Measuring Meat Free Monday

Section 1: Beef Burgers and Baths

Activity 1: Discussion

Start this section by discussing the ways water is used in meat production generally. A vast amount of water is needed to grow the grass, forage and feed that cattle eat over their lifetimes and there is also the water needed for drinking, cleaning and processing. Ask the students what they think this means in terms of the amount of water used in producing just one 150g beef burger. Ask them to guess roughly how many bath tubs of water would be needed. After some discussion, say that the maths unitary method will be used to get an answer to this question.

Activity 2: Introducing the Unitary Method

The unitary method is a way of adapting some given information involving two or more variables (e.g. '5 oranges cost £1.50') into a form that is desired for some other purpose (e.g. '9 oranges cost ?'). It involves scaling down one of the variables to a single unit (e.g. '1 orange costs ?'), and then performing an operation to alter it to the desired value. Start with some simple examples, such as those below. Here, each scaling operation is indicated in bold and an arrow points to the result of the operation.

Example 1

5 oranges cost £1.50. How much do 9 oranges cost?

Answer:

5 oranges cost £1.50
÷5 → 1 orange costs 30p
x9 → 9 oranges cost £2.70

Example 2

4 tins of beans weigh 1.83 kg. If a shopper doesn't want to carry more than 10 kg, how many tins can they buy at one time?

Answer:

4 tins weigh 1.83 kg
÷1.83 → $\left(\frac{4}{1.83}=\right)$ 2.19 tins weigh 1 kg
x10 → 21.9 tins weigh 10 kg

So the shopper can buy at most 21 tins of beans.

Background

Animal agriculture results in vast amounts of greenhouse gases being released into the atmosphere. It requires increasingly unsustainable levels of precious resources including land, water and energy. It is a major contributor towards global environmental degradation and climate change. This series of lessons will prompt students to calculate for themselves the environmental impact of meat production and present their findings using measurements of comparison which are easy for people to assimilate.

Introduction

This resource is divided into three sections. The first section introduces the maths of the unitary method and is about water usage. The second section relates to the cutting down of Amazon rainforest to make way for cattle pasture. And the third section relates to the environmental benefit of doing Meat Free Monday against driving fewer miles in a car.

Learning Objectives

Students should :

- **learn the unitary method**
- **develop confidence in using the unitary method to convert factual data from one form to another**
- **gain practice in converting between different units of measure**
- **appreciate the power of algebra to embrace multiple scenarios**
- **gain practice in using a spreadsheet**
- **consider how data can be presented in different ways in order to raise awareness of an issue**
- **understand the positive impact of eating less meat**

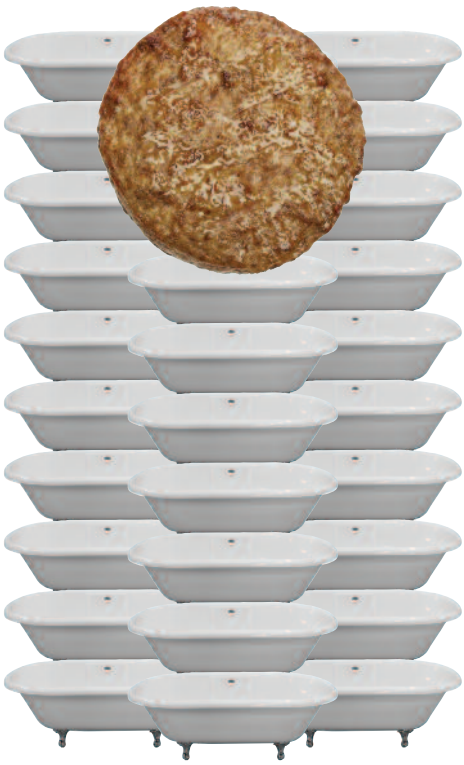
Accompanying Materials

Measuring Meat Free Monday – Sources

Activity 3: Beef burger versus Bathing

Once your students are confident in using the unitary method, move on to comparing the amount of water used in producing a beef burger to that used in taking a bath or shower by talking through the following calculations.

It is known that, on average, the amount of water used in producing one 150g beef burger is 2350 litres. It is also known that, on average, one bath uses 80 litres of water.
(See **Sources** for details.)



Start by condensing the given information into a short sentence focussing mainly on the numbers:

$$80 \text{ litres of water} \quad \approx 1 \text{ bath}$$

Step 1 (How much of a bath uses 1 litre of water)

$$\div 80 \rightarrow \quad 1 \text{ litre of water} \quad \approx \frac{1}{80} \text{ of bath}$$

Step 2 (How many baths use 2350 litres of water)

$$\times 2350 \rightarrow \quad 2350 \text{ litres of water} \approx \frac{2350}{80} \text{ of baths}$$

$$\frac{2350}{80} = 29.375, \text{ which is just a bit less than } 30.$$

Conclusion: The amount of water used in producing one 150g beef burger is enough to fill roughly 30 bathtubs.

Activity 4: Beef burger versus Showering

This time, instruct the students to work in groups to come up with the answer. Give them the following information.

It is known that, on average, the amount of water used in producing one 150g beef burger is 2350 litres. It is also known that on average, one 8-minute shower uses 62 litres of water.
(See **Sources** for details.)

Teacher notes:
Start by condensing the given information into a short sentence focussing mainly on the numbers:

$$62 \text{ litres of water} \approx 8 \text{ minutes of 1 shower}$$

Step 1 (How many minutes of shower use 1 litre of water)

$$\div 62 \rightarrow \quad 1 \text{ litre of water} \quad \approx \frac{8}{62} \text{ minutes of shower}$$

Step 2 (How many minutes of shower use 2350 litres of water)

$$\times 2350 \rightarrow \quad 2350 \text{ litres of water} \approx 2350 \times \frac{8}{62} \text{ minutes of shower}$$

Step 3 (How many hours of shower use 2350 litres of water)

$$\div 60 \rightarrow \quad 2350 \text{ litres of water} \approx \frac{2350 \times 8}{60 \times 62} \text{ hours of shower}$$

$$\frac{2350 \times 8}{60 \times 62} = 5.05$$

Bring the class together and see what answers the students came up with. They should have found:

The amount of water used in producing one 150g beef burger is enough to have a five-hour shower.

Section 2: Rate of Amazon Deforestation

Activity 1: Discussion

Start a discussion about tropical rainforests. Establish that tropical rainforests draw in carbon dioxide and give out oxygen. Destroying areas of the Amazon rainforest, the largest in the world, reduces this benefit and also results in larger amounts of greenhouse gases entering the atmosphere. Deforestation also destroys the homes of millions of species of animals and plants. There are vast areas of the Amazon rainforest being cleared to make space for cattle farming.

Ask the students to imagine the size of a football pitch, and then ask them how many 'football pitch sized' areas they think are cut down every hour to create room for grazing cattle. After some discussion, say that the maths topic of converting between different units of measure will be used to get an answer to this question.

Activity 2: Planning the Calculation

Begin by asking the students what information they think will be needed in order to make the comparison. After some discussion around this, tell them that international organisations give the amount of Amazon rainforest cut down for cattle as a number of square kilometres per year. Also, from FIFA rules, the area of a football pitch is calculated as a number of square metres. Then guide the students to realising that, in order to convert the number of square kilometres per year to a number of 'football pitch sized areas per hour', it is necessary to work out:

- **the number of square metres in a square kilometre**
- **the number of hours in a year**
- **the area of a football pitch in square metres**

The conversion can then be carried out as follows.

km^2 *per year*

→ m^2 *per year*

→ m^2 *per hour*

→ *'football pitches' per hour*

Activity 3: Doing the Calculation

Use the following facts:

- **In 2016, the area of Amazon deforestation was 7893 square kilometres.**
- **The percentage of deforested area used for cattle pasture was in the range 70-80%. For this project, assume a figure of 70%.**
- **FIFA approved football pitch dimensions are: length between 90 and 120 metres, and width between 45 and 90 metres. A pitch 100 metres long and 60 metres wide has area (100 x 60 =) 6000 square metres.**

(See **Sources** for details.)

Suggest to the students that they might find it useful to work through the following steps.

Step 1 (Finding the number of square kilometres cut down for cattle grazing per year)

The number of square kilometres cleared for cattle each year = 70% of 7893

$$= \frac{70}{100} \times 7893 = 5525.1$$

Step 2 (Changing to square metres per year)

1 kilometre = 1000 metres, so
1 square kilometre = 1000000 square metres

The number of square metres cleared for cattle each year = 5525.1 x 1000000
= 5,525,100,000

Step 3 (Number of hours in a year)

1 year = 365 days
1 day = 24 hours

The number of hours in a year = 24 x 365
= 8760

Step 4 (Changing to square metres per hour)

The number of square metres cleared for cattle each year = 5,525,100,000
The number of hours in a year = 8760

The number of square metres cleared for cattle each hour $= \frac{5,525,100,000}{8760} = 630719$

Step 5 (Changing to football pitches per hour)

Area of forest cleared for cattle each hour = 630719 square metres

Area of football pitch = 6000 square metres

Number of football pitch sized areas cleared for cattle each hour $= \frac{630719}{6000} = 105.1$

Conclusion: An area of Amazon rainforest the size of more than a hundred football pitches is cut down every hour to create room for grazing cattle.

Activity 4: Algebraic Formula

Talk through the following.

The calculation in Activity 3 was based on particular values for the area of Amazon deforestation (7893 km^2), the percentage of this used for cattle (70%) and the area of a football pitch (6000 m^2). In the next activity, these numbers are replaced by symbols.

Suppose that:

- **the annual average area of Amazon deforestation is x square kilometres,**
- **the percentage cleared for cattle pasture is p%,**
- **the area of a football pitch is y square metres.**

How many football pitch sized areas of Amazon rainforest are cut down each hour to make room for cattle grazing?

Step 1 (Finding the number of square kilometres cut down for cattle grazing per year)

The number of square kilometres cleared for cattle each year $= p\%$ of x

$$= \frac{p}{100} \times x$$

$$= \frac{px}{100}$$

Step 2 (Changing to square metres per year)

1 kilometre = 1000 metres, so

1 square kilometre = 1000000 square metres

The number of square metres cleared for cattle each year

$$= \frac{px}{100} \times 1000000$$

$$= 10000\,px$$

Step 3 (Number of hours in a year)

1 year = 365 days

1 day = 24 hours

The number of hours in a year = 24×365

$= 8760$

Step 4 (Changing to square metres per hour)

The number of square metres cleared for cattle each year = $10000px$

The number of hours in a year = 8760

The number of square metres cleared for cattle each hour

$$= \frac{10000\,px}{8760}$$

$$= \frac{1000px}{876}$$

Step 5 (Changing to football pitches per hour)

Area of forest cleared for cattle each hour

$$= \frac{1000\,px}{876} \text{ square metres}$$

Area of football pitch = y square metres

Number of football pitch sized areas cleared for cattle each hour

$$= \frac{1000\,px}{876} \div y$$

$$= \frac{1000\,px}{876y}$$

So an area of Amazon rainforest the size of $\frac{1000px}{876y}$ football pitches is cut down every hour to create room for grazing cattle.

Activity 5: Using a Spreadsheet

Ask your students to start a new spreadsheet and type the following headings in the following squares.

In B2, type 'area cut down'
In D2, type '% for cattle'
In F2, type 'football pitch area'
In H2, type 'pitches per hour'
In H3, type: =(1000*B3*D3)/(876*F3) and drag this down the H-column for, say, 10 rows.

Students can now type in any values for the area cut down, the percentage for cattle and the football pitch area in the squares B3, D3 and F3 (respectively) and a figure will automatically appear in the square H3. This figure will be the number of football pitch sized areas of Amazon rainforest cut down each hour to make room for cattle grazing (corresponding to the values entered in B3, D3 and F3).

They can do the same thing for rows 4, 5, and so on, to get a whole range of different scenarios.

Activity 6: Conclusions

Eye-catching statistics and newspaper headlines can sometimes be misleading. The statement about the number of football pitches lost to cattle grazing per hour is valid, but students should be aware that there are three variables involved:

(a) The number of square kilometres of Amazon deforestation per year,
(b) The percentage of (a) cleared for cattle pasture,
(c) The area of a football pitch.

There is variation in (a) according to which year is considered or which range of years is considered (from which an average annual figure is calculated) and there is variation in (c), as FIFA specified lengths and widths of pitches have a fairly wide range (even different ranges for international matches and non-international matches). There is even some variation in (b), as these figures are very difficult to estimate and depend on which subsidiary factors are taken into account. Recent papers indicate a range of 70-80%.

In view of the variation in these three variables, students could explore what choices of their values give various different answers. For example, they could consider the average annual deforestation over the ten years 2007-2016 (7502 sq km), a cattle percentage mid-way in the range (75%) and the smallest international-sized pitch (6400 sq m). (These values also give that an area of Amazon rainforest the size of more than a hundred football pitches is cut down every hour to create room for grazing cattle.)

Although less related to the current situation, students could also consider the extreme values of the data: the 2004 figure of 27772 sq km of deforestation, 80% for cattle and a 4050 sq m football pitch size. These values give a figure of 626 pitches per hour. This could be presented as '10 a minute' or as 'one every six seconds'. Which of these do your students think has the most impact? Their answers could lead on to a more general discussion about choices in the presentation of statistics.

Having seen how varying inputs on the spreadsheet produces varying outputs, students may wish to do some online research and construct their own spreadsheets for sets of data in other areas. If they come up with any new hard-hitting Meat Free Monday facts, please send them to info@meatfreemondays.com – we'd love to see them!

Section 3: Meat Free Monday versus Not Using the Car

Activity 1: Discussion

Burning petrol or diesel when driving a car emits carbon dioxide into the atmosphere. It is known that, for a person whose car does 30 miles to the gallon, doing Meat Free Monday would reduce their carbon footprint by the same amount as driving 448 fewer miles each year. (See **Sources** for details.) How can we use this fact to explore the various consequences of people doing Meat Free Monday? How many days of taking a car off the road would reduce greenhouse gas emissions by the same amount as someone skipping meat one day a week for a year? Or if everyone did Meat Free Monday for a year, how many hours of all cars being taken off the road would that be equivalent to, in terms of benefit to the environment?

Extension Idea

Having estimated the impact of one person doing Meat Free Monday for a year (in terms of a period of their car being off the road), further work could include an investigation of the environmental impact of *everyone* skipping meat for just *one* day. Additional data needed would be population and car total figures which, for Great Britain in 2016, were 63.8 million and 30.9 million, respectively. Assumptions similar to those used earlier in this lesson lead to the conclusion that, if every person in Great Britain skipped meat for one day, it would reduce our carbon footprint by more than if every car was taken off the road for one day!

Activity 2: Applying the Unitary Method

Guide your students through the following calculations.

Start by condensing the given information into a short sentence focussing mainly on the numbers:

1 person going meat free for 52 days ≈ 1 car with 30 mpg reducing driving by 448 miles.

This sentence has 5 variables, rather than just two or three as in the earlier examples, but the same principle of successively writing parallel sentences applies. Other (British) data to be used are:

- **Average driving per car in one year = 7800 miles**
- **Average fuel consumption = 45 mpg**

(See **Sources**.)

Step 1 (Changing to average fuel consumption)

1 person going meat free for 52 days ≈ 1 car (30 mpg) reducing driving by 448 miles.

÷30 → 1 person going meat free for 52 days ≈ 1 car (1 mpg) reducing driving by $\frac{448}{30}$ miles

×45 → 1 person going meat free for 52 days ≈ 1 car (45 mpg) reducing driving by $45 \times \frac{448}{30} = 672$ miles

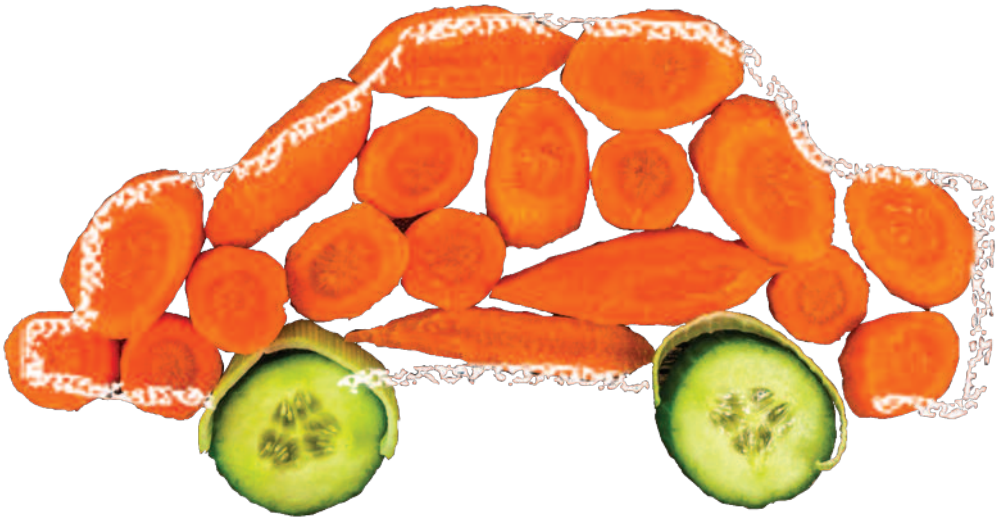
Step 2 (Changing to 'driving days')

Car drives 7800 miles in 365 days

÷7800 → Car drives 1 mile in $\frac{365}{7800}$ days

×672 → Car drives 672 miles in $672 \times \frac{365}{7800} = 31.4$ days

Conclusion: Doing Meat Free Monday for a year reduces a person's carbon footprint by more than taking their car off the road for 31 days – a whole month!



Activity 3: Algebraic Formula

Talk through the following.

The calculation in Activity 2 was based on a person driving 7800 miles a year with a car whose fuel consumption was 45 mpg. In order to consider different scenarios, we can consider cars with different fuel consumptions and drivers with different annual mileages. We are then varying the number of miles per gallon and the number of miles driven in a year, and considering these numbers as variables.

Suppose a person has a car with fuel consumption of x miles per gallon and they drive an average of y miles a year. How much time of not driving their car has the same environmental benefit as skipping meat for one day a week?

As before, begin with the fact that for person driving a car with a fuel consumption of 30 miles per gallon, skipping meat for one day a week reduces their annual carbon footprint by as much as reducing their driving distance by 448 miles.

Remind your students to start by condensing the given information into a short sentence focussing mainly on the numbers:

1 person going meat free for 52 days ≈ 1 car with 30 mpg reducing driving by 448 miles.

Then ask the students to work on their own (or in groups) through the following two steps.

1 **Changing to x miles per gallon**
2 **Changing to 'driving days'**

It may be helpful to talk with the class as a whole, consolidating the first step before going on to the second.

Step 1 (Changing to x miles per gallon)

1 person going meat free for 52 days ≈ 1 car (30 mpg) reducing driving by 448 miles

÷30 → *1 person going meat free for 52 days ≈ 1 car (1 mpg) reducing driving by* $\frac{448}{30}$ *miles*

× x → *1 person going meat free for 52 days ≈ 1 car (x mpg) reducing driving by* $\frac{448}{30}x$ *miles*

Step 2 (Changing to 'driving days')

Car drives y miles in 365 days

÷ y → *Car drives 1 mile in* $\frac{365}{y}$ *days*

× $\frac{448x}{30}$ **→** *Car drives* $\frac{448x}{30}$ *miles in* $\frac{448x \times 365}{30y}$ *days*

As $\frac{448 \times 365}{30} = \frac{16352}{3}$ the conclusion is that skipping meat for one day a week reduces the person's annual carbon footprint by as much as not driving their car for $\frac{16352x}{3y}$ days.

So now, rather than just using the average fuel consumption and average annual mileage, students can work out the environmental benefit (in terms of the number of days of the car being off the road) for any combination of fuel consumptions and annual mileages.

Activity 4: Questions

The following questions could be given to the students to work on in groups. Alternatively, you may wish to set them as homework.

1 **A person has just bought a new car which does an average of 52 mpg and they drive 9,000 miles in the first year. How many days would they have had to leave their car off the road in order to reduce their carbon footprint by the same amount as by doing Meat Free Monday for the year? (Answer: 31.5 days)**
2 **A person has an older car which does an average of 30 mpg and they only drive 5000 miles a year. How many days of not driving their car has the same environmental benefit as doing Meat Free Monday for a year? (Answer: 32.7 days)**
3 **A person who drives their car 6000 miles a year knows that if they kept if off the road for 40 days each year, this would reduce the amount of carbon dioxide emitted into the atmosphere by the same amount as if they skipped meat for one day every week. What is the fuel consumption (mpg) of the car? (Answer: 44 mpg)**

Activity 5: Using a Spreadsheet

Ask the students to start a new spreadsheet and type the following headings in the following squares.

In B2, type 'mpg' (for 'miles per gallon')
In D2, type 'Annual mileage'
In F2, type 'Non-driving days'
In F3, type: =(16352*B3)/(3*D3) and drag this down the F-column for, say, 10 rows.

They can now type in any values for the fuel consumption and annual mileage in the squares B3 and D3 (respectively) and a figure will automatically appear in the square F3. This figure will be the number of days of taking the car off the road which (for the mpg and mileage values in B3 and D3) has the same environmental benefit as doing Meat Free Monday for a year.

Students can do the same thing for rows 4, 5 and so on and get a whole range of different scenarios.

Every increase in the mpg in the B column gives an increase in the non-driving days in the F column and every increase in the mileage in the D column gives a decrease in the non-driving days in the F column. So students can explore what combinations of mpg and mileage values give various different values for the number of non-driving days.

Measuring Meat Free Monday – Sources

Section 1: Beefburger versus Bathing or Taking a Shower

1.1. Water for Baths and Showers

Average amounts of water used in taking a bath (80 litres) or shower (62 litres) are given at: www.waterwise.org.uk/news.php/11/showersvs.bathsfactsfigures andmisconceptions (accessed 16 October 2017).

1.2. Water for Burgers

The average amounts of water used in producing one 150g beef burger (2350 litres) and one 150g veggie burger (158 litres) are given in the article *The water footprint of soy milk and soy burger and equivalent animal products,* by Ercin AE, Aldaya MM and Hoekstra AY, in Ecological Indicators, 18, 2012, p.400. (As 2350 ÷ 158 = 14.9, it follows that the amount of water used in producing a beef burger is roughly 15 times the amount used in producing a veggie burger.)

Section 2: Rate of Amazon Deforestation

2.1. Amazon Deforestation

The numbers of square kilometres per year of deforestation are calculated from the figures given by PRODES for each of the years 2004 to 2016 [Instituto Nacional de Pesquisas Espaciais, INPE – PRODES (2016) at http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes (accessed 16 October 2017). These figures are as follows.

2004: 27772	2009: 7464	2014: 5012
2005: 19014	2010: 7000	2015: 6207
2006: 14286	2011: 6418	2016: 7893
2007: 11651	2012: 4571	
2008: 12911	2013: 5891	

In addition to the figures used in 'Measuring Meat Free Monday' for the single years 2016 and 2004, the average for the 10-year period 2007-2016 was used. This was obtained by adding the relevant 10 annual figures and dividing by 10: 75018/10 = 7501.8.

2.2. Cattle Pasture Percentage

A source for the percentage of deforested area used for cattle pasture being in the range 70-80% is:
Bustamente MMC, et al., *Estimating greenhouse gas emissions from cattle raising in Brazil*, Climatic Change, 115 (2012) pp 559–577 [DOI 10.1007/s10584-012-0443-3].
Although this paper was published in 2012, it was confirmed in September 2017 by a Senior Manager in Tropical Forest and Agriculture at the National Wildlife Federation that 70% continues to be a conservative estimate for the percentage of deforested area used for cattle pasture.

2.3. Football Pitch Sizes

FIFA approved football pitch dimensions are given on page 34 of FIFA's 'Laws of the Game 2017/2018' (www.fifa.com/mm/Document/FootballDevelopment/Refereeing/02/90/11/67/Lawsofthegame2017-2018-EN_Neutral.pdf, accessed 16 October 2017)
The length of the pitch must be between 90 and 120 metres, and the width must be between 45 and 90 metres. For international matches, the length must be between 100 and 110 metres, and the width must be between 64 and 75 metres.

Section 3: Meat Free Monday versus Not Using the Car

3.1. Food Miles

In the paper *Food-miles and the relative climate impacts of food choices in the United States*, by CL Weber and HS Matthews, in Environmental Science & Technology (2008), 42(10), pp 3508-13, it is stated that an average US household shifting their calories from red meat to a vegetable-based diet for 52 days (one day a week for one year) reduces GHG emissions by an amount equivalent to the emissions from a car, with a petrol consumption of 25 miles per US gallon, driving 1160 miles. The 2000 US Census gives the average number of people per US household to be 2.59, and 1160 divided by 2.59 is 448. A petrol consumption of 25 miles per US gallon is the same as 30 miles per UK gallon (as 1 UK gallon is roughly 1.2 US gallons and 25 x 1.2 = 30). So we have that one person shifting their calories from red meat to a vegetable-based diet for 52 days reduces GHG emissions by an amount equivalent to the emissions from a car, with a petrol consumption of 30 miles per UK gallon, driving 448 miles.

Remark. In going from '25 miles per US gallon, 1 US household ~ 1160 miles' to '30 miles per UK gallon, 1 person ~ 448 miles', there are two applications of the unitary method which, in themselves, could be used as exercises for students.

3.2. Car Mileage

The figure of 7800, for the average number of miles within Great Britain (England, Wales and Scotland) driven by an England-registered car in 2016, is given in 'National Travel Survey: England 2016' (p.12) at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/633077/national-travel-survey-2016.pdf (accessed 16 October 2017).

3.3. Fuel Consumption

Table Env0103 from the UK Government's fuel consumption statistics at: www.gov.uk/government/statistical-data-sets/env01-fuel-consumption (accessed 16 October 2017) gives the average fuel consumption in 2015 for new cars in Great Britain to be 52.1 mpg for petrol and 61.7 mpg for diesel. The figures for the previous five years (2010-2014) are between 44.7 and 51.1 for petrol, and between 51.9 and 60.0 for diesel. The figure of 45, chosen for the application of the unitary method, is at the lower end. Using a higher figure would give a result higher than 31.4 days.