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Energy embodied in household cookery: the missing part of a sustainable food system? Part 1: A method to survey and calculate representative recipes

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Abstract

This paper firstly reviews the current state of knowledge on sustainable cookery and the environmental impacts of the food consumption phase. It then uses the example of a dish of roast beef and Yorkshire pudding to explore energy use in food production and consumption. Part 1 of this paper conducts a meta-analysis of 33 roast beef and Yorkshire pudding recipes in order to create a representative recipe for analysis. Part 2 of this paper then uses life cycle assessment and energy use data is coupled with the representative recipe of roast beef and Yorkshire pudding, to calculate the embodied energy of the meal. Seven interventions are modelled to illustrate how sustainable cookery can play a role as part of a sustainable food system. Interventions show that sustainable cookery has the potential to reduce cookery related energy use by 18%, and integrating sustainable cookery within a sustainable food system has the potential to reduce the total energy use by 55%. Finally, the paper discusses the issue of how the adoption of the sustainable cookery agenda may help or hinder attempts to shift consumers towards sustainable diets.

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Keywords: Energy demand and resource use in food consumption; life cycle assessment; cooking; home-made meals; Environmental impacts; LCA; food; meal; food energy and water nexus; energy and resource use in food consumption

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1. Introduction

The production, transport, and consumption of food uses energy and has global environmental impacts [6,8,25,35,67,70]. One of the major environmental impacts is anthropomorphic climate change. This is caused by greenhouse gas emissions (GHGE) related to human activity – such as food production and consumption. Climatic change will affect many aspects of global life, including the food system; altering crop production rates due to extreme weather events (floods and droughts) leading to food shortages and hunger [66].

A way to reduce GHGE is to change our production methods and consumption patterns to be less GHGE intensive. Currently food production and consumption is interlinked with GHGE generating energy generation methods (such as coal and gas), with the UK food system estimated to contribute about 9% and 20% of total UK GHGE from agriculture (in 2015) and the total food system (in 2008), respectively[2,13,30]. The latest UK GHGE reduction targets – as outlined in the 5th Carbon Budget and the Paris Agreement – are a 57% reduction from 1990 GHGE values by 2032, and an 80% reduction by 2050 [13]. Change towards a lower energy use, and lower GHGE generating food production and consumption system is necessary to meet the UK's legally binding GHGE reduction targets [65].

UK agricultural production systems are increasing in energy efficiency, and there is growing consumer awareness of what makes a sustainable healthy diet [3,7,40,62], with other countries adopting sustainable national dietary guidelines[26,29,33,37,46,47]. This shift towards a sustainable low energy food system is occurring to a lesser extent within household cooking practices. There has been less of a connection in the minds of consumers, industry, and government policy between cookery practices and their environmental impacts, even though the household cookery and storage phase may be up to half the total energy use in a food product's life cycle [10]. This is a missed opportunity and a necessary step to create a sustainable food system.

Currently 10% of yearly UK household energy use is related to cooking, while 13.8% is related to cold appliances. In addition, 20% of peak UK load is used for cooking and 10% for cold appliances [19,52]. This is less than it was 40 years ago, with the household energy use associated with cooking having more than halved since the 1970s [14]. However, these gains have not typically come from energy efficiency increases in cooking methods and cold storage appliances. Instead, gains in energy efficiency have come from the adoption of more efficient cooking devices (such as microwaves – more energy efficient when compared to traditional oven usage [45]), and the expansion in 'ready meals' and takeaways being eaten at home, and an increase in the number of meals eaten outside the home [14,22].

Previous research has used life cycle assessment methods to compare the energy and environmental impacts of homemade, ready meals, and takeaways. Examples of meals compared include a roast chicken dinner [57,58]; a chicken ready meal [17]; a cottage pie [20,21]; a hamburger [11]; a meatball meal [60,61]; ready meals of pork chops, sausages, pea chops, or pea burgers [18]; and a pasta meal, lamb meal, sausage meal, chicken fillet meal, and tortellini meal [5]. In addition, the energy impact of the typical Spanish diet [48] and the UK diet [39] have been modelled, along with the energy impacts of a variety of ingredients [10,44,68] and cooking methods [28]. Due to the number of variables to consider the results are mixed as to if home cooking or ready meals are more energy efficient. What is certain is that the consumption at home of 'ready meals' and takeaways, and the increase in eating outside the home is shifting energy use away from household into the rest of the food system.

Eating out in the UK is on the rise [64], with 75% of the population eating out of home at least once in seven days in 2014, rising from 65% in 2010. However, the majority (63%) of the 75% who do eat out, only do so once or twice a week. Only 14% of the 75% who do eat out (11% of the total UK population), do so with any frequency (6 times a week or more), and 23% eat out 3 to 5 times per week [41]. It is known that the energy consumption of the hospitality sector is different to that of households, with industry being motivated to reduce energy consumption due to financial drivers [1,9,11,16,34,51]. An Australian study has modelled that the consumption of food outside the home has lower energy, water, GHGE and waste footprints than household food consumption [56]. However, there is an overall lack of research examining the sustainability and energy implications of eating outside the home compared to eating at home and the implications of this demand shift.

At home the methods of cooking food have changed little over the last forty years with either baking in an oven (convection), frying on the stove top (conduction), or cooking in a microwave (radiation) being the most popular methods of cooking [14,31,42,43,71]. In addition, the majority of home cooking is still being performed at peak energy demand times [24,42]. It has now been identified that different consumers do cook differently and have differing relationships with food production, shopping, cooking and consumption, and these differences lead to different energy usage footprints for different types of individuals and households [23,38,50]. Interventions are now being designed to target specific groups to shift cooking away from peak energy demand times [24,42].

Other strategies to reduce energy use include influencing consumers to change their diet (changing what or how much they eat to less energy intensive products) or change how they cook their foods [36]. The latter of these strategies has been encouraging switching from traditional cooking methods towards lower energy methods such as slow cookers, microwaves, and – most recently – sous vide cookery.

The sous vide (French for ‘‘under vacuum’’) method has become an increasingly popular form of cooking that provides cooks with exacting control over the ‘doneness' and texture of foods [4]. The hospitality industry has used sous vide cookery since the 1970s, with the method having wider industry adoption by the mid-2000s. Since the early 2010s sous vide machines have been available to the global domestic market [4,55,63]. The sous vide cooking method involves the placing the raw food in a vacuumed plastic pouch/bag and submerging this in a heated water bath for several hours until the internal core temperature reaches the desired temperature, this is then cooked in the water bath for the desired time duration. As sous vide cookery features a long cooking time, it has the advantage of cooking occurring at off peak times, thus spreading the energy demand across the temporal spectrum.

Energy use data on household cooking appliances is difficult to source as there are many variables to take into account [12]. In addition, lists of typical kWh energy use for domestic appliances are not published frequently, and when they are published, there is a lack of harmonisation and detail among them. For example, in some literature domestic ovens use typically use 2kWh [68] but have been reported in other papers to be as high as 2.5 kWh [49,69]. In addition, these kWh readings are for a typical usage cycle, and I have been unable to find detailed data on oven energy usage at different temperatures.

In these two papers I couple life cycle assessment data with the recipe of roast beef and Yorkshire pudding to explore the energy use in food production and consumption. In this paper (part 1) I conduct a meta-analysis of roast beef and Yorkshire pudding recipes to create a representative recipe. To illustrate how sustainable cookery can play a role as part of a sustainable food system, in part 2, I then model how seven possible interventions impact on energy use within the context of this recipe. Interventions include different cooking methods, ingredient change, and increasing appliance efficiency.

I have selected roast beef and Yorkshire pudding as it is a traditional British dish dating back to the 1700s that involves primarily oven cookery. It was selected as it is a relatively ‘simple’ meal to prepare with minimal ingredient variation between recipes; one roasts a joint of beef, mixes a batter of eggs, flour, and milk or water, and then cooks this batter in a small amount of hot fat (dripping or oil) in an oven while the joint is resting [32,72]. Historically, the batter pudding was served prior to the beef, in order to fill up (satiate) the eater, (and thus eat less beef). However, modern recipes serve both at once, with larger portions of beef than were historically served. As roast beef and Yorkshire pudding contains a large amount of animal products, this meal is representative of many typical western/British foods, and has relatively high environmental impacts. If this meal's impacts can be reduced, similar methods can be applied to other contemporary meat centric dishes.

2. Methods

2.1. Meta-analysis of recipes

This section outlines a meta-analysis of recipes as a method to create a representative median recipe for further analysis.

Recipe books provide a set of instructions, ingredients and cooking methods that are the recommendation of that book's compiler. However, there is no one authentic or true recipe for each dish, as each cook has their own version, unique to that time, place and ingredients to hand [54]. Nevertheless, in order to analyse a recipe data (ingredients, methods, timings, temperatures, weights and measures) are required. Previous studies have used recipes sourced from nutritional composition guides or single recipe books [11,40,53,59]. However, published recipes in books may be inadequate for providing up-to-date insight as – by virtue of being a printed medium – they do not represent current cooking methods, tastes and portion size. In addition, a single recipe does not provide the culinary nuances found across many recipes (i.e. additional ingredients).

To address variation among recipes, ingredients and methodology, and to access recipes that were up-to-date and representative of contemporary cooking methods; I sampled recipes from website search engines (google) or online recipe archives and repositories (allrecipes.co.uk [73], thekitchn.com [74], deliciousmagazine.co.uk [75], theguardian.com [76], Aunties Recipes [77], BBC food [78], food52.com [79], yummly.uk [80], and food.com [81]). The internet was selected in preference of published recipe books due to ease of access, and the fact that recipes published on the internet are representative of contemporary cooking methods used by people at home not professional or celebrity chefs, and if on a food forum (i.e. food.com, yummily etc.) rated, modified and commented upon by the online community.

The search was conducted using the search term “Roast Beef and Yorkshire Pudding Recipe”. As shown in table 1, many items that matched this search term were found. 33 recipes were found that had both roast beef and Yorkshire pudding ingredients (with weights), a cooking methodology, and a stated number of portions. The cooking methods and ingredients of the 33 recipes were then statistically analyzed using Statistics for Google Sheets to find the median or a typically representative recipe (ingredients, methods of cooking, portion sizes, and cooking times). Note that some ingredient weights were missing from some recipes, for instance one of the 33 had only “joint of beef” rather than an exact size. These have been expressed in the results section by providing an n for all graphs to illustrate how many recipes reported weighted amounts of each ingredient.

Table 1. The websites searched for “Roast Beef and Yorkshire Pudding Recipe”, and the number of recipes that matched the criteria.

Search engine	Number of items found (3/2/2017)	Number of items that matched search criteria
google.co.uk	~366,000	13
allrecipes.co.uk	20	2
thekitchn.com	3785	-*
deliciousmagazine.co.uk	5771	-*
theguardian.com	462	2
Aunties Recipes	20	7
BBC food	10	2
https://food52.com/recipes	0	0
yummly.uk/recipes	150	6
food.com	1	1
Total		**33**

* no recipes found that were roast beef and Yorkshire pudding in one single recipe.

Once sampled the recipes were converted into metric weights and volumes. Eggs were considered to be 50g per egg [15]. Weight and volume, cup, teaspoons and tablespoon conversions were sourced from McCance and Widdowson's The Composition of Foods and allrecipies.co.uk [27,82]. If multiple cooking times for doneness were present in the recipe, the cooking time and temperature for “medium” doneness (55c to 60c internal temperature[83]) was selected. Gravy was not made as part of this median recipe, though it did feature in some – but not all – recipes sampled.

3. Results

3.1. Meta-analysis of recipes

Within the 33 recipes there were a total of 40 ingredients, of these 7 feature in the majority of recipes, and were found to be ‘core’ to the concept of what a Roast Beef and Yorkshire Pudding is. The typical recipe requires a joint of beef to be roasted (weight provided in n=30 recipes), and a batter made from milk (n=32), egg (n=33), flour (n=33), water (n=7), and oil (n=24). The batter is placed into a tin that has had heated dripping (n=11) or oil (n=24), already placed into it, this hot oil/dripping and batter mixture is then baked.

Portion sizes in the sample recipes ranged from 4 to 12 portions per recipe, with the median being 8 portions (Figure 1). Portions of beef ranged from 125g to 800g with the median portion of beef weighing 250g (Figure 2). Portions of milk ranged from 9ml through to 150ml, with the median portion of milk weighing 43ml (Figure 3). 32 of the recipes had a measured volume of milk. Portions of water ranged from 5ml through to 37ml, with the median portion of water weighing 15ml (Figure 5). Only 7 recipes featured water in a measured volume; in these recipes the amount of water was equal to or less than the amount of milk. Portions of flour ranged from 6g to 83g with the median portion of flour weighing 28g (Figure 5). Portions of oil ranged from 0.6ml through to 25ml, with the median portion of oil weighing 4ml (Figure 6). Portions of dripping ranged from 3ml through to 19ml, with the median portion of dripping weighing 7ml (Figure 7). Oil and dripping were present together in 6 of the recipes, in others they were used as substitutes. Portions of egg ranged from 6g to 100g, with the median portion of egg weighing 25g – half an egg per portion (Figure 8).

The sampled recipes featured oven cooking times ranging from 67 minutes through to 285 minutes, with a median time of 125 minutes - including 20 minutes of preheating (Figure 9). The median starting oven temperature was 200C, with temperatures varying after starting point in all recipes. However, in Figures 9 and 10, there is a cluster of three data points that are low starting temperatures (55-60C) and long cooking times (greater than 200 minutes). These represent a divergent cooking method that is termed the “low oven” method. This involves searing the joint of beef in a pan and then transferring the beef to a low oven (55-60C) until the internal core temperature of the joint was between 55-60C – i.e.200-250 minutes. The Yorkshire puddings are then cooked in the ‘traditional’ hotter oven. In all recipes Yorkshire puddings cooking times ranged between 15 and 45 minutes (including 5 minutes to heat the oil or dripping in the oven), with a median time of 25 minutes (Figure 11).

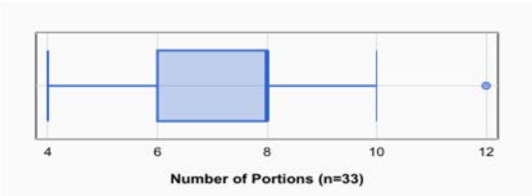

Fig. 1. Number of portions per recipe. Median 8. n=33

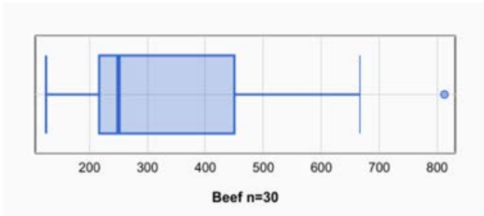

Fig. 2. Weight of beef portion (g). Median 250g. n=30

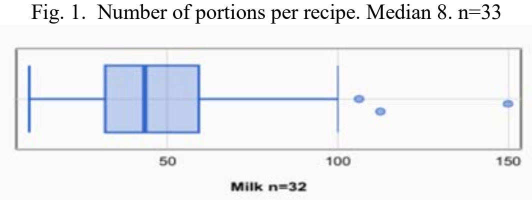

Fig. 3. Volume of milk portion (ml). Median 43ml. n=32

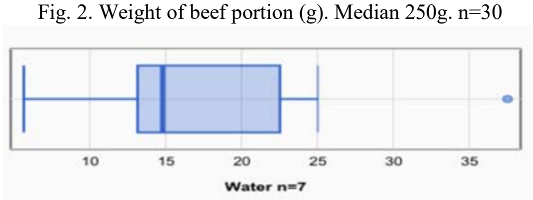

Fig. 4. Volume of water portion (ml). Median 15ml. n=7

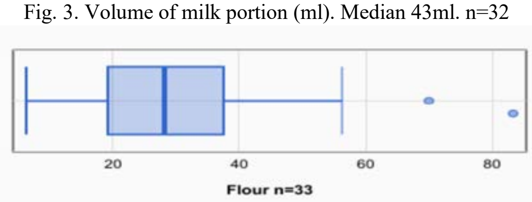

Fig. 5. Weight of flour portion (g). Median 28g. n=33

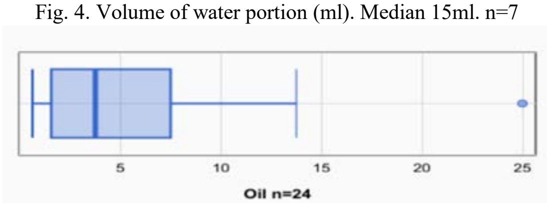

Fig. 6. Volume of oil portion (ml). Median 4 ml. n=24

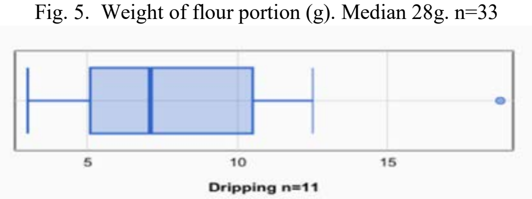

Fig. 7. Volume of dripping portion (ml). Median 7 ml. n=11

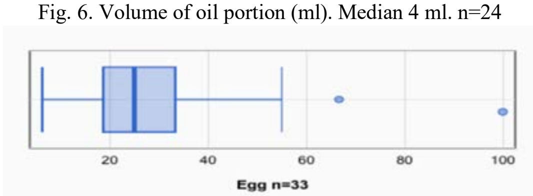

Fig. 8. Weight of egg portion (g). Median 25g. n=33

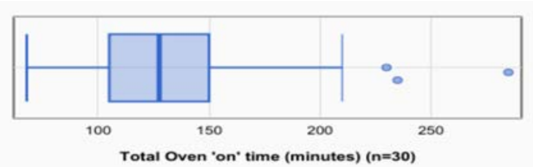

Fig. 9. Range of oven cooking times (min). Median 125 min. n=30

Fig. 10. Range of starting oven temperatures (°C). Median 200°C. n=33

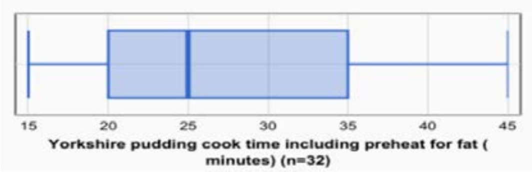

Fig. 11. Range of Yorkshire pudding cooking times (min). Median 25 min. n=32

4. Discussion

Part 1 of this paper has provided a methodology to create a representative recipe that illustrates the range of ingredient and cooking variations. This methodology is superior to using single recipes for analysis, as it provides a level of variation and confidence not found in single recipes. In addition to life cycle assessment, this method can also be used in the nutritional sciences and in gastronomy, to examine the representative nutritional content, or to examine how the recipes have evolved over time. Future studies could source recipes from online, books and magazines; and could compare recipes from different authors (cultures, nationalities, time periods, etc).

5. Conclusion

Part 1 of this paper has provided a methodology to create a representative recipe that illustrates the range of ingredient and cooking variations. Part 2 will use life cycle assessment and energy use data is coupled with the representative recipe of roast beef and Yorkshire pudding calculated in this paper, to calculate the embodied energy of the meal.

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