
Final report

Review of literature about freezing food at home



Report summarising information from online sources, together with peer-reviewed literature and reference works, for a selection of products, in order to inform WRAP's and industry's guidance to consumers on freezing food at home as a means to prevent food waste.

WRAP's vision is a world without waste,
where resources are used sustainably.

We work with businesses, individuals and
communities to help them reap the
benefits of reducing waste, developing
sustainable products and using resources
in an efficient way.

Find out more at www.wrap.org.uk

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Front cover photography: Freezing bread source: lovefoodhatewaste.com

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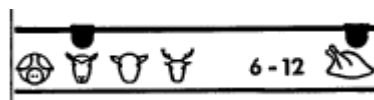
Executive summary

UK consumers are currently throwing away at least 800,000 tonnes (£2 billion) of food each year, due to it 'not being used in time', much of which could have been frozen to eat at a later date. Confusion about whether a product is suitable for freezing and how best to freeze it, to maximise its quality, are some of the reasons why foods are thrown away rather than frozen. This research aims to identify 'best practice' in terms of home freezing a range of foods, to inform customer communications and on-pack freezing guidance.

WRAP's retailer survey¹ has highlighted that there is scope for improvements to the labelling of some products to make consumers more aware that they can be frozen. However, scientific studies related specifically to home freezing and storage, rather than commercial production of frozen products, are not widespread. Despite the limited amount of published scientific data, there is considerable advice and guidance on internet websites maintained by a wide variety of organisations and individuals. In most cases, but not all, general advice such as suitability for freezing is in agreement but there is less uniformity in suggested storage lives, and freezing and thawing methods.

This report summarises information from such online sources, together with limited peer-reviewed literature and reference works, for a selection of products. The work aims to enable WRAP to communicate optimum freezing guidance to consumers through Love Food Hate Waste (www.lovefoodhatewaste.com) and partner activities and, in some cases, to provide the evidence for improvements to the freezing information provided on-pack / on-line by the food industry. WRAP has already developed a freezing guidance decision tree² for the food industry, in conjunction with the Food Standards Agency (FSA) and provides consumer guidance on freezing through Love Food Hate Waste. This research is intended to further support the development and provision of detailed freezing and thawing guidance to the food industry, and to consumers.

The review included textbooks and industry guidance, peer-reviewed scientific journal papers, trade press articles, online advice websites maintained by government and commercial bodies, and (where appropriate) sites maintained by private individuals. Discussion sites and blogs were excluded. For some products e.g. bread, previous WRAP reports were also drawn upon for further scientific and industry comment and background data. Freezer manufacturers' manuals and on-appliance storage life guides are other useful sources of information for consumers. These were not formally included in this study but some good examples have been noted within the report. For example, manuals refer to numbers shown next to product symbols (within the unit) that indicate the recommended storage periods in months for each product (shown here).



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.

¹ Ref o6b; hereafter called 'WRAP survey'. Selected data from the WRAP survey is given in Appendix 2.

² Available at: http://www.wrap.org.uk/downloads/Freezing_decision_tree.86d00971.11085.d1853d4a.11178.pdf

An initial review of published literature concentrated on assessing the quality of available data for 41 products³ selected by the project team. Where data existed, the product's suitability for freezing was recorded. The assessment looked at whether the product:

- can be successfully frozen with little cellular damage (and therefore changes to texture and structure);
- can be successfully frozen but on thawing there will be cellular damage; or
- cannot be frozen successfully; and
- is likely to sustain any changes in flavour / sensory characteristics resulting from freezing.

The literature review found that the majority of the products were suitable for home freezing, with just soft cheeses (cottage, Philadelphia, brie etc.) being generally unsuitable for freezing and conflicting advice existing on the suitability of freezing cream and cream-based sauces. There were, however, sometimes marked differences between quoted Practical Storage Lives (PSLs) for seemingly similar products. The results are summarised in Appendix 1.

Using this initial data, the project team selected 12 products⁴ for more extensive critical review. The selection was based on 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.

In compiling results from the literature review, as might be expected, it was found that many items of advice and guidance were applicable to all products. The report, therefore, begins with sections of general guidance and information relating to the safety and quality aspects of freezing, freezing rates in domestic freezers and general home freezing guidance. It then moves on to summarise the results from the detailed review for the 12 products. Where appropriate the results from the literature review are compared with data from WRAP's retailer survey 2011.

While all 12 products were generally deemed to be suitable [safe] for home freezing by most, if not all sources, there were considerable differences in suggested storage lives. Reasons for such variability are discussed in the individual product chapters and report conclusions. They include:

- initial product quality and age;
- storage before freezing and handling procedures;
- packaging;
- freezing method and rate of freezing;
- frozen storage conditions; and
- thawing method and rate and use after thawing (e.g. used straight away or cooked).

In all cases, limitations to storage life were based on quality reduction rather than food safety concerns, with freezing and frozen storage being considered to suspend microbial activity. The lack of information for some products suggests that there are real benefits to ensuring consumers have access to good freezing guidance either through communications activity or on-pack.

³ The 41 products selected were: sliced and 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 cheese (cottage, Philadelphia, brie), yoghurt, leftover cooked vegetables, vegetables (sauces / pureed, raw), vegetables (blanched, raw), vegetables (whole / chopped, raw), fruit cake, sponge cake.

⁴ The 12 products selected 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).

WRAP will use the information collected through this research to update and augment current freezing guidance provided by Love Food Hate Waste, and to inform discussions with the food industry on how current on-pack freezing guidance can be improved to give consumers the confidence to freeze foods they may not have time to eat whilst fresh, and thereby reduce food and drink waste.

Some key opportunities are to increase the prevalence of the snowflake logo on-pack to highlight that the product is suitable for home freezing, and reduce instances of text stating 'not suitable for home freezing' on e.g. milk, yoghurt, juice and cooking sauce. It will also help consumers for all freezing guidance to be accompanied by defrosting guidance and a suggested storage life (related to quality) of 1 or 3 months.

WRAP will use this report to work with the food industry and Love Food Hate Waste partners to continually improve the freezing guidance provided to consumers.

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Glossary

Freezer burn

Typically appearing as greyish-brown, dried out patches on the surfaces of frozen / thawed food, freezer burn is caused by water molecules leaving the food, predominantly through sublimation of ice into the surrounding air. This can be driven by temperature fluctuations during storage. It is not a food safety risk, and affected areas can be trimmed before use. As it can occur even in sealed packages containing sufficient air (where loose ice crystals or in-pack frosting can be observed) the best ways to minimise freezer burn are to avoid temperature fluctuations due to overly frequent door openings and introduction of too much non-frozen food all in one go or too warm food, and to ensure that tightly wrapped, air impermeable and sealed packaging is used.

Freezer loading Freezer fullness.

Frozen storage Period of time within a freezer.

Freezer wrap Cling film designed for freezer use.

ISB In Store Bakery.

Oxidation and rancidity

Fats in food (and particularly in fatty fish and meat) are prone to chemical reactions when exposed to oxygen in the air. The reactions result in development of rancidity, with attendant off-flavours and discolouration. They are catalysed by naturally present enzymes, the activity of which can be lessened by heat treatment, chemical additives such as ascorbic acid etc.

Practical Storage Life (PSL)

This is the period of frozen storage at a given temperature during which the product retains its characteristic properties and remains fully acceptable for consumption or intended processing. In practice, it is the time for which food can be stored before a consumer can notice a change in flavour, texture etc. Variations in reported PSL can result from PPP factors (see below) or from different methods (microbiological, sensory, chemical) used to assess end of PSL.

Product processing and packaging (PPP) factors

These are factors other than storage temperature and time which can affect the storage life of foods. Product refers to the nature and inherent quality of the food e.g. origin, microbiological quality, freshness on freezing etc. Processing refers to the preparation and presentation of the food, with preparation including added ingredients, physical processes such as cutting/mincing, heat treatment etc. and presentation, including factors such as block frozen rather than individual frozen. Packaging includes the type of packaging, degree of air permeability, quality of seal etc. and determines the degree of protection from oxidation and dehydration afforded to the food.

Refrigeration capacity

The amount of heat which the freezer's refrigeration system can remove, measured in Watts (W). For domestic freezers, which are designed to maintain frozen temperatures rather than freeze food, the refrigeration capacity tends to be limited and the system can easily be overloaded by introducing too much non-frozen food all in one go or too warm food.

Staling (bread)

Staling is a complex quality issue, with a major contributor thought to be starch retrogradation (Ribotta, 2007, Ref p18). Staling results in several changes, the predominant being increased firmness of the crumb and decreased firmness of the crust, with associated loss of flavour. The rate at which bread goes stale is reported to increase as storage temperature is lowered until it reaches a maximum at 4°C (Cauvain, 1998, Ref p19). At temperatures lower than this the rate decreases again. The process of freezing subjects bread to the maximum staling rate zone twice, once as it freezes and again as it thaws. It is, therefore, advantageous to freeze and thaw quickly to minimise the duration of maximum staling. Smaller, tightly-wrapped pack sizes with excess air removed will help to achieve this.

Warmed-over flavour

Resulting from the same reactions as those involved in fat oxidation and rancidity formation, warmed-over flavour occurs predominantly in cooked and subsequently re-heated meats. Descriptors for warmed-over flavour range from 'stale' and 'cardboard-like' to 'painty' and 'rancid'. As with oxidative rancidity of all fatty foods, prevention or minimisation of warmed-over flavour can be achieved using antioxidants, vacuum packing etc.

Acknowledgements

With thanks to Dr Neil Hipps, East Malling Research for helping to set up and manage the project.

Note

A note on Extension Service website references

The Cooperative Extension Service, also known as the Extension Service of the USDA, is a non-formal educational program implemented in the United States designed to help people use research-based knowledge to improve their lives. The service is provided by designated land-grant universities in various states. The websites share much of the information presented but nevertheless there are differences and inconsistencies.

A note on referencing within this report

Throughout this report, references are indicated with a letter / number that relates to the listing shown in §4.

1.0 Introduction

1.1 Safety and quality aspects of freezing

1.1.1 Safety

Freezing and frozen storage of food tends to result in degradation of quality rather than in any food safety risks. Freezing to below -12°C prevents growth of all microbes (bacteria, yeasts and moulds) present in food. Usually temperatures in domestic freezers will be much lower than -12°C so, as long as these temperatures are maintained during storage, there will be no growth or multiplication of these organisms.

However, while freezing can kill some microbes as a result of osmotic shock and dehydration (NZFSA, 2007 Ref o8), it will not kill all microbes, so once the food is thawed they can again become active, multiplying under the right conditions to levels that can lead to food-borne illness. Since the micro-organisms will then grow at about the same rate as they would on fresh food, thawed items should be handled in the same way as any perishable food. The FSIS website (Ref i32) states that while *Trichinella* and other parasites can be destroyed by sub-zero temperatures, home freezing cannot be relied upon to destroy all parasites. Thorough cooking from frozen or after thawing, however, will destroy all parasites.

1.1.2 Quality

According to the sources reviewed (FSIS website, Ref i32 and IIR Red Book, Ref o1), several quality traits can be affected by freezing and frozen storage, and it is these (rather than safety aspects) which limit the length of time that food can be stored. Of importance in this respect are changes to flavour, texture and colour. In addition, there may be attendant losses of nutrients.

There may also be moisture loss from the food, particularly with poorly sealed or air-permeable packaging. This can result in 'freezer burn', which typically appears as greyish-brown, dried out patches on the surfaces of the food. It is caused by water molecules leaving the food, predominantly through sublimation of ice into the surrounding air. Freezer burn is not a food safety risk, and affected areas can be trimmed before use of the remaining food. As it can occur even in sealed packages containing sufficient air (where loose ice crystals or in-pack frosting can be observed) the best method of minimising freezer burn is to ensure that tightly wrapped, air impermeable and sealed packaging is used.

Changes to flavour can include the onset of rancidity in fatty foods, formation of off-flavours in fruits and vegetables and in some cases the transfer of flavours from other stored products. Texture can deteriorate as a result of damage to cell walls during ice crystal formation, as a consequence of associated treatments such as blanching of vegetables, and in extreme cases, from freezer burn – particularly in poorly packaged meat and fish. Colour changes can occur due to (bio)chemical activity such as enzyme activity, physical effects such as drying or freezer burn, or again as a result of associated treatments e.g. leaching of pigments during blanching.

The severity of these changes depends on the type of food and can in many cases be mitigated. An example of this is blanching of vegetables, which inactivates enzymes which would otherwise degrade flavour, texture and colour. The relative susceptibility to changes is reflected in the Practical Storage Lives (PSLs) suggested by many sources for particular foods. The PSL of a food is defined as the period of frozen storage at a given temperature during which the product retains its characteristic properties and remains fully acceptable for consumption or intended processing. The somewhat subjective nature of this definition and

the impact of different levels of initial quality result in sometimes marked differences between quoted PSLs for seemingly similar products.

1.2 Freezing rates in domestic freezers

Domestic freezers are generally designed to accept frozen food for storage rather than to freeze chilled food. They have limited refrigeration capacity and lack the airflow required for fast heat transfer. In comparison with commercial freezing equipment, which typically operates at temperatures such as -30°C or lower, their temperatures are also higher.

For example, in a relatively small scale study of domestic freezers and freezing rates undertaken for the New Zealand Food Safety Authority in 2007 (Ref o8) it was found that the overall mean temperature of all freezers was -16.6°C. Only 28% of surveyed freezers operated at or below a mean temperature of -18°C, and 68% operated with mean temperatures between -13°C and -18°C. (NB, freezing to below -12°C prevents growth of all microbes (bacteria, yeasts and moulds) present in food.) Interestingly, freezer types (fridge-freezers with top or bottom freezer sections, upright freezers and chest freezers) were not statistically different in terms of mean temperature. A further type, not included in the temperature results, is the older design of ice-box in fridge for which freezer temperatures are more likely to be warmer. Differences were, however, found between top, middle and bottom positions within the freezers with the top being on average 2°C to 2.5°C warmer, probably due to colder, denser air falling to the bottom.

The same report included an experimental study of the times taken by domestic freezers to reduce temperatures in chicken breasts from 0°C to -5°C. In this case, one type of freezer (the fridge-freezer with bottom freezer section) took longer than the others (although again the reason is not apparent as air temperatures were very similar). The effect of loading position was as expected, in that the colder, bottom sections took significantly less time to reduce the chicken to -5°C than the warmer, top section. Similarly, the effect of the degree of loading was that half full and quarter full freezers with lower temperatures took significantly less time to reduce the chicken to -5°C than full freezers.

Freezing rates are important because slow rates can result in the formation of large ice crystals, which can cause damage to product texture / structure and result in increased loss of weight on thawing. However, while deterioration in quality during freezing is to some extent inevitable, there are unlikely to be safety issues as long as the following conditions are met:

- the freezer is operated at suitable temperatures (below -12°C) and is not overloaded with food to be frozen;
- the food has not been temperature abused prior to being frozen; and
- food packs / portions are of suitable size to avoid very slow freezing.

Even with slow rates of freezing in domestic freezers, the surfaces of food will be cooled quickly to temperatures where bacterial growth is suspended. However, temperatures in the internal regions of large food portions will take much longer to reduce, and such growth may not be suspended for some time. Larger amounts of food should, therefore, be portioned into smaller, thinner packs which will cool more quickly.

Published advice on portion size for home freezing includes a suggestion that anything weighing over 1kg will result in poorer quality after freezing, although this will obviously depend on its shape (CookUK website, Ref i4). A food with a thickness of 50 mm should freeze within 2 hours (FSIS website, Ref i32), and precautions such as avoidance of stacking, spreading out packages for freezing and leaving air gaps will help to ensure adequate freezing rates. If these precautions are taken, slow freezing rates in the domestic freezer should not present bacterial safety issues, and it has even been suggested that slow freezing

can damage and kill more bacteria than fast freezing (New Zealand government 'Foodsmart' Website, Ref i2 and NZFSA 2007, Ref o8).

Overloading the freezer with too much (or too warm) food to be frozen should be avoided as this will introduce more heat to the freezer than its refrigeration system can remove. If this happens, the freezer temperature will rise and this will both slow down rates of freezing and at the same time may affect the food already stored in the freezer.

There are also some technical aids to help avoid slow freezing, such as fast freeze and fast thaw functions found on many appliances. Fast freeze is usually a manual over-ride of the freezer thermostat to keep the compressor running, thereby lowering the freezer temperature below its normal storage temperature. Fast thaw is achieved in separate compartments with relatively warm air temperatures, giving accelerated thawing but avoiding use of ambient room temperature to thaw. Both of these functions have been found to be successful in reducing freezing and thawing times (Anderson *et al*, 2004) but fast freezing is likely to incur increased energy consumption and fast thawing needs careful use to avoid bacterial growth temperatures, hence usual guidance to defrost in a refrigerator.

A more simple method of accelerating freezing is suggested by several sources (e.g. CookUK website, Ref i4). This is to reduce the set point of the freezer several hours before introducing the product to be frozen, although it is of course only applicable to separate freezers and to fridge-freezers with dual thermostats. Assuming the appliance is capable of maintaining the lower air temperatures in the freezer, the temperature difference which drives heat transfer will be increased, giving shorter freezing times. Again, this will require greater energy consumption until the thermostat is re-set, so care must be taken to remember to do this.

1.3 General home freezing guidance

While different types of food may require specific handling or treatments to achieve the best results from frozen storage, many techniques and available guidance or advice are general to all types of food. These are summarised below and general advice of this type could be usefully included on retailer / brand websites and in magazines.

Pre-freezing

- Use products which are as fresh and high quality as possible as freezing will not improve quality.
- For best quality, freeze as soon as possible after purchase or (for home-made foods) as soon as soon as possible after production / cooking (and within 2 days).
- For store-bought foods carrying a 'use by' date, it is safe to freeze them any time before⁵ the 'use by' date, then defrost in the fridge and use within 24 hours.
- Cool warm products quickly before freezing e.g. use ice or cold water to cool pans of warm food.
- Separate products to be frozen into pieces, portions etc. Faster freezing gives smaller ice crystals and better quality, so keep packs / portions as small as possible.
- Wrapping foods well is critical, as it helps avoid moisture loss, air ingress and freezer burn.
- Slightly undercook foods if you're planning to freeze them to allow for cooking during reheating.
- Write the date you are freezing the food on the pack, so that you know how long it has been frozen for; use stock rotation if needed.

⁵ 'Before' is used to ensure the consumer still has time within the original shelf life to defrost and use the product.

- The cartons that come with milk, cottage cheese and yoghurt are not moisture-vapour resistant enough for long term frozen storage and do not have seals which are airtight enough for optimum freezing, so it is advisable to re-package these products for freezing in more suitable packaging (e.g. Figure 1).
- Foil and cardboard take-away containers should generally not be re-used as they do not seal well. Plastic take-away containers may be acceptable if they seal well or can be overwrapped with a sealable bag.
- Seasonings and flavours such as curry, garlic and chilli can strengthen or migrate between components during frozen storage and some can shorten shelf life e.g. salt has been found to accelerate the development of fat rancidity (Evans 2008, Ref o9). It may be advisable, therefore, to add seasoning after thawing and / or reheating.

Figure 1 Lakeland Soup 'n' Sauce Bags
(<http://www.lakeland.co.uk>)



1 litre Soup 'n' Sauce Bags

★★★★★ (12 reviews) Like

Anyone who regularly makes batches of home-made soup, stock and sauce is going to love these bags.

Being heavy gauge and gusseted, filling them is very easy because they stand upright of their own accord, leaving your hands free for pouring.

Taking up much less space in the freezer than ordinary storage boxes, they are helpfully graduated, and have strong zip-seal fasteners to keep their contents secure.

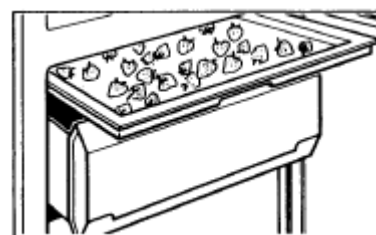
Pack of 20. 1 litre.

Cat Ref: 10914

Microwave safe
 Freezer safe

Freezing

- Where possible, avoid freezer temperature fluctuations (by avoiding loading warm food etc.), as these encourage large ice crystals and freezer burn to develop.
- Leave gaps between products while freezing (e.g. if freezing par-boiled potatoes or soft fruits) freeze individual items separately on a baking tray, then push together or bag when frozen (shown here, image taken from freezer manual).
- Don't stack anything on top until fully frozen to avoid crushing and deformation.
- For fast freezing, place packages as close as possible to the cold evaporator in the freezer. Depending on type, this will be behind the back and side walls or in visibly apparent circuits built into the shelves.
- Use fast freeze setting if you have one, particularly for large items.
- For separate freezers and fridge-freezers with dual thermostats, the freezer thermostat setting can be lowered to speed up freezing if there is no fast freeze function, but remember to re-set it to its normal storage temperature to avoid excessive energy use.
- Air trapped in packs can shorten shelf life and affect food colour, flavour and texture. Consider using a vacuum packing machine if you freeze large amounts of food – available for relatively low cost e.g. Figure 2. As an alternative, use a straw to suck excess air out of sealable freezer bags.



Frozen storage

- Frozen storage generally affects quality (rancidity, texture, freezer burn etc.) rather than safety (bacteria, moulds, etc.).
- Try to ensure the freezer is running at -18°C or colder (use a freezer thermometer). Warmer temperatures such as -12°C are likely to result in quicker deterioration in quality.
- Where possible, avoid freezer temperature fluctuations (by minimising door opening), as these encourage large ice crystals and freezer burn to develop.
- Rotate stock according to the date it was frozen, to minimise the length of time product is kept in the freezer and optimise product quality.
- Storage lives of home frozen goods can be shorter than industrially frozen products due to slower freezing and inferior packaging (IIR Red Book, Ref o1).
- Don't keep food in a freezer indefinitely; try to eat them within ca. 3 months.

Figure 2 Example of home vacuum packing machine, available from Lakeland (<http://www.lakeland.co.uk>)



Seal-a-Meal®

★★★★★ (3 reviews)

[Like](#)

By extracting all the air and keeping the freshness locked in, leftovers and just-bought food can be kept as fresh as the day they are stored, without fear of freezer burn, and in a fraction of the space a box would take up. It's a real time-saver, and so versatile too; you can prepare meals in advance, freeze in Seal-a-Meal bags and then microwave or boil for easy reheating, or even marinate in minutes rather than hours.

With built-in roll storage and cutter, this version is even easier to use than before as there's nothing to line up – once your food is in the bag, just put the open end into the machine, press the button and Seal-a-Meal will automatically suck out all the air and seal the bag.

Includes 3 x 940ml bags, 3 x 3.78L bags, 1 x 28cm x 3m (11" x 10') roll and an accessory hose.

Cat Ref: 15349



Thawing and use

- Freezing interrupts the development of food spoilage. The storage period prior to freezing has a large impact on storage life after a product is thawed. If a product is stored for a long time prior to freezing it cannot be expected that the product will have an extended storage life once thawed. This helps explain why advice on deterioration after thawing is mixed, with some sources stating that thawed food spoils more quickly than fresh, whilst others advise treating thawed food as fresh.
- It is possible to cook, bake or toast some products from frozen without thawing.
- Only thaw or use what is needed e.g. slices of bread for toast, portion of sauce, etc. keeping the rest in the freezer for when it is needed.
- For most foods, thawing is best done in a refrigerator to avoid parts of the food rising to temperatures which can promote bacterial growth (and some sources advise that thawing of products with meat, fish, dairy and eggs should only be done in a refrigerator).
- When thawing products such as meat and fish in a refrigerator, they should be kept sealed and placed on a tray or plate, and where possible placed at the bottom of the refrigerator to avoid spillage of drip and cross-contamination of other products.
- It is possible to thaw in sealed bags placed in cold water, refreshed every 30 minutes.
- Defrost foods in a microwave only if you intend to cook them straightaway as microwave heating is uneven and may have started to heat areas of the product (higher temperatures accelerate microbial growth).
- Some products e.g. bakery should be thawed at ambient room temperature, as extended periods at refrigeration temperatures increase staling.

- For products which require cooking after freezing, the purpose of thawing before cooking is to ensure that, during cooking, the food is heated sufficiently to kill any harmful bacteria. However, many products can be cooked from frozen if sufficient cooking time is allowed and (where available) manufacturers' guidelines are followed.

Re-freezing

- If products are frozen raw in the home, then thawed and cooked, the product can be re-frozen.
- If products are bought frozen, then thawed and cooked, the product can be re-frozen.

New regulations⁶ require:

- foods to be labelled with the date of freezing or the date of first freezing in cases where the product has been frozen more than once; and
- where foods have been frozen before sale and which are sold defrosted, the name of the food is accompanied by the designation "defrosted".

This is to ensure the final consumer is appropriately informed of the food's condition, but given freezing and thawing undertaken in the supply chain is done under controlled conditions, it does not preclude freezing the product in the home, if required. In these cases, the general home freezing guidance described above should be followed.

⁶ REGULATION (EU) No 1169/2011, Article 24 requires the date of freezing or the date of first freezing in cases where the product has been frozen more than once, in accordance with point (3) of Annex X.

2.0 Results from the in-depth literature review

All the 'general' home freezing guidance above (§1.3) will be relevant to the individual products discussed in this section. This section aims to give more detail and, where appropriate, additional guidance, over and above the general guidance, as reported in the literature.

2.1 Bread

2.1.1 Reported practical storage life

As highlighted in the 2011 WRAP report 'Reducing household bakery waste' (Ref o7), 32% of shop-bought bread ends up being thrown away, around 80% of which is from packs which have been opened but not finished. Freezing in the home could have a huge impact on reducing the level of bakery waste. For example, sliced loaves can be frozen (whole or split; for best quality, this should be as soon as possible after purchase and before their 'best before' date) and individual slices thawed or toasted straight from frozen when required.

With careful packaging to minimise quality deterioration, and assuming levels of consumption which ensure use within recommended PSLs, the routine rather than accidental waste from such bakery products could be virtually eliminated (although there is evidence in the above report that many bread ends (crusts) are discarded because consumers do not consider them to be useable parts of the loaf).

Store-bought bread is suitable for home freezing, with a relatively large number of internet references suggesting PSLs and tips for freezing. Although there are relatively few peer-reviewed references, text book references, which include sections on freezing of bread and other bakery products, were available. The range of stated PSLs at -18°C and their sources for loaves (Table 1) and rolls and baguettes (Table 2) are shown below, each ranked from shortest PSL to longest PSL.

Table 1 Reported Practical Storage Lives (PSLs) for loaves at -18°C

PSL at -18°C	Source	Ref.
2-3 weeks (in shop wrapper)	Favorite Freezer Foods website, USA	i7
4-6 weeks	Extension Service website, Oregon, USA	i28
1-3 months	New Zealand Government 'foodsmart' website, NZ	i2
3 months	BBC GoodFood website, UK	i5
3 months	Cook UK website	i4
3 months	Extension Service website, Missouri, USA	i23
3 months	Extension Service website, Clemson, USA	i36
3 months	IIR Red Book	o1
3-6 months	Extension Service website, Nebraska, USA	i24
4 months (moisture proof wrapping or foil)	eHow Food website, USA	i8
4 months	WikiHow website, USA	i47
6 months (vacuum packed or freezer wrap)	Favorite Freezer Foods website, USA	i7
4-6 months	Extension Service website, Kentucky, USA	i35
6-8 months	Extension Service website, Georgia, USA	i25

Table 2 Reported Practical Storage Lives (PSLs) for bread rolls and baguettes at -18°C

PSL at -18°C	Source	Ref
4-6 weeks	Extension Service website, Oregon, USA	i28
8 weeks	ASHRAE Handbook	o2
2-3 months	Extension Service website, Texas, USA	i34
2-3 months	Extension Service website, Kentucky, USA	i35
3 months	Cook UK website	i6
3-6 months	Extension Service website, Nebraska, USA	i24
6-8 months	Extension Service website, Georgia, USA	i25

Although there are some outliers, most of these figures are in general agreement with the advice derived from the study of household bakery waste (WRAP 2011, Ref o7), which suggests keeping frozen bread for no longer than 3 months for best flavour.

The WRAP survey found that 99% of shop-bought packaged bread had freezing guidance on pack, with storage times of 1 month (31% of packs) and 3 months (27% of packs) being advised. A lower percentage, 84%, of packaged rolls had freezing guidance on pack, with storage times of 1 month (47% of packs) and 3 months (10% of packs) being advised. For in-store bakery (ISB) bread and rolls, guidance on pack was rare, with only 1% of loaves and 7% of rolls having freezing guidance. Similarly, defrosting guidance was not common, being found on just 33% of packaged bread and 49% of packaged rolls.

2.1.2 Reported quality issues caused by freezing

Quality issues affecting frozen storage of bread include staling, textural change, drying, freezer burn and physical damage during freezing and thawing, an example of which is the fracture of sliced bread during separation of individual slices.

Staling is a complex quality issue, with a major contributor thought to be starch retrogradation (Ribotta, 2007, Ref p18). Staling results in several changes, the predominant being increased firmness of the crumb and decreased firmness of the crust, with associated loss of flavour. The rate at which bread goes stale is reported to increase as storage temperature is lowered until it reaches a maximum at 4°C (Cauvain, 1998, Ref p19). At temperatures lower than this the rate decreases again. The process of freezing subjects bread to the maximum staling rate zone twice, once as it freezes and again as it thaws. It is therefore advantageous to freeze and thaw quickly to minimise the duration of maximum staling. Smaller, tightly wrapped pack sizes with excess air removed will help to achieve this.

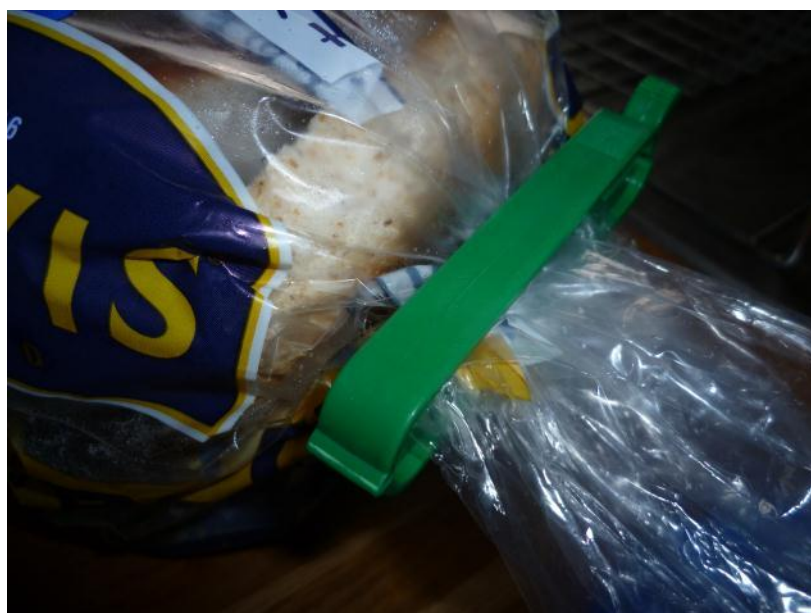
Varying results have been found in studies on crumb firmness during frozen storage. While Fik and Surowka (2002, Ref p16) found no significant differences in crumb hardness during 11 weeks of frozen storage, Barcenas *et al.* (2003, Ref p1) found that crumb hardness increased with duration of frozen storage, and that the crumb hardening rate increases with frozen storage time. Novotni *et al.* (2011, Ref p3) found that bread firmness was not affected by storage time or, interestingly, packaging material.

Drying and freezer burn result from inadequate packaging and contact with air (USDA FSIS website, Ref i32), and can be aggravated by temperature fluctuations during storage. Air-tight packaging in materials suitable for frozen storage and removing as much air as possible before sealing can minimise such problems. If necessary, freezer-burnt areas can be trimmed before use (New Zealand Government Foodsmart website, Ref i2).

2.1.3 Pre-freezing guidance

- Bread selected for freezing should be of high initial quality (e.g. Favorite Freezer Foods website, Ref i7).
- All types of bread can be frozen, including sliced and unsliced shop-bought or home-made loaves, rolls, baguettes etc. (eHow Food website, Ref i8).
- Wrapping is critical; many references suggest using freezer wrap, foil and bag or vacuum pack (for example Refs i7 and i8). Others recommend the original plastic bag as being acceptable for shorter term storage, particularly if sealed properly (e.g. with a bag clip, Figure 3, being better than re-using the sticky tape seal) or kept un-opened (About.com website, Ref i48).
- Sliced bread is particularly suitable for freezing as single slices can be used without thawing the whole loaf (Food Reference website, Ref i51).
- WRAP / Hovis report suggests 'banging the loaf' prior to freezing to avoid slices sticking together (WRAP 2011 Report, Ref o7).

Figure 3 Example of bread bag clip



2.1.4 Freezing guidance

- Keep loaves separate to promote fast freezing.
- Do not stack to avoid crushing.
- Keep ends of sliced loaves in place to protect inner slices (WRAP 2011 Report, Ref o7).

2.1.5 Thawing guidance

- Sliced bread can be toasted straight from frozen, slice by slice (Food Reference website, Ref i51).
- Thawing in pack without opening will help to minimise drying and also help to avoid condensation or moisture from warm ambient air onto the bread. Care does need to be taken if any ice has built up in the storage bag as this can thaw and cause the bread to become soggy in places.
- Some references advise thawing in the refrigerator (About.com website, Ref i48), and some at ambient temperatures (WikiHow website, Ref i47). Thawing in a refrigerator will take longer and subject the bread to longer periods during which staling can take place, so it is advisable to thaw at room temperature or microwave-thaw (see below), or even to toast from frozen.

- Bread can be microwave-thawed but as in-pack moisture can make bread soggy, careful microwave timing is required (Favorite Freezer Foods website, Ref i7). Variable results from microwave-thawing have been reported (e.g. WikiHow website, Ref i47) with sogginess and chewy or rubbery texture found by some and acceptable results found by others particularly when microwave-thawing slices removed from packaging.
- Single slices can be thawed on a kitchen worktop in 5-10 minutes (Favorite Freezer Foods website, Ref i7).
- Sandwiches can be made with frozen slices which will defrost by lunchtime (WRAP 2011 Report, Ref o7).

2.1.6 Storage after thawing

The WRAP retailer survey found only 7% of loaves with advice on use after thawing, the majority of which advised use within 24 hours. Depending on when it was frozen, in relation to its 'best before' date, thawed bread will last as fresh.

2.1.7 Re-freezing guidance

- Try not to re-freeze once thawed – this is not a safety issue, but there is a greater risk of staling and quality loss if re-frozen.
- However, if thawed bread can't be used in time, it could be made into breadcrumbs and re-frozen to be used in cooking. The breadcrumbs should be packed tightly into an air-tight bag or container and used for breading products (e.g. fish, escalopes), making stuffing or adding a crispy topping to an oven bake.
- Stale bread can also be used in a summer pudding or bread pudding to prevent waste, or toasted.

2.1.8 Other factors and differences due to bread type

Sliced bread - Shop-bought bread wrappers are not designed for long term frozen storage, for which re-wrapping is advised (Favorite Freezer Foods website, Ref i7). In particular In-Store Bakery (ISB) wrappers are often open, paper or thin film and these should be replaced with sealable freezer bags or plastic freezer wrap. For other pre-packed bread not baked in store, wrappers are generally acceptable for shorter term storage (up to 3 months) and are predominantly labelled as such.

Un sliced bread - Slicing or portioning before freezing will allow partial thawing and use. As with sliced bread, ISB wrapping on unsliced bread is often loose and sometimes open; this should be replaced with sealable freezer bags or plastic freezer wrap.

Rolls - Wrap individually, or in numbers likely to be required, in sealable freezer bags or plastic freezer wrap before freezing (Favorite Freezer Foods website, Ref i7).

2.2 Pork (cooked sliced ham, bacon, raw and cooked sausage)

2.2.1 Reported practical storage life

Cooked sliced ham, bacon and pork sausage in either the raw or cooked state are suitable for home freezing. Table 3, Table 4 and Table 5 below present reported PSLs. The factor responsible for limiting the storage life of such products is predominantly the fat content (CookUk website, Ref i4) with greater amounts of fat increasing the risk of rancidity occurring during frozen storage.

Table 3 Reported Practical Storage Lives (PSLs) for cooked sliced ham at -18°C

PSL at -18°C	Source	Ref.
1 month	Extension Service website, Missouri, USA	i23
1-2 months	Food Safety and Inspection Service USDA website USA	i32
1-2 months	Extension Service website, Kentucky, USA	i35
1-2 months	Extension Service website, Clemson, USA	i36
1-3 months	Extension Service website, Nebraska, USA	i24
2-3 months (half and slices)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44

The relatively short storage lives for cooked ham reflect the risk of rancidity and other changes to flavour, odour and texture. Ham was surveyed in the WRAP survey, which found no packs with freezing guidance and 6% labelled as not suitable for freezing.

Table 4 Reported Practical Storage Lives (PSLs) for bacon at -18°C

PSL at -18°C	Source	Ref.
1 month	Extension Service website, Missouri, USA	i23
1 month	Extension Service website, Texas, USA	i34
1 month	Extension Service website, Clemson, USA	i36
1 month	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
1-2 months	Food Safety and Inspection Service USDA website USA	i32
2-4 months	British Frozen Food Federation website, UK	i1
18 months (vacuum packed)	IIR Red Book	o1

Bacon and other cured meats have relatively short storage lives for the same reasons as ham, although industrially vacuum packed and frozen bacon can be stored for much longer (IIR, Ref o1). The WRAP survey found that 91% of pre-packed bacon carried freezing guidance, with 79 and 8% recommending storage for 1 month and 3 months respectively. 81% of packs gave defrosting guidance. No freezing guidance was found on bacon packs produced by in-store delicatessen counters.

Table 5 Reported Practical Storage Lives (PSLs) for raw and cooked sausages at -18°C

PSL at -18°C	Source	Ref
1-2 months (raw)	Food Safety and Inspection Service USDA website USA	i32
1-2 months (raw)	Extension Service website, Kentucky, USA	i35
1-2 months (raw)	Extension Service website, Clemson, USA	i36
1-2 months (raw - pork, beef, turkey)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
6 months (raw)	British Frozen Food Federation website, UK	i1
1-2 months (cooked)	Extension Service website, Texas, USA	i34
1-2 months (cooked)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44

Apart from one exception, raw or cooked sausage is reported to have a PSL of 1 to 2 months (the reason for the exception is not apparent but may be due to less robust packaging). Sausages were not included in the WRAP survey.

2.2.2 Reported quality issues caused by freezing

Fats are susceptible to rancidity during frozen storage, primarily resulting from oxidation. Reactions between long-chain fatty acids and oxygen result in formation of compounds which have marked effects on flavour and odour. Rancidity in frozen meat should, therefore, be minimised whenever possible by trimming off all excess fat before freezing and by removing as much air as possible from packs and using air-tight packaging (Helpwithcooking website, Ref i6).

Cilla *et al* (2006, Ref p12) found that the instrumentally measured odour, flavour and texture of cooked sliced ham are affected by frozen storage, although changes were only slight during long-term frozen storage. Odour and flavour were reduced by frozen storage and texture became more uniform with softer muscles hardening and harder muscles softening. However, consumer panel scores did not vary significantly.

It is reported that cured meats can go rancid more quickly than other meats due to their high fat contents and acceleration of rancidity development caused by high salt contents (Evans, Ref o9 and National Center for Home Food Preservation website, Ref i3). It should, however, be noted that many references for cured meats are relatively old and cover products that had higher salt contents than most 'current' products.

2.2.3 Pre-freezing guidance

- Freeze fresh meat as soon as possible to retain quality (e.g. CookUk website, Ref i4).
- Raw meat will store better in the freezer than cooked meat as it has much higher water content (Helpwithcooking website, Ref i6).
- Storing meat raw also adds an additional safety factor as meat will be cooked after thawing and the heat during cooking is likely to be sufficient to kill any bacteria on the meat surface. The same will be true of reheating any previously cooked, and then frozen, meat.
- If the meat is cooked prior to freezing, cool it quickly to chilled temperatures and then freeze. This avoids adding excessive heat loads from warm meat to the freezer, which will slow freezing and could partially thaw food already in the freezer.

2.2.4 Freezing guidance

- Wrap with freezer wrap or foil and then bag in a sealable freezer bag. If possible vacuum pack.
- Freeze unopened bacon vacuum packs as they are, or for longer storage, overwrap with foil.
- Wrap individual slices of ham or loose bacon (or the number of slices likely to be required) so that they can be thawed as required (CookUk website, Ref i4).

2.2.5 Frozen storage guidance

Keep frozen storage times short if possible (ca. 1-2 months) to minimise development of rancidity.

2.2.6 Thawing guidance

- Thaw raw and cooked meat by preference in a refrigerator or in sealed packaging in a bowl of cool water, or in a microwave oven if cooking immediately (e.g. FSIS USDA website, Ref i32 and Cook's Thesaurus website, Ref i55). Do not thaw at room temperature (New Zealand Foodsmart website, Ref i2).

2.2.7 Storage after thawing

Store in the fridge. Defrost and use within 24 hours.

2.2.8 Re-freezing guidance

If cooked after thawing, defrosted sausages, ham and bacon can be re-frozen.

2.3 Vegetables

2.3.1 Reported practical storage life

Most vegetables are suitable for home freezing, but many should be blanched first to halt enzymic activity which can cause changes in flavour, colour, texture and nutritive value (Extension Service Iowa website, Ref i29). Blanching is a short period of cooking which can be achieved in boiling water or steam, followed by rapid cooling such as in ice-water to prevent the vegetables undergoing extended cooking (Foulsham & Company website, Ref i40). An alternative method is to microwave-blanch followed by rapid cooling, although the microwave heating may be uneven and may cause vitamin and colour deterioration (Extension Service Iowa website, Ref i29).

There is considerable variability in reported storage lives, depending on the vegetable type, pre-freezing treatment and packaging, as shown in Table 6. Storage times are generally relatively long, and the most important issues are whether (and how) to blanch, leave whole or process before freezing. It should be noted that some references do not clearly describe whether 'raw' means blanched and not further cooked, or not even blanched. Guidance on blanching, based on vegetable type, is available from various sources, for example:

- http://www.allotment.org.uk/allotment_foods/Storing_the_Surplus_Freezing.php
- http://www.growveggies.net/harvesting_and_storing/freezing_vegetables_a_to_z

In addition, many cookery books will have more detailed advice.

Table 6 Reported Practical Storage Lives (PSLs) for vegetables at -18°C

PSL at -18°C	Source	Ref.
3 months (home frozen blanched)	Cook UK website	i4
6 months (cauliflower blanched)	Helpwithcooking website, UK	i6
8 months (shop bought blanched)	Extension Service website, Missouri, USA	i23
10 months (home frozen blanched)	Extension Service website, Missouri, USA	i23
12 months (many blanched)	Foulsham & Company website, UK	i40
1-12 months (asparagus blanched)	Helpwithcooking website, UK	i6
12-18 months (blanched)	British Frozen Food Federation website, UK	i1
12-18 months (blanched)	Bai du website, China	i19
12-18 months (dep. on type blanched)	Food Safety and Inspection Service USDA website USA	i32
18 months (leeks blanched)	IIR Red Book	o1
12-18 months (blanched)	British Frozen Food Federation website, UK	i1
2 months (tomatoes raw)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
3-4 months (tomato wedges raw)	Extension Service website, Clemson, USA	i36
6 months (bell peppers raw)	Extension Service website, Texas, USA	i34

PSL at -18°C	Source	Ref.
6-8 months (whole raw)	Helpwithcooking website, UK	i6
8 months (beans raw)	Extension Service website, Texas, USA	i34
8 months (beans, green or waxed raw)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
8 months (mushrooms raw)	IIR Red Book	o1
10 months (home frozen raw)	Food Safety and Inspection Service USDA website USA	i31
8-12 months (stir-fry raw)	Extension Service website, Oregon, USA	i28
8-12 months (many veg, raw)	Extension Service website, Kentucky, USA	i35
8-12 months (many veg, raw)	Extension Service website, Clemson, USA	i36
10-12 months (carrots, celery, spinach, squash, raw)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
6-24 months (depending on type, raw)	IIR Red Book	o1
12-24 months (vacuum packed, raw)	Food Safety and Inspection Service USDA website USA	i31
6-8 months (pureed tomatoes)	Helpwithcooking website, UK	i6

2.3.2 Reported quality issues caused by freezing

Enzyme activity is the main limiting factor to long term storage, resulting in deterioration of quality rather than safety. This can be minimised by blanching and by maintenance of low temperatures (Helpwithcooking website, Ref i6).

There is conflicting advice on freezing of starchy vegetables such as potatoes. While some sources advise that they do not freeze well (e.g. National Center for Home Food Preservation website, Ref i3) and tend to go soft, water-logged, crumbly and mealy, others advise that they freeze well with little change to texture when defrosted (Helpwithcooking.com website, Ref i6). The condition of the potatoes before freezing is not fully described, and it may be that some sources refer to raw potatoes and others to cooked. Other sites include advice on freezing cooked potatoes only, with the inference being that potatoes or parts of potatoes in the raw state should not be frozen (Garden Guides website, Ref i65). The Potato Council recommends that if you have potatoes that need using up, they should be parboiled before freezing⁷. It is also worth bearing in mind that potatoes can be stored for long periods without freezing if kept in a cool, dark place, so the benefits from freezing potatoes on their own rather than as ingredients are not as pronounced as those for more perishable items.

Watery vegetables (e.g. lettuce, cucumber, bean sprouts and radishes) do not freeze well (BBC Good Food website, Ref i5). Leafy vegetables (e.g. cabbage, lettuce, endives etc.) also do not freeze well, and tend to go limp, water-logged, and quickly develop oxidized colour, aroma and flavour (National Center for Home Food Preservation website, Ref i3). Mohammadi *et al* (2004, Ref p15) found that length of storage up to 6 months did not affect chopped leafy vegetable quality attributes (colour and flavour) or overall acceptability, but that storage temperature did affect acceptability. Three temperatures were applied to reflect home freezing; -18°C, -12°C and -9°C and the lowest of the three temperatures gave the best results, as might be expected.

High water content vegetables (e.g. tomatoes) may be better pureed before freezing, particularly if intended for use in that condition (Foulsham and Company website, Ref i40).

⁷ http://www.lovepotatoes.co.uk/the-potato/faq/#Can_I_freeze_potatoes?

Pureeing also has the benefit that the product can be stored in a smaller volume (i.e. no air gaps around product) and enables portions to be frozen in air-tight containers or bags.

2.3.3 Pre-freezing guidance

- Blanch appropriate vegetables to inactivate enzymes. It should be noted that although blanching will minimise or halt enzyme activity, it is also likely to destroy a small amount of vitamins and nutrients in the vegetables (Helpwithcooking website, Ref i6). Any loss of vitamins or nutrients needs to be balanced against the losses that would occur naturally if the product remained chilled. Losses of nutrients and vitamins occur rapidly after harvest and so unless product is consumed soon after harvest, frozen products are likely to have a higher nutrient content than equivalent chilled products.
- Blanching may also inactivate or kill some of the surface bacteria present on vegetables (Allotment.org website, Ref i22)
- Blanch in boiling water immediately followed by rapid cooling in ice water to halt cooking. Extensive product-specific guidance is available online e.g. Garden Guides website, Ref i65) (example shown below).

Carrots Wash and scrub carrots and cut large carrots into pieces. Blanch 3 minutes in boiling water. Chill in iced water 3 minutes. Drain. Spread on a tray in a single layer and freeze after 30 minutes. Pack in freezer bags, remove air, label and seal. Keeps for up to 6 months.

Courgette Slice into 1 inch pieces without peeling. Sauté gently in a little melted butter until barely tender. Cool, pack into plastic containers leaving headspace at the top. Freeze for up to 3 months. Use in sauces / soups

(Source Garden Guides website, USA - Ref i65)

- It is possible to also blanch in steam, cool immediately afterward to avoid further cooking (Extension Service website, Ref i29).
- It is possible to blanch in a microwave (FSIS USDA website, Ref i32) but this can result in uneven heating with some missed areas and others overheated.
- If fully cooking vegetables before freezing, make sure they are quickly cooled before freezing to minimise overcooking and also to reduce the time spent in a moderate, bacteria-friendly temperature zone.

2.3.4 Freezing guidance

Some vegetables are better frozen on trays to keep them separate, and then bagged when frozen. This reduces how long it takes for them to freeze, giving better quality retention, and also avoids them sticking together so that only part of the frozen pack needs to be thawed for use (Extension Service website, Ref i29).

2.3.5 Thawing guidance

Most frozen vegetables can and should be cooked, or used as ingredients, without thawing (e.g. Cook's Thesaurus website, Ref i55 and Extension Service website, Ref i29). Either cook and eat immediately or cook as ingredients in soups, stews etc. which then can be either used or frozen.

2.4 Fruit

2.4.1 Reported practical storage life

Fruit can be divided into the four main groups:

- 1 tree and stone fruit;
- 2 citrus fruit;
- 3 soft fruit and berries; and
- 4 exotic fruit.

Most fruits are suitable for home freezing, but some e.g. bananas, strawberries, apples and melons do not freeze as well in an unprocessed form (although they can be used in cooked products such as cakes, breads, desserts and then frozen successfully, or in the case of bananas, eaten frozen).

Soft fruits generally freeze well, but stone fruits (which are more fibrous) are reported to turn soft when thawed (BBC Food website, Ref i71). Often, better results can be achieved if the fruit is packed with sugar or syrup. A syrup is a solution of sugar in water, typically 40% sugar by weight dissolved in warm or cold water, but the amount of sugar may be varied depending on the type or ripeness of fruit e.g. more being used for sour fruit (Extension Service website, Ref i66).

Blanching is generally not required for fruits due to high levels of natural acidity, but for fruits such as apples which can darken, treatments such as citric acid or sugar and citric acid mixtures and lemon juice give useful if less effective results. Some fruits such as apples are better pureed or stewed for use in jam or pie fillings. Reported PSLs for fruits are shown in Table 7.

Table 7 Reported Practical Storage Lives (PSLs) for fruits at -18°C

PSL at -18°C	Source	Ref.
4-6 months (citrus in original form)	Extension Service website, Missouri, USA	i23
6-8 months (in original form)	Helpwithcooking website, UK	i6
4-12 months (dep. on type in original form)	Extension Service website, Clemson, USA	i36
6-12 months (in original form)	Extension Service website, Oregon, USA	i28
8-12 months (except citrus in original form)	Extension Service website, Missouri, USA	i23
8-12 months (in original form)	Bai du website, China	i19
8-12 months (in original form)	Extension Service website, Iowa, USA	i29
8-12 months (many fruits in original form)	Extension Service website, Kentucky, USA	i35
12 months (in original form)	Family Education website, USA	i31
18 months (peaches, apricots, cherries in original form)	Commonwealth Scientific and Industrial Research Organisation website, Australia	i33
18 months (peaches, apricots, cherries in original form)	IIR Red Book	o1
24 months (raspberries, strawberries in original form)	Commonwealth Scientific and Industrial Research Organisation website, Australia	i33
24 months (raspberries, strawberries in original form)	IIR Red Book	o1
6-8 months (pureed)	Helpwithcooking website, UK	i6

PSL at -18°C	Source	Ref.
6-12 months (puree)	Extension Service website, Oregon, USA	i28
8-12 months (in syrup)	Extension Service website, Iowa, USA	i29
9-12 months (syrup or sugar frozen)	Helpwithcooking website, UK	i6
18 months (peaches, apricots, cherries in syrup)	IIR Red Book	o1
24 months (raspberries, strawberries in syrup)	IIR Red Book	o1

2.4.2 Reported quality issues caused by freezing?

- Strawberries tend to lose firmness and go mushy on thawing (Helpwithcooking website, Ref i6).
- Vitamin C and antioxidant levels in strawberries and cherries may be reduced by home freezing and storage (Poiana et al, 2010, Ref p8).
- It's reported that citrus fruits may not store as long as non-citrus fruits (Extension Service Missouri website, Ref i23).
- Enzyme activity in fruits is normally inhibited by natural acids (FSIS website, Ref i32), but some may benefit from addition of chemicals such as ascorbic acid to act as anti-darkening agents (Helpwithcooking website, Ref i6). Other treatments such as citric acid or sugar and citric acid mixtures and lemon juice can also be used as a surface treatment to reduce browning caused by enzyme activity (Extension service websites, Ref i30 and Ref i29).

2.4.3 Pre-freezing guidance

- Wash fruit before freezing and dry if dry packing with sugar (see below).
- Remove green or bruised areas, and chop or slice as required for intended use (e.g. Allotment.org website, Ref i22 and Extension Service website, Ref i29).
- Treat with anti-darkening agents if required, such as ascorbic acid, citric acid or lemon juice (e.g. Extension Service website, Ref i29).
- Dry pack in sugar or pack in syrup or tray freeze and bag when frozen for free flowing fruits such as berries (e.g. Extension Service website, Ref i29 and Extension website, Ref i30). These can be then used in pies or desserts or could be made into jam (it should be noted that when time permits it would be more energy efficient to make jam instead of freezing for jam, as jam does not require any form of refrigeration).
- Pureeing fruit can save freezer space and enables fruit to be packed in air-tight containers in suitable portions. For products such as strawberries that do not freeze well pureeing is an ideal means to store product that can be used for smoothies, desserts and sauces.
- Alternatively many fruits can be made into sorbet or ice cream products to be served directly from frozen.

Guidance on how to prepare fruits for freezing is available online e.g. from Extension Service website, Purdue, USA: Ref i66 (example shown below).

Apples (full flavoured, firm, crisp, ripe, free from bruises and decay)

Wash, peel, and core.

Syrup pack: Slice apples directly into cold 40% syrup to which 1/2 teaspoon of crystalline ascorbic acid for each quart of syrup is added. Press fruit down in containers, and add enough syrup to cover.

Sugar pack: To prevent darkening during preparation, slice apples into a solution of 2 tablespoons of salt to a gallon of water. Hold in this solution no more than 15 to 20 minutes. Drain. To retard darkening during freezing, steam single layers of sliced apples for 1.5 to 2 minutes. Cool in cold water, and drain. Sprinkle 1/2 cup of sugar over each quart of apple slices, and mix well.

Unsweetened pack: Follow directions for sugar pack, omitting sugar.
Apple sauce/stewed apples: Pack cool apple sauce into container.

(source Extension Service website, Purdue, USA: Ref i66)

2.4.4 Freezing guidance

- Freeze as soon as possible after picking / purchase for best quality.
- Choose fruits which are ripe, but not over-ripe.
- Slightly over-ripe fruits may be better pureed for freezing.
- Small, soft fruits like raspberries can be frozen spread out on trays and then bagged to avoid crushing and clumping together, as can sliced or diced fruit (Extension Service website, Ref i29 and Extension website, Ref i30).

2.4.5 Thawing guidance

- There is differing advice on thawing, with some suggesting that fruits are best thawed in the refrigerator (Cook's Thesaurus website, Ref i55) but others suggesting that fruits are best thawed at room temperature in their sealed packs or, if faster defrosting is required, lukewarm water or microwave defrosting can be employed (Extension Service website, Ref i29).
- A useful tip, if serving frozen fruits as fresh, is to serve them when they still have a small amount of ice remaining, which will give firmer texture and compensate for any softening caused by frozen storage (e.g. National Center for Home Food Preservation, Ref i3).
- Depending on use, fruits may not need to be thawed and can be served frozen or cooked from frozen (About.com website, Ref i69).

2.4.6 Re-freezing guidance

If refrigerator-thawed or if some ice crystals still remain, fruit can be re-frozen (Ministry of Health, Ontario, Canada website: Ref i67) but it may be better to cook and then freeze as the texture will be altered after thawing and products will have less structure.

2.5 Pasta meals (home-made)

2.5.1 Reported practical storage life

Cooked pasta is suitable for home freezing, but results depend both on the type of pasta and the type of sauce. Cooked dried pasta may store longer when frozen than cooked fresh pasta. Tomato-based sauces freeze well, but creamy sauces do not freeze well as they are emulsions which can separate during freezing and appear curdled (FSIS website, Ref i32).

Reported storage life data are limited, but show good agreement with average PSL at -18°C being around 3 months (Table 8).

Table 8 Reported Practical Storage Lives (PSLs) for home-made pasta meals at -18°C

PSL at -18°C	Source	Ref.
2-3 months	Helpwithcooking website, UK	i6
2-3 months	Extension Service website, Oregon, USA	i28
2-4 months	Extension Service website, Georgia, USA	i25
3 months	Extension Service website, Nebraska, USA	i24
3 months	About.com website, USA	i43

2.5.2 Reported quality issues caused by freezing?

- Some sauces (e.g. creamy / milk) do not freeze well as they will tend to curdle and separate on thawing⁸ (Extension Service website, Ref i23). Egg-based sauces may separate (BBC GoodFood website, Ref i5) but other sauces such as tomato-based recipes do freeze well (FSIS website, Ref i32).
- Sauces may thicken during freezing and frozen storage so add extra water to recipe if freezing (Helpwithcooking website, Ref i6). This could be done after thawing (when reheating the meal) to better gauge the amount to add, and minimise how much water is being frozen.
- Texture and the water holding capacity of cooked pasta can be damaged – dependent on freezing rate (Olivera and Salvadori, 2009, Ref p5).
- Ice crystal formation (particularly from slow freezing) can rupture/break pasta.
- Cooked dried pasta will freeze better than cooked fresh pasta (BBC Good Food website, Ref i54).
- Cooked pasta frozen alone can have mushy texture and warmed-over flavour (Extension Service website, Ref i23).
- Fresh home-made pasta can be frozen successfully but won't taste as good as when eaten on the day of preparation (BBC Good Food website, Ref i54). It is likely that this will also apply to store-bought fresh pasta.

2.5.3 Pre-freezing guidance

- Cool rapidly after cooking.
- Whilst it's unlikely that you'd cook pasta specifically to freeze, if it was necessary, it should be undercooked slightly to allow for some cooking during re-heating (Extension service website, Ref i25 and About.com, Ref i43).
- Pasta meals can be frozen assembled, but uncooked (Extension service website, Ref i25) e.g. lasagne. As with many other foods, pack in sealed containers, but leave headspace for expansion during freezing.

2.5.4 Freezing guidance

- Freeze in portions rather than bulk-freeze to allow thawing and use in smaller quantities.
- Freeze sauces separately (from the pasta) if possible as sauces will store for longer (BBC Good Food website, Ref i54).

2.5.5 Thawing guidance

Pasta meals can be cooked from frozen without thawing (Extension service website, Ref i25). Alternatively pasta meals can be heated over boiling water (Extension service website, Ref i25). If thawing in a refrigerator, thaw overnight (About.com website, Ref i43).

2.6 Rice meals (home-made)

2.6.1 Reported practical storage life

Home-made rice meals (such as risotto, biryani / curry, Chinese rice dishes, Japanese, Greek dolmades etc.) are suitable for home freezing, although care must be taken to avoid extended periods at moderate (e.g. room) temperature after cooking and thawing.

Uncooked rice can contain spores of *Bacillus cereus*, a bacterium that can cause food poisoning. When the rice is cooked, the spores can survive. If the rice is left standing at room temperature, the spores can grow into bacteria. These bacteria will multiply and may produce toxins (poisons) that cause vomiting or diarrhoea.

⁸ Note that industrially manufactured sauces may contain a stabiliser and so may freeze more successfully than home-made sauces.

The longer cooked rice is left at room temperature, the more likely it is that the bacteria or toxins could make the rice unsafe to eat. Cooked rice should, therefore, be quickly cooled and frozen as soon as possible after cooking, and either cooked from frozen or thawed carefully in a refrigerator rather than at room temperature. Once thawed it should be fully reheated and used, with no subsequent re-freezing of leftovers (Basis NHS Choices website, Ref i64). Storage life data for rice meals are scarce, as shown in Table 9.

Table 9 Reported Practical Storage Lives (PSLs) for home-made rice meals at -18°C

PSL at -18°C	Source	Ref.
2-4 months	Extension Service website, Georgia, USA	i25
3 months	Extension Service website, Nebraska, USA	i24
3 months	Favorite Freezer Foods website, USA	i43

2.6.2 Reported quality issues caused by freezing?

- Cooked rice will soften during freezing and can be overcooked during re-heating (Extension service website, Ref i25 and About.com website, Ref i43).
- Cooked rice stales in a similar way to bread due to starch retrogradation but this can be minimised by rapid freezing and frozen storage at suitable temperatures (Yu et al, 2010, Ref p6).

2.6.3 Pre-freezing guidance

- Cool rapidly after cooking, aided by cold or ice water if need be (Extension Service website, Ref i25).
- Whilst it's unlikely that you'd cook rice specifically to freeze, if it was necessary, slightly undercook rice to allow for some cooking during re-heating (Extension service website, Ref i25 and About.com website, Ref i43).

2.6.4 Freezing guidance

- Freeze cooked rice as soon as cooled as starch retrogradation (staling) will make the rice rigid and tough if left unfrozen (Yu et al, 2010, Ref p6).
- Portion freeze rather than bulk pack, this allows for faster freezing and thawing of only what is required for use.

2.6.5 Thawing guidance

- Defrost in the refrigerator, not at room temperature.
- Rice meals can be cooked from frozen without thawing (Extension service website, Ref i25). Alternatively rice meals can be heated over boiling water (Extension service website, Ref i25).

2.6.6 Re-freezing guidance

It is best to avoid re-freezing as thawed rice can experience warm temperatures which allow bacterial growth and toxin production.

2.7 Chilled ready meals

2.7.1 Reported practical storage life

Chilled ready meals are generally suitable for home freezing. Published data on storage lives of home frozen, but bought as chilled, ready meals were not found during the review. The IIR Red Book (Ref o1) states that it does not give guidance on storage lives due to the wide variety of ingredients and preparation methods, but it does give storage lives for industrially produced frozen meals of up to 24 months. However, these relate to rapidly frozen meals with individually quick frozen ingredients and robust packaging. Storage lives after home

freezing of chilled meals would be far shorter, as reflected by the advice found on chilled ready meal packs during the WRAP survey. This found that 99% of chilled ready meals had on-pack freezing information, with 90% advising a storage life of 1 month and 9% advising 3 months.

Since the WRAP survey was undertaken, Marks & Spencer and Sainsbury's have changed their product labelling to indicate products like ready meals can be frozen any time up to the product's 'use by' date, rather than only on the day of purchase (Figure 4). When the customer wants to eat the frozen product, it should be defrosted and used within 24 hours.

Figure 4 Changes to M&S and Sainsbury's on-pack labelling, in line with WRAP / FSA Freezing Decision Tree⁹ (top images show previous text with new text shown below for each retailer).



2.7.2 Pre-freezing guidance

General advice can be followed, such as 'cool quickly' if the meal has been cooked before freezing (i.e. leftovers rather than freezing the full pack), and portion before freezing if bulk packed. Information for rice and pasta meals (above) is also generally applicable to other ready meals.

2.7.3 Frozen storage guidance

Follow manufacturer's instructions as supplied on pack (Chilled Foods Association website, Ref i57). In line with the general guidance given (§1.3) aim to use them within 3 months of freezing. Storing for longer than 3 months will not be a food safety issue, as long as the food has been maintained frozen, but the quality may not be as expected.

⁹ Available at: http://www.wrap.org.uk/downloads/Freezing_decision_tree.86d00971.11085.d1853d4a.11178.pdf

2.7.4 Thawing guidance

- Frozen ready meals can mostly be cooked or re-heated from frozen. The need for defrosting depends on how the meal was prepared – if a meal has previously been fully cooked it only needs reheating which is best done from frozen, but if it has only been partially cooked it needs further cooking which is best done from the thawed state.
- Some chilled meals frozen at home only have 'cook from chilled' instructions so it may be best to return the frozen meal to the chilled state to follow the chilled cooking instructions to make sure the food is fully heated.
- Thaw in a refrigerator. Store in the fridge. Defrost and use within 24 hours.

2.8 Milk

2.8.1 Reported practical storage life

Limited sources advise that milk is suitable for home freezing, with some citing problems with curdling or separating and changes to flavour and texture (Helpwithcooking website, Ref i6 and Extension service website, Ref i36). This is likely to be related to the fat content of the milk, with higher fat milk (e.g. full fat milk) being most likely to separate or curdle. Lower fat milk such as semi or full skimmed milk is likely to freeze most successfully. Reported practical storage lives are shown in Table 10.

Table 10 Reported Practical Storage Lives (PSLs) for milk at -18°C

PSL at -18°C	Source	Ref
1 month	Extension Service website, Missouri, USA	i23
1 month	Extension Service website, Clemson, USA	i36
6 weeks	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
1-3 months	Extension Service website, Kentucky, USA	i35
3-4 months	IIR Red Book	o1

Only 24% of semi-skimmed milk packs found in the WRAP survey included freezing guidance, with 7% of packs advising storage for up to 1 month. However, 12% of semi-skimmed milk packs surveyed were labelled as not suitable for freezing.

2.8.2 Reported quality issues caused by freezing?

- Expansion of milk inside a sealed bottle can damage packaging, causing spillage and breaking the seal (Favorite Freezer Foods website, Ref i70).
- Freezing is reported to affect the flavour and appearance (Extension service website, Ref i36).
- Fat can separate but can be re-homogenised after thawing by shaking the bottle (Favorite Freezer Foods website, Ref i70).
- Milk protein becomes destabilised and 'texture' changes (Dairy Council of California website, Ref i58).

2.8.3 Pre-freezing guidance

Freeze as soon as possible after purchase when initial quality should be high, and before the 'use by' date.

- Plastic containers are suitable for freezing but the milk will expand on freezing so some free space around the container is needed. Pour out a small amount (and use in a cup of tea) to allow for this.

2.8.4 Freezing guidance

- It is better to avoid freezing in glass bottles as they may shatter due to expansion of contents on freezing or thermal shock on thawing. Figure 1 (earlier) is a suggestion of a suitable alternative container.
- Cardboard cartons are not as suitable for freezing as plastic containers as their barrier properties are not as good, but they can be used.
- Larger packs e.g. 2 litre plastic bottles will take longer to freeze than smaller packs, but there is no published evidence that this is a safety issue.

2.8.5 Thawing guidance

- Thaw in refrigerator (Extension Service website, Ref i36) or in cold water.
- Shake to re-combine (Favorite Freezer Foods website, Ref i70).
- If thawing out of the refrigerator, try to put the pack in the refrigerator when some ice crystals still remain, which indicates that the milk has not warmed to ambient temperatures throughout.

2.8.6 Storage after thawing

Store in the fridge. Defrost and use within 24 hours.

2.9 Store-bought yoghurt

2.9.1 Reported practical storage life

There is conflicting advice on the suitability of yoghurt for home freezing, but the majority of sources suggest that it is suitable. Storage life data are limited (Table 12), but the consensus is relatively short storage of 1-2 months for plain yoghurt, and longer for some flavoured yoghurts due to the presence of fruit acids and sugar (Extension service website, Ref i23). Yoghurt was surveyed in the WRAP survey, but no freezing guidance was found and 41% of packs advised against freezing.

Information on the effect of freezing on live cultures present in some yoghurts is limited to anecdotal evidence rather than the references listed in this report. This suggests that such cultures become dormant when frozen but largely revive when thawed, and this would seem in agreement with general microbiological knowledge.

Table 11 Reported Practical Storage Lives (PSLs) for store-bought yoghurt at -18°C

PSL at -18°C	Source	Ref.
1 month (plain)	Extension Service website, Missouri, USA	i23
1-2 months	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
1-2 months	Extension Service website, Kentucky, USA	i35
1-2 months	Extension Service website, Clemson, USA	i36
2 months	Extension Service website, Texas, USA	i34
5 months (flavoured)	Extension Service website, Missouri, USA	i23

2.9.2 Reported quality issues caused by freezing?

- Freezing causes textural changes (Extension Service website, Ref i36) e.g. yoghurt can 'thin out' and become 'runny' on thawing (About.com website, Ref i60).
- May taste more acidic after thawing (Extension service website, Ref i68).
- Dairy products may separate on thawing, but are still safe (Extension Service website, Ref i34). If products separate these can often be recombined by stirring or can be used in smoothies or other cooked sauces or meals.

2.9.3 Freezing guidance

- Limited freezing guidance was found but there are some anecdotal indications that yoghurt pots can be placed straight in the freezer (head space and pot seal need to be sufficient to cope with expansion).
- Pots can be separated to allow for quicker freezing but this may not be required as the multi-packs maintain reasonable air gaps between pots.
- Multi-packs should be placed on a shelf rather than on top of other food and space left to allow for airflow (eHow Food website, Ref i59).
- Larger e.g. 500g packs can be portioned out into suitable containers – leave headspace for expansion.
- Yoghurt can also be used to create lollies if portioned into ice lolly moulds or used to create yoghurt based frozen desserts (e.g. yoghurt ice cream).

2.9.4 Thawing and use guidance

- Thaw in the refrigerator (About.com website, Ref i60). Stir well before using.
- Can be eaten from frozen.

2.10 Fruit juice

2.10.1 Reported practical storage life

Both shop bought or home-squeezed fruit juices are reported to be suitable for home freezing, although sources are limited. Storage lives are detailed in Table 12. As with the whole fruit (above), non-citrus juice is reported to store for longer than citrus. The WRAP survey found that only 19% of fruit juice packaging carried freezing guidance, with 13% advising a storage life of 1 month.

Table 12 Reported Practical Storage Lives (PSLs) for fruit juice at -18°C

PSL at -18°C	Source	Ref.
Several months	Kalyn's Kitchen website, USA	i9
4-6 months	Extension Service website, Missouri, USA	i23
6 months	Extension Service website, Utah, USA	i30
8-12 months (cartons)	Extension Service website, Clemson, USA	i36
12 months (home frozen)	Extension Service website, Texas, USA	i34

2.10.2 Reported quality issues caused by freezing?

Citrus may not store as well as non-citrus (Extension Service website, Ref i23). This may be that flavour loss is more apparent in acidic drinks, or that acidity accelerates chemical reactions. Some types of juice (e.g. plum juice) may thicken and concentrate during storage and may need to be diluted with water for use (Hub pages website, Ref i53).

2.10.3 Pre-freezing guidance

- Strain home-made juices to remove any pieces of pith (Hub pages website, Ref i53).
- Portion juice into smaller containers to increase freezing rate.
- Can freeze in plastic bottles, leaving headspace for expansion (Canadian Produce Marketing website, Ref i46). Cardboard cartons are not as suitable for freezing as plastic containers as their barrier properties are not as good, but they can be used.
- To halt enzymatic action, which can turn juice brown during extended storage, the fruit or the juice can be boiled and then cooled before freezing (Hub pages website, Ref i53). Shop bought pasteurised juices have already been through this process and so it is only necessary for fresh unpasteurised juice.

2.10.4 Freezing guidance

- Can freeze in ice cube trays and when frozen transfer to a sealed bag (Canadian Produce Marketing website, Ref i46).
- If freezing juice in bags, double bag to minimise any leakage (Hub pages website, Ref i53) or use a freezer bag designed for liquids e.g. Figure 1 above.
- Lay bags flat to freeze so that they can be stacked (Hub pages website, Ref i53).
- Fruit juice can also be used to create lollies if portioned into ice lolly moulds.

2.10.5 Thawing guidance

- Thaw in the refrigerator but allow a good amount of time for thawing (due to carton shape and size, and high water content, thawing can be quite slow).
- Can thaw at room temperature and then refrigerate (Kalyn's Kitchen website, Ref i9).
- Can microwave with care, but avoid overheating as this will diminish the flavour (Kalyn's Kitchen website, Ref i9).
- Shake well before using.

2.11 Ambient cooking sauces

2.11.1 Reported practical storage life

Although there are no published data on home freezing of ambient cooking sauces, logic suggests that they are suitable for home freezing as long as opened jars have been handled correctly after opening. In this respect it is important to note that opened jars may have had bacteria introduced, so must either be kept refrigerated before freezing (for the length of time indicated on-pack e.g. 'use within 3 days of opening') or be frozen straight away.

As with store-bought ready meals, there may be differences in suitability for freezing based on composition of the sauce, with dairy and fat based sauces being less suitable than tomato based sauces as they are emulsions which can separate and appear curdled (FSIS, Ref i32).

The WRAP survey found that only 20% of ambient tomato-based cooking sauce packs carried freezing guidance, but interestingly 98% of chilled tomato-based cooking sauces carried freezing guidance. Of these almost all (97% of all packs) suggested a frozen storage life of 1 month.

2.11.2 Pre-freezing guidance

Keep opened jars refrigerated and freeze as soon as possible. Use or freeze within the length of time indicated on-pack e.g. 'use within 3 days of opening'.

2.11.3 Freezing guidance

Avoid freezing in glass jars, re-pack contents in bags, containers etc.

2.11.4 Thawing guidance

Thaw in the fridge. Defrost and use within 24 hours. Shake well before using.

2.12 Meat joints (raw and cooked)

2.12.1 Reported practical storage life

Raw meat joints are suitable for home freezing, and suggested PSL data for each species are relatively abundant, as shown in Tables 13-16 below.

Table 13 Reported Practical Storage Lives (PSLs) for raw beef joints at -18°C

PSL at -18°C	Source	Ref.
1-3 months	Extension Service website, Nebraska, USA	i24
4-12 months (roasts)	Food Safety and Inspection Service USDA website USA	i32
4-12 months (roast)	Extension Service website, Clemson, USA	i36
6 months (joints)	Helpwithcooking website, UK	i6
6-12 months (roast)	Extension Service website, Texas, USA	i34
6-12 months (roast, steaks)	Extension Service website, Kentucky, USA	i35
6-12 months	Damen & Steenbekkers, 2007	p13
10-12 months (steaks, roasts)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
12 months	British Frozen Food Federation website, UK	i1
18 months	Commonwealth Scientific and Industrial Research Organisation website, Australia	i33
18 months (steaks / cuts)	IIR Red Book	o1

Table 14 Reported Practical Storage Lives (PSLs) for raw lamb joints at -18°C

PSL at -18°C	Source	Ref.
4 months	Damen & Steenbekkers, 2007	p13
6 months (joints)	Helpwithcooking website, UK	i6
4-12 months (roasts)	Food Safety and Inspection Service USDA website USA	i32
4-12 months (roast)	Extension Service website, Clemson, USA	i36
6-12 months (roast)	Extension Service website, Texas, USA	i34
6-12 months (roast, steaks)	Extension Service website, Kentucky, USA	i35
8-12 months (chops, roasts)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
10 months	British Frozen Food Federation website, UK	i1
18 months	Commonwealth Scientific and Industrial Research Organisation website, Australia	i33
18 months (steaks)	IIR Red Book	o1

Table 15 Reported Practical Storage Lives (PSLs) for raw pork joints at -18°C

PSL at -18°C	Source	Ref.
4 months	Damen & Steenbekkers, 2007	p13
4-12 months (roasts)	Food Safety and Inspection Service USDA website USA	i32
4-12 months (roast)	Extension Service website, Clemson, USA	i36
6 months	British Frozen Food Federation website, UK	i1

PSL at -18°C	Source	Ref.
6 months (joints)	Helpwithcooking website, UK	i6
6-12 months (roast)	Extension Service website, Texas, USA	i34
6-12 months (roast, steaks)	Extension Service website, Kentucky, USA	i35
8-12 months (chops, roasts)	Canadian Partnership for Consumer Food Safety Education website, Canada	i44
10 months	Commonwealth Scientific and Industrial Research Organisation website, Australia	i33
10 months (steaks, cuts)	IIR Red Book	o1

There is considerable variability in suggested storage lives, with some of the shorter lives being for joints and other cuts as single 'lumped' values, and some of the longer possibly being for more rapidly frozen and well-controlled storage. There are fewer reported PSLs for cooked meat joints, as shown in Table 16.

Table 16 Reported Practical Storage Lives (PSLs) for cooked meat joints at -18°C

PSL at -18°C	Source	Ref.
1-2 months	New Zealand Government 'foodsmart' website, NZ	i2
1-2 months	Extension Service website, Oregon, USA	i28
1-3 months	Extension Service website, Nebraska, USA	i24
2-3 months	Food Safety and Inspection Service USDA website USA	i32
2-3 months	Extension Service website, Clemson, USA	i36
2-4 months	Extension Service website, Georgia, USA	i25
3-6 months (pork)	Extension Service website, Missouri, USA	i23
6-9 months (lamb, veal)	Extension Service website, Missouri, USA	i23
6-12 months (beef)	Extension Service website, Missouri, USA	i23

2.12.2 Reported quality issues caused by freezing?

- Fats are susceptible to rancidity during frozen storage, primarily resulting from oxidation.
- Cooked meat does not store frozen as well as raw meat, due to the reduced water content (FSIS USDA website, Ref i52).
- If not properly wrapped, meat can become freezer burnt (Helpwithcooking, Ref i6).
- Formation of ice crystals, particularly during slow freezing, can result in damage to cell walls and loss of fluid which becomes evident on thawing. This is known as 'drip loss' and has been the subject of extensive and varied scientific trials for many years. The influence of freezing rate, storage temperature and time, thawing rate etc. have been studied with differing and often contradictory results as described for example by Ngapo *et al* (1999, Ref p17).

2.12.3 Pre-freezing guidance

- Cut (or ask the butcher to cut) joints into smaller pieces if necessary (CookUK, Ref i4).
- Rancidity in frozen meat should be minimised whenever possible by trimming off all excess fat before freezing (e.g. CookUK website, Ref i4 and Prepared Pantry website, Ref i21) and by removing as much air as possible from packs and using air-tight packaging (Helpwithcooking website, Ref i6).
- Wrap several times in foil and fold in edges, then place in sealable freezer bag, extract air and seal. Label the bag with the date frozen (CookUK website, Ref i4).

2.12.4 Thawing guidance

- Although meat can be cooked from frozen, allowing additional time to ensure full cooking throughout (Extension Service website, Ref i68), it is safer to fully thaw before cooking to help ensure that joints are cooked through (e.g. NHS Choices website, Ref i64). Larger joints, cooked from frozen, will take longer to cook and are more likely to overcook on the outside whilst the centre is undercooked.
- Thaw in a refrigerator rather than at room temperature. This can however, require lengthy thawing periods and careful planning. Cool running water can also be used to thaw meat in sealed bags (Extension Service website, Ref i68).
- If microwave thawed using the “defrost” setting, cook straight away as microwave heating will be uneven and may have started to cook parts of the meat (Extension Service website, Ref i68).
- When thawing raw meat, do so overnight in a clean, covered container at the bottom of the fridge, to prevent any juices from dripping onto food which may be eaten without cooking. Once defrosted, keep the meat in the fridge and use it within two days.
- Do not thaw at room temperature, as doing so exposes food to the “danger zone” between 8°C and 63°C when harmful bacteria can grow quickly.

3.0 Conclusions

Table 17 provides a summary of the conclusions for each of the 12 products considered.

Most striking is the variability in storage life for each product reported. This may be due to a variety of factors. Generally, storage at lower temperatures will achieve longer storage life. In this analysis -18°C has been considered as the approximate temperature achieved in a home freezer. The data extracted have, wherever possible, been applied to home freezing and this is likely to be slower than an industrial process and there may be a greater level of temperature fluctuation than in an industrial process. Nevertheless, it is not always possible to determine the exact condition or methodology under which PSLs were determined and this may have an influence over the variations in PSLs reported.

Much of the scatter in data is likely to be due to a variety of product processing and packaging (PPP) factors. PPP factors have an influence over PSL by:

Product

- 1 Variations in the raw material between samples from different breeds or cultivars can have an intrinsic effect of storage life.
- 2 Time between harvest or slaughter and initial chilling has been shown to have a major influence on storage life.
- 3 Initial quality of samples, ripeness, cleanliness and physical damage.
- 4 Handling during harvest/slaughter, transport and processing.
- 5 Seasonality of the product.

To have maximum shelf life, the food should have good initial microbiological, physical and sensory qualities and undergo as few higher temperature processes as possible (apart from some decontamination procedures such as pasteurisation).

Process

Processing factors also have a major influence on storage life. Cutting, slicing and dicing can increase enzymatic activity by cutting cells and can distribute and accelerate growth of micro-organisms. Mincing can also reduce shelf life in a similar way by spreading bacteria from the surfaces of the meat to the inner tissues and creating greater exposed surface area, and also by adding heat during the mincing process. Addition of fat to mince can also lower storage life by increasing exposed fat surfaces which are susceptible to oxidation and rancidity. To help minimise this, a high grade wrapping material, which has the ability to exclude air, must be used to wrap the product.

Additives, such as antioxidants and many spices (which contain antioxidants) can be used to extend shelf life. Oxygen scavenging compounds, such as ascorbic acid, reduce the availability of oxygen for oxidation reactions and slow down the onset of rancidity. However, some additives e.g. salt, are oxidising agents and can act to promote oxidation and rancidity.

Packaging

Packaging has a large direct effect on storage life of frozen foods, especially fatty foods. It can also, in extreme cases, indirectly affect storage life due to substantially increasing the freezing time. Wrapping in a tightly fitting pack, with a low water and oxygen permeability (such as a vacuum pack) can more than double the storage life of a meat product. Waterproof packing also helps to prevent freezer burn and tight packing helps to prevent an ice build-up in the pack.

The variations in PPP factors often leads to variable and contradictory conclusions and recommendations, and therefore care needs to be taken when applying published data.

It was apparent during the review that there is a relatively high incidence of online advice originating from American and also Canadian websites. While this may partly reflect differences in use of this medium between countries, languages, cultures etc. it is also partly due (at least in America) to a conscious effort to provide non-formal educational programmes designed to help people use research-based knowledge to improve their lives. This is coordinated in the USA by the Co-operative Extension Service, also known as the Extension Service of the USDA, provided by many of the American states' designated land-grant universities.

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.

This research has found that the majority of foods are suitable for home freezing. Increasing freezing of foods could save at least 800,000 tonnes of food (costing £2 billion) being thrown away each year in the UK. 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 consumers have access to good freezing guidance either through communications activity or on-pack. Manufacturers are encouraged to carry out product freezing trials to help inform advice given on their products, and to their customers.

Some key opportunities are to increase the prevalence of the snowflake logo on-pack to highlight that the product is suitable for home freezing, and reduce instances of text stating 'not suitable for home freezing' on e.g. milk, yoghurt, juice and cooking sauce. It will also help consumers for all freezing guidance to be accompanied by defrosting guidance and a suggested storage life of 1 or 3 months.

WRAP will use this report to work with the food industry and Love Food Hate Waste partners to continually improve the freezing guidance provided to consumers.

Table 17 Summary and conclusions on freezing of considered products

Product	Availability of info	Suitable for freezing	Main detrimental issues during freezing	Published range of PSLs at -18°C (months)	Advice
Bread	Good	Yes	Staling, dehydration	0.5 to 8	Freeze in air-tight packaging. Freeze when as fresh as possible. Freeze in portions to speed up freezing rate and for ease of use.
Pork (cooked sliced ham, bacon, raw & cooked sausage)	Good	Yes	Rancidity, oxidation	1 to 6 (with 24 months suggested for commercial storage)	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.
Vegetables	Good	Generally yes (if blanched)	Loss of flavour, colour, texture	1 to 18	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. Individually freeze items if possible as freezing is faster and portioning is simpler, then transfer to bags. Most vegetables can be cooked directly from frozen.
Fruit	Good	Mostly yes	Loss of structure	4 to 24	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.

Product	Availability of info	Suitable for freezing	Main detrimental issues during freezing	Published range of PSLs at -18°C (months)	Advice
Pasta meals (home-made)	Limited	Mostly yes	Separation of sauces, texture of pasta	2 to 4	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.
Rice meals (home-made)	Limited	Mostly yes	Bacteria growth prior to freezing	2 to 4	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.
Chilled ready meals	Very poor	Yes	Separation of sauces, texture of meal	No review data, WRAP survey shows most packs give 1	For best quality, freeze when fresh. Safe to freeze up to use by date (defrost and use within 24 hours). Cook from frozen or defrost in fridge.
Milk	Limited	Mostly yes	Separating and curdling	1 to 4	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 recombine.
Store-bought yoghurt	Limited	Mostly yes	Texture and separation	1 to 2 plain Up to 5 flavoured	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 recombine. Consider making yoghurt ice cream or lollies to use up spare yoghurt.

Product	Availability of info	Suitable for freezing	Main detrimental issues during freezing	Published range of PSLs at -18°C (months)	Advice
Fruit juice	Limited	Yes	Thickening	4 to 12	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 recombine. Consider making lollies to use up spare juice.
Ambient cooking sauces	Very poor	Mostly yes	Separation of sauces, texture of meal	No review data, WRAP survey suggests 1	Freeze unopened sauces as soon as possible after purchase. Decant sauces sold 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 pasta / rice meals.
Meat joints (raw and cooked)	Good	Yes	Rancidity, oxidation	1 to 12	Freeze when fresh. Safe to freeze up to use by date (defrost and use within 24 hours). Wrap in air-tight packaging. Freeze in small portions if possible. Cook and eat soon after thawing or cook smaller portions from frozen. Remove as much fat as possible prior to freezing.

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Appendix 1 - Initial assessment of 41 products

The project team undertook an initial assessment of 41 products – sliced and 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 cheese (cottage, Philadelphia, brie), yoghurt, leftover cooked vegetables, vegetables (sauced / pureed, raw), vegetables (blanched, raw), vegetables (whole / chopped, raw), fruit cake, sponge cake. 21 of these were grouped, and taken forward to the second stage assessment.

Table A1 shows the initial assessment results for the 21 products that were taken forward to the second stage assessment. Table A2 shows the full results for the remaining 20 products. The full results from the initial assessment are not shown for the 12 products because these results were superseded by the second stage assessment and results presented in the main report.

Table A1 Results from initial assessment for the products carried forward to the second stage assessment

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref
Sliced and unsliced bread	x x x x x x x x x x x x x X(part baked)	x(part baked)		i2 i5 i6 i7 i8 i21 i23 i24 i25 i28 i35 i36 p1 p3 p16
Fruit juice - Fresh (assumed frozen as juice and not components)	x x x x(home frozen) x(cartons)			i9 i23 i30 i34 i36
Fruit frozen in current form	x x x x x x		x(high water content) x(apples, melons)	i6 i23 i19 i28 i29 i30 i31

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref
	x(berries, cherries, peaches, pears, pineapples, strawberries) x(raspberries, strawberries, peaches, apricots, cherries) x(many fruits) x(many fruits) x(raspberries, strawberries, peaches, apricots)		x(bananas) x(apples, avocados, bananas)	i31 i33 i35 i36 o1 p8
Fruit treated before freezing	x(many fruits sugared, pureed or syrup) x(puree) x(syrup etc.) x x(raspberries, strawberries, peaches, apricots in syrup) x(melon, cubed in syrup)			i6 i28 i29 i30 o1 o2
Cooked Pasta	x x(fresh)		x	i6 i23 i35 p5
Cooked Rice	x x		x	i6 i23 p6
Bacon	x x x x x x x x(vacuum packed)			i1 i4 i23 i32 i34 i36 i44 o1
Pasta meals	x(tomato sauces) x x x x x	x(creamy) x	x(egg-based sauces)	i6 i6 i5 i24 i25 i28 i43 i54 p5
Rice meals	x x x x			i6 i24 i25 i43
Ready Meals	x(meat, IQF blanched veg)	x x		o1 p9 p10
Pork	x x(joints, chops, mince) x x x(roasts, steaks, mince) x(roasts, steaks) x(steaks, roasts, chops)			i4 i6 i32 i33 i34 i35 i36

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref
	x(chops, roasts) x(steaks, cuts) x			i44 o1 p13
Sausages (raw)	x x x x x x(pork, beef, turkey)			i4 i6 i32 i35 i36 i44
Home cooked meat joint	x x x x x x x x x			i2 i6 i21 i23 i24 i25 i28 i32 i36
Cooked sliced ham	x x x x x x x(half and slices)			i6 i23 i24 i32 i35 i36 i44 p12
Sausages (cooked)	x x x	x		i6 i34 i44
Yoghurt	x x x x		x	i5 i23 i34 i35 i36 i44
Leftover Cooked Vegetable	x(beans, pulses) x(veg dishes)		x(potato, pepper, courgette, squash) x(creamed)	i20 i25 i44
Vegetables Sauced/pureed (raw)	x(tomato) x(raw and cooked) x(tomato)			i6 i40 o2
Vegetable blanched (raw)	x x(most) x(many) x x x x x(many) x(leeks)			i1 i4 i6 i19 i22 i23 i32 i40 o1 p11
Vegetable whole/chopped (raw)	 x(starchy) x(many veg!)	x	x(high water content) x(high water content)	i5 i6 i6 i6

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref
	x(stir fry types) x(home frozen) x(vacuum packed) x(bans) x(bell peppers) x(many veg) x(many veg) x(bans, carrots, celery, spinach, squash, tomatoes) x(many veg) x(mushrooms)		x(cabbage, cucumbers, leafy))	i23
			x(lettuce, greens, tomato)	i25
				i28
				i31
				i31
				i34
				i34
			x(lettuce, onions)	i35
			x(artichokes, lettuce, onions, radishes)	i36
			x(leafy)	i44
				i44
				o1
				o1
		x(green beans)		p14
		x (leafy)		p15
Milk	x			i4
			x	i6
	x			i23
	x			i35
		x		i36
	x			i44
	x			o1

Table A2 Results from the initial assessment for 20 products

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
Rolls and Baguettes	x			i6			3 months	i6	Part bake home-made rolls and buns for freezing Baked goods without filling are safe to thaw at room temperature
	x			i24			3-6 months	i24	
	x			i25			6-8 months	i25	
	x			i28			4-6 weeks	i28	
	x			i34			2-3 months	i34	
	x			i35			2-3 months	i35	
	x			o2			8 weeks	o2	
World Breads	x			i5	French crusty bread will suffer crust damage	i5	3 months	i5	Baked goods without filling are safe to thaw at room temperature Wrap well (Ref i7)
		x(French)		i5	World breads store better than yeast breads	i8	4 months	i7	
	x			i7	Frozen part baked French bread appearance and texture preferred to fresh French bread after up to 7 days frozen storage	p2	6 months	i8	
	x(French)			i8			2-3 months	i21	
	x			i21			3 months (tortillas)	i36	
	x(tortillas)			i36					
	x(French)			p2					
Pizza	x			i3	Freeze in shop packaging for bought	i13	3 months (home-made)	i13	Can bake before freezing (home-made)
	x			i13	Use airtight container for homemade	i13	12 months (shop)	i13	Omit toppings such as pepperoni, add later (home-made)
	x			i25	Slight quality advantage in fast freezing, but benefit lost during	p4	1 month (home-made)	i25	Can prepare as usual but freeze unbaked (home-made)

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x			i28	frozen storage		1 month (home-made)	i28	Good method is to freeze on tray then heavy foil or freezer grade plastic wrap
	x			i31			1-2 months	i31	
	x			i36			1-2 months	i36	
	x			o1			6 months	o1	
Smoothies (assumed frozen as smoothie rather than components)	x			i10	Fruit and dairy mixtures freeze well	i10	A few weeks	i11	Freeze in small, portion sized containers which thaw (fully or partially) quickly
	x			i11	Some difference of opinion over whether dairy based smoothies freeze well				Air tight containers will help to avoid fruit degrading
	x(except those with yoghurt, ricotta, cottage cheese)		x(those with yoghurt, ricotta, cottage cheese)	i37					
Eggs	x(egg whites)			i2	Cooked yolks also acceptable to freeze	i2	12 months (egg whites)	i2	Do not freeze in shell
	x(whole ex-shell)			i6	Cooked egg whites not acceptable to freeze	i2	9 months	i6	Can beat into mixture, or freeze yolks or whites separately
	x(egg yolks)			i6	Omelettes and soufflés cooked with thawed eggs may not rise as well as fresh	i12	12 months	i14	Can freeze individually in ice cube trays and then put in bags
	x(egg whites)			i6	Add salt to fresh yolks to stop them going lumpy	i14	9-12 months	i23	Do not thaw at room temperature
		x(egg yolks)		i5	Break whole eggs and mix yolks/whites prior to	i28	6 months (whole ex shell, whites, yolks)	i28	Can add salt if destined for savoury use, or sugar for sweet - will help avoid skin

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
			x(shell eggs)	i5	freezing Add sugar corn syrup or salt to prevent graininess	i28	12 months (whites)	i32	formation and stickiness Adding salt or sugar stops yolks going lumpy
			x(whole)	i12	Cover yolks with water	i34	12 months (whites, yolks)	i34	Use as for fresh eggs but souffles and omelettes may not rise as much
	x(yolk)			i12	In shell eggs break and lose quality	i36	12 months (whites, yolks)	i35	
	x(white)			i12	Yolks can clump	i36	12 months (whites)	i35	
	x(yolk with salt)	x(yolk without salt)	x	i14			4 months (ex shell)	i44	
	x(white)			i14			12 months (whole egg magma)	o1	
							> 12 months (whole, yolks, whites)	o2	
	x(whole, white, yolks)			i23					
	x	x	x	i28					
	x(whites)			i32					
	x(whites, yolks)		x(whole)	i34					
	x(whites, yolks)		x	i35					
	x(whites)		x(in shell, yolks)	i36					
	x(ex shell)		x(in shell)	i44					
	x(whole egg magma)			o1					
	x(whole, yolk, white)			o2					
Quiche	x			i15			6 months	i15	Prepare and bake as normal or freeze unbaked
	x(uncooked)			i16			1 month (uncooked)	i16	If baked, allow to cool fully on wire rack before freezing
	x(cooked)			i16			1 month (cooked)	i16	If unbaked, part freeze on tray to firm,

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x(cooked / uncooked)			i38			by inference 2 months (cooked)	i38	then wrap Wrap in foil and freezer paper
	x			i39			1 month (uncooked)	i38	Thaw in refrigerator
Oily Fish	x			i1	Use ascorbic acid dip, then ice glaze or ice block	i17, i6	4 months	i1	Best to freeze fillets (Ref i17)
	x			i6	Frozen storage reduces omega3 in cooked sardine	p7	2-3 months	i6	Use ascorbic acid dip prior to freezing (2 teaspoons ascorbic acid in 1 l water)
	x			i17	Oxidative changes (rancidity) limit life	o2	2-3 months	i18	Can glaze by part freezing, dip, freezing, dip to build up several layers
	x			i18			2-3 months	i23	Thaw in refrigerator
	x			i23			2-3 months	i30	
	x			i31			5 months	i33	
	x			i33			2-3 months	i34	
	x			i34			2-3 months	i35	
	x			i35			2-3 months	i36	
	x			i36			2 months	i44	
	x			i44			5 months (glazed)	o1	
	x(glazed)			o1			6 months (herring, whole)	o2	
		x(cooked sardine)		p7			3 months (mackerel, packed)	o2	
	x			o2			4-6 months (chubb, pink slamon)	o2	
							5-9 months (mackerel, sea herring)	o2	
							4-6 months (sardines, tuna)	o2	
White fish	x			i1	Use brine dip, then ice glaze or ice block	i6	8-10 months	i1	Best to freeze fillets (Ref i6)

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x			i6			6 months	i6	Use brine dip prior to freezing (50g salt in 1l water for 20s)
	x			i23			3-6 months	i23	Can glaze by part freezing, dip, freezing, dip to build up several layers
	x			i31			6 months	i31	Can place in deep tray with water and freeze as block, remove and bag when frozen
	x			i33			9 months	i33	Thaw in refrigerator
	x			i34			6 months	i34	
	x			i35			6 months	i35	
	x			i36			6 months	i36	
	x			i44			6 months	i44	
	x			o1			9 months	o1	
	x			o2			11-12 months (haddock)	o2	
							6 months (packed cod)	o2	
							9 months (packed bass, halibut)	o2	
							>12 months (packed cod, haddock)	o2	
Prawns	x			i1	Texture may become mushy (cooked)	i36	6 months	i1	Can freeze raw, cooked in shell, or cooked and de-shelled
	x(cooked)			i31			3 months (cooked)	i31	If cooked, fully cool before freezing, use refrigerator if need be
	x(uncooked)			i31			3-6 months (uncooked)	i31	Can place in deep tray with water and freeze as block, remove and bag when frozen
	x(cooked)			i33			5 months	i32	Thaw in refrigerator
	x(uncooked)			i34			12 months	i34	
	x			i35			3-6 months	i35	
	x(raw)		x(cooked)	i36			3-6 months	i36	
	x(raw, cooked)			i44			2-4 months	i44	

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x(cooked, peeled)			o1			6 months (cooked, peeled)	o1	
Mashed Potato	x			i21	Texture damaged, goes towards watery consistency	i42	2-4 weeks	i24	Freeze in straight sided container or in portions
	x			i24			2-4 weeks	i25	Can add beaten egg and shape into patties for freezing, fry on thawing
	x			i25			2-3 months (scoops)	i41	
	x(scoops)			i41					
		x		i42					
Meat pie	x			i6			1-2 months (-29°C)	i4	Cool quickly after cooking, use ice water if need be
	x			i24			3 months	i24	For home-made, cook filling until nearly done, omit potato
	x			i25			4-6 months	i25	Top crust only may be better, avoids soggy pastry on bottom
	x			i28			2-3 months	i28	Need not be baked before freezing Bake from frozen
Soup	x(many types)			i5	Leave out some ingredients if freezing e.g. Pasta	i5	2-3 months	i2	Cool quickly after cooking, use ice water if need be
	x		x(cream or egg)	i6	Not creamy or egg versions	i6			Meat or veg soups, thaw in refrigerator
	x			i25			4-6 months	i25	Cream or puree soups, cook from frozen in pan over boiling water, stir
	x(meat and veg)			i28			2-4 months (meat and veg)	i28	
	x(cream)			i28			2-3 months (cream)	i28	
	x(meat and veg)			i31			2-3 months	i31	
	x			i32			2-3 months (meat and veg)	i32	
	x			i35			2-3 months	i35	
	x(broth)		x(cream)	i36			4 months (broth)	i36	

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x(leftovers)			i44			4 months (leftovers)	i44	
Beef	x			i4	Little change in structure, freshness or nutrients	i6	10-12 months	i1	Freeze cooked or raw
	x(joints, cuts, mince)			i6			8-12 months (-29°C)	i4	If cooking to freeze, cook to rare condition to allow for cooking during reheating
	x			i24			8 months	i4	Thaw in a refrigerator not at room temperature
	x (raw roasts)			i32			6 months (joints)	i6	Avoid overlarge, thick pieces
	x			i33			3 months (chops)	i6	Freeze as soon as possible to retain quality
	x(roasts, steaks, mince)			i34			2-3 months (mince)	i6	Fat does not store as well (due to rancidity) so trim off as much as possible
	x(roasts, steaks)			i35			1-3 months (home)	i24	
	x(steaks, roasts)			i36			4-12 months (raw roasts)	i32	
	x			i44			18 months	i33	
	x(steaks, cuts,mince)			o1			6-12 months (roast)	i34	
	x			p13			6-9 months (steaks)	i34	
	x(mince)			p13			2-3 months (mince)	i34	
							6-12 months (roast, steaks)	i35	
							6-12 months (steaks)	i36	
							4-12 months (roast)	i36	
							10-12 months (steaks, roasts)	i44	
							18 months (steaks/ cuts)	o1	
							10 months (mince)	o1	
							6-12 months	p13	
							2-3 months (mince)	p13	
Chicken / Turkey	x			i1	Little change in	i6	12 months	i1	Freeze cooked or raw

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x			i2	structure, freshness or nutrients		6 months	i2	If cooking to freeze, cook to rare condition to allow for cooking during reheating
	x			i4			9 months (-29°C)	i4	Thaw in a refrigerator not at room temperature
	x			i6			12 months	i7	Avoid overlarge, thick pieces
	x			i7			12 months	i23	Freeze fresh meat as soon as possible to retain quality
	x			i23			1-3 months	i24	Protect sharp edges (bones) with folded foil, wrap bird or pieces twice in foil and place in freezer bag - remove air
	x			i24			3 months	i31	
	x(whole, parts)			i32			12 months (whole)	i32	
	x(parts)			i32			9 months (parts)	i32	
	x (raw)			i33			18 months (raw)	i33	
	x(whole, parts)			i32			12 months (whole)	i34	
	x(whole, parts)			i34			6-9 months (parts)	i34	
	x(whole, parts)			i35			12 months (whole)	i35	
	x(whole, parts)			i36			6-9 months (parts)	i35	
	x(whole, pieces)			i44			12 months (whole)	i36	
	x(whole, parts)			o1			9 months (parts)	i36	
							12 months (whole)	i44	
							6 months (pieces)	i44	
							18 months (whole, parts)	o1	
Lamb	x			i4	Little change in structure, freshness or nutrients	i6	10 months	i1	Freeze cooked or raw
	x(joints, chops, mince)			i6			6-9 months (-29°C)	i4	If cooking to freeze, cook to rare condition to allow for cooking during reheating
	x			i32			6 months (joints)	i6	Thaw in a refrigerator not at room temperature

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x			i33			3 months (chops) 2-3 months (mince)	i6 i6	Avoid overlarge, thick pieces Freeze fresh meat as soon as possible to retain quality
	x(roasts, steaks, mince)			i34			4-12 months (raw roasts) 18 months	i32 i33	
	x(roasts, steaks)			i35			6-12 months (roast)	i34	
	x(steaks, roasts, chops)			i36			6-9 months (steaks)	i34	
	x(chops, roasts)			i44			2-3 months (mince)	i34	
	x(steaks)			o1			6-12 months (roast, steaks)	i35	
	x			p13			6-12 months (steaks)	i36	
							(steaks) 4-12 months (roast)	i36 i36	
							4-6 months (chops)	i36	
							8-12 months (chops, roasts)	i44	
							18 months (steaks)	o1	
							4 months	p13	
Cream (single, double)			x(single)	i5	Emulsions may curdle or separate	i6	6-8 weeks	i23	Conflicting advice on suitability
	x(double)		x(single)	i6	Texture changes	i36	2 months	i34	
	x			i23			4 months (half and half)	i36	
	x			i34			12 months	o1	
		x(half and half)		i36					
	x			o1					
Hard Cheese (cheddar, stilton etc.)	x(grated)			i5	Can crumble when slicing	i36	6-9 months	i23	Some negative comments on textural changes. Grate before freezing
	x			i23			4 months	i30	

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x x x	x		i30 i34 i36 i44			6 months 6 months 12 months	i34 i36 i44	
Soft Cheese (cottage, Philadelphia, brie etc.)	x(ricotta) x(firm - as opposed to hard)	x x	x x x(ricotta, cottage cheese) x(cottage cheese, soft)	i5 i30 i34 i35 i36 i36 i44	Can go watery Texture can change	i5 i36	4 months (ricotta) 6 months 3 months (firm - as opposed to hard)	i34 i36 i44	Generally unsuitable for freezing Can go watery Texture can change
Fruit cake	x x(baked) x(unbaked) x x			i21 i24 i24 i35 i36	Cakes without icing/marzipan freeze well (wrapped)	i21	3 months 2-4 months (baked) 2 weeks (unbaked) 12 months 12 months	i23 i24 i24 i35 i36	Freeze whole or sliced with grease-proof paper between slices Freeze in boxes to avoid crushing Thaw at room temperature unless iced or filled, in which case thaw in the fridge
Sponge cake	x x(cake) x			i21 i23 i24	Cakes without icing/marzipan freeze well (wrapped)	i21	4-6 months 6 months (egg-white cakes) 4-6 months (whole	i24 i25 i25	Freeze whole or sliced with grease-proof paper between slices Freeze in boxes to avoid crushing Thaw at room temperature unless iced or

Product	Can be frozen with little cellular damage	Can be frozen with some cellular damage	Cannot be frozen successfully	Ref	Comments on quality and safety changes / methods etc.	Ref	PSL (at -18°C unless stated)	Ref	Summary of advice for each product
	x			i25			egg cakes) 2 months (egg yolk cakes)	i25	filled, in which case thaw in the fridge
	x			i35			2 months	i35	
	x			i36			4-6 months	i36	
	x(cakes)			o1			15 months (cakes)	o1	

Appendix 2 – Selected data from WRAP's 2011 Retailer Survey

Table A3 Proportion of products carrying freezing and defrosting guidance¹⁰ | Base: 6,157

Product category	Product sub category	Freezing present	Defrosting present	Sample size
Bread	Packaged bread	99%	33%	882
	ISB bread	1%	1%	177
Rolls	Packaged rolls	84%	49%	624
	ISB rolls	7%	<1%	234
World bread	Pitta	87%	62%	193
	Wraps	97%	41%	290
	Naans - ambient	90%	75%	172
	Naans - chilled	94%	94%	31
Chicken	Chilled	100%	86%	313
Bacon	Bacon - packed	91%	81%	486
	Bacon - deli	-	-	12
Milk		24%	22%	447
Ready meals	Ready meals - chilled	99%	81%	328
Orange juice		19%	19%	629
Cooking sauce	Chilled	98%	71%	98
	Ambient	20%	-	1241
Total		63%	45%	6157

Table A4 Prevalence of guidance not to freeze, by product category | Base: 12,149

Product category	Product sub-category (where pertinent)	Guidance not to freeze only	Guidance not to freeze with crossed out snowflake
Rolls	Pre-packaged	1%	<1%
	ISB	3%	
Carrots	Standard	9%	
	Pre-prepared	7%	
Ham	Pre-packed	6%	5%
Cheese	Pre-packed	2%	
Yoghurt	Single	32%	8%
	Multipack	9%	3%
Milk		12%	
Juice		2%	2%
Cooking sauce	Ambient	2%	
Mayonnaise		43%	
Total – percentage of all products		5%	1%

¹⁰ Omits guidance not to freeze, includes guidance in the form of symbols with associated text.

Table A5 Guidance given on length of time to freeze products | Base: 6157

Category or sub-category	Length of time product may be frozen for	Overall percentage of this category giving this guidance
Bread packaged	1 month	31%
	3 months	27%
Bread ISB	1 month	1%
	3 months	
Rolls packaged	1 month	47%
	3 months	10%
Rolls ISB	1 month	<1%
	3 months	4%
World bread - pitta	1 month	64%
	3 months	
World bread - wrap	1 month	30%
	3 months	43%
World bread - naan - ambient	1 month	73%
	3 months	
World bread - naan - chilled	1 month	90%
	3 months	
Chicken - chilled	1 month	96%
	3 months	
Bacon - packed	1 month	79%
	3 months	8%
Milk	1 month	7%
	3 months	
Ready meals - chilled	1 month	90%
	3 months	9%
Juice	1 month	13%
	3 months	
Cooking sauce - chilled	1 month	97%
	3 months	
Total percentage branded / own-label	1 month	34%
	3 months	57%

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