

THE POTENTIAL FOR SAVING FOOD WASTE BY FREEZING FOOD AT HOME

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ABSTRACT

UK consumers currently throw away around 800,000 tonnes of food (worth around €2.5 billion) each year due to it not being used in time (WRAP, 2009), much of which could be frozen to eat later rather spoiling or passing its 'use by' date. There is however confusion about whether products are suitable for freezing, and for how long they might be stored.

This paper presents results from a literature and internet-based information review, which found that although the majority of products are reported as suitable for home freezing, there is conflicting advice on some products and also marked differences between reported Practical Storage Lives (PSLs). Although offering the potential to reduce waste, increasing the use of home freezers also leads to greater energy consumption. The scale of this increase was therefore assessed experimentally and the additional costs and carbon dioxide emissions compared with those associated with the reduced food waste.

1. INTRODUCTION

Previous research (WRAP, 2009) has identified that consumers in the UK currently throw away around 2.9 million tonnes of food each year because it was not 'used in time'. Around 800,000 tonnes (worth around €2.5 billion) of this is 'freezable' food (bread, meat etc.) that could have been frozen before it reached its 'use by' or 'best before' date and eaten at a later date. Consumer research has shown that confusion about whether products are suitable for freezing and how best to freeze them to maximise their quality often leads to foods being thrown away rather than frozen (WRAP, 2010). Unfortunately scientific studies related specifically to home freezing and storage rather than commercial production of frozen products, which might help to address this issue, are scarce. There is however considerable advice and guidance on internet websites maintained by a wide variety of organisations and individuals.

Information was therefore gathered from such online sources, including advice websites maintained by government and commercial bodies, and where appropriate sites maintained by private individuals. This information was combined with the more limited data from academic publications (peer-reviewed scientific journal papers and textbooks) and commercial sources (industry guidance notes and trade press articles). The results were analysed with the aim of assessing suitability for home freezing of a range of food products, and deriving 'consensus' values for the reported storage lives of each of these products (WRAP, 2012).

Advising greater use of home freezing has an impact on the amounts of energy used by freezers (both to freeze food and because doors are opened more frequently). The scale of this increased energy use (and its cost and carbon dioxide emissions) was therefore assessed experimentally and compared with the cost and embodied CO₂e associated with the food added to the freezer (WRAP, in preparation). This paper presents a summary of the information review and results for the experimental assessment of energy impact.

2. METHOD

2.1 Literature and information review

An initial review of published literature from academic, trade and online sources concentrated on assessing the quality of available data on home freezing suitability and frozen storage life of 41 chosen food products.

The products were sliced / unsliced bread, rolls and baguettes, world breads, pizza, fruit juice, smoothies, eggs, quiche, oily fish, white fish, prawns, fruit frozen in current form, fruit treated before freezing, cooked pasta, cooked rice, mashed potato, pasta meals, rice meals, ready meals, meat pie, soup, bacon, beef, chicken / turkey, lamb, pork, sausages (raw), home cooked meat joint, cooked sliced ham, sausages (cooked), cream, hard cheese, milk, soft cheeses, yoghurt, leftover cooked vegetables, vegetables (sauced / pureed, raw), vegetables (blanched, raw), vegetables (whole / chopped, raw), fruit cake, sponge cake.

Where explicit comments on suitability for freezing of a particular product were not found, the presence of reported storage lives was taken to imply suitability. Where comments on suitability were found, the assessment determined whether it was reported that a product

- can be successfully frozen with little cellular damage (and minimal impact on texture and structure);
- can be frozen but with cellular damage (and significant degradation to texture and structure);
- can be frozen but with resultant changes to other quality traits e.g. flavour, odour or appearance;
- cannot be frozen successfully.

Using the initial assessment data, 12 products were selected for more extensive review. The selection was based on several factors: the likely impact on reducing household food waste if freezing was more widely practised; the need for information required by consumers to allow more widespread freezing, and; the availability of guidance related to home freezing, which industry might usefully employ on food packaging. The 12 products were bread, pork (cooked sliced ham, bacon, raw and cooked sausage), vegetables, fruit, pasta meals (home-made), rice meals (home-made), chilled ready meals, milk, store-bought yoghurt, fruit juice, ambient cooking sauces and meat joints (raw and cooked).

For these products there were considerable differences in suggested storage lives. The review therefore focussed on possible reasons for this, which included:

- initial product quality and age;
- storage before freezing and handling procedures;
- packaging;
- freezing method and rate of freezing;
- frozen storage conditions;
- thawing method and rate;
- need for cooking after thawing.

Where such reasons were stated, they were recorded, but often no reasons were given. In these cases only the suggested storage lives were recorded. Much of the guidance and advice was general to all products, and this was reported in a comprehensive general section separately from the specific product material.

2.2 Assessment of energy impact

An example of the UK best selling stand-alone upright freezer in 2010, the Beko TZDA504FW, was purchased and installed in a controlled environment test room running at 20°C ±0.5°C. A stand-alone freezer was chosen rather than a fridge-freezer because the energy impact is more direct and therefore measurable. This is because most fridge-freezers are controlled by a thermostat in the fridge section not the freezer

section, so the effect of adding warm food to the freezer takes longer to impact on the energy used, and the analysis of the impact is complicated by temperature behaviour in the fridge as well as the freezer section.

The freezer was loaded to approximately $\frac{3}{4}$ full in each compartment with a selection of typical frozen food items which acted as a base load. Calibrated t-type thermocouples were positioned to measure air and product temperatures at the top, middle and bottom sections of the freezer, which was connected to a power supply via a calibrated power meter (Northern Design, UK). All temperature and power data were recorded at 1-minute intervals using a Measurement Systems Datascan data logging system. A purpose-built door opening mechanism was attached to the freezer to automatically simulate a domestic door opening regime. The freezer door was opened during 2 one-hour periods each day to simulate breakfast and evening meal periods. In each of these periods the door was opened for a duration of 15 seconds every 10 minutes to an open angle of greater than 60 degrees.

The appliance was allowed to achieve stable operation at its default (as supplied) thermostat setting, but was then adjusted to achieve an approximate mean frozen food temperature of -16.7°C ($\pm 1^{\circ}\text{C}$) to match the European average freezer temperature defined in Lot 13 (2005). As the freezer had an automatic on-demand defrost, which was initiated at varying intervals of up to 5 days apart, temperatures and power were recorded at each thermostat setting until at least a full day of stable operation had been achieved after defrost.

To assess the impact of adding a mixture of chilled and ambient food to the freezer, four typical products were added:

- beef lasagne (enough for two) in air tight container, cooled to approximately 20°C ;
- beef cottage pie ready meal (approximately 400 g two person portion from an 800g pack) in original packaging of plastic tray, cooled to approximately 20°C ;
- chicken breasts (two out of a pack of four) in a freezer bag, at fridge temperature of approximately 7°C ;
- half a loaf of white sliced bread in original packaging, at temperature of approximately 7°C .

The addition of the food to the freezer was timed to be half way between two defrosts. The door opening mechanism was stopped and the freezer door manually opened to an angle of 90° . One of the portions of food was added to each of the drawers within the freezer and thermocouples were positioned in the centre and at the surface of each portion. The door was then closed and the automatic door opening mechanism re-started. The time required to add the food was approximately 2 minutes in total. The temperature and power data were again recorded until at least a full day of stable operation had been achieved after defrost to allow comparison with the stable operating period.

The additional heat load on a freezer during food addition comes from a combination of heat from the warm food added and heat gained through having an additional (and relatively lengthy) door opening. To determine the relative amounts of these heat loads, a further consecutive trial was undertaken. A period of stable operation was monitored to ensure that temperatures were equivalent to those in the previous stable period i.e. the freezer had not become iced due to insufficient defrosting. The door opening part of the food addition trial was then repeated but this time without adding the food.

3. RESULTS

3.1 Initial assessment

For the initial range of 41 products, information on suitability for freezing, practical storage life at -18°C and advice on pre-freezing treatments and handling was extracted from 71 reputable online sources, 20 peer-reviewed scientific journal papers and 9 reference books and guidance reports (including some previous WRAP publications). As might be expected the availability of data varied considerably between products, with some having multiple sources of comprehensive data and others having no sources at all. Where multiple sources were found, the advice on freezing and the values for PSL were not necessarily in

agreement. An example of this is shown in Figure 1, which presents PSLs at -18°C for frozen loaves of bread.

The majority of sources reported only one value for PSL but several gave ranges e.g. 3 to 6 months, represented on the chart by connected maximum and minimum values. Such variability could result from various factors such as

- Product: type of bread, ingredient variability, packaging materials and seal;
- Equipment: freezing rate, different patterns of fluctuations in storage temperature;
- Methods of assessment: Basis of assessment (i.e. which quality traits were assessed), measurement techniques and equipment, etc.

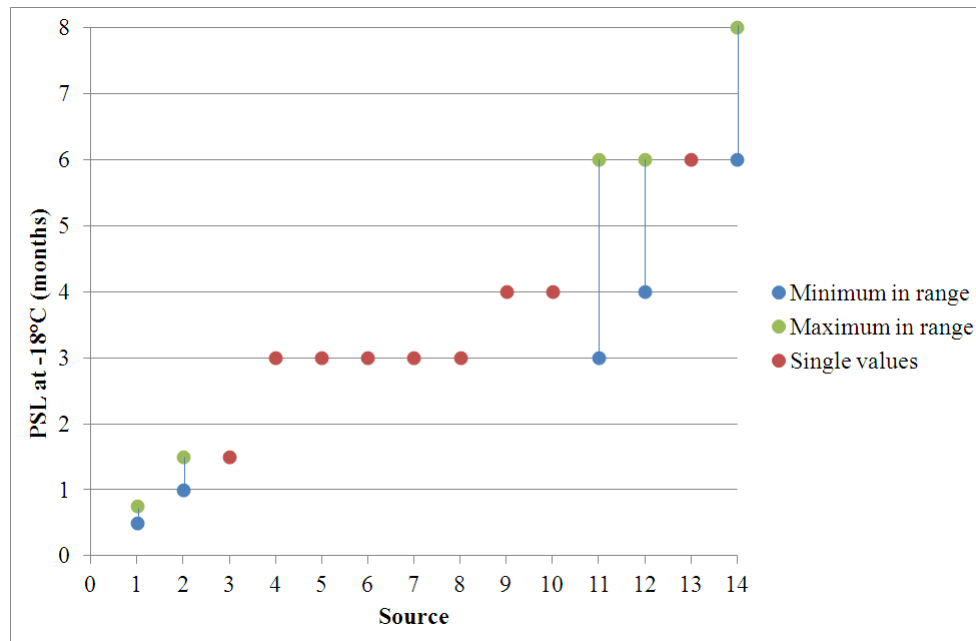


Figure 1. Reported Practical Storage Life (PSL) values for bread stored at -18°C

For the example shown, reasons for some outliers were apparent. The lowest values were for bread stored in normal plastic shop packaging with tape seals, while other larger values were for bread in more robust freezer packaging with greater moisture and oxygen impermeability and air-tight seals. However, such reasons were not always apparent and in many cases a full description of all of the above factors was not available. In these circumstances a decision to include or exclude certain sources would have been subjective and it was decided to report all values but then to determine an average ‘consensus’ value. In the case of loaves of bread, this value was taken to be 3 months.

The published report (WRAP, 2012) includes tabulated results for all 41 products, as well as both general advice and guidance for home freezing, and specific product advice.

3.2 In-depth review for 12 selected products

For the 12 selected products, all were either explicitly reported to be suitable for freezing or if PSLs were suggested it was assumed that freezing with little or no detriment to quality was possible. For each of these products, data were compiled on all reported PSLs at -18°C (which is a temperature widely used in experimental trials and for which there are therefore likely to be more abundant data).

For the sake of brevity, a summary of the product specific findings is shown in Table 1 and more extensive coverage is given in the project report (WRAP, 2012).

Table 1. Brief summary of product specific freezing information

Product	Availability of info	Suitable for freezing	Main detrimental issues during freezing	Published range of PSLs at -18°C (months)
Bread <i>Freeze in air-tight packaging. Freeze when as fresh as possible. Freeze in portions to speed up freezing rate and for ease of use.</i>	Good	Yes	Staling, dehydration	0.5 to 8
Pork (cooked sliced ham, bacon, raw & cooked sausage) <i>For best quality, freeze when fresh. Safe to freeze up to use by date (defrost and use within 24 hours). Wrap in air-tight packaging. Defrost in fridge. Remove as much fat as possible prior to freezing.</i>	Good	Yes	Rancidity, oxidation	1 to 6 (with 24 months suggested for commercial storage)
Vegetables <i>Some high water content vegetables not suitable for freezing, but many can be chopped and successfully frozen. Freeze as soon as possible to retain vitamins/nutrients. Blanching prior to freezing is essential to inactivate enzymes. Wrap in air-tight packaging. Freeze in small volumes for best results. Most vegetables can be cooked directly from frozen. Individually freeze items if possible as freezing is faster and portioning is simpler, then transfer to bags.</i>	Good	Generally yes (if blanched)	Loss of flavour, colour, texture	1 to 18
Fruit <i>Wrap in air-tight packaging. Freeze as soon after harvest / purchase as possible. Individually freeze fruits if possible to accelerate freezing rate and reduce loss of structure on thawing, then transfer to bags. Consider making fruits into sauces or purees to freeze, to save space and to utilise fruits that are likely to lose structure after thawing.</i>	Good	Mostly yes	Loss of structure	4 to 24
Pasta meals (home-made) <i>Cool rapidly after cooking. Freeze in portions, freeze in air-tight container or bag. If preparing food specifically to freeze, undercook meal to allow reheating after meal is thawed. Keep thawed product in fridge for up to 1 day before eating.</i>	Limited	Mostly yes	Separation of sauces, texture of pasta	2 to 4
Rice meals (home-made) <i>Cool rapidly after cooking. Freeze in portions, freeze in air-tight container or bag. If preparing food specifically to freeze, undercook meal to allow reheating after meal is thawed. Keep thawed product in fridge for up to 1 day before eating.</i>	Limited	Mostly yes	Bacteria growth prior to freezing	2 to 4
Chilled ready meals <i>For best quality, freeze when fresh. Safe to freeze up to use by date (defrost and use within 24h). Cook from frozen or defrost in fridge.</i>	Very poor	Yes	Separation of sauces, texture of meal	No review data WRAP survey found most packs advise 1
Milk <i>For best quality, freeze when fresh. Safe to freeze up to use by date (defrost and use within 24 hours). Freeze in small quantities if possible. Leave headspace / decant into suitable container. Thaw in fridge. Shake after thawing to re-combine.</i>	Limited	Mostly yes	Separating and curdling	1 to 4
Store-bought yoghurt <i>Freeze as soon as possible after purchase. Freeze in small quantities if possible. Freeze in air-tight container. Thaw in fridge. Stir after thawing to re-combine. Consider making yoghurt ice cream or lollies to use up spare yoghurt.</i>	Limited	Mostly yes	Texture and separation	1 to 2 plain Up to 5 flavoured
Fruit juice <i>Freeze as soon as possible after purchase. Pasteurise fresh juices. Freeze in small quantities if possible. Freeze in air-tight container. Thaw in fridge. Shake after thawing to re-combine. Consider making lollies to use up spare juice.</i>	Limited	Yes	Thickening	4 to 12
Ambient cooking sauces <i>Freeze unopened sauces as soon as possible after purchase. Decant sauces in glass jars to plastic containers / bags. Once opened, refrigerate immediately, use / freeze within time indicated on the label. If made into meals, follow guidance for home-cooked meals.</i>	Very poor	Mostly yes	Separation of sauces, texture of meal	No review data WRAP survey results suggest 1
Meat joints (raw and cooked) <i>Freeze when fresh. Safe to freeze up to use by date (defrost and use within 24h). Freeze in small portions if possible. Remove as much fat as possible prior to freezing. Wrap in air-tight packaging. Cook and eat soon after thawing or cook smaller portions from frozen.</i>	Good	Yes	Rancidity, oxidation	1 to 12

3.3 Energy impact of increased freezer use

Temperatures in domestic refrigerators and freezers are controlled by thermostats which turn the refrigeration system (compressor) on when temperatures are too warm and off when temperatures are satisfactory. The result is a cyclic on/off operation during which temperatures repeatedly pull down when the compressor is turned on and then rise again when the compressor is turned off. When the compressor is running, the power is generally very similar regardless of the heat load, as the power of the compressor

varies little while switched on. However, under greater heat loads, it is the length of time for which the compressor runs which increases overall energy consumption.

To determine the appropriate analysis periods for pull-down after loading and for stable operation, average air temperatures were calculated using the measurements from the three thermocouples positioned in the top, middle and bottom sections of the freezer. Averages were also calculated for the temperatures measured in the centres and at the surfaces of the four added food products. Figure 2 shows these average temperatures during the period following addition of the warm foods.

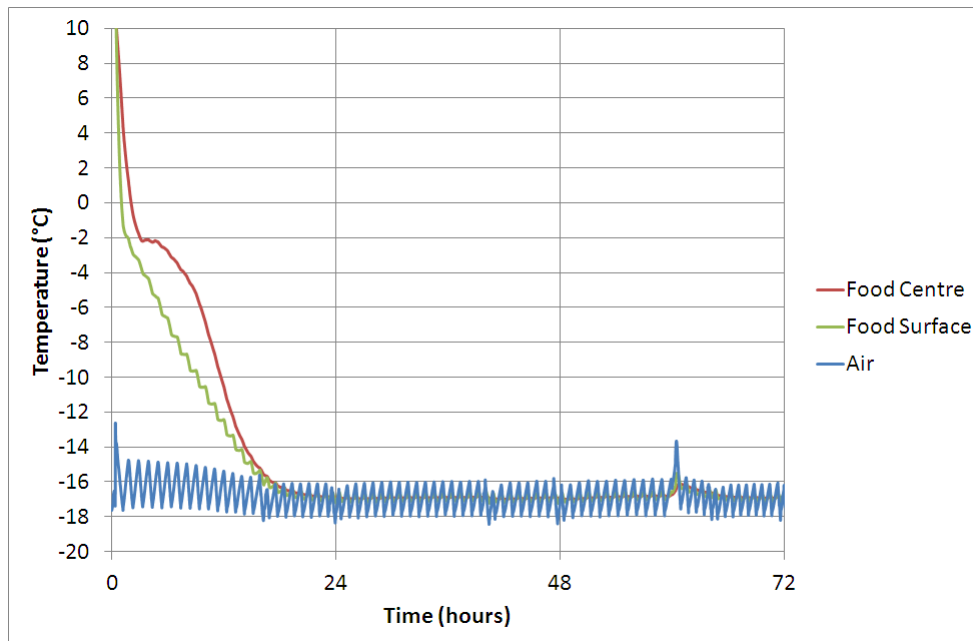


Figure 2. Average air, food centre and food surface temperatures in the freezer

The air temperatures rose initially due to the added heat load from the additional door opening and the warm food added. By the start of the second 24 hour period, the freezing process was complete and air temperatures returned to values which were similar to those in stable periods. During the third 24 hour period the freezer initiated a defrost, causing a slight rise in the average temperatures, although these quickly dropped back to stable values. The period following the additional door opening without added food showed a similar pattern, but with less of an impact on temperatures in the first 24 hours. To make sure the freezer was not progressively icing up (which could affect its performance) the lengths of defrosts in each section of the trials were checked and found to be unaffected by the warm food or additional door opening, and temperatures recovered to the same values after defrosts. Analysis periods of 24 hours were therefore chosen for assessing additional energy used after adding food or opening the door without adding food.

As described above, greater heat loads on the freezer, such as those from increased door opening or addition of warm food, will result in the compressor having to run for longer periods. This is reflected in the run times, which are the percentage of time on each day for which the compressor ran. Table 2 shows that opening the door increased the run time by a small amount (3.1 percentage points), and opening the door and adding warm food increased the run time by a greater amount (8.2 percentage points).

As expected, the energy consumed by the freezer closely aligned with its run times. For example when warm food was added, the power consumption rose by 26.7% over the first 24 hours, and the run time increased by 27.3%. When the additional door opening only was applied these increases were 9.9% and 10.6% respectively.

Table 2. Refrigeration compressor run-time and average power

Test period (<i>each of 24h duration</i>)	Run time (%)	Average power (W)
Stable operation before food added	30.0	24.0
Warm food added during 2 minute door opening	38.2	30.4
Stable operation after food added	30.2	24.2
No food added but 2 minute door opening only	33.3	26.6
Stable operation after door opening only	30.1	24.1

The extra average power from door opening and warm food was 6.4 W while that from door opening only was 2.4 W. Converting the power values to the units of energy paid for by consumers (kWh) gives the figures shown in Figure 3.

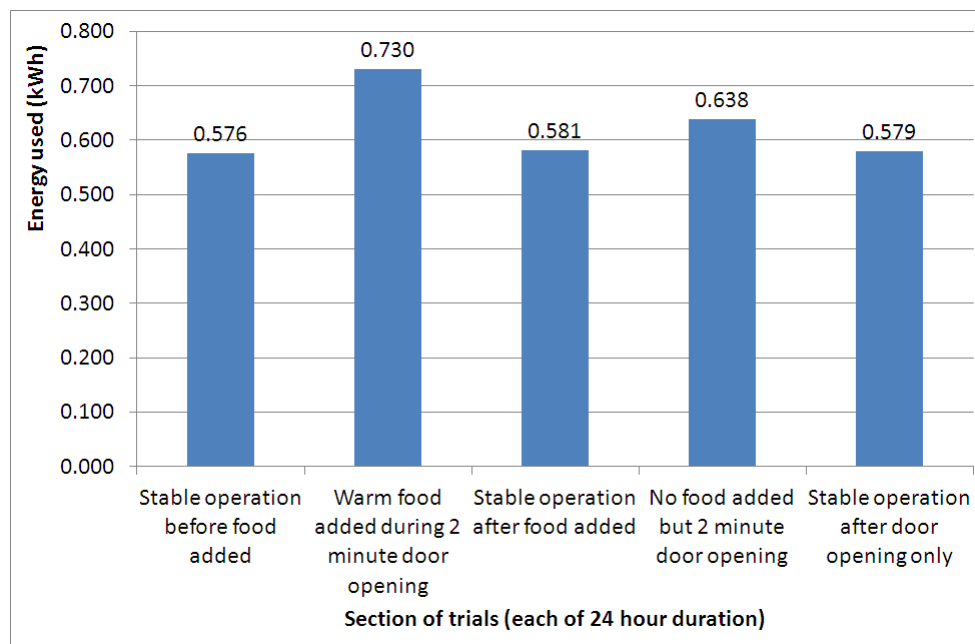


Figure 3. Energy consumed by the freezer during each 24h test period

To allow comparison of the costs and associated carbon dioxide emissions of the food saved and the increased energy, the following calculations were applied:

- The increase in energy due to food addition was $6.4 \text{ W} * 24 / 1000 = 0.154 \text{ kWh}$.
- This can be split into the increase caused by adding the warm food (4.0 W or 0.096 kWh, equivalent to 62.3%) and that caused by the door opening (2.4 W or 0.058kWh, equivalent to 37.7%).
- The cost of this extra energy was $0.154 \text{ kWh} * \text{€ } 0.139 \text{ per kWh}$ (average UK domestic price per unit: source DECC, 2011) = € 0.021. The cost of the food saved was € 6.43, giving a ratio of over 1:300 in favour of saving the food.
- The CO₂e emissions associated with the extra energy were $0.154 \text{ kWh} * 0.5246 \text{ kg CO}_2\text{e} / \text{kWh}$ (Carbon Trust, 2011) = 0.081 kg CO₂.
- The CO₂e associated with the food saved was $2.302 \text{ kg} * 3.8 \text{ kg CO}_2\text{e} / \text{kg food}$ (estimate of average CO₂e associated with wasted food, WRAP 2009 – Appendix E) = 8.75 kg CO₂e. This gives a ratio of over 1:100 in favour of saving the food.

4. DISCUSSION

The review of literature and online information found that the majority of foods are reported as being suitable for home freezing. A wide range of information sources were reviewed, with extensive and consistent information being available for some products. The lack of information for other products suggests that there are real benefits to ensuring that consumers have access to good freezing guidance either through publicity activities or in-store notices and on-pack labelling. Manufacturers are encouraged to carry out product freezing trials to help inform advice given on their products, and to their customers (for further guidance, see for example WRAP website www.wrap.org.uk/groceryresearch).

It was apparent during the review that there is a relatively high incidence of online advice originating from American and Canadian websites. An important question is whether the guidance given by such sources in one country is equally applicable in another. As food production methods, retail distribution chains and domestic freezer equipment in these countries are similar, it is probable that the advice is generally applicable, but care should be taken to ensure that advice relates to similar products with similar packaging.

Experimental assessment of the energy impact of increased home freezing showed that the potential cost and CO₂e savings associated with the saved food waste far outweigh the cost and CO₂e associated with the increased energy use. As a result, if all of the 800,000 tonnes of 'freezable' food wasted each year in the UK was instead frozen and subsequently eaten, the net value saved would be close to the value of the food (€ 2.5 billion) and the net saving in wasted emissions would be over 3 million tonnes CO₂e.

5. CONCLUSION

The vast majority of food products can be successfully frozen with little or no damage to quality. Experimental assessment showed that savings in cost and associated emissions resulting from home freezing and later consumption of food rather than disposal can be achieved with negligible increases in energy cost and emissions. The challenge is to maximise such savings through widespread publicity and increasing availability of freezing guidance in literature as well as in-store information and on-pack labelling.

6. ACKNOWLEDGMENTS

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7. REFERENCES

1. DECC (2011) UK energy prices, available online at <http://www.decc.gov.uk>, accessed September 2012.
2. Lot 13 (2005) Refrigerators and freezers. Part 2 – present situation. Task 3: economic and market analysis, Rev 1.0. Preparatory studies for Eco-design requirements for EuPs.
3. WRAP (2009) Household food and drink waste in the UK. Report available online at <http://www.wrap.org.uk/content/report-household-food-and-drink-waste-uk>
4. WRAP (2010) Understanding consumer use of the freezer. Report available online at <http://www.wrap.org.uk/content/understanding-consumer-use-freezer>
5. WRAP (2012) Review of literature about freezing food at home. Report available online at <http://www.wrap.org.uk/content/review-literature-about-freezing-food-home-0>
6. WRAP (in preparation) Estimating the impact of improved freezer use.