. Two asterisks (**) are used to indicate a p-value less than 0.01. Three asterisks (***) denote a p-value less than 0.001.

Table 4 Relations of demographics to meat consumption compared to hypotheses

Demographic	Direction predicted	Direction observed	Result
Age	Higher average age → **More** meat	Higher average age → **Less** meat	Reject hypothesis
Gender	More males → **More** meat	More males → **More** meat (not significant)	Reject hypothesis
Income	Lower income → **More** meat	Lower income → **More** meat (not significant)	Reject hypothesis
Education	Lower education → **More** meat	Lower education → **Less** meat	Reject hypothesis
Population density	Lower density → **More** meat	Lower density → **More** meat	Confirm hypothesis
Health	Bad health → **More** meat	Bad health → **More** meat	Confirm hypothesis
Politics	More conservative → **More** meat	More conservative → **Less** meat	Reject hypothesis
Buddhism	Fewer Buddhists → **More** meat	Fewer Buddhists → **Less** meat	Reject hypothesis
Hinduism	Fewer Hindus → **More** meat	Fewer Hindus → **More** meat	Confirm hypothesis

people are more likely to over-report vegetarianism (Mohr and Slich 38), this dataset supports the idea that older age groups do indeed have somewhat lower meat consumption. Advocates should consider this when planning which groups to target for meat reduction advocacy.

It was also somewhat surprising to see higher consumption of meat products associated with higher average education and a lower proportion of council seats belonging to the Conservative party. Again, these associations are contrary to existing research, which generally shows that vegetarians, vegans, and meat-reducers are more likely to be more educated and left-leaning (Bryant 8; Mohr and Slich 38). These discrepancies may be related to our narrow slice of the overall food sales; we only observed the food sold in one supermarket. It might be the case that older people, for example, are more inclined to buy their meat at a specialist butcher, and less inclined to buy it at Tesco. In such a case, the analysis presented here may be limited in the generalisability of its predictions. Further research, including further analysis of the Tesco 1.0 dataset, could elucidate these findings.

Moreover, the fact that the proportion of males did not significantly influence meat consumption stood in contrast with the findings of previous studies that found that males consume more meat (e.g. Keller and Siegrist 34). An explanation for this could point to a limitation of the study. While the gender variable refers to the Tesco shoppers rather than the Open Access LSOA Atlas dataset from the London Datastore, it is possible that the gender variable does not accurately depict potential consumption differences between males and females since females may still be responsible for the majority of grocery shopping. Also, it was found that the level of income did not significantly influence meat consumption. While this was contrary to the hypotheses of this study, it supports the results of Beardsworth and Bryman (4) that there is no clear link between meat reduction and demographics correlated with income. Thus, it does not seem that areas with higher income report lower meat consumption.

Among the strongest demographic predictors of meat consumption were the population of religious groups. Areas with a higher proportion of Jews, Muslims, Hindus, Sikhs, and atheists all had lower meat consumption, while contrary to our expectations, areas with a higher proportion of Buddhists had higher meat consumption. Many of these religions have specific rules prohibiting consumption of some meat, and their adherents may come from cultures with a high proportion of traditional vegetarian dishes. As for Buddhists, the results might reflect a higher number of individuals identifying as Buddhists without necessarily adopting the practices. Religious involvement, personal religiosity, and spirituality are still viewed as highly desirable characteristics, therefore prone to social desirability and adherence may thus be over-reported (Jones and Elliott 30). While this explanation is very hypothetical, another explanation could be the low number of Buddhists overall. With only about 2.4% of Buddhists residents in each area on average, it might not be possible to draw a strong link here.

The most notable limitations of this study relate to the aggregated nature of the data source. Although this method allows us to access actual purchase data, which is more reliable than self-reported intentions or behaviour, it does not allow us to observe the behaviour of individuals, only the aggregated data of residents of a given area in a given month. As a result of this, our analyses are somewhat limited.

Three key limitations to consider are the age of the dataset, the limited geographical scope, and the ambiguity of some product categories. First, temporally, the dataset is somewhat old, and consumption of meat and animal products is likely to have fallen since 2015. According to Stewart et al. (51), total meat consumption per capita in the UK fell from 99.9 g/day in 2014–15 to 86.3 g/day in 2018–19, representing a decline of around 14% in 4 years. Both red and processed meat declined significantly, whereas the consumption of pork increased and fish consumption stayed the same. Similarly, retail data shows that 2015 was the start of an exponential increase in sales of chilled vegetarian foods in the UK. Between 2015 and 2019, sales more than doubled from £58 million/year to £124 million/year (Kantar 32). Likewise, UK dietary surveys have shown the number of meat avoiders increasing year-on-year, including a 138% increase in the number of vegans between 2019 and 2022 (Finder 16). However, it is important to note that despite this trend, vegetarian foods still make up only a very small percentage of total sales in comparison to other meat products (Trewern et al. 54). Likewise, the number of people who identify themselves as vegetarians or vegans is still comparatively low (Finder 16).

Second, geographically, consumption of meat and animal products is likely to be lower in London compared to other regions of the UK. A 2021 survey of UK diets found that 24% of Londoners were meat-free, compared to just 14% of the country overall. London was home to the highest number of meat-avoiders by far; the next highest regions were Scotland (17%), the East of England (17%), the West Midlands (16%) and Wales (15%) (Finder 16). YouGov surveys in 2019 and in 2020 concur: London is the top of the list of UK regions by the proportion of both vegetarians and vegans (YouGov 55, 56). In summary, it is likely that this dataset contains data from a higher number of meat-avoiders than one might find in other areas of the country in 2015, but a lower number of meat-reducers than one would find in London today.

One further limitation of this study relates to the ambiguity of some of the food categories included in the Tesco dataset with respect to animal products. Readymade, sweets, fats and oils, and sauces may or may not contain animal products, and were therefore not counted as either. This may have caused analyses to overlook some animal product consumption, especially in the 'readymade' category, which includes both meat-based and plant-based foods.

Future research should further explore the Tesco 1.0 dataset and other food purchase datasets to identify meat and animal product consumption trends. Where possible, these datasets can be related to real-world events to investigate the impact of these events on consumption for different groups.

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Author contributions
CB conceived the study, cleaned and analysed data, wrote and edited the manuscript. RCB cleaned and analysed data, wrote and edited the manuscript. KH cleaned and analysed data, wrote and edited the manuscript.

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Declarations

Competing of Interests
Author RCB and KH declares no conflicts of interest. Author CB consults for meat alternative companies and meat reduction non-profits through Bryant Research Ltd.

Data availability
All data is available Open Access.

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