Delay Times between Harvesting or Collection of Food Products and Consumption for Use in Radiological Assessments

A L Jones and J C Sherwood

ABSTRACT

The time delay between the harvesting or collection of a foodstuff and its consumption must be taken into account when estimating the intake of radionuclides by man as a result of deposition onto a food producing area of land. This is because a proportion of the radioactive material present in the foodstuff at the time of harvest or collection will have decayed. In the case of short-lived radionuclides, the amount of this material that decays may be a significant fraction of the total. This report updates earlier work, taking into account changes and modernisation in industrial food processes, and also the changing popularity of different foods, since that time. Information is also presented for more foodstuffs. Factors such as industrial processes and preparation times, storage time at the producer's, storage time in the home and the shelf-life of the product have been taken into account. For each type of food, a typical range, an average and a minimum delay time are presented. The average time is the value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment. The minimum delay is more appropriate to dose assessments where a cautious estimate of dose is required, for example in an assessment of doses to the critical group.

© Health Protection Agency
Centre for Radiation, Chemical and Environmental Hazards
Radiation Protection Division
Chilton, Didcot, Oxfordshire OX11 0RQ

Approval: August 2008
Publication: September 2008
£21.00
ISBN 978-0-85951-624-2

This report from HPA Radiation Protection Division reflects understanding and evaluation of the current scientific evidence as presented and referenced in this document.

This work was undertaken under the Environmental Assessment Department's Quality Management System, which has been approved by Lloyd's Register Quality Assurance to the Quality Management Standards ISO 9001:2000 and TickIT Guide Issue 5, certificate number 956546.

Report version 1.0

EXECUTIVE SUMMARY

Radioactive material routinely released will be transferred through the environment and may lead to the irradiation of man via the ingestion of contaminated foodstuffs. The time delay between the harvesting or collection of a foodstuff and its consumption must be taken into account when calculating the dose to man. Since radionuclides decay with a radioactive half-life, a proportion of the radioactive material present in the foodstuff at the time of harvest or collection will have decayed before consumption. In the case of short-lived radionuclides the amount of the radioactive material that decays may be a significant fraction of the total, leading to reduced doses to the population from consumption of the foodstuff. The effect will be less for longer-lived radionuclides, as less of the radioactive material will have decayed.

This report updates earlier work, taking into account changes and modernisation in industrial food processes, and also the changes in popularity of different foods that have occurred over the past 15 years. Most of the data used are from the late 1990s or early 2000s with some more recent data added where available and are given for the whole of the United Kingdom (UK). Factors such as industrial processes and preparation times, storage time at the producer's premises, storage time in the home and the shelf-life of the product have been taken into account. For each type of food, a typical range, an average and a minimum delay time are presented. The typical range applies to the average consumer buying the majority of their food from supermarkets or smaller retail outlets. The average time is the value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment. The minimum delay is more appropriate to dose assessments where a conservative estimate of dose is required, for example in an assessment of doses to the critical group or to a representative person.

Overall the delay times presented are in the same range as those given in the previous report, although the shelf-life of many products has increased. The key changes are for dairy products, due to improvements in the quality of raw milk and the pasteurisation process increasing the shelf-life. Also, changes in shopping habits from daily to weekly or even monthly, means that milk is stored for longer in the home and is less likely to be drunk on the day of purchase. Delay times for the following foodstuffs have changed as indicated below:

- the delay time for fresh liquid milk has increased from an average of 2 days to 4 days and the range has also widened from 1-5 days to 2-30 days;
- for dairy cream the average delay time has increased from 4 days to 5 days and the range has been extended from 2-7 days to 2-90 days (although the upper limit of the range is highly dependent on the type of cream);
- the average delay time for butter has decreased from about a month to 2 weeks, the minimum has increased from 1 day to 2 days and the range has been extended from 14-56 days to 4-365 days;

- for hard cheese (Cheddar type), the average delay time has increased from 4 months to 6.5 months and the minimum has increased from 2 days to 1 month.

The following table gives the delay times for a selection of the main categories of foodstuffs given in this report.

Table showing delay times for key foodstuffs

Foodstuff	Type	Minimum delay time, days	Average delay time, days
Milk	Fresh, pasteurised	0*	4
Butter		2*	14
Cheese	Hard, Cheddar type	30 (mild)	195
Yogurt and fromage frais	Fresh	1*	6
Wheat product	Bread	N/A	210
Potatoes, maincrop	Fresh	0	165
	Frozen	N/A	365
Turnips, swedes, parsnips	Fresh	0	5
Cauliflower, cabbage, Brussel sprouts	Fresh	0	5
Fruit	Fresh, soft – strawberries, raspberries, blackberries	0	4
	Fresh, hard	0	90
	Canned, hard	N/A	180
	Frozen, hard	N/A	180
Beef	Fresh, butchers	14	16
Offal	Fresh	0	3
Marine fish	Fresh	2	8
Salmon, trout	Smoked	4	10
Shellfish	Frozen	4	7

* The minimum delay is based on the unpasteurised product consumed or sold at the farm.

N/A denotes where the minimum delay time is not applicable due to the production processes involved for the foodstuff.

When specifying a single composite delay time it is necessary to proceed with caution and it may not be appropriate to use a composite value in some radiological assessments, as it is necessary to take into account the radionuclide involved and its half-life as well as the particular foodstuff. If required, a number of approaches to calculating single composite delay times may be used depending on the circumstances. A delay time may be calculated for an overall food group with components having differing delay times by weighting each of the delay times by the consumption rate. This may still result in an underestimate of the resulting radiation dose if the radionuclide concerned is short-lived and some of the delay times involved are longer than this time period. A single delay time can also be calculated that would give rise to the equivalent integrated activity resulting from the multiple delay times of the food group. This would need to be done for each radionuclide involved in the assessment. Finally, a simple approach would be to apply judgement and choose a single delay time for a food group that is representative. This may result in either an over-estimate or under-estimate of dose depending on the delay time chosen and the radionuclide involved.

When using foodchain models to estimate activity concentrations in foodstuffs, it may be necessary to take account of any delay times that may be implicitly included as part of the model.

CONTENTS

1 INTRODUCTION

Assessments of the radiological impact of releases of radionuclides to the environment consider the transfer of radionuclides to foodstuffs and their subsequent ingestion by people. It is important to take into account the time delay between harvesting or collection of the foodstuff and its consumption. This is because, since radionuclides decay, a proportion of the radioactive material present in the foodstuff at the time of harvest or collection will have decayed before consumption. In the case of short-lived radionuclides the amount of the radioactive material that decays may be a significant fraction of the total, leading to reduced radiation doses to the population from consumption of the foodstuff. The effect will be less for longer-lived radionuclides, as less of the radioactive material will have decayed.

An earlier report (Haywood, 1983) reviewed the data available at that time on the delays involved in the food production system before consumption, and estimated average and minimum delay times for use in dose assessments in the UK. The present study updates the earlier report, taking into account the changes and modernisation in industrial food processes, and also the changing popularity of different foods, since that time. This study also presents information for more foodstuffs than the earlier report. Factors such as industrial processes and preparation times, time of storage at the manufacturers, storage time in the home and the shelf-life of the product have been taken into account.

For each type of food, a typical range, an average and a minimum delay time are presented. The **typical range** applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets. The **average** time is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment. The **minimum** delay is more appropriate to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in dose assessments where a conservative estimate of dose is required, for example in an assessment of dose to the critical group[*], ie the group which comprises those individuals in a population who will receive higher radiation doses than average because of their location, dietary or other habits.

Changes to the radioactive content of harvested food can occur as a result of the production process of foodstuffs. For example, the radioactive content of oil extracted from rape seeds is significantly reduced compared to the radioactive content of the seeds or other parts of the plant. The same can be said for sugar beet, whilst milk products can have higher activity concentration than liquid milk. However, this report is only concerned with delays leading to radioactive decay and these other factors have

[*] Recent ICRP publications (see, for example, ICRP, 2008) use representative person as an alternative to the critical group classification. The term critical group will be used for the purposes of this report.

not been considered. More information on such losses can be found in Green and Wilkins, 1995.

The data used in this report were the latest data available at the time of collation, and mostly refer to the late 1990's or early 2000's. Where possible, data are given for the whole of the UK, although in many cases information was only available for England and Wales. This report considers only food produced and consumed in the UK; imported or exported products were not considered.

2 FACTORS INFLUENCING DELAY TIMES

The length of time that elapses between the harvesting or collection of a foodstuff and its consumption is influenced by a number of factors. These include:

a the perishability of the foodstuff and the availability of preservation techniques
b storage between harvest/collection and processing
c the duration of manufacturing processes, production of by-products and packaging
d storage after processing and before sale
e storage in the retail outlet
f storage in the home before consumption.

Many of these delays are of variable duration but they are limited by the perishability of the foodstuff and the commercial need to market fresh produce. It is the perishability of the raw foodstuff, and the availability of preservation techniques that are the key factors in determining the delay between harvest/collection and consumption, although manufacturing processes, packaging and storing techniques will also have an effect.

A fresh foodstuff nearly always undergoes some processing treatment prior to sale, for example the pasteurisation of milk and the washing, trimming and/or packaging of most vegetables. Transport and processing times, for many foodstuffs, are negligible compared to the storage times involved in their production. There are however some exceptions, such as fresh milk, new potatoes or lettuces, where the product is delivered as quickly as possible to the customer. The main delays for these are due to transport from the producer to the retailer, and due to subsequent storage in the home.

Many fresh foodstuffs are highly perishable and become unfit for consumption within a short period. These include animal products such as milk and meat, soft fruits, and most green vegetables. In general, these foodstuffs in a fresh form will be consumed within, at most, a few weeks of harvest or collection. Due to their perishability, significant fractions of these foods undergo preservation processes that considerably extend their storage lives. Many techniques may be employed in food preservation but the most common are freezing and canning. Freezing, applicable particularly to meat, fish and vegetables may increase storage times to in excess of one year. Canning generally preserves food for longer periods than freezing, with tinned meat and fish in particular still being consumable after several years.

A number of less perishable fresh foods also undergo processes for commercial reasons which increase their storage lives, for example considerable quantities of potatoes are sold in processed frozen form. An increase in the proportion of food sold in forms that increase their storage times, particularly frozen products, is one area of change since the previous study. Some indication is given later in the report of the proportion of various foodstuffs that are frozen and canned prior to retailing.

To assess the significance of each of these influences on the total delay time, a wide range of institutes, organisations, retail bodies and advisory services associated with food processing and production were contacted. In addition, considerable quantities of data were obtained from key publications and this information was completed where necessary by contact with relevant professionals. To identify the forms of foodstuffs that are significant in the UK diet, both production and consumption figures have been reviewed.

3 ESTIMATES OF DELAY TIMES FOR VARIOUS FOOD PRODUCTS

Four broad categories of foodstuff have been considered. These are:

a dairy products
b cereals and cereal products
c vegetables and fruit
d animal products (other than cows' milk), including fish.

Information relating to delay times for these categories is reviewed and summarised below. For each category, average and minimum as well as ranges of delay times are suggested.

3.1 Dairy products

Milk is a foodstuff that may be converted into many different end products before it is consumed. In 2006, there were 2 045 000 dairy cows in the UK yielding around 6 577 litres per cow (Defra, 2007). The gross production available for human consumption was 13 480 million litres of which 12 864 million litres were available to UK dairies (Defra, 2007b). Of this, just over 50% (6 549 million litres) was utilised for liquid drinking milk; the remainder was used for manufacture of (the following information was obtained from Defra, 2007b):

a cheese 60% (3 772 million litres)
b butter 3.5% (235 million litres)
c condensed milk 4.5% (289 million litres)
d whole milk powder 9.5% (601 million litres)
e skimmed milk powder 10% (637 million litres)
f cream 5% (315 million litres)

g yogurt 3.5% (231 million litres)
h other products 3% (189 million litres)
i stock change/wastage 1% (88 million litres from total) (not discussed further).

These different categories of milk products are discussed below.

3.1.1 Liquid milk

The UK dairy herds produce virtually all the liquid milk consumed in the UK. Most dairy herds are milked twice a day, generally early in the morning and again in the evening (Living Countryside, 2006). The milk is placed in a refrigerated farm vat where it is cooled and stored at not more than 4.5ºC. Milk is collected in a tanker from several farms in an area. It is usual for milk stored on the farm to be collected daily, depending on the availability of dairy tankers (Living Countryside, 2006b). Milk typically arrives at the dairy 8-48 hours after milking depending on whether the farm is subject to daily collection or second day collection. Following arrival at the dairy, the milk will usually be processed within 24 hours or as soon as possible (Watson, 2007).

The incoming liquid milk is checked for quality and, if accepted, most is heat-treated to kill any harmful bacteria. There are three types of heat treatment: pasteurisation, sterilisation and ultra heat treatment (UHT). The most common form of heat treatment is pasteurisation, where the milk is heated to a temperature of 71.7°C for at least 15 seconds and then rapidly cooled to a temperature of 6°C or lower. The milk is then bottled or poured into cartons or polyethylene bottles. The fat content of milk can be varied to produce semi-skimmed milk with a fat content 1.5-1.8% (whole milk contains about 4% fat) or skimmed milk which has up to 0.5% fat content. Some of the milk goes on to be homogenised to prevent the further separation of the cream layer and can be kept fresh for the same periods (around 10 days) as whole, semi-skimmed and skimmed milk if refrigerated. Due to their lower fat content, semi-skimmed, skimmed and homogenised milk can be frozen for up to a month in a plastic container or waxed carton (Dairy Council, 2002).

Milk can also be sterilised, whereby the milk is pre-heated, homogenised and poured into bottles which are closed with an airtight seal. The bottles are then heated to 115-130ºC for 10-30 minutes and then cooled. If unopened, sterilised milk will keep for several months without refrigeration. Once opened, it will keep for up to 5 days. This treatment results in a slight change in taste and colour and also slightly reduces the nutritional value of the milk (Dairy Council, 2002).

Milk can also be ultra heat treated (UHT) which is a form of sterilisation where the milk is heated to not less than 132.2ºC for at least one second. The flavour and nutritional value of the milk are less affected by this process. As with sterilised milk, the UHT variety can be kept for up to 6 months. Once opened the milk should be refrigerated and used within 5 days (Dairy Council, 2002).

The majority (82% in 2000) of the liquid milk sales in England and Wales are to the household market, with the remainder going to milk product manufacturers (liquid and dried form), the catering industry, hospitals, prisons, schools, etc. Most of the milk purchased by households is pasteurised fresh milk (89.5%), with UHT milk taking 6.9%

of the market, and sterilised milk 2.2% (the remainder is Channel Islands milk and other types of milk, for example, soya (National Dairy Council, 1995)). In Scotland, virtually no sterilised milk is sold, raw milk is illegal and there are no figures available for the consumption of the other types of milk. It is, however, reasonable to assume that they are the same or very similar to those for England and Wales (Scottish Dairy Association, 1997). For the purposes of dose assessments, the delay time for liquid milk intake is dominated by that for fresh milk.

3.1.1.1 Fresh pasteurised milk

Pasteurised milk was traditionally sold as whole milk. Now, sales of semi-skimmed and skimmed milks have substantially increased. Sales of semi-skimmed milk dominate with 60% of the pasteurised liquid milk market; whole milk makes up 29% and fully skimmed the remainder (Defra, 2006). Milk is normally distributed to retail outlets and doorstep delivery companies on the day following packaging and is available to the consumer, either on the doorstep or in the shop by the following day. Once packaged, pasteurised milk now has a shelf life of up to 10 days. This is longer than was estimated in the previous study, and reflects improvements both in the quality of raw milk and in the pasteurisation process since the early 1980's. Shops, and in particular supermarkets, usually have a quick turn-around, and milk is normally sold several days before its 'best by' date. About 89% of liquid milk in the UK is sold by retailers and 11% by doorstep delivery (Milk Development Council, 2006); the proportion sold through shops is increasing as the popularity of doorstep deliveries declines.

Combining the fresh milk distribution times after processing in the dairy and shop or doorstep with the milking to dairy times estimated above, it can be estimated that most fresh milk is in the shop or on the doorstep 48-72 hours after milking. Adding to this an average delay in purchasing from shops of 12-24 hours implies that a typical average delay time between milking and the milk being in the possession of the consumer is 3 days.

Once the milk is in the home, it is probably consumed within the next 24-48 hours if it has been delivered or within the next 5 days if it was bought in a shop. Since no data could be found on the relative percentages of people consuming milk within 1 day compared with longer times, it is cautiously advised that 1 extra day for the average storage time in the home is added to the average delay time for fresh milk, giving a total average delay time for fresh milk of 4 days. However, if the milk is frozen, the milk can potentially be stored in the home for up to 1 month and so a typical range of 2 days to 1 month is suggested (Waitrose, 2007).

Theoretically, there is potentially virtually instantaneous consumption after milking by farmers and purchasers of raw milk, and the minimum time delay for fresh milk consumption is therefore 0 days. Current legislation in England and Wales (Statutory Instrument, 2006) means that unpasteurised milk may be sold by registered milk production holdings direct to consumers. However the number of producers is very low (149 in 2005) and so represents a very small fraction of total milk consumption. In Scotland the sale of raw cows' milk and cream was banned in 1983. In Northern Ireland similar controls to England and Wales exist but there are no known sales (FSA, 2005).

3.1.1.2 UHT milk

Ultra High Temperature (UHT) milk is stored in cartons. It may be in the form of full cream, semi-skimmed or skimmed milk. Almost 7% of milk for the household market is consumed in this form. Although UHT milk does not take any longer to produce than fresh milk, it may be consumed at any time during the next 6 months. Once the milk has been treated and packaged, it may stay at the dairy for up to 4 days. This is because the dairy tests each batch of milk prior to release to ensure that the UHT process, and more particularly the packing operation, has been carried out correctly. To do this, samples are taken throughout the processing run and these samples are incubated. If there has been any fault in the process the samples will not be sterile and bacteria will grow. These tests take a few days (Komorowski, 2003). There is, therefore, a typical range of 7 days (to include transport) to 6 months, with an average delay time of 3 months. A minimum delay time to the critical group is not included as the milk treatment involves an industrial process followed by mass distribution.

3.1.1.3 Sterilised milk

Sterilised milk represents 2.2% of household market sales. Sterilised milk, like UHT, takes 1-5 days to be packaged. It may then be kept for several days at the dairy before distribution. When unopened, sterilised milk has a shelf-life of 3-6 months without the need for refrigeration, and once opened it keeps for up to 5 days. Like UHT milk, the longer storage life of sterilised milk compared with fresh milk will mean that it is stored for longer periods in the home than is the case for fresh milk (Dairy Council, 2002). Therefore a typical range minimum of 7 days, to include transport, with a maximum of 3 months and an average of 1.5 months is suggested. A minimum delay time to the critical group is not included as the milk treatment involves an industrial process followed by mass distribution.

3.1.2 Other milk

3.1.2.1 Goats' milk

There has been an increasing demand in recent years for goats' milk and it is becoming more available in supermarkets and health shops, although it is still mainly sold directly from the farm. It is widely available in both pasteurised and unpasteurised forms. Goats are seasonal breeders, and most of the milk is produced over the spring and the summer. Half of the UK production goes to liquid milk, which is often frozen to increase its shelf-life by up to 3 months. The rest of the milk is turned into cheese, yoghurt, butter and ice cream which have the same shelf-life as cows' milk produce. As for cows' milk there is the potential for virtually instantaneous consumption and so a minimum delay time of 0 days is possible (FSA, 2005).

The delay times for fresh goats' milk are similar to those for cows' milk although since it is often consumed in unpasteurised form, the minimum and average delays are feasibly somewhat shorter: a minimum of 0 days and a cautious average of 3 days are advised. For frozen goats' milk a typical range of 2 days to 3 months and an average of 1.5 months are suggested (for all other goats' milk products, see the dairy products estimates).

3.1.2.2 Ewes' milk

Only 6 000 ewes in the UK are kept for milking, and most of their milk is turned into cheese or yoghurt. It is however possible to buy sheep milk in frozen form. Cheese and yoghurt made from ewes' milk have the same shelf-life as cows' milk produce. Once thawed, the milk should also be treated like cows' milk. These products are available year-round, in limited quantities. The delay times for frozen ewes' milk are the same as for goats' milk.

3.1.3 Summary of delay times for liquid milk

A summary of delay times for liquid milk is presented in Table 1.

TABLE 1 Summary of delay times for liquid milk, days

Type of liquid milk	Minimum delay	Average delay	Typical Range
Fresh pasteurised milk	0*	4	2 – 30
UHT milk	N/A	90	7 – 180
Sterilised milk	N/A	45	7 – 90
Goats' and ewes' milk			
Fresh	0*	3	2 – 30
Frozen	N/A	45	2 – 90

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

* The minimum delay is based on the unpasteurised product consumed or sold at the farm.

3.1.4 Canned and powdered milk

3.1.4.1 Evaporated milk

Evaporated milk is sterilised milk with twice the concentration of ordinary milk. The milk is evaporated under reduced pressure at a temperature of between 60-65ºC. It is then homogenised to prevent a cream line forming when settled, poured into cans and sealed. The cans are sterilised at 115-120ºC for 10 minutes after which time they are left to cool. The shelf-life is commonly stated as 1 year but in practice the product should keep for even longer. The production time in the dairy is thought to be only about a day longer than that for fresh milk, but storage between production and distribution may add a further few days, giving a typical range minimum of 3 days and a maximum shelf-life of 12-18 months (Dairy Council, 2002). An average delay time of about 9 months is advised.

3.1.4.2 Condensed milk

Sweetened condensed milk is commonly used in the production of confectionery and so a proportion of condensed milk produced is subject to the additional delay times of sweets such as toffee and fudge. Condensed milk is homogenised before being boiled under vacuum and packed. Sugar is added and condensed milk has more than twice the concentration of ordinary milk (Dairy Council, 2002). Condensed milk has a shelf-life of up to approximately 2 years (Practically Edible – Food Encyclopaedia, 2007). The production times are not significantly longer than for pasteurised milk (1 day) but the packaged products can easily be stored for a few days before being despatched to retailers or to export companies (Dairy Council, 2002). Therefore it is thought that the delay before condensed milk is supplied to the outlet is somewhat longer than the delay for fresh milk. The typical range minimum is therefore 3 days with a maximum of 2 years and an average of 9 months.

3.1.4.3 Dried milk powder

Dried milk powder is obtained from either whole or skimmed milk which is homogenised, heat treated and dried. The most commonly used drying processes are spray drying and roller drying; the time taken in the drying process is relatively short and so the difference in the delay between the two is thought to be negligible. Skimmed milk powder has a shelf-life of up to a year. Full-cream milk powder will keep for less time - about 6 months - because of its higher fat content. Once reconstituted, dried milks should be treated as pasteurised milk and refrigerated, and used within 4-5 days. Dried milk powder does not represent a large share of the household market sales. Instant dried milk and dried infant and baby milk combined make up less than 3% of the total milk market (not including milk products) (Defra, 2008). The delay times associated with the production of powdered milk are a typical range minimum of 3 days for both types, a maximum of 6 months (full fat) or 12 months (skimmed milk) with an average of 3 months for full fat and 6 months for skimmed (Dairy Council, 2002).

3.1.5 Cream

Almost all the cream consumed in the UK is produced from UK dairy herds. In the UK 2% of liquid milk is used for the production of cream. It is sold in either pasteurised, UHT, sterilised or frozen form. Cream is subject to similar milking-to-processing time to liquid milk, reaching the final product within 1-3 days of milking depending on the processes involved (it should be noted that 3 days is the maximum and processing is ideally done as soon as possible) (Watson, 2007). After milking, cream is separated from the milk by centrifugal force in a mechanical separator. The remaining skimmed milk is used in the production of other milk products such as yoghurt and cottage cheese. The cream is then heat treated to destroy any harmful micro-organisms. Pasteurised cream will keep for 1-3 weeks depending on the original quality of the milk (Watson, 2007). Sterilised cream is sold in cans and will keep for up to 2 years. UHT cream will keep for up to 6 months in a refrigerator, depending on fat content, so double and whipping cream have shorter shelf-lives than single and half creams. There are six main types of fresh cream available: half, single, soured, whipping, double and clotted. The major differences between them are their fat content and thickness. Whipping cream, double and clotted cream may all be frozen; whipping and double cream for up

to 2 months, clotted cream for up to 1 month (Practically Edible – Food Encyclopaedia, 2007). Specifically packaged and marketed frozen cream is no longer widely available although it can be bought through specialist frozen goods suppliers. It is estimated frozen cream can be kept in the home for up to 12 months.

Like raw milk, a large proportion of cream is used in the manufacture of other dairy products such as butter and cream cheese. In these situations cream is subject to the delay times for production of these foodstuffs, which are discussed elsewhere.

No data are available on the occurrence of farmers, their families and local people buying unpasteurised cream directly from the farm but this group could theoretically consume cream only a few hours after milking, and for them the minimum delay time should be assumed to be 0 days.

In the production of ice cream the ice cream mix undergoes pasteurisation and, generally, homogenisation before being cooled and allowed to age for up to 72 hours. Practices vary between manufacturers but, apart from soft-serve varieties, the packaged ice cream goes through a 'hardening' period before distribution. The shelf-life of the finished product is 12-18 months if stored at temperatures below -20ºC (Ice Cream Alliance, 2007).

In summary, there will be on average 5 days between milking and consumption of fresh pasteurised cream, including a mean delay in the home of 2 days; this average lies within a range of 2-21 days (a maximum of 3 months applies to those varieties which may be frozen but this is not a common practice and so has not been included in the average). The maximum and average delay times for UHT, sterilised and frozen cream is longer. For UHT cream sold in cans, a maximum of 6 months is estimated, with an average of 3 months, and for that sold in aerosol cans a maximum of 3 months is estimated, with an average of 1 month. For frozen cream a maximum of 12 months is estimated, with an average of 6 months and for sterilised cream a maximum of 2 years is estimated, with an average of 12 months. For UHT, frozen and sterilised cream the typical range minimum delay introduced through production and transport is 7 days.

Ice cream is a separate case in that it may be stored for up to 18 months but the delay time introduced by home storage may be minimal. An average delay time of 1 month is suggested with a typical range of 7 days to 18 months. For ice cream the minimum delay is considered to be to those consuming 'home-made' ice cream made using raw milk. For this group the minimum delay time of 0 days for raw milk is advised with an additional 1 day (of ageing).

3.1.6 Yoghurt and fromage frais

In 2005/2006, 201 g of yoghurt and fromage frais (meaning 'fresh cheese') were consumed per person per week in the United Kingdom (Defra, 2006). Yoghurt has become increasingly popular and now comes in many different types including stirred and set, Greek yogurt, fruit or plain. The raw milk, which is usually about 2 days old, is pasteurised and homogenised then cooled and the starter culture is added. The overall fermentation and production process takes a little under 24 hours from pasteurising the milk to the packaged product (Yeo Valley, 2007). The total process from milking to the

packaged product depends on the age of the milk used in the manufacture of the yogurt. From this point both yoghurt and fromage frais have a mean shelf-life of about 19 days.

The average delay time between milking and consumption is estimated to be 6 days (assuming the product is eaten after a mean delay of 2 days in the home); while the total range is 5-22 days. Yoghurt and fromage frais can be made from raw milk in 1 day, and this should be assumed to be the minimum delay time. Yogurt, essentially a live culture, is sensitive to extremes in temperature and so freezing can alter the quality of the product (Watson, 2007). Therefore, home freezing of yogurt is not considered in this report.

3.1.7 Butter

In 2006, less than 2% of liquid milk produced in the UK went into the production of butter (more than 60% of butter consumed in the UK was imported). Aged cream is turned into butter by a churning machine, where the fat coalesces into larger and larger lumps; salt is added and acts as a preservative. The remaining liquid, buttermilk, is dried and sold as a food ingredient for use in baking, ice cream and even for feeding livestock (Defra, 2007b; Dairy Consultant, 2007). The cream used in the butter manufacturing process is usually left to age for a minimum of 48 hours at the processing plant to allow the fat to crystallise; in addition there is usually 1-2 days where the liquid is in the milk/cream state prior to ageing. The churning and packaging process takes only a few minutes. It will then be stored under cool conditions and distributed to retailers within a few days (MD Foods, 1998). Butter has a typical shelf-life after manufacture of 6 weeks chilled or 12 months frozen (Watson, 2007; Arla Foods, 2007).

The range for the delay time between milking and butter consumption is therefore 4 days to 1 year, allowing for frozen storage. A reasonable average is 2 weeks, assuming the butter is stored in the shop and the home combined for 1 week. On farms, the shortest time for butter production (from raw milk) will be about 2 days, allowing for minimal ageing of the cream and churning, and this is therefore taken as the minimum delay time.

3.1.8 Cheese

In 2002, 25% of liquid milk produced in the UK was used in the production of cheese. Of all the cheese produced in the UK 95% is made at creameries and the remaining 5% produced at the farm. There are thought to be about 300 cheese makers in the UK, most of whom are small scale producers (Milk Development Council, 2004; Defra, 2001a; National Farmers' Union, 1997). In 2005/2006, an average of 116 g of cheese was consumed per person per week, including both natural and processed cheese (Defra, 2006).

Cheese types can be divided into soft cheeses and semi-hard or hard cheeses, the distinction being that semi-hard and hard cheeses involve the pressing of the curd. Hard cheeses represent roughly 80% of total consumption, and most of this (about 67% of all cheese) is Cheddar (Defra, 2001a). Hard cheese can be frozen.

The use of whey has also been considered. In general, two key constituents of whey are incorporated into food production: lactose and protein. Lactose is hydrolysed to simple sugars, forming a sweet syrup which is used in cakes and confectionery. Protein is isolated and used in, for example, protein supplements. Additionally, whey powder may be used in many other products. Whey is widely used by manufacturers as stabilisers and emulsifiers, or concentrated or dried for use in the food industry or as animal feed because of its high protein values (Dunn, 2005). Whey proteins may be extracted in advance of these processes to make whey protein concentrates (British Cheese Board, 2001). Varying processes are used in the incorporation of whey products in food manufacture, with widely varying delay times and for this reason delay times for whey are not considered further.

3.1.8.1 Soft cheeses - unprocessed

In the UK, soft cheeses are produced in an un-ripened state, and they can be eaten as soon as the manufacturing process is complete, unlike ripened soft cheeses such as Camembert and Brie (Practically Edible – Food Encyclopaedia, 2007). Cottage cheese acquired its name because it is relatively easy to make in the home. It is made from skimmed milk and takes about 1 day to process and has a shelf-life of as little as 3 days when unpackaged. It is unsuitable for freezing (British Cheese Board, 2007; Practically Edible – Food Encyclopaedia, 2007). Cream cheese, as the name suggests, is made from cream, which has been pasteurised, homogenised, cooled and a quantity of starter culture added. This variety cannot be frozen as this may alter the texture of the product (Kraft, 2006).

Many of the full fat, medium fat and reduced fat soft cheeses, even those which are not subject to processing, have extended shelf lives as long as they remain refrigerated and unopened. A typical range for the time delay before consumption of unprocessed soft cheese is 3-26 days, with an average of 6 days (including a mean delay time in the home of 2 days). The minimum delay time to produce soft cheese domestically (from raw milk) is 1 day.

3.1.8.2 Soft cheeses - processed

Soft cheeses may also be processed, especially soft cream cheeses. The process involves a further heat treatment and the addition of emulsifiers which extend the shelf-life. Overall lifetime is highly dependent on the type of cheese and the packaging but it is generally measured in weeks and the products are generally stored chilled (Watson, 2007). Processed cheeses do not take significantly longer to make than unprocessed cheese, but they can be consumed over a longer period. The range of delay times between milking and consumption of processed soft cheese is thought to be between 5 days and 8 weeks, with an average of 4 weeks. Processed soft cheeses would not be produced domestically, and so a minimum delay time for processed cheese is not applicable.

3.1.8.3 Hard cheese - Cheddar

The production of hard cheeses requires the mixing of a starter culture and rennet (an enzyme which breaks down the milk proteins to assist coagulation) with pasteurised milk. In the UK artificial rennet, mostly of vegetable origin, is used for most cheese which makes it suitable for vegetarians (Dairy Consultant, 2007b). Very little cheese is now made from rennet extracted from calves' stomachs (National Farmers' Union, 1997). After a few hours, the curd is separated from the whey. The curd is then pressed for 1-2 days to produce hard cheeses.

Cheddar cheese is ripened over a period of time. This can be between 12 weeks for mild cheese and 18 months for strong cheese (British Cheese Board, 2007). The quality of the cheese is graded after 2–4 months to determine whether it could be stored for longer and then sold as a medium or mature cheese. Very mild Cheddar can be marketed after as little as 4 weeks, but this is unusual (British Cheese Board, 2001). Most of the mild Cheddar is 2-4 months old when bought by the consumer, and can be eaten over the next 6 weeks. Medium Cheddar is usually matured for around 6 months before sale. Mature Cheddar can be sold when at least 9 months old, when it can be referred to as "Farmhouse", but is rarely older than 12 months because storage costs make this uneconomic for the producer (British Cheese Board, 2007; MD Foods, 1998). Roughly a quarter of the Cheddar sold in Britain is mild, 60% is mature and the rest is medium (British Cheese Board, 2001).

To summarise, a minimum delay of 1 month can occur between milking and producing packaged mild Cheddar cheese. The total range for Cheddar cheese, for a typical consumer, is 3-18 months. The median average delay for all types of Cheddar considered here is 6.5 months. This is based on an average of 3 months of ageing for mild Cheddar, 6 months of ageing for medium Cheddar and 9 months of ageing for mature Cheddar, and includes a combined delay in the supermarket and home of 2 weeks. This value should still be a cautious estimate due to the greater popularity of the mature variety over the mild. A minimum delay for very mild Cheddar of 1 month is suggested (British Cheese Board, 2001; British Cheese Board, 2007; MD Foods, 1998).

3.1.8.4 Semi-hard and hard cheeses – territorial cheeses

There are eight 'territorial cheeses' widely available in the UK: Cheshire, Caerphilly, Derby, Double Gloucester, Lancashire, Leicester, Stilton and Wensleydale. The systems of production are very similar to that of Cheddar, and the main differences in the process come from the starter culture, the temperature at which the curd is kept, the acidity in the curd, the degree of moisture and the maturation time after the pressing of the cheese.

There are three types of Cheshire cheese: red, white and blue. The red and white varieties are ready for consumption at 4-8 weeks old. Blue Cheshire is quite rare and is a variation that develops blue veins on its own; it takes 4-8 weeks to mature (Practically Edible – Food Encyclopaedia, 2007). Caerphilly cheese is said to have been popular with Welsh miners because cheese was known to absorb the toxic substances in the air. Caerphilly is sold when approximately 2 weeks old. It may be matured for any length up to 12 weeks, depending on the desired flavour (Practically Edible – Food Encyclopaedia, 2007). Derby is one of the least common English cheeses. It is similar

in texture to Cheddar. There is a plain Derby, which is sold from 4 weeks old, and can be matured for up to 6 months. There is also a green-veined, herb-flavoured variety called Sage Derby which is ready in 1-3 months (cheese.com, 2007; British Cheese Board, 2007). Double Gloucester was traditionally coloured using carrot juice or saffron but it is now done with a vegetable dye called annatto, largely shipped from South America. It is also normally sold when 3-4 months old (British Cheese Board, 2007). Traditional Lancashire cheese is traditionally made from the curds of 2-3 days' milking which are then milled, salted and pressed. There are three classifications of Lancashire cheese: the farmhouse creamy (typically matured for 2-3 months), the farmhouse crumbly (matured for 6-8 weeks) and the farmhouse tasty (matured for over 6 months) (British Cheese Board, 2007). Leicester is russet red in colour, again from the vegetable dye annatto. It is matured for 3-4 months (British Cheese Board, 2007). Stilton is historically referred to as "The King of Cheeses" (cheese.com, 2007). There are two types: blue and white. Standard Blue Stilton is produced in 2 months, but mature Blue Stilton is typically matured for around 3 months and this can be extended to 6-8 months. The typical production time for Blue Stilton is 9-15 weeks (Stilton Cheesemakers' Association, 2004). The white, immature variety is available after as little as a few weeks. Finally, Wensleydale cheese is produced more commonly now as a white cheese, but was originally a blue cheese which is still made but in smaller amounts. Production of Wensleydale takes from 1-3 months (British Cheese Board, 2007).

A certain number of other cheeses are produced locally, both in creameries and farmhouses, but they are normally only available in the locality of production and do not have a significant impact on the average UK diet.

New starter cultures are consistently being developed which aid the cheese ripening process. Some such cultures are in use in Australia and in the USA, and they are beginning to be used in the UK. The effect of these cultures is to reduce the time necessary to ripen the cheese; they also have applications in eliminating spoilage and extending shelf-life of dairy products other than cheese (Dahm, 2006). The full impact of these new developments on production in creameries in the UK is not yet significant, but it is possible that they will in the future have some influence on national delay times for cheese.

In summary, a minimum delay time of 2 weeks is appropriate for semi-hard and hard cheeses, excluding Cheddar. An average delay of 3 months would seem to be appropriate, within a range of 2 weeks to 9 months.

3.1.9 Summary of delay times for milk products

A summary of the delay times associated with the production of milk products is presented in Table 2.

TABLE 2 Summary of delay times for milk products, days

Dairy product	Minimum delay	Average delay	Typical Range
Canned milk (evaporated)	N/A	270	3 – 540
Canned milk (condensed)	N/A	270	3 – 730
Skimmed powdered milk	N/A	180	3 – 365
Full-cream powdered milk	N/A	90	3 – 180
Pasteurised cream	0*	5	2 – 90˜
UHT cream - cans	N/A	90	7 – 180
- aerosol cans	N/A	30	7 – 90
Sterilised cream	N/A	365	7 – 730
Frozen cream	N/A	180	7 – 365
Ice cream	1*	30	7 – 540
Yogurt and fromage frais	1*	6	5 – 22
Butter	2*	14	4 – 365
Unprocessed soft cheese	1*	6	3 – 26
Processed soft cheese	N/A	28	5 – 56
Hard cheese: Cheddar type	30 (mild)	195	90 – 540
Semi-hard and hard cheese: territorial	14	90	14 – 270

Note: Yoghurt is mostly made from concentrated skimmed milk but can also be made from powdered or condensed milk, but these types are not considered here.

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

* The minimum delay is based on the unpasteurised product consumed or sold at the farm.

˜ The upper value in the range applies to cream that may be frozen (relevant for whipping and double cream; for clotted cream a 60 day maximum is appropriate). Single, half and soured cream have a maximum delay time of 21 days.

3.2 Cereals

Of the total area in the UK that is used for crop production, about 60% is currently used for growing cereals. Of this, nearly 70% is used for growing wheat, 25% for barley, and most of the remainder is used for oats (estimates based on figures from Defra, 2006b). Around a fifth of the wheat production is exported, but some wheat is also imported. Of all the wheat used domestically, around 40% is used for flour milling and another 50% for animal feed. Of the barley crop, under a third is used for brewing and distilling and a very small percentage goes into food; the remainder is either exported or used as animal feed (Home-grown Cereals Authority, 2004). In contrast, over half of the oats grown in the UK are used for milling and less than 40% for animal feed (MAFF, 2001).

Although not considered as cereals, hops are treated in this section with barley since they are used in the beer-making process. They represent the equivalent of 0.1% of the crop growing area. Maize is not grown in the UK for human consumption, and only in small quantities for animal feed, although this may be in the process of changing due to the development of new breeds of plants. There is also very little rye grown in this country, and two-thirds of the UK needs are still imported. Rye and mixed corn together represent less than 0.05% of cereals in area (MAFF, 2001). There is no evidence that individuals grow and use their own cereal products to make flour, beer etc and so they are not normally considered in critical group dose assessments (EA et al., 2002). The minimum delay times are therefore not applicable to these products and are not included.

3.2.1 Wheat and wheat products

Only delay times for wheat intended for human consumption in the form of baked flour are considered here. Of the total wheat produced just over 40% is used for flour milling, the remainder goes to animal feed (~50%), seed and other uses (~10%) (Defra, 2007c).

Over 95% of the wheat grown in the UK is winter-sown (drilled between mid-September and the end of October) and it is harvested between mid-August and mid-September. Wheat grain is a commodity that can theoretically be stored for years, if kept in the right conditions, but such storage times rarely occur as excess crop is usually sold on the world market (National Farmers' Union, 2006; National Association of British and Irish Millers, 2007).

Millers' usage of UK grown wheat has risen steadily over the last few decades. In 2006, 85% of total wheat usage was home grown wheat (National Association of British and Irish Millers, 2007b). A soft wheat grain is traditionally produced in the climate enjoyed by the UK, which is not always strong enough to be used in all varieties of bread. The remaining wheat is mostly imported from North America, which produces hard wheat higher in protein and gluten. However, a new method of baking bread was developed in 1961 called The Chorleywood Bread Process, or CBP, by the Flour Milling and Baking Research Association at Chorleywood[*]. This method allows the use of a higher proportion of home grown wheat flour (Federation of Bakers, 2003).

After harvest, the grain can be stored on the farm for any time between 1 week and 1 year (Doves Farm Foods, 2003). After 1 year the storage facilities are needed for the next harvest. The farmer usually sells his crop to a merchant who, in turn, sells it to a mill. Merchants tend to have a very quick turn-around, and the mills have storage space for 2 weeks' worth of grain supply, and for 1-2 weeks' worth of flour. On average wheat will spend 1-4 weeks at the mill. Under normal circumstances, almost all the wheat is used up (i.e. turned into flour) within 12 months due to the harvest and production cycle. In previous years excess crop may have been bought up and kept in EU Intervention Stores but the excess is now nearly always sold on the world market (National Association of British and Irish Millers, 2007).

[*] In 1995 The Flour Milling & Baking Research Association merged with the Campden Food and Drink Research Association to form the Campden & Chorleywood Food Research Association.

3.2.1.1 Flour

In 2006/2007, 68 mills produced 4.4 million tonnes of flour in the UK. Of this 64% went into commercial bread making – 54.5% white bread, 3% brown and 6.5% wholemeal bread – 12% into commercial biscuit and cake manufacture, 4% to home baking and household flour, and 20% to other human and industrial usage. Flour can be stored for up to a year but in most cases is used much sooner (Defra, 2007d; National Association of British and Irish Millers, 2007). Based on the grain harvest and production cycle a typical range for flour is 1-18 months with an average delay of 7 months.

3.2.1.2 Bread

Bread is the principal end use of flour and the main contributor to human cereal consumption. Small bakers buy a few sacks of flour at a time while large industrial bakeries have their flour delivered in tankers. In both cases, it is likely that the flour will be turned into bread in a matter of days. In-store bakeries within supermarkets (ISBs) hold a 15% share of the market by volume, with traditional bakers now accounting for less than 5% of the bread market volume. ISBs use either bake-off products or bake products from scratch. The bake-off method involves dough that is part-baked and frozen, then baked off later at the retail outlet. In the case of bake-off products, the products are produced in 12 minutes, in the case of products made from scratch the process takes 2 hours, 1 hour for proofing and 1 hour for baking. Products made using the bake-off method have a very short shelf life. The additional delay time is therefore very small. Large plant bakers make the remainder of the volume of bread (81%). About 9 million large loaves of bread (800 g each) are produced every day in the UK. More than 64% of bread loaves sold in the UK are white, 8% brown and 28% wholemeal. The ratio of loaves to rolls, ready-made sandwiches and other breads is approximately 3:1. In the period 2005-2006 a total domestic consumption of 701 g of bread was consumed per person per week, though this number is in decline (Defra, 2006; Defra, 2008; The Federation of Bakers, 1999).

The bread-making process takes a few hours, after which bread from large bakeries is despatched to retailers within the next 24 hours, and freshly baked bread from small bakers' is sold in the next 2 days. Different types of bread have different shelf-lives. Crusty bread has less moisture and therefore usually only lasts for one day or so. French sticks will go stale after only a few hours. Wrapped bread stays fresh for 3-4 days at room temperature (17ºC/63ºF), but will go stale quicker in the refrigerator. On average, bread is probably eaten within 3 days or less of arriving in the home, giving an average delay of 1.5 days in the home. The practice of freezing bread in the home is more and more widespread, and fresh wrapped loaves may be kept in the freezer for up to 3 months (Federation of Bakers, 2003b). A minimum delay is not applicable in the case of bread as the grain is processed by a miller before the bread making process can even begin and grain storage is the limiting factor. A suitable average delay is 7 months, taking into account transport and home storage and freezing delays in addition to the mean grain storage. The typical delay range from wheat harvest to consumption of bread is therefore 1-18 months.

3.2.1.3 Sandwiches

The Family Food Survey (Defra, 2008) indicates that in 2005-2006, 1.7% of bread sales were for ready-made sandwiches. Sandwiches are a growing market, with 80% of workers consuming sandwiches at least once a week. It is cautiously assumed that these sandwiches are made from freshly-baked bread. Once the filling is added the final product has a shelf-life of up to a few days. Those sandwiches bought from retail outlets are assumed to be for consumption on the day of purchase, so the delay times would be the same as for bread loaves.

3.2.1.4 Biscuits and cakes

In 2005-2006, an average of 165 g of biscuits and 168 g of cakes were consumed per person per week in the UK (Defra, 2008). Flour is about 50%, by weight, of the ingredients in biscuit and cake manufacture. The delays between harvest and baking are the same as for bread. The main difference between these types of products arises from their shelf-lives: bread and most soft cakes can only keep for a few days (it is suggested that the delay times for bread are also applicable for cakes), whereas some dry biscuits have shelf-lives of up to 1 year and could be eaten at any time during this period. However, large shops have a very quick turnover of all products and it is unlikely that biscuits would be stored for much more than a month. It is assumed that once in the home these products will be consumed within a maximum of 2 weeks after purchasing, with a mean of 1 week.

3.2.1.5 Frozen cereal products

This category includes frozen foods with an important proportion of flour, such as frozen cakes and pastries or frozen pizzas. However, a proportion of these foods are imported. Most frozen foods have a shelf-life of up to 1 year, and a mean delay time of 3–4 months on top of the average delay between harvest and production seems reasonable.

3.2.1.6 Breakfast cereals

Some of the breakfast cereals available on the British market contain wheat, others are based on oats, rice or corn. Wheat products in the form of wheat cereal are usually made almost exclusively from UK wheat (National Association of British and Irish Millers, 2007b). Some other breakfast cereals may contain durum wheat, which is not grown in this country. Also, some breakfast cereals are made from oats and rice, which have similar delay times to wheat cereal products.

3.2.2 Summary of delay times for wheat and wheat products

The delay time between harvest and consumption of wheat and wheat products is largely influenced by the grain storage time. The age of the grain at the time it is used in baking is very dependent on the time of year. For example, flour used in baking in January is likely to be made of grain harvested the previous September, *i.e.* a delay of about 4 months, whereas flour used in August will most likely have been harvested almost a year before. There is no evidence of people growing, harvesting and milling

their own grain in the UK. Grain from all over the country is sold to grain merchants, who sell on to millers, where the grain is mixed.

The most important wheat product is bread, but the average delay time from the making of bread to its consumption is negligible compared to the storage times of the wheat grain and flour. The suggested baseline average delay time for wheat products is therefore 7 months, within the typical range of 1-18 months. A minimum plausible delay time for consumption of wheat products is about 1 month after the grain is harvested taking into account the minimum times the grain spends at the farm, merchants, mill and bakers. Some wheat products have longer delays due to the extended shelf-life in their processed form.

A summary of the delay times associated with wheat and wheat products in the UK can be found in Table 3.

TABLE 3 Summary of delay times for wheat and wheat products, days

Wheat product	Minimum delay	Average delay	Typical range
Bread	N/A	210	30 – 540
Flour	N/A	210	30 – 540
Cakes	N/A	210	30 – 540
Biscuits	N/A	220	30 – 730
Frozen cereal products	N/A	300	30 – 730
Breakfast cereals	N/A	240	30 – 730

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.2.3 Barley and beer

Almost 60% of the UK barley crop is destined for animal feed, and most of the remainder goes into malting for brewing and distilling (MAFF, 2001). Very little barley is eaten as pearl barley or crushed as wholegrain for breakfast cereals. The principal barley product in the human diet is beer.

Although in the UK over half of the barley is winter-sown, malting barley is mostly spring-sown. Britain is almost entirely self-reliant on barley. Of the malting barley produced in the UK, the Scottish crop accounts for 40%, 80% of which is spring-sown. Of the barley grown in the rest of the UK, winter-sown barley makes up about 35% of the total market and spring-sown barley approximately 20% (Home-grown Cereals Authority, 2004). Winter Barley is typically drilled in September or October but can be drilled as late as February; it is typically harvested in July/August. Spring barley is drilled in March/April, and is harvested during the last 3 weeks of August (Banff and Moray Grain Group, 2007; Ridealgh, 2005). There are many different varieties of malting barley and they take different lengths of time to germinate, but, in

general, malting barley does not keep as long as wheat. The majority of the barley crop is used up within 12 months of harvest but there is generally a period of storage of at least 6 weeks in the malting process used by most maltsters (Maltsters' Association of Great Britain, 2007).

Over 90% of the beer consumed in the UK is produced in the UK (National Statistics, 2005). About 60% of beer is sold on draught, and hence is consumed outside the home. There are four main categories: ales, porters, stouts and lagers. Porters are now rarely brewed. Ales cover a wide range of styles and tastes. Lagers are brewed, fermented and matured at relatively low temperatures, and then conditioned and stored for periods longer than other beers. Lagers represent two-thirds of sales in the UK and over one-half of the production (by volume) (British Beer and Pub Association, 2002).

The main ingredients of beer in this country, in decreasing order of importance by weight, are:

a water
b malted barley
c sugar
d un-malted barley
e other cereals (often wheat)
f hops.

Only the malted barley will be considered here, as it is the dominant ingredient (other than water) used in the brewing process (Maltsters' Association of Great Britain, 2007). Since hops constitute a small proportion of beer this food product will not be considered any further.

Once out of dry storage, to overcome natural germ dormancy (an approximately 6 week period), barley grains are steeped in water and allowed to germinate for up to 5 days. Drying in a kiln arrests the germination. The result is malt. The malt is mixed with hot water in a process akin to tea making to produce the wort, a sweet brown liquid. The wort is then boiled with the hops before being cooled and fermented with yeast. The fermentation process typically takes 7-10 days, but can be shorter. Finally, the drink is conditioned and packaged, and possibly stored, depending on the type of beer and the particular wishes of the brewer. Ales are quick to produce, with possibly as little as 1 week from the raw materials to the packaged product, whereas lagers have to be stored before consumption. Some types of beer can be stored for up to 6 months but this is very unusual. On average, 8 weeks are necessary from the grain to the final product but practices vary with manufacturer (Brewing Research International, 1997; Brewers and Licensed Retailers Association, 1996; Maltsters' Association of Great Britain, 2007).

As for wheat, the delay times for the consumption of barley are highly dependent on the time of the year. From the barley harvest to the brewers, there is a typical delay range of 1-12 months, and an average of 6 months. From the beginning of the brewing process to the consumption of beer, there is a typical delay range of 2-6 months and an average of 3 months. The overall delay times for barley are estimated at an average of 9 months with a range of 3-18 months.

3.2.4 Oats

Oats in the UK can be either winter-sown or spring-sown. Winter oats are usually drilled in late September and the first half of October and harvested at the beginning of August. Spring oats are drilled from mid-February to mid-April, and harvested slightly later, from the end of August to early September. The overall bias in the UK is around 4:1 in favour of winter-sown varieties (Blake, 2007). The proportion of winter oats increases from north to south: in England and Wales in 1995 it was 90% but only 50% in Scotland (Outsider's Guide to Crop Production, 1999). Of the total oat production in the UK, 55% goes to human and industrial consumption, the majority of which are foods (but a small proportion goes into products such as soaps, shampoos and talcum powders); the remainder is used for animal feed, seed and other uses (Home-grown Cereals Authority, 2007; Oat Services Limited, 2002).

Oats are mainly eaten in the form of rolled oats and oatmeal in porridge and muesli and are one of the least processed cereals available. The whole oat that remains when the hull has been removed is the groat, which forms the basis of all oat products. The outer coating of the groat is removed, and the oats are cleaned, dried and rolled or cut. Finally, they are steamed for a short while to de-activate the enzymes that would otherwise accelerate the fats turning rancid. Oats may also be steel-cut, although this process does not involve steaming and results in a shorter shelf-life. The delay times for oat products are greatly influenced by their long shelf-life (Practically Edible - Food Encyclopaedia, 2007). A typical home storage of no longer than 6 months in an airtight container is recommended (Waitrose; 2007). Taking into account storage after harvest, an average delay time of 7 months is suggested, with a typical range of 3 weeks to 2 years.

3.2.5 Sweetcorn

A small amount of agricultural land is given over to the production of sweetcorn, especially in the south of England where it grows well. Sweetcorn is harvested in August/September and is either eaten fresh, frozen or canned. If the product is fresh then it is best eaten within 48 hours of picking (FoodFen, 2001).

Over the crop year 2001, 1 110 hectares of land in England and Wales were planted with sweetcorn. This yielded 11.3 tonnes per hectare (Defra, 2001b).

The delay times for fresh UK-produced sweetcorn are suggested to be a minimum of 0 days, an average of 3 days with a range of 1-7 days.

3.2.6 Summary of delay times for barley, oats and sweetcorn

A summary of the delay times generally associated with oats, barley and sweetcorn are presented in Table 4.

TABLE 4 Summary of delay times for cereals other than wheat, days

Cereal	Minimum delay	Average delay	Typical range
Barley and Beer	N/A	270	90 – 540
Oats	N/A	210	21 – 730
Fresh sweetcorn	0	3	1 – 7

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.3 Vegetables and fruit

Only vegetables and fruit grown outdoors in the UK are considered in this section.

Data on UK production and consumption figures were reviewed to determine which vegetables and fruit should be considered in detail (Defra, 2005; Defra, 2005b; Defra, 2006).

In the UK, half of all fresh vegetables and fruit are retailed through the major supermarkets. Direct sales (farm sales, including Pick Your Own) hold 12% of the market. More than half of all vegetables are processed by freezing, canning, pickling or chilling, and this especially applies to peas, carrots, beans and beetroot.

The critical group for fruit and vegetables consists of people who have direct access to the crops, such as farmers, allotment holders and direct sales customers.

3.3.1 Root vegetables

The consumption of root vegetables in the UK is largely made up of potatoes, followed by carrots and alliums (onions and leeks).

3.3.1.1 Fresh potatoes

Potatoes are a major component of the UK diet; approximately 99% of the population eat potatoes, as crisps, canned, jacket, chips, etc (Smith and Jones, 2003). Approximately 30 kg of fresh potatoes are eaten per adult annually (Defra, 2008), together with approximately 13 kg of processed potatoes, of which a significant proportion (around half) are frozen (Defra, 2008; MAFF, 2000).

The UK potato crop is divided into two:

a *first earlies* (new potatoes), which are planted from January-March and harvested from the beginning of May to the end of July. These made up just over 4% of the total home produced potatoes marketed in the crop year 2005/2006;

b *second earlies,* planted from February to May*,* and *maincrop potatoes*, which are planted in late March and April. Maincrop potatoes are lifted in September and October. Harvesting of second earlies begins in July and continues through the maincrop harvest. Maincrop potatoes accounted for 80% of the total percentage grown in the crop year 2005/2006 (Defra, 2007e, Potato Council, 2007).

Around 5% of the remainder are potatoes used for seed and the rest is waste or retained for stock-feed.

New potatoes are immature and, as they lose their quality very quickly, have to be eaten within 10 days of lifting, unless they are canned or specially stored. In order to provide consumers with new potatoes throughout the year much of the second cropping (August – October) is retained in specialist storage buildings to supplement imported new potatoes in the winter and spring months (British Potato Council, 2001). New potatoes can be eaten within hours of being harvested, but more often they would be bought the day after, having been lifted one afternoon and delivered to the market or to the retailers the next morning. On average, earlies are probably eaten 2-3 days after lifting, within a range of 1-10 days (British Potato Council, 2001). A minimum delay time of 0 days is suggested.

The UK is almost entirely self-reliant in maincrop potatoes. The maincrop are planted from March and harvesting starts in August in the warmer regions and can go on until November. Maincrop potatoes are harvested when mature and can be kept until the beginning of the following year's harvest in appropriate conditions. The harvesting is ideally completed over a two week period, after which the potatoes are "cured" for up to a week in relatively warm conditions to dry and heal any damage from the lifting process. After curing, the temperature is lowered and the store ventilated to allow long term storage. Second earlies kept in long term storage are also available throughout the year. Farmers with refrigerated storage can sell their crop at any time up until the next harvest (Processed Vegetable Grower's Association, 2007). Most of the production is sold within 7 months, with an average of 5 months of storage at the producers' premises.

Different varieties are grown for different end uses and each grower aims for a particular market. The producer may store potatoes destined for the catering industry for up to a year. Supermarkets require the potatoes to be washed, graded and bagged in small plastic bags prior to purchase. In this case the potatoes go from the growers to packing stations before arriving on the shelves, and this process can take a couple of days. Once on the shelves, supermarkets aim to sell maincrop potatoes within 4 days.

It is estimated that it takes between 3 weeks and 12 months for maincrop potatoes to be available for consumers to buy, with an average of 5 months at the producer's and 1 week between the producer and the shops. Once in the home, fresh potatoes can be kept for several months, but in most cases are stored in conditions too warm to keep for

more than 2 weeks. A reasonable average delay time between lifting and consumption of fresh potatoes is therefore 5.5 months, with a total range of 3 weeks to 13 months and a minimum delay time of 0 days. As for cereals, the delay time between digging potatoes and consuming them is highly dependent on the time of the year.

3.3.1.2 Processed potatoes

A study conducted in 2005 found that approximately 50% of the potatoes consumed in the UK were processed (British Potato Council, 2006). Most of the processed products are crisped or frozen/chilled including foodstuffs such as oven chips. New potatoes are often canned to increase their shelf-life.

Most processed main crop potatoes are consumed in the form of frozen products, crisps and snacks. They can also be canned, peeled and sold as fresh peeled potatoes, or used as components of pasties and pies. Potatoes of poorer quality are often turned into powdered and dehydrated products. Potato processors usually have their own stores to keep their supply throughout the winter. Where there is no storage space, the potatoes can be delivered from the farm and processed in the same day.

Sealed potato crisps can keep for up to 6 months although the shelf-life is often marked as less for marketing reasons (Bradshaw, 2007). Frozen potato chips have a shelf-life of up to 2 years once processed (Bradshaw, 2007). Canned potatoes should keep for about 2 years, powdered potatoes for several years. Maincrop potatoes for processing may be eaten 1-2 days after processing for pasties and pies, a few months after processing in the case of frozen chips and crisps, and up to a few years later for canned and powdered potatoes. The minimum delays for frozen, canned and powdered potato products and potato crisps are not considered to be relevant values because of the production processes involved and subsequent large scale storage and distribution. Frozen potato products are estimated to have an average delay of 12 months and a range of 1 month to 3 years from harvest to consumption. Canned and powdered potatoes are estimated to have a slightly longer average delay of 18 months and a range of 1 month to 3 years and 4 years respectively. Crisps and potato snacks are estimated to have a typical range of 1-18 months and an average delay of 9 months.

3.3.2 Summary of delay times for potatoes

A summary of the delay times for potatoes is given in Table 5.

TABLE 5 Summary of delay times for potatoes, days

Root vegetable	Minimum delay	Average delay	Typical range
Fresh new potatoes	0	3	1 – 10
Fresh maincrop potatoes	0	165	21 – 390
Frozen potato products	N/A	365	30 – 1090
Crisps and potato snacks	N/A	270	30 – 540
Canned potatoes	N/A	540	30 – 1090
Powdered potatoes	N/A	540	30 – 1450

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.3.2.1 Other root vegetables

Root vegetables other than potatoes include, by order of consumption, carrots, onions, leeks, turnips, swedes, parsnips and beetroots.

Carrots are an important root vegetable in the UK diet. On average approximately 10 000 hectares have been planted with carrots in the UK over the past 5 years, with an average yield of 70 tonnes per hectare (Defra, 2005). They are grown all year round for the fresh market and for processing, by a succession of drillings and liftings of different varieties. Carrots take 12-24 weeks to grow. Growers store carrots in the ground even after they are ready to harvest to preserve them and market them during autumn and winter. Once lifted, they can keep for up to 1 month (Processed Vegetable Grower's Association, 2007). On average, carrots reach the customers 3-5 days after lifting, and are usually eaten over the following week. Therefore, an average delay time of 7 days (0 days for the minimum delay) with a range of 1-30 days is estimated.

Home-grown onions are now produced all year round. The main crop (planted in spring and lifted from late August) can be stored until the following summer and the winter-hardy varieties drilled the previous August give mature bulbs in June to August (Processed Vegetable Grower's Association, 2007). In the crop year 2004/2005, 9 063 hectares were planted, yielding 39 tonnes of dry bulb onions per hectare (Defra, 2005). This supplied roughly half of the market. Onions are grown for the fresh market, for processing and for pickling. Onions have to be dried for 1-3 weeks, after which they can be stored at an appropriate temperature for up to 6 months. In the home, it is usually difficult to keep onions for much over 1 month before they start deteriorating but they may be diced and frozen (Practically Edible – Food Encyclopaedia, 2007). Supermarkets have a 'sell by' date on onions of about 10 days. The average delay time for onions is estimated to be 6 weeks (3 weeks drying and

producer storage and 3 weeks combined in the supermarket and the home), within a range of 1 week to 6 months. The minimum delay is 0 days.

Leeks are available in the UK from July to April. In the crop year 2004/2005, 1 813 hectares of land were planted with leeks which yielded 21 tonnes of leeks per hectare (Defra, 2005). Most of the UK market is home-grown. Leeks are either sown in the fields or are transplanted outdoors in March and April. The main sales outlets for leeks are the supermarkets, but the processing industry also takes an important share of the production for soup making. Once dug, fresh leeks are not put into long-term storage but are prepared and transported for sale (Processed Vegetable Grower's Association, 2007). Leeks can keep for around a week if packaged and refrigerated. They are normally kept for up to 2 days by supermarkets. A likely average delay time for leeks is 4 days, which includes 1 day of storage in the home. The typical range is 1-11 days with a minimum delay of 0 days.

The main crop of turnips is available from August to March. Swedes are available all year round from sowings made between March and July. In the crop year 2004/2005, 2 683 hectares were planted with turnips and swedes and 39 tonnes per hectare were produced (Defra, 2005). Most turnips are raised from successive sowings outdoors and some early crops, lifted and marketed from April to July, are grown under plastic covers. Widely grown for feeding to cattle and sheep, they are also consumed by humans. Turnips are usually marketed within a few days of lifting (Processed Vegetable Grower's Association, 2007). Early swedes are now being produced from transplants raised under glass and planted out to extend the season from September to May. Swedes are normally sold within 3 days in supermarkets, after which they can be stored for up to a week in the home. The average delay time for turnips and swedes is therefore 5 days, from lifting to consumption, allowing for 2 days of storage in the home. The typical range is 1-11 days with a minimum delay of 0 days.

Parsnips are drilled in the fields from February to early May. In the crop year 2004/2005, 3 060 hectares were planted yielding 30 tonnes per hectare (Defra, 2005). Successive drillings of different varieties ensures continuity of supply almost all year round (August to April), although the demand is greater during the winter. As with carrots, parsnips keep well in the ground and can be stored in the ground during winter. However once they are lifted they are marketed as quickly as possible (Processed Vegetable Grower's Association, 2007). Therefore the typical range is estimated to be 1-14 days after harvest with an estimated average delay of 5 days and a minimum delay of 0 days.

Beetroot is sown from March to July. During the crop year 2004/2005, 1 666 hectares were planted which yielded 36 tonnes per hectare of beetroot (Defra, 2005). The main crop for harvesting from July onwards is grown on a field scale for mechanical harvesting. The crop may be left in field storage for a short period (1-2 weeks) but will be lifted by November for storage in refrigerated stores for marketing through to the next spring. Much of the crop is grown for processing, and beetroot can be bought fresh, or cooked and vacuum-packed, or cooked and pickled (Moorhouse, 2007). Fresh beetroot is best eaten straight after purchase but can be stored at home in the fridge for several days. Delay times for fresh beetroot (including the crop preserved in cold stores) are in the range of 1-180 days with a minimum of 0 days. In practice, the delay for beetroot is

highly dependent on the time of year as the length of storage by the processor is the dominant factor. A cautious value for the average delay of 7 days (for purchase in the early autumn) is advised.

3.3.2.2 Processed root vegetables

All canned vegetable products can be stored for many years, but manufacturers usually give a cautious 'best before date' of 2-3 years. Many vegetables intended for canning are harvested at an early stage of maturity as they become less suitable as they ripen (Del Monte, 2008). The delay times for all canned products are in the range of 2 weeks to 3 years, with an average of 4 months at the retailers' and 2 months in the home, giving an overall average of 6 months.

Most vegetables can also be frozen following harvest. This extends their shelf-life considerably providing households with fresh vegetables of many varieties all year round, even when they are not in season. Pickling of certain vegetables is also carried out, especially onions and beetroot. This preserves the vegetables and extends their shelf-life. Frozen vegetables can be kept for up to around 18 months (depending on the vegetable in question) (Martin's Sea Fresh Local Fish, 2008), and a similar period is estimated for pickled vegetables. There was little information that could be found on the production processes for these products but a cautious range from 1 week to 18 months is advised for both. The average delay is cautiously estimated to be 2 months for both sets of products.

3.3.3 Summary of delay times for other root vegetables

In summary, most root vegetables are grown and lifted all year round. A summary of the delay times for all root crops is shown in Table 6.

TABLE 6 Summary of delay times for other root vegetables, days

Root vegetable	Minimum delay	Average delay	Typical range
Fresh carrots	0	7	1 – 30
Fresh onions	0	40	7– 180
Fresh leeks	0	4	1 – 11
Fresh turnips and swedes	0	5	1 – 11
Fresh parsnips	0	5	1 – 14
Fresh beetroot	0	7	1 – 180
Canned vegetables	N/A	180	14 – 1090
Frozen vegetables	N/A	60	7 – 540
Pickled vegetables	N/A	60	7 – 540

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.3.4 Leafy green vegetables (brassicas and lettuces)

Only brassicas and lettuces are considered in this section, as they are the most widely consumed, outdoor-grown, leafy green vegetables.

Cauliflowers are available all year round from UK producers, who supply 90% of the market. Summer and autumn varieties are planted out in the fields between March and May and are harvested from July to November; winter varieties are sown in June and harvested after November (Gardeners Calendar, 2007). In the crop year 2004/2005, 9 947 hectares were planted, yielding 16 tonnes per hectare (Defra, 2005). Cabbages are available all year round and almost 100% of the UK requirement is home-produced. Summer and autumn varieties are sown from January to June for harvest through July to November; winter varieties are sown between early June and late August and are harvested in October, November, December, April and May (Gardeners Calendar, 2007). In the crop year 2004/2005, a total of 8 107 hectares of all varieties of cabbage were planted, yielding 33 tonnes per hectare (Defra, 2005). Once cut, brassicas have to be kept cool to ensure a good quality product, but in these conditions can then keep fresh for up to 3 weeks. Supermarkets, however, aim at selling them within 2 days of distribution, to allow the customers another week of storage. The average delay time for cabbages and cauliflowers is estimated to be 5 days in total; 3 days from cutting to the consumer and 2 days in the home, within a total range of 1-21 days (a minimum delay of 0 days).

In the crop year 2004/2005, 4 278 hectares of land were planted with Brussels sprouts, yielding 12 tonnes per hectare (Defra, 2005). UK grown Brussels sprouts are available from December to March. Around 75% of the harvest is sold fresh, and the remainder is frozen. Supermarkets aim to only store Brussels sprouts for 1 day, after which they have to be eaten within 10 days. Overall, they can be professionally stored in a controlled atmosphere for up to 6 weeks, giving a delay time range between cutting and consumption of 1 day to 7 weeks. A reasonable average is 5 days; 3 days to reach the consumer and 2 days in the home, except after the end of the season, when they may have been stored for a few weeks to increase the season of availability in the shops. The minimum delay is 0 days.

Lettuces can also be grown all year round in glasshouses, but predominantly from May to October outside. Once cut, they are highly perishable and have to be consumed within a few days. Most of the UK consumption is home-produced. In the crop year 2004/2005, 5 224 hectares were planted yielding 24 tonnes per hectare (Defra, 2005). Leafy salads represent about a quarter of the total green vegetables consumed by weight. The firmer types of lettuces, such as iceberg lettuce, can be kept for up to 3 days by supermarkets, but in general the maximum shelf-life of these products is 1 day. The time from picking to the supermarket shelf is around 1 day (Dyas, 2007). Lettuces of all types are easily grown by gardeners, for whom a delay time of 0 days is appropriate. The average delay time should be taken as 3 days (including 1 day in the home), and the total range is 1-14 days (for certain varieties).

3.3.5 Summary of delay times for leafy green vegetables

A summary of delay times for leafy green vegetables is presented in Table 7.

TABLE 7 Summary of delay times for leafy green vegetables, days

Green vegetable	Minimum delay	Average delay	Typical range
Fresh cauliflower	0	5	1 – 21
Fresh cabbage	0	5	1 – 21
Fresh Brussel sprouts	0	5	1 – 49
Fresh leafy salads	0	3	1 – 14

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.3.6 Oilseed rape

Oilseed rape, *Brassica napus*, is a Brassica crop. It may be sown twice a year. The winter crop is sown from mid-August to early-September, and it flowers from the end of March to early May and is harvested by mid to late July. The spring crop is sown from mid-March until mid-May, the crop flowers from early to late June through to July and early August, and it is harvested from early September until early November, depending on when it was sown. Once harvested the seeds, which contain about 40% oil, are sold to crushers who extract the oil. The remaining part of the seed is used as animal feed (Food and Farming Education Service, 2001). The seed may be sold to the crushers any time from 1 day to 11 months after harvest. In 2006, 575 000 hectares of land were planted, which yielded 3.3 tonnes per hectare of oilseed rape. Of this yield, around 90% was used in the UK (Defra, 2006c; Defra, 2005c). It is mainly grown along the eastern side of England and Scotland (Genewatch, 2001).

The crude oil produced by the crushing process is processed and then refined before being used to produce liquid oil, margarine, low-fat or reduced fat spreads, crisps, mayonnaise and ice cream. The oil is also used in the soap and detergent industry, as well as for industrial uses such as paint manufacture, specialist lubricants and now substantially in biodiesel (Outsider's Guide to Crop Production, 1999; Home-grown Cereals Authority, 2007b). The quality of the oil has been improved so that nutritionists now rate it as one of the healthiest oils available. In 2005-2006, margarine and low fat spread consumption exceeded butter consumption; consumption rates were 2 kg per person per year of butter compared to 3.9 kg per person per year of margarine and low fat and reduced fat spreads (Defra, 2008).

In 2000, over 40% of the liquid vegetable oils produced in the UK were from rapeseed. The rest was made up of palm, soya bean and sunflower oils (Defra 2002a). Liquid oil can be produced within 1.5 weeks and has a shelf-life of 1 year. Margarine and spreads can also be produced within 1.5 weeks but only have a shelf-life of 4 months (Purafoods, 2001). Therefore the range from harvest to consumption for liquid oil is 1.5 weeks to 1 year and for margarine and spreads 1.5 weeks to 4 months. The

average delay is 28 days for both oil and spreads and takes into account a 7 day delay from manufacturer to the supermarket. No separate minimum delay time is suggested fro these products as there are no data available on home or farm production.

3.3.7 Summary of delay times for oilseed rape and oilseed products

A summary of the delay times for oilseed rape and its products are given in Table 8.

TABLE 8 Summary of delay times for oilseed rape and products, days

Product	Minimum delay	Average delay	Typical range
Liquid oil	N/A	28	11 – 365
Margarine and spreads	N/A	28	11 – 120

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.3.8 Legumes

The only other domestic (UK grown) vegetables considered in this study are peas and beans. Other vegetables, such as tomatoes, aubergines and peppers are mostly grown under glass or are grown on a small scale and are therefore not likely to have a radiological significance.

Beans are sown in the UK from February to June, and are available from the end of May to the beginning of October (Royal Horticultural Society, 2007). The majority of the beans consumed in the UK, except canned baked beans, are UK grown (80%).

Most beans consumed fresh are runner beans or, to a lesser extent, broad beans. The majority of frozen beans consumed are French beans and broad beans, and these species are grown close to the processing plants, which are mostly located in eastern England. Broad beans crop in the earlier part of the season (June to August), whereas French beans are produced until early autumn.

Peas are sown between February and the beginning of June, and are harvested from July (in the south) to September (in the north). As they are highly perishable, the majority of the production is frozen. The remainder is canned, dried or sold fresh, often on "Pick-Your-Own" farms, to reduce the delay time between picking and eating. Nearly all of the peas for human consumption in the UK are home produced and they are grown all over the UK.

Legumes are widely grown in allotments and gardens because they are easy to grow, and as the products can be eaten very fresh, there is likely to be a minimum delay time of 0 days. Once picked, fresh legumes will remain in good condition for up to 1 week. Consumption is higher during the cropping season, especially for fresh beans (60% of

the yearly consumption is eaten between July and September). An average delay for fresh legumes is 3 days, with a typical range of 1-7 days. The minimum delay is 0 days.

Canned and frozen legumes are consumed all year round, in roughly equal quantities. Canned products keep for 3 years, and a reasonable average time between picking and the food being consumed by the public is 6 months. A typical range would be from 2 weeks to 3 years. Frozen legumes can be stored for 1 year (Practically Edible – Food Encyclopaedia, 2007), leading to a typical range of 2 weeks to 1 year, with an estimated average of 3 months. Dried legumes can be stored for years, although the 'best before date' is usually 2 years from the time of packaging. The processing times are slightly longer than for canning or freezing, leading to a range minimum of 3 weeks. Therefore a typical range would be from 3 weeks to 2 years, with an estimated average delay of 1 year. Minimum delay times are not included for these product types as it is considered that these products are processed with the intention of being stored beyond the fresh food's average shelf-life and mass production processes ensure distribution to retailers within the typical range.

3.3.9 Summary of delay times for legumes

A summary of delay times for legumes is presented in Table 9.

TABLE 9 Summary of delay times for legumes, days

Legume	Minimum delay	Average delay	Typical range
Peas and beans – Fresh	0	3	1 – 7
Peas and beans – Canned	N/A	180	14 – 1095
Peas and beans – Frozen	N/A	90	14 – 365
Peas and beans – Dried	N/A	365	21 – 730

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.3.10 Domestic fruit and fruit products

3.3.10.1 Hard fruit (apples and pears)

Apples and pears are harvested between August and October in the UK and the varieties that are stored for marketing all year round are usually picked during the latter part of this period. Less than half of the apples consumed in the UK are home-produced, and less than a third of the pears. In the crop year 2004/2005, 5 207 hectares produced on average 18.5 tonnes per hectare of dessert apples and 3 943 hectares of culinary apples produced on average 27.5 tonnes per hectare. For pears, 1 673 hectares produced on average 13.5 tonnes per hectare. The production of cider apples and perry pears has also been increased and in the crop year 2004/2005, 5 190 hectares were planted (Defra 2005b).

A third of the British production of culinary apples (mostly Bramleys) is processed, for pie filling, apple products, juices and ciders. Most of the production of dessert apples consists of Cox's Orange Pippin, which are marketed from September to April, although there is increasing production of varieties such as Gala. Some varieties of apples and pears store for a few months in controlled atmosphere (Prodfact 1988).

Once bought, pears ripen very quickly and can only be kept for a few days. Apples can be stored in the home for a few weeks, in conditions of low temperature and little light. Overall, the delay time associated with British grown hard fruits is directly related to the time of the year when the consumption takes place. In August to September, the delay is a matter of days. Depending on the variety and the time of the year, supermarkets only keep apples on the shelves for 2-7 days, and pears for 2-4 days. From September to April, the average delay is about 3.5 months, as the fruit are taken out of cold stores when required on the shelves, delivered overnight to retailers and bought within a few days. The typical range of delay time for apples and pears is 1 day to 6 months, with a minimum delay of 0 days and an overall average of 3 months.

The shelf-life of processed apple and pear products depends on the type of packaging they are marketed in. Canned pears usually have a 'best before' date of 3 years, fresh apple pies of less than a week, and frozen apple pies of up to 3 months. It is considered that 'fresh' products, such as fresh apple pie, should be treated to have the same delay times as the unprocessed fruit as there is no significant influence on overall delay times from the production process. Canned products are estimated to have a range of 2 weeks to 3 years, with an average delay of 6 months. Frozen products are estimated to have a range of 2 weeks to 1 year and an average delay of 6 months. Minimum delay times to the critical group are not included for canned and frozen product types as it is considered that these products are processed with the intention of being stored beyond the fresh food's average shelf-life and mass production processes ensure distribution to retailers within the typical range.

3.3.10.2 Stone fruit (plums and cherries)

Stone fruit are a much less important part of the average annual UK diet than hard fruit but, because they are seasonal, consumption rates can be significant over the summer (over 60% of the yearly consumption is eaten between July and September).

About one-third of stone fruit consumed in the UK is home produced. In the crop year 2004/2005, 381 hectares were planted with cherries which yielded on average 2.6 tonnes per hectare (Defra 2005b). Cherries are available from late June to August and plums from July to October (British Summer Fruits, 2007). Cherries are mainly grown for fresh markets, whereas a large proportion of plums are processed (Prodfact 1988). In the crop year 2004/2005, 978 hectares were planted with varieties of plums which yielded on average 14 tonnes per hectare (Defra, 2005b). Fresh stone fruit can be stored for up to 14 days if covered and refrigerated, although many are probably eaten within a couple of days of reaching the consumer's home, unless preserved. Supermarkets only keep cherries on the shelves for 1 day, and plums for 2-3 days, temperature allowing. The average delay time for fresh stone fruit is therefore 4 days (including 1 day in the home), with a range of 1-14 days and a minimum delay to the critical group of 0 days.

Preserved stone fruit can easily keep for 2 years, but are probably mainly eaten over the first year after the fruit has been picked, i.e. an average of 6 months for the delay between picking and consumption. A cautious minimum delay of 1 day is suggested for preserves sold from farms or made in the home.

3.3.10.3 Soft fruit

Soft fruits are available seasonally, approximately from May to September, with different fruits available at different times. About 65% of the strawberries consumed in the UK are home produced. Over 70% of the UK strawberry crop is marketed in June-July and is the most popular fruit at 'Pick-Your-Own' (PYO) outlets. The strawberry season lasts from June to late September but glasshouse produce means there are strawberries available for most of the year (British Summer Fruits, 2007). In the crop year 2004/2005, 3 299 hectares were planted and yielded on average 14.5 tonnes per hectare (these figures exclude glasshouse produce) (Defra, 2005b).

In the crop year 2004/2005, 1 505 hectares were planted with raspberries and yielded on average 7 tonnes per hectare, and 2 987 hectares of blackcurrants were planted with an average yield of 6.5 tonnes per hectare (figures exclude glasshouse produce) (Defra 2005b). Raspberries grow from June to September but producers use glasshouses to market them from April to December. Blackcurrants grow from late June to mid August and gooseberries throughout June and July (British Summer Fruit, 2007). Raspberries, blackcurrants and gooseberries perish very quickly and are often frozen or used for making jam, both in the home and industrially. Most of the Scottish production of raspberries is frozen, whereas the English crop is mostly sold fresh, over half of it through PYO farms. PYOs are a relatively important sales outlet for fresh blackcurrants too although the majority (80%) of the production is used for juice and jam making. Fresh soft fruits deteriorate within a few days of picking.

Strawberries, raspberries and blackberries have thinner skins, and hence shorter shelf-lives, than gooseberries and currants. Once picked, farmers aim to have strawberries, raspberries and blackberries in cold storage (2-5ºC) within 30 minutes. Once the field heat is removed the produce can be packaged, transported and available in supermarkets the day after picking. Fresh produce can keep for 5-7 days but it is preferable for it to be sold within 3 days so it is in best condition when it reaches the consumer's home. With regard to currants and gooseberries, they will last longer due to their tough skins although growers will aim for a similar regime during harvest (Raffle, 2007). The average delay time for fresh strawberries, raspberries and blackberries is about 4 days, with a typical range of 1-8 days. Gooseberries and currants have a slightly longer estimated average delay of 6 days and a range of 1-14 days. The minimum delay to the critical group for all fresh soft fruits is 0 days. Soft fruit keeps for up to 12 months frozen and, once processed into jam or juice, can be stored for up to 2 years (Practically Edible – Food Encyclopaedia, 2007). Frozen soft fruit is estimated to have a typical range of 2 weeks to 1 year with an average of 6 months.

3.3.10.4 Rhubarb

In 1999, an average of 104 g per person of rhubarb was consumed (MAFF, 2000). A total of 323 hectares were used to grow rhubarb in the crop year 2004/2005 yielding 52.6 tonnes per hectare (this includes forced rhubarb under cover) (Defra, 2005). English rhubarb is available from April to November (Waitrose, 2007) although indoor forced rhubarb is also available and is not reliant on the season (Bailey, 2007). If stored well and refrigerated rhubarb can keep for around 2 weeks, including a few days in the supermarket if applicable, if stored well and refrigerated (Rhubarb Compendium, 2004). The total range of delay times for fresh rhubarb is therefore 1-14 days, with an average of 4 days and a minimum delay to the critical group of 0 days.

3.3.11 Sugar and honey

The UK's climate is not suitable for growing sugar cane but is suitable for growing sugar beet. Farmers are contracted by processors to grow it. Beet is mainly grown around the sugar processing factories in the East of England and the West Midlands. In 2006, 131 000 hectares of land were planted with sugar beet, which yielded on average 54.7 tonnes per hectare. Sugar beet is then converted into refined sugar, of which 70% of the UK's demand is produced in the UK (in 2006, 1 100 000 tonnes of refined sugar was produced in nine factories around the country) (Defra, 2005d). The yearly average consumption of sugar and preserves was 6.7 kg per person in 2006 (Defra, 2006).

Normally, drilling of sugar beet takes place in a three-week period around the end of March and early April. Harvesting starts in September with the early liftings delivered directly to the factories. As the soil conditions deteriorate in October and November, the later crops are lifted and clamped under bales of hay to protect them from frost. The tops of the sugar beet are removed before harvest, and can be either fed to cattle or sheep, used to make silage or ploughed back into the field. Another by-product is molasses which is used in the food and chemical industry (Outsider's Guide to Crop Production, 1999).

Most of the sugar is refined between September and January, and once packaged, it can keep for years. During this time, it can be stored in shops or in the home, where it is probably consumed over a few weeks to a few months. A reasonable average delay between the lifting of sugar beet and the consumption of white sugar is 9 months, within a range of 1-24 months (Food and Farming Education Service, 2001). No data were available on refined sugar being sold on farms and refining is a complex process. Hence a minimum delay time to the critical group has not been identified.

Bees only produce honey when the temperature is above 10°C. They collect pollen from approximately the end of May to the end of July in the south of England, and over a shorter period further north. The honey is collected by the beekeepers at the end of the summer and can be stored for very considerable periods, if kept in a sealed container. In most cases however, the honey is probably consumed over the next 1-2 years at most. A reasonable average delay between collection and consumption for honey is 6 months, within a range of 1 week to 2 years. The minimum delay is 0 days.

3.3.12 Summary of delay times for fruit and fruit products

A summary of the delay times for fruit and fruit products is presented in Table 10.

TABLE 10 Summary of delay times for fruit and fruit products, days

Fruit	Minimum delay	Average delay	Typical range
Fresh apples and pears	0	90	1 – 180
Canned hard fruit	N/A	180	14 – 1095
Frozen hard fruit	N/A	180	14 – 365
Fresh stone fruit	0	4	1 – 14
Stone fruit jams	1	180	14 – 730
Fresh strawberries, raspberries and blackberries	0	4	1 – 8
Fresh gooseberries and currants	0	6	1 – 14
Frozen soft fruit	N/A	180	14 – 365
Fresh rhubarb	0	4	1 – 14
Sugar	N/A	270	30 – 730
Honey	0	180	7 – 730

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.4 Animal products

3.4.1 Eggs

Around 90% of eggs consumed domestically or used in industry in the UK are produced in the UK, with a total of about 30 million eggs per day consumed. The ratio of those eggs sold in shells to those processed is 3:1. The most common method of commercial egg production in the UK is the laying cage system. The barn, free range and organic systems are other methods of production (Defra, 2005e; British Egg Information Service, 2004). The production of eggs is split as follows: 70% laying cage system, 24% free-range and 6% perchery/barn (British Egg Information Service, 2003).

Eggs can be in the shops within 2–3 days of being laid. There are regulations in force that require eggs to be collected from farms every 3 days and packaged within 2 days of collection, with a further day for delivery. Therefore an average delay time of 6 days, allowing for a few days of home storage, would be appropriate. The BEIS (British Egg Information Service) Lion Code of Practice sets a standard “best before” date of 21 days from packaging, i.e. 23-24 days from laying, whereas the EU regulations set a maximum life of 28 days from laying (Deans Foods, 2003; Botterill, 2004). A total range of 2-21 days would therefore seem appropriate (Botterill, 2004). The minimum time of 0 days is for instantaneous consumption, mainly by farmers and direct sales to customers.

3.4.2 Summary of delay times for eggs

A summary of the delay times for eggs is given in Table 11.

TABLE 11 Summary of delay times for eggs, days

Product	Minimum delay	Average delay	Typical range
Eggs	0	6	2 – 21

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.4.3 Meat

In the UK during the 2005-2006 period about 12 kg of poultry, 11.8 kg of carcass meat and 30 kg of meat products were eaten per person. Of the 11.8 kg of carcass meat eaten, 53% was beef, 23% pork and 24% mutton and lamb (Defra, 2008). The consumption of rabbit meat is extremely low and is not considered further. The average consumption of game over the whole UK population is also very low, but for some individuals game is of some significance in their diet and delay times for game have therefore been considered.

The meat industry in the UK is extremely complex, due to the many different end-products and types of packaging. There is very little formal and unified regulation regarding the shelf-life of meat products, and each manufacturer may determine how long their packaged product will remain safe for consumption. The term ‘fresh meat’ covers all un-processed meat, including frozen or chilled (kept at 0ºC). Chilled meat is usually vacuum-packed, presented in oxygen permeable plastic, or modified atmosphere packed (MAP). In general, plastic wrapped meat keeps for a few days, MAP meat for a week and vacuum-packed products for up to 4-8 weeks depending on the quality of the meat when packaged. Frozen meat can be kept for a few months but freezing can affect the quality of products that are neither minced or diced (Red Meat Industry Forum, 2007). The meat market is divided between independent butchers and supermarkets, increasingly in favour of the latter.

It is a fundamental requirement of the meat hygiene regulations (Statutory Instrument, 1995a; Statutory Instrument, 1995b; Statutory Instrument, 2002) that animals intended for human consumption are taken to a licensed slaughterhouse. Private slaughter is lawful in a licensed slaughterhouse and the farmer may then sell the meat in, for example, a farm shop or bed and breakfast enterprise. This is because the meat would have been produced in accordance with various regulations and marked fit for human consumption. If the farmer carries out the slaughter ‘on-farm’, then he would only lawfully be able to consume the meat himself. It would be unlawful to supply such meat to his immediate family, bed and breakfast enterprise or farm shop as the relevant regulations would not have been adhered to. These regulations (Statutory Instrument, 2002) apply to cattle, sheep and goats. Pigs, poultry, farmed game species and rabbit are not under these controls and the farmer may supply these meats to the

rest of his household, although not to any other third party i.e. farm shop or bed and breakfast enterprise (FSA, 2003).

3.4.3.1 Poultry

In terms of poultry meat, the UK is 75% self-sufficient (Defra, 2007f). The poultry meat industry output consists mostly of broiler chickens (reared for meat) at roughly 80% of the market, turkey at 12%, with ducks and geese at 4%.

The broiler market grew during the BSE crisis and other health scares associated with red meat (Outsider's Guide to Animal Production, 1998). Most of the broiler production in Britain is based on intensive indoor rearing. At around 42 days old, when the chickens reach an average live weight of 2-2.2 kg, they are slaughtered (Griffiths, 2007). They are converted into the oven-ready product at large, flow-line plants handling thousands of birds each day. They are stunned, killed and prepared in a matter of minutes, before being cooled or frozen and packed (Griffiths, 2007). They are delivered to the supermarkets the next day. Some fresh chilled products can have a shelf-life of up to 14 days, but more often of 7 days. The typical product turnover is only a few days (Griffiths, 2007). Unwrapped non-eviscerated chickens can keep for up to 4 weeks at 0 ^{o}C, but these are of minor importance on the market. Cooked chicken can then keep for up to 3 days refrigerated.

The multiple retail outlets have been steadily increasing their share of the chicken market, especially for processed chicken products. The processed market is divided into three sections: ready-cooked, fresh portions (marinated, coated, rolled or stuffed) and frozen (complete portions, sausages or hamburgers). The delays introduced by processing are not normally significant. The main differences between fresh and processed chicken are the increased shelf-life of the processed products.

Most turkey consumed in the UK is home produced. Turkeys are especially popular at Christmas and, to a lesser extent, at Easter, but they are available all year round. Killing takes place at various weights when the birds are around 21 weeks old. A minority of the Christmas turkeys are purchased from local farmers and butchers as 'traditional farm fresh' and these have normally been hung for a week to mature (National Farmer's Union, 1997; Griffiths, 2007; Outsider's Guide to Animal Production, 1998). There has been a rapid increase in the range of prepared or processed turkey dishes in recent years; this has led to an overall increase in consumption. Further processes include pre-packs of specified joints, reconstituted slices and special turkey preparations for the catering trade.

Over half of the ducks produced in the UK are used by the catering industry. The production is based on farms that market their product (seven-week-old ducklings) as frozen and oven-ready. Duck can also be found chilled, and some specialists still sell the 'fresh-plucked' birds with head and feet (Prodfact, 1988; Outsider's Guide to Animal Production, 1998; Griffiths, 2007).

Goslings are only hatched in the spring, and geese are most commonly sold for roasting at Christmas. The birds are typically 20-25 weeks old at slaughter (Griffiths, 2007). A limited number are available throughout the year, especially at Easter, but most of the

birds are killed between September and December and supplied by farmers who raise a small numbers of birds. Frozen birds represent around a quarter of the total production (Prodfact, 1988, Outsider's Guide to Animal Production 1998). All frozen uncooked birds can keep for 4-6 months and frozen cooked birds for up to 2 months. Fresh birds should be cooked within 3 days of purchase, and can be stored cooked for 3 days (Prodfact, 1988).

There is a clause which exempts the private slaughter of poultry from the *Poultry Meat, Farmed Game Bird Meat and Rabbit Meat (Hygiene and Inspection) Regulations 1995* (Statutory Instrument, 1995b; Statutory Instrument, 2005; FSA, 2003) that requires meat for human consumption to be slaughtered in licensed premises. The clause is called the "under 10 000 exemption", that allows a farmer to slaughter on his holding birds reared there and then sell them for human consumption provided he rears and slaughters less than 10 000 per year. It is envisaged therefore that a farmer and the rest of his household may consume poultry meat on the day of slaughter thus a delay time of 0 days would be appropriate in this circumstance.

For fresh poultry meat a minimum delay time to the critical group (including consumers buying directly from the farm) between slaughter and consumption of 0 days is appropriate. For consumers buying from larger retailers a typical range is 1-17 days and a reasonable average is 4 days (assuming 1 day from slaughter to retailer, 2 days in the shops and 1 day in the home). For frozen poultry meat, a minimum delay is not appropriate; a typical range of 1 week to 6 months and an average of 3 months are advised. These estimates are largely based on data for broiler chickens.

3.4.3.2 Cattle meat

In the UK, much beef production is a by-product of the dairy herd, since dairy cows have to produce calves to produce milk. There is some import of beef meat, particularly from Ireland (75% of domestically consumed beef and veal is produced in the UK – Defra, 2007g). There is very little veal production and consumption in this country. Calving can be arranged at any season, and animals slaughtered at a range of ages. There is therefore year-round availability of beef. Most of the animals slaughtered are between 12 and 26 months, depending on the system of production (Red Meat Industry Forum, 2007b). Due to Bovine Spongiform Encephalopathy (BSE), legislation insisted meat from cattle over 30 months old could not be slaughtered for human consumption. As a consequence, older dairy and suckler cows could not enter the food-chain; such requirements have gradually been removed and animals are likely to be finished at times dictated by the market (Red Meat Industry Forum, 2007b).

In 2004, around 14% of the household volume purchases of beef were from butchers (Red Meat Industry Forum, 2004). Beef carcasses or beef hind-quarters are usually kept for a minimum of 14 days by independent butchers, for improved flavour and texture. This keeping period may be as long as 4 weeks. Prime cuts (grilling and roasting beef) are vacuum-packed for maturation for 7-14 days. However, there is no minimum hanging time enforced for beef and for products bought in supermarkets the delay is likely to be much shorter. Lesser cuts are wrapped and on the shelves after 4 days and with a shelf-life of 4-10 days depending on packaging method (Meat and Livestock Commission, 2007). Ground or minced beef is a growing market and cuts

may have been vacuum-packed for 1-2 weeks before mincing. Minced meat can be packaged in a modified atmosphere, which extends its shelf-life to 4 days, or in the more traditional trays with a shelf-life of only 1 day (Davis, 2007; Meat and Livestock Commission, 2007). Around 43% of the household beef used is minced (Red Meat Industry Forum, 2007). Once cooked, beef should not be kept in the home for more than 2 days.

The average delay time between the killing of the animal and the consumption of fresh beef is of the order of 8 days via supermarkets or 16 days via independent butchers, for grilling and roasting cuts, with a typical range of 4-30 days. The minimum delay via supermarkets is 3 days, representing the minimum time for cutting, packing and distribution. The minimum delay for beef sold at butchers is 14 days.

Beef freezes well both at home and industrially and it retains its original quality for longer than pork or lamb. Frozen uncooked beef can be stored for up to 12 months, and is probably eaten at an average of 3 months from slaughter. Cooked meat pies, stews and meat dinners that are bought frozen have a shelf-life of 3 months in most cases. Canned beef products can keep for a number of years.

Farmers can legally slaughter cattle on their premises and may consume the meat themselves. However, it would be unlawful for anyone in the farmer's household to consume the meat, including any bed and breakfast enterprise being run on the premises (Statutory Instrument, 1995a; Meat and Livestock Commission, 2005; FSA, 2003).

In consideration of the delay times appropriate to critical groups, the situation can be envisaged in which meat may be consumed a short time after slaughter by the farmer. However, beef is inedible for about 2 days after slaughter, requiring chemical changes to break down the resistant structure. These minimum times should not be used in critical group dose assessments where the dose over a period is evaluated, as such short delays would only apply immediately following slaughter and it may be assumed that the remainder of the animal would be consumed over a longer period.

3.4.3.3 Pig meat

In 2006, the UK produced 57% of the pork consumed in the UK, and 43% of the bacon and ham consumed (Defra, 2007g). In 2005-2006, 5.8 kg per person per year of bacon and ham, 2.7 kg per person per year of carcase pork and 3 kg per person per year of pork sausages were consumed (Defra, 2008). The majority of pigs are kept indoors and reared intensively on concentrates. About a quarter of the breeding sows are housed outdoors, and the piglets are weaned after 3-4 weeks. Pigs are killed at 4-7 months, depending on future use (Red Meat Industry Forum, 2007c). After slaughter, the carcasses are chilled immediately and butchery is usually completed on the following day, although in the case of meat sold through independent butchers this may take somewhat longer. The minimum maturation time recommended by the Meat and Livestock Commission for pork is 4 days for legs and 6 days for loins but commercial practice does not always achieve these times (Matthews, 2007).

In 2004, 14% of the household purchases of pork by volume were from butchers (Red Meat Industry Forum, 2004). Pork carcasses are normally kept by independent butchers for approximately 4 days, and start deteriorating after about 8 days. Once cut, the raw meat will keep for 2-3 days in the cold, cooked meat products for up to 7 days after cooking. Vacuum-packed chilled pork joints have a storage life of up to 4 weeks. Ground pork only keeps for 24-48 hours unless packed in a modified atmosphere. Fresh pork sausages have a shelf-life of around 7 days once packaged (Matthews, 2007). Although it is not a hard and fast rule, normally pig meat would not be consumed until a minimum of 48 hours after slaughter (Matthews, 2007). Regulations (Statutory Instrument, 2002) do allow a farmer to slaughter and supply pig meat to his household, although not to a third party (FSA, 2003).

The suggested delay times for fresh pork meat are: a minimum delay of 1 day, a typical range of 3-32 days, with an average of 7 days. For critical group assessments, as for beef, if the assessment of dose is to be evaluated over a period such a short delay time may not be appropriate.

A traditional method for curing bacon is to inject whole sides with the curing solution and to leave them immersed for 3 days, after which they are placed on pallets and drained for 7 days. Once packaged, bacon can keep for up to 5 weeks, or 6 months if vacuum-packed, although once in the home it is likely to be used up within a few days (after the packaging has been open, bacon and ham will keep for up to 10 days). The range of suggested delay times for bacon is: a minimum of 11 days, a maximum of 6.5 months, and an average of 3 weeks.

After cutting or cooking, almost any pig meat product can be frozen, which increases its shelf-life to 6 months. Recommendations on freezing meat recommend pork should not be frozen for more than 3 months as oxidation processes will reduce the quality of the meat. However, this will not make the meat unsafe to eat and a cautious value for freezing of 6 months is assumed (Broad-stripe Butchers, 2007). The suggested delay times for frozen pig meat are an average of 3 months with a typical range of 1 week to 6 months.

3.4.3.4 Sheep meat

In 2005-2006, 2.8 kg per person per year of mutton and lamb were consumed (Defra, 2008). The UK is a net importer of sheep meat, importing mainly from New Zealand (and to a lesser extent Australia and the Irish Republic). Imports tend to be at their seasonal peak from January to June, when UK production is seasonally low. However, UK production is dominant in the UK diet. Summary data for sheep meat shows that in 2006, 378 400 tonnes of sheep meat was consumed. The breakdown shows that 63% was from UK production (238 700 tonnes of the 333 500 tonnes produced); the remainder was imported (Defra, 2007g).

There are many different breeds and systems of production for sheep meat. Most of the meat sold in the UK is lamb (under 1 year old). It is difficult to find mutton, which is usually sold to restaurants or to processing companies. Lamb is available all year round and is slaughtered at various ages at weight 36-42kg (Red Meat Industry Forum, 2007d).

In 2004, around 20% of the volume of lamb bought by households in the UK was from butchers (Red Meat Industry Forum, 2004). The situation for ageing is similar to that of beef meat except that lamb is already more tender than beef and so generally requires less hanging. The Meat and Livestock Commission recommend 14 days of hanging (Davis, 2007). Independent butchers hang lamb carcasses for 5-9 days for improved flavour and texture, and supermarkets have the carcasses cut early and the cuts vacuum-packed for maturation. Once cut, the raw meat keeps for up to 5 days in a refrigerator and for up to 4 weeks at suitably low chilling temperatures. The time interval between slaughter and retail display should be at least 7 days. Vacuum-packed chilled lamb can be stored for 10-16 weeks, and lamb can be imported in this form. Once cooked, lamb should be consumed within 2 days. Frozen lamb can be stored for 4-6 months giving a maximum delay including home freezing of 9 months (Davis, 2007). The estimated average delay for frozen lamb is 7 weeks. Unprocessed lamb products probably take around a week to reach the customer. Suggested delay times for fresh lamb are: a minimum of 7 days, a typical range of 7 days to 3.5 months, with an average of 9 days. As for pork and beef, for critical group assessments, if the assessment of dose is to be evaluated over a period such a short delay time may not be appropriate.

3.4.3.5 Offal

The generic term offal includes organs such as the heart, liver, kidney, feet and brain of cattle, pigs and lambs. Cattle brain is not available any more, as a result of the BSE crisis, and in general very little brain is used for consumption (roughly 0.5% of the total sheep and pig brains are extracted for use). Livers, kidneys and hearts are the predominant types of offal on the market. Pigs' feet are the only animal's feet still consumed. Cattle and sheep feet are used for rendering and disposed of (Meat and Livestock Commission, 1997). In 2005-2006, household consumption of lambs' liver was 0.05 kg per person per year and pigs' liver was 0.05 kg per person per year (Defra, 2008).

Offal is widely used in the processed meat products industry (in pies, pâtés, etc.). Offal deteriorates quickly and may only be kept for up to 6 days after slaughtering if packed in a modified atmosphere and for a maximum of 4 months if frozen. Frozen lambs' liver and kidney are imported from New Zealand. Most of the offal is consumed through processed meat products which have various shelf-lives depending on the processing they underwent. For example, pasties and pies have a shelf-life of around 10 days from the packaging date, but once frozen, they can keep for at least 3 months. These products can also be canned (especially pâtés) or vacuum-packed. Once cooked in the home, offal should be eaten within 2 days. Overall, it is difficult to evaluate an average delay time for offal. A cautious assumption for fresh offal is that the typical delay range is 1-9 days, with an average of 3 days and a minimum of 0 days.

3.4.3.6 Game

Farmed deer are killed when 15-27 months old, at the farm or the abattoir. Most of the fresh venison comes from red deer and is sold between August and January. Because of the low fat content of the meat, it freezes very well for over 12 months and this extends the season of availability of the product. Fresh venison is hung for a time,

depending on the temperature and personal preferences, usually around 10-12 days (New Mexico State University, 1997). Wild deer can be shot at any age from a few months to over 15 years and may be legally sold throughout the year, unlike other game. However, there are still seasons for shooting deer and the meat tends to be eaten once it has matured rather than stored for long periods. Seasons vary with the species of deer in question and the seasons in Scotland are out of phase with those of the rest of the UK (Prodfact, 1988; British Association for Shooting and Conservation, 2007).

Game such as pheasant, grouse or hare have a specified shooting season and it is illegal to sell game more than 10 days after the end of the season. The season varies with species, for example grouse can be hunted between August and December, partridge between August and February, pheasant between October and February, and duck and goose from September to February. Pheasant accounts for over 50% of the game birds shot in the UK. There are around 8 million birds bred in the wild and an estimated 20 million reared birds released at the start of the season. There are up to 400 000 partridge pairs in the wild, of which there are red-leg and grey varieties, with an estimated total of 2-3 million released each year. Grouse are very difficult to successfully rear and release and so gamekeepers nurture the wild population on grouse moors. There are around 250 000 breeding pairs. The process of rearing game from hatchlings takes around 6 weeks. They are kept in exposed pens after just 2 weeks (British Association for Shooting and Conservation, 2005; British Association for Shooting and Conservation, 2007).

Game has to be carefully hung for microbes to break down the tissues, thus tenderising the flesh and improving the flavour. However, the habit of hanging meat is not necessarily observed. Hare is usually hung for 7-8 days, wild duck for 1-2 days, other birds for 1 week. Once cooked, game meat can be kept in the cold for a few days with a typical range of 1-16 days and an average of 8 days. Around 80% of game shot in the UK is exported, but the remainder is largely sold as fresh produce. Most game birds should not be stored frozen for more than 6 months, giving an overall range of 10 days to 8 months, or 12 months to include venison, with an average of 4.5 months (British Association for Shooting and Conservation, 2005; New Mexico State University, 1997).

As for meat, the slaughter of game birds comes under regulations (Statutory Instrument, 2005) that require slaughter in licensed premises. There is, however, a circumstance under this Regulation called the “under 10 000 exemption”, that allows a farmer to slaughter his holding birds and then sell them for human consumption provided he rears and slaughters less than 10 000 per year. It is envisaged therefore that a farmer and the rest of his household may consume a game bird on the day of slaughter thus a delay time of 0 days would be appropriate in this circumstance. However, he would not be able to supply this meat to a third party even under these circumstances.

In summary, the minimum delay time for fresh game is assumed to be 0 days with a typical range of 1-16 days and an average of 8 days. For frozen game a typical range of 10 days to 1 year is estimated with an average of 4.5 months. For frozen game a minimum delay to the critical group is not appropriate due to the extended storage time.

3.4.4 Summary of delay times for meat

A summary of the delay times for all meats is given in Table 12.

TABLE 12 Summary of delay times for meat, days

Product	Minimum delay	Average delay	Typical range
Poultry meat (chicken)			
Fresh	0	4	1 – 17
Frozen	N/A	90	7 – 180
Beef			
Fresh (supermarkets)	3	8	4 – 30
Fresh (butchers)	14	16	4 – 30
Frozen	N/A	90	7 – 365
Pig meat			
Fresh	1	7	3 – 32
Bacon	11	21	11 – 195
Frozen	N/A	90	7 – 180
Sheep meat			
Fresh	7	9	7 – 110
Frozen	N/A	49	10 – 270
Game			
Fresh	0	8	1 – 16
Frozen	N/A	135	10 – 365
Offal (fresh)	0	3	1 – 9

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group – for manufactured products it is considered that the minimum delay to the critical group is no shorter than to the wider population and so the minimum delay is not applicable to these products.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

3.4.5 Marine fish, aquaculture and shellfish

In the UK, fish can be caught at sea, in inland waters or farmed in the growing aquaculture industry. In 2006, demersal and pelagic fish each accounted for 34% of the total catch with shellfish making up the other 32%. The main seafish caught (by weight) are cod, haddock, whiting and saithe. These four species account for 64% of all demersal fish landed by UK vessels. Pelagic fish landed in the UK are mainly herring and mackerel which account for almost 94% of pelagic landings (Marine and Fisheries Agency, 2006). The main species farmed are salmon and rainbow trout, with trials ongoing on other non-salmonid species such as turbot, halibut and cod.

Shellfish can also be caught in the wild or farmed. The main species are crabs, nephrops, prawns, langoustine (whole prawns) and scallops. Farming of mussels, oysters and clams is common and trials of scallop farming are being carried out.

3.4.5.1 Marine fish

There are four conditions in which fish can reach the home consumer: fresh, frozen, smoked or tinned. Retail outlets are fishmongers, supermarkets, restaurants and take-aways. The trimmings from the food fish sector and fish species for which human consumption is currently very limited or non-existent, are used in the animal feeds industry. Fishmeal is rich in protein and beneficial oils and is thought to provide health benefits to livestock. In 2000, 50 000 tonnes of fishmeal were produced and were used as a supplement in the feed of poultry (45%), fish, (30%), pigs (14%), ruminants (10%) and others (1%). Of the ruminants, most were dairy cows (60%) with 30% sheep and 10% cattle bred for meat (Fishmeal Information Network, 2002). The high liver lipid content of fish such as cod or haddock is exploited to produce cod liver oil.

Although a large number of demersal species are caught and landed in the UK, in 2006 by far the largest quantity of fish were haddock (28%) and blue whiting (15%). Cod made up only 9% of the total demersal catch, with the amount of cod landed decreasing by 34% since 2002. In 2006, the UK Fleet caught 21 000 tonnes of cod. Of this weight, 40% were caught in the North Sea, 16% off the Norwegian coast, 3% Irish Sea, 2% west of Scotland and 39% others. For haddock, the UK fleet caught 40 000 tonnes in 2006. Most of this was caught in the North Sea (81%); the vast majority of the remainder (12% of the total) was caught off the west of Scotland (Marine and Fisheries Agency, 2006).

In 2006, of all pelagic species caught by the UK fleet, 46% were herring and about 43% were mackerel. Most of the 110 000 tonnes of herring were caught in the North Sea (63%), the majority of the remainder from the west of Scotland (17%) and the Norwegian coast (11%). Of the 103 000 tonnes of mackerel caught, 60% were caught off the west of Scotland, with 31% being caught in the North Sea (Marine and Fisheries Agency, 2006).

Large fishing vessels go to sea for up to 2 months at a time. They have on board large freezers into which they place their catch. Fish may, therefore, be stored frozen on a fishing boat for up to 2 months out at sea and up to 1 year in freezers in warehouses on shore, before being sold for consumption to the public (Sea Fish Industry Authority, 2002). Frozen white fish will keep on board for up to 3 months, oil-rich fish for 2 months and smoked fish for 3 months (Fresh fish online, 2002).

Supermarkets prefer to buy from smaller fishing vessels that go out for a maximum of 4 days. Added to this there is 1 day to land the fish and ship to the processor, and a further 24 hours for distribution to stores. Once on display in the shops, the shelf-life is 2 days (Tesco Customer Services, 2002). Fresh fish from supermarkets therefore has an average delay time of 8 days, a minimum of 2 and a range of 2-12 days.

Smoked fish has the same delay times as for fresh fish, i.e. a minimum of 2 days, a maximum of 12 days with an average of 8 days.

3.4.5.2 Aquaculture

The main species farmed are salmon and rainbow trout. Salmon are mainly produced in Scotland (Defra, 2001c). The fresh fish are killed and gutted, placed on ice slurry (which

keeps the fish cool but not frozen), and despatched to a processor the same day. The processor will then fillet and cut the fish into steaks, or carry out other processes, package and then the product will be despatched to the shelves of fishmongers or supermarkets. This will take a minimum of 2 days. For smoked fish the process takes a little longer so the delay time minimum is about 4 days. Very little farmed salmon is frozen, although it can be once in the home (Scott, 2002). Vacuum packed and stored at 2-5°C, smoked salmon has a shelf-life of 2-3 weeks and can be frozen for 3-6 months. It would seem reasonable therefore that an average delay time for smoked salmon would be 10 days (Arbroath Fisheries, 2003).

The other type of farmed freshwater fish is trout. This species is produced at inland farms throughout Britain, but concentrated in Scotland and the south of England. The main species farmed is Rainbow trout, *Oncorhynchus mykiss*, which accounts for about 75% of all trout produced by the 360 trout farms in Britain. It is the most popular species to farm because it copes well with the climate and farming system used. The second most popular species is brown trout, *Salmo trutta* which is the only indigenous species farmed in the UK (British Trout Association, 2002).

Trout farms tend to concentrate on one aspect of the fish's lifecycle. The types of farms are: hatchery, fingerling, re-stocker, table producer and fishery. The table producer and fishery type sell direct to the public. The hatchery, fingerling and re-stockers supply fish to table producers and/or fishery farms.

When the fish are harvested they are 8-18 months old, depending on their size. The fish are then gutted and either sold whole, smoked, filleted or in steaks. Some fish are frozen. The fresh fish are kept for 1 day from harvest in the farm shop and can be kept for up to a further 5 days in the refrigerator in the home. Frozen fish can be kept for up to 2 months, smoked for up to 8 days in the refrigerator (Lobb, 2002).

The following delay times are recommended for farmed fish. For fresh fish a minimum delay time of 1 day, an average of 2 days and a range of 1-5 days. For frozen fish the range is from 2 days to 2 months, an average of 2 weeks and a minimum of 2 days. Smoked fish delay times are a minimum of 4 days, an average of 10 days and a range of 4-21 days.

3.4.5.3 Shellfish

Shellfish is available to the general public in three conditions: live, fresh or frozen. Like fish, shellfish reaches the general population via the retail market from fishmongers, supermarkets, restaurants and takeaways. The main species of shellfish landed are crabs, nephrops, langoustine and scallops (Seafish Education, 2002).

In 2006, 30 000 tonnes of crab were landed. Most were caught in the North Sea (38%), the west of Scotland (28%), the English Channel (17%) and the Irish Sea (5%). Of the 41 000 tonnes landed in 2006, most of the nephrops caught were from the North Sea (51%), the remainder originating off the west of Scotland (33%) and the Irish Sea (15%). Scallops make up a large proportion of the remainder (Marine and Fisheries Agency, 2006).

The majority of crabs and lobster are sold live. They are caught overnight and can then remain in tanks for 12-24 hours, although the time they spend in the tanks is limitless, or to the end of their useful lives. If they are cooked, they are boiled alive. The remainder is usually frozen. When frozen, shellfish will keep for 2 months (Fresh fish online, 2002).

Langoustine, also known as whole prawns, are either sold as fresh or frozen. They are usually taken from boats that have been to sea for 3-4 days and therefore the minimum delay time is 4 days when fresh. If the prawns are frozen then they will usually have a shelf-life of up to 2 years but the regular shelf-life is 18 months.

In summary, the delay times for fresh shellfish are a minimum of 0 days, since some species may be eaten on the day of catching, an average of 1 week and a range of 1-9 days. For frozen shellfish, the range is from 4 days to 18 months, with a minimum of 4 days and an average of 7 days.

3.4.6 Summary of delay times for marine fish, aquaculture and shellfish

A summary of delay times for marine fish, freshwater fish and shellfish is given in Table 13.

TABLE 13 Summary of delay times for marine fish, aquaculture and shellfish, days

Product		Minimum delay	Average delay	Typical range
Marine fish				
	Fresh and smoked	2 (small fishing vessels)	8	2 – 12
	Frozen on board	60 (large fishing vessels)	90	60 – 365
Aquaculture fish				
	Fresh	1	2	1 – 5
	Frozen	2	14	2 – 60
	Smoked	4	10	4 – 21
Shellfish				
	Fresh	0	7	1 – 9
	Frozen	4	7	4 – 540

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

4 USE OF DELAY TIMES IN RADIOLOGICAL ASSESSMENTS

The use of delay times very much depends on the application. For each type of food, either an average or a minimum delay time may be used. The average delay time is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment. The minimum delay is more appropriate to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in dose assessments where a cautious estimate of dose is required, for example in an assessment of dose to a critical group. Also, it is only necessary to consider delay times when assessing doses from short lived radionuclides; therefore, it is not necessary to consider them in solid waste management assessments.

Caution is required in specifying single composite delay times and in general the specification of a composite delay time is not appropriate for use in radiological assessments. For example, the average delay time for fresh milk is 4 days, 45 days for sterilised and 90 days for UHT milk. The consumption percentages respectively are 87%, 4% and 6%. A composite delay time for total liquid milk based on weighting by consumption is therefore approximately 10 days. However, applying this composite delay time to, for example, a release of ^{131}I, which has a half-life of 8 days, will result in a dose that is underestimated. A considerable proportion of the activity will have decayed by 10 days and would be excluded from the doses, whereas in reality it would still be present in any fresh milk consumed.

It is possible to estimate a crude ‘effective’ average delay time for a particular radionuclide and foodstuff. A single delay time can be calculated that would give rise to the equivalent integrated activity resulting from the multiple delays of the different components. However, it is not practical to do this in this report because of the number of short-lived radionuclides that could be considered.

A simpler approach would be to use a single delay time for a particular component of the foodstuff and apply this to the total foodstuff. It should be borne in mind that this would produce doses which could be either over- or under-estimates of the true dose depending upon which delay time was selected, as was shown in the example above for ^{131}I in liquid milk.

In the estimation of activity concentrations in any foodchain model, it is necessary to take account of any implicit delay time. If the model only gives concentrations at the point of harvest or production, then the delays given in this report can be used directly. However, it might be that the model has taken into account the harvest and storage of crops in estimating the activity concentrations and then a modified delay time is required to avoid double counting. For example, delay times are implicitly included in the predicted activity concentrations for cereals and root vegetables in the FARMLAND model, but not for any other food product (Brown and Simmonds, 1995). The

FARMLAND model forms the foodchain pathways of the PC-CREAM package (Mayall, *et al*, 1997).

In FARMLAND, for cereals it is assumed that there is a single discrete harvest and that this harvest is eaten over the following year. The radioactive decay that occurs in the harvested cereal crop over that year is built into the predicted activity concentrations. Any additional delay between the time of harvest and the start of consumption should be included separately, using the values discussed in section 3.2. For root vegetables, including potatoes, the situation is more complex as it is assumed that part of the harvest is picked continuously over a period and consumed over the same period; no delays are implicitly included in the concentrations. The remainder of the crop is assumed to be harvested over a period and then stored for consumption over the rest of the year. The average activity concentration in the stored root vegetable is used and is subject to radioactive decay over the period of consumption; this decay is built into the predicted activity concentrations. Any delay between harvest and consumption, appropriate for the fraction of the harvest consumed that is not stored, and any delay between harvest and start of consumption of the stored crop need including explicitly, outside FARMLAND. See section 3.3 for a discussion of the delay times associated with these crops.

5 CHANGES SINCE 1983

The present report is an update of an earlier report published in 1983 (Haywood, 1983). In the last 20 years, many aspects of the food industry have changed, whether in the quality of processes, the farming practices or the variety of products now available. In many cases comparisons are difficult between the new and previously recommended delay times as more details are presented in this report. Overall, delay times are in the same ranges, although shelf-lives for many products have increased.

The delays given in the earlier report include composite delays for a food group rather than for specific products. Foods considered as representative of their food groups have been chosen from this review to make a comparison.

Table 14 highlights some important changes that have occurred between the earlier version of this report and this version.

TABLE 14 Important changes in delay times between M-83 and this review, days

Foodstuff	M-83 delay time		New delay time	
	Average (Range)	Minimum	Average (Range)	Minimum
Fresh liquid milk	2 (1 – 5)	*0**	4 (2 – 30)	*0**
Dairy cream (single)	4 (*2* – 7)	*0**	5 (*2* – 21)	*0**
Butter	28 (14 – 56)	1*	14 (4 – 365)	2*
Hard cheese: Cheddar type	120 (7 – 365)	2*	195 (90 – 540)	30 (mild)

Numbers in italics indicate no change.

* The minimum delay is based on the unpasteurised product consumed or sold at the farm.

The changes are due to the improvements in the quality of raw milk and pasteurisation process, therefore, the shelf-life of pasteurised milk has been extended. Also, since there has been a move towards weekly supermarket shopping by most families, milk tends to be stored longer in the home (including home freezing) and is not always drunk on the day of purchase. The same is also true for cream.

The minimum delay applies to individuals with ready access to a fresh food supply, such as farmers and their families, allotment holders and those who purchase food directly from farms. This value is most applicable in an assessment of dose to the critical group.

The average delay is an estimate of the delay time in the food production process for food consumed by a typical individual. It is this value that is most appropriate for use in an assessment of dose to a typical individual or in a collective (or population) dose assessment.

The typical range applies to the average consumer, buying the majority of their food from supermarkets or smaller retail outlets.

There are additional changes to those shown in the table, eg for green vegetables where the maximum delay has increased. In this case the delays presented in the 1983 report (Haywood, 1983) are composites for food groups and so are not comparable with the delays for individual foodstuffs. There have also been changes in the amount of different foods eaten and the types of food people choose. Table 15 shows the differences in the amount of food eaten between 1983 and 2006 and Figure 1 shows the percentage difference in consumption of the major groups of food during the period 1983 – 2006.

TABLE 15 Difference in consumption of selected household foods in 2006 as compared to 1983 (grams per week, per person unless otherwise stated, rounded)

Foodstuff	Difference	
	Decrease	Increase
Liquid whole milk (ml)	1700	
Skimmed milk (ml)		1100
Yoghurt and fromage frais (ml)		130
Total milk and cream (ml)~	**500**	
Natural cheese	3	
Processed cheese		5
Total cheese~	**3**	
Eggs (number)	1.6	
Oranges and other citrus fruit		15
Apples and pears	15	
Bananas		140
Total fresh fruit		290
Fruit juice		190
Total other fruit	50	
Total fruit~		**420**
Potatoes	470	
Fresh green vegetables	80	
Other fresh vegetables		110
Canned vegetables	90	
Frozen vegetables		15
Other vegetables and products*	1	
Total vegetables~	**520**	
Bread	240	
Flour	90	
Cakes and pastries		5
Biscuits	45	
Breakfast cereals		30
Total cereals (excluding bread)~		**90**
Bread and cereal products	150	
Sugar	250	
Preserves	30	
Tea	30	
Coffee	4	
Total beverages	45	
Fresh white fish	10	
Fresh blue fish and salmon		15
Shellfish		10
Cooked (takeaway) fish	10	
Total fish and fish products~		**20**
Butter	50	
Margarine	100	
Lard	50	

Foodstuff	Difference	
	Decrease	Increase
All other fats[+]		70
Vegetable oils		30
Low fat spreads		5
Reduced fat spreads		35
Total fats[~]	**130**	
Beef and veal	50	
Mutton and lamb	60	
Pork	50	
Bacon and ham	20	
Pork, bacon and ham	70	
Poultry		80
Sausages	45	
Total meat and meat products[~]	**60**	

Source: (Defra, 2008)

[~] Totals may include other foods so may not equal the sum of subgroups.

* Includes canned and frozen.

[+] Includes vegetable and salad oils, reduced and low fat spreads.

It can be seen from Table 15 that whilst there has been an overall reduction in the amount of milk and cream consumed (see Figure 1), there has been an increase in the amount of skimmed milk, yoghurt and fromage frais consumed. There has also been an increase in the total fresh fruit and cereals eaten over the period, and a decrease in the cheese, vegetables, fish, fish products, fats, meat and meat products. The decrease in vegetables is dominated by a reduction in consumption of potatoes to just over 400g per week. However, the diet discussed in this section includes all foods from this country and abroad whereas the delay times discussed earlier only considers UK produced foods.

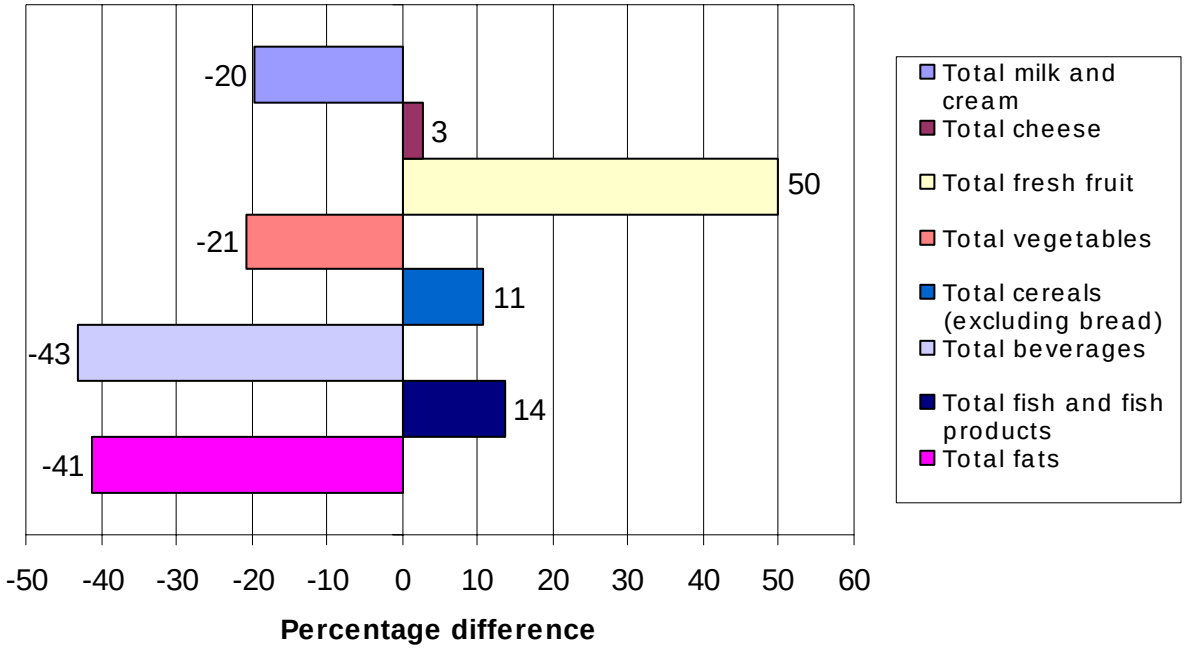

FIGURE 1 Percentage difference in consumption of selected household foods, 1983 - 2006

6 CONCLUSION

From a radiological protection point of view, the inclusion of delay times when carrying out assessments of radiation dose from consumption of home-grown foods is important. Since 1983, when the original report was issued, there have been changes and modernisation in industrial food processes, changes in diet and also changes in the availability of food in the United Kingdom. In this new report more foods have been considered and data for existing foods have been reviewed to check whether manufacturing processes or procedures have changed the shelf-life of any products. For some foods there have been changes made to the delay times because of changes in manufacture or handling of the fresh foodstuff. A discussion is included on the use of delay times in assessments.

7 ACKNOWLEDGEMENTS

The authors are grateful for the considerable help they have received from the various food institutes, research organisations, advisory bodies and individuals whose assistance is referred to in the report. They would particularly like to thank Celine Tournette for her contribution to the early part of this work.

8 REFERENCES

Arbroath Fisheries (2003). *Salmon*. [Online]. www.arbroath-smokie.co.uk.

Arla Foods (2007). Julie Brooke, Customer Relations Manager. [Response to query on product shelf-life] [e-mail] (Private Communication, 14 November 2007)

Bailey R (2007). *Rhubarb Rhubarb Rhubarb*. National Vegetable Society. [Online]. http://www.nvsuk.org.uk/growing_show_vegetables_1/growing-rhubarb.php

Banff and Moray Grain Group (2007). *Barley Production*. [Online]. www.banffandmoraygrain.co.uk.

Blake J (2007). ADAS environmental specialists. [Introduction to oat harvest dates] [e-mail] (Private communication, 10 August 2007)

Botterill, H. (2004). British Egg Information Service. [Response to questions on the production and sale of eggs] [e-mail] (Private communication, 4 February 2004)

Bradshaw P (2007). British Potato Council. [Processed potato storage times] [e-mail] (Private communication, 23 November 2007)

Brewers and Licensed Retailers Association (1996). [Now British Beer and Pub Association] Documents and private communication. http://www.beerandpub.com/index.aspx

Brewing Research International (1997). Documents and private communication. http://www.brewingresearch.co.uk/

British Association for Shooting and Conservation (2005). *Aim of the Game: Driven Game Shooting in Britain Today*. Stamford, Lincs: Bourne Publishing Group Ltd. Available at http://www.basc.org.uk/media/aim_of_game.pdf

British Association for Shooting and Conservation (2007). *Shooting Seasons*. [Online]. http://www.basc.org.uk/content/shootingseasons

British Beer and Pub Association (2002). *Beer ingredients*. [Online]. http://www.beerandpub.com/beer_ingredients.aspx

British Cheese Board (2001). Linda Kelly. [Comments on a draft version of the report] (Private communication, 1 November 2001).

British Cheese Board (2007). Documents: *Cheddar; Derby; Double Gloucester; Lancashire; Red Leicester; Wensleydale.* [Online]. http://www.cheeseboard.co.uk/

British Egg Information Service (2003). *Egg Production*. London: BEIS.

British Egg Information Service (2004). *Egg Market Data*. [Online]. http://www.britegg.co.uk/

British Potato Council (2001). Documents: *New Potato Definition; Standard of Grading for New Potatoes*. Oxford: BPC.

British Potato Council (2006). *Yearbook of Potato Statistics in Great Britain*, May 2006 Edition. Oxford: BPC. [Online]. Available at http://www.potato.org.uk/media_files/MIS_reports_2006_07/yearbook06.pdf

British Summer Fruits (2007). Documents: *Cherries; Strawberries; Blackcurrants*. [Online]. http://www.britishsummerfruits.co.uk/

British Trout Association (2002). Documents: *Breeds of Trout, Statistics, Trout Farming Explained*. [Online]. http://www.britishtrout.co.uk/facts.htm

Broad Stripe Butchers (2007). *Storing Your Meat*. Derby: Broad Stripe Butchers. [Online]. http://www.broadstripebutchers.co.uk/storing.aspx

Brown, J and Simmonds, J R (1995). *FARMLAND - a dynamic model for the transfer of radionuclides through terrestrial foodstuffs.* Chilton: NRPB. NRPB-R273.

Cheese.com (2007). Documents: *Cottage cheese; Derby.* [Online] http://www.cheese.com

Dahm L (2006). 'Enzymes and Cultures'. *Dairy Field*. June 2006. [Online] Available at http://www.dairyfield.com/content.php?s=DF/2006/06&p=17

Dairy Consultant (2007). *Buttermaking.* [Online] http://www.dairyconsultant.co.uk/pages/buttermaking.htm

Dairy Consultant (2007b). *Cheese Making.* [Online] http://www.dairyconsultant.co.uk/pages/cheese_making.htm

Dairy Council (2002). Information Sheet: *Varieties of Milk*. London: The Dairy Council.

Davis P (2007). EBLEX, Meat and Livestock Commission. [Discussion on meat processing after slaughter] [Telephone] (Private communication, 30 August 2007)

Dean Foods (2003). Documents: *FAQ, freshness.* [Online]. http://www.deansfoods.com

Del Monte (2008). Documents: *Product FAQ*. [Online]. http://www.delmonte.com/answers

Defra (2001a). *Milk statistics,* 26 October 2001. National Statistics. London: HMSO.

Defra (2001b). *Survey of vegetables and flowers*, January 2001. National Statistics. London: HMSO.

Defra (2001c). Aquaculture and fish health, www.Defra.gov.uk/fish/aquacult.htm. National Statistics. London: HMSO.

Defra (2002a). *Margarine, Other Table Spreads and Solid Cooking Fat Production in the United Kingdom and the Refined Oils and Animal Fats Used in their Manufacture*. National Statistics. London: HMSO.

Defra (2002b). *UK Sea Fisheries Statistics 1999 and 2000.* National Statistics. London: HMSO.

Defra (2005). *Vegetable Details, Basic Horticultural Statistics - 2005.* National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/bhs/2005/veg.pdf

Defra (2005b). *Fruit Details, Basic Horticultural Statistics - 2005*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/bhs/2005/fruit.pdf

Defra (2005c). *Table 5.5 Oilseed rape*, National Statistics. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/auk/2005/5-5.xls

Defra (2005d). *Table 5.7 Sugar and Sugar Beet*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/auk/2005/5-7.xls

Defra (2005e). *Table 5.19 Hen Eggs*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/auk/2005/5-19.xls

Defra (2006). *Family Foods in 2005-2006*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/efs/2006/complete.pdf

Defra (2006b). *June Agricultural Survey 2006*. National Statistics. London: HMSO.

Defra (2006c). *2006 Harvest: Final Estimates of Oilseed Rape Production United Kingdom.* National Statistics. London: HMSO.

Defra (2007). *Table 5.17 UK Milk, Agriculture in the UK 2005*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/auk/2005/5-17.xls

Defra (2007b). *Milk Statistics*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/statnot/milk.pdf

Defra (2007c). *Table 5.2 Wheat, Agriculture in the UK 2005.* National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/auk/2005/5-2.xls

Defra (2007d). *Wheat Milled and Flour Production*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/statnot/flourpn.pdf

Defra (2007e). *Table 5.11 Potatoes*, *Agriculture in the UK 2005.* National Statistics. London: HMSO. [Online].

Defra (2007f). *Poultry and Poultrymeat Statistics Notice*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/statnot/ppntc.pdf

Defra (2007g). *Quarterly Supplies and Totals for Domestic Usage of Meat in the United Kingdom*. National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/statnot/qlymtpn.pdf

Defra (2008). *Family Food 2006 Datasets.* National Statistics. London: HMSO. [Online]. http://statistics.Defra.gov.uk/esg/publications/efs/datasets/default.asp

Doves Farm Foods (2003). Jane Strauss, Quality Officer. [Response to questions on grain]. [e-mail] (Private communication, 19 February 2003).

Dunn J. (2005). 'Whey to Add Value'. *Food Manufacture magazine*. 13 June 2005. [Online] Available at http://www.foodmanufacture.co.uk/news/fullstory.php/aid/1686/Whey_to_add_value.html

Dyas J (2007). *UK Lettuce Production and Sale.* British Leafy Salads Association Ltd. [e-mail] (Private communication, 04 September 2007)

Environment Agency, Scottish Environment Protection Agency, Northern Ireland Department of Environment, National Radiological Protection Board and Food Standards Agency (2002). *Authorisation of Discharges of Radioactive Waste to the Environment*. *Principles for the Assessment of Prospective Public Doses*. www.environment-agency.gov.uk/business/444304/444637/ras/452235/.

Federation of Bakers (1999). *Factsheet 3, 'The British bread and morning goods market*. London: FoB.

Federation of Bakers (2003). *How bread is made*. London: FoB. [Online]. Available at www.bakersfederation.org.uk/breadmade.htm.

Federation of Bakers (2003b). *Factsheet 18, 'Keeping bread fresh'*. London: FoB.

Fishmeal Information Network (2002). www.gafta.com/fin/fin.html.

Food and Farming Education Service (2001). Documents: *Sugar beet; Oilseeds.* [Online]. www.foodandfarming.org.

FoodFen (2001). [Now FoodEast] 'Life getting sweeter still for UK Corn Producers'. *FoodFen,* 26 March 2001. [Online]. http://www.foodeast.com/news/advertising.asp

Food Standards Agency (2003). *Private slaughter of livestock guidance for local enforcement authorities in England*. [Online]. http://www.food.gov.uk/multimedia/pdfs/privatekillguidance2006.pdf

Food Standards Agency (2005). *Historical background to the different control requirements for raw drinking milk and raw cream in the difference countries of the UK*. [Online]. http://www.food.gov.uk/aboutus/ourboard/boardmeetoccasionalpapers/rawmilkintpaper

Fresh-fish-online (2002). *Frozen Fish*. [Online]. http://www.fresh-fish-online.com/frozenfish.htm

Gardeners Calendar (2007). Documents: *Cauliflowers; Cabbages*. [Online]. http://www.the-gardeners-calendar.co.uk/Plant_Database/Plants.asp

GeneWatch UK (2001). *Spring Oilseed Rape.* UK Farm Scale Trials. [Online]. www.genewatch.org

Green N and Wilkins BT (1995). *Effects of processing on radionuclide content of foods: derivation of parameter values for use in radiological assessments*. Chilton: NRPB. NRPB-M587.

Griffiths R (2007). British Poultry Council. [Discussion of poultry production] [Telephone] (Private communication, 12 September 2007)

Haywood, S M (1983). *A review of data on the time delay between harvesting or collection of food products and consumption*. Chilton: NRPB. NRPB-M83.

Home-grown Cereals Authority (2004). *Report of Cereal Industry Review*, 17 November 2004. London: HGCA.

Home-grown Cereals Authority (2007). *Annual UK Supply and Demand Estimates*. [Online]. http://www.hgca.com/document.aspx?fn=load&media_id=3705&publicationId=99

Home-grown Cereals Authority (2007b). *Overview of the World Oilseeds Market*. HGCA Knowledge Centre. [Online]. http://www.hgca.com/minisite_manager.output/2005/2005/Knowledge%20Centre/Markets/Overview%20of%20the%20World%20Oilseeds%20Market.mspx?minisiteId=11

Ice Cream Alliance (2007). *Technical Fact Sheet No. 5, Manufacturing*. [Online]. http://www.ice-cream.org

ICRP (2008). *ICRP Publication 103: Recommendations of the ICRP, Annals of the ICRP vol. 37.* Elsevier.

Komorowski, E. (2003). Technical Director, Dairy UK. [Comments on dairy processing] [e-mail] (Private communication, 4 February 2003)

Kraft (2006). *Philadelphia FAQ*. [Online] http://www.philadelphia.co.uk/philadelphia1/page?siteid=philadelphia1-prd&locale=uken1&PagecRef=673#faq9

Living Countryside (2006). *Introduction to Livestock Farming*. [Online]. http://www.ukagriculture.com/livestock/milk_production_dairy_day_4_00pm.cfm

Living Countryside (2006b). *Introduction to Livestock Farming*. [Online]. http://www.ukagriculture.com/livestock/milk_production_dairy_day_6_00pm.cfm

Lobb T (2002). Clearwater Trout Farm, East Hendred. [Response to questionnaire on trout farm] [Fax] (Private communication, 23 May 2002)

Maltsters' Association of Great Britain (2007). *How Malt Is Made*. Newark: MAGB. [Online]. http://www.ukmalt.com/howmaltismade/maltmade.asp

Martin's Sea Fresh Local Fish (2008). Document: *Maintaining the Quality and Safety of Frozen Foods Throughout the Distribution Chain*. University of Leeds. [Online].

http://www.martins-seafresh.co.uk/frozen_facts.htm

Matthews K (2007). Meat and Livestock Commission. [Discussion on the production and storage of pig meat] [Telephone] (Private communication, 7 November 2007)

Mayall, A, Cabianca, T, Attwood, C A, Fayers, C A, Smith, J G, Penfold, J, Steadman, D, Martin, G, Morris, T P, and Simmonds, J R. (1997). *PC CREAM 97* (Code updated in 1998-PC CREAM 98). Chilton: NRPB. EUR 17791 (NRPB-SR296).

Marine and Fisheries Agency (2006). *UK Sea Fisheries Statistics 2006*. National Statistics. London: HMSO. [Online] http://www.mfa.gov.uk/statistics/documents/UKSeaFishStats_2006.pdf

MAFF (2000). *National Food Survey 1999*. London: HMSO.

MAFF (2001). *Agriculture in the United Kingdom 2000*. London: HMSO.

Meat and Livestock Commission (1997). *A Pocketful of Meat Facts.* Milton Keynes: MLC. ISBN 0-904650-87-1.

Meat and Livestock Commission (2005). Bullock J, Senior Press Officer. [Response to queries on UK meat production and import] [e-mail] (Private communication, 7 November 2005)

Meat and Livestock Commission (2007). *Shelf Life of Fresh Meat*. Milton Keynes: MLC.

MD Foods (1998). Stephen Corcoran. [Comments on a draft version of the report] (Private communication, 24 March 1998).

Milk Development Council (2004). *Dairy Facts and Figures 2003.* Cirencester: MDC. Available at http://www.dairyuk.org/pdf/MDC_DFactsFig_1612.pdf

Milk Development Council (2006). *Dairy Statistics: An Insider's Guide*. Cirencester: MDC. Available at http://www.mdcdatum.org.uk/PDF/Pocketbook.pdf

Moorhouse, E R (2007). Technical Director, G's Marketing Ltd. *Harvest, Storage and Processing of Beetroot.* [Telephone] (Private communication, 14 September 2007)

National Association of British and Irish Millers (2007). Private communication.

National Association of British and Irish Millers (2007b). *UK Flour Milling Industry 2007.* [Online] http://www.nabim.org.uk/images/pdf/Milling_Industry_Guide_2007.pdf

National Dairy Council (1995). Documents: *Farmhouse English Cheese; Facts on Cheese;* Dairy Factsheets: *The Range of Milk, Milking, Packaging; The Liquid Milk Report 1995.* NDC.

National Farmers' Union (1997). Documents and private communication. London: NFU.

National Farmers' Union (2006). *Harvest Update 2006*. NFU. [Online] http://www.nfuonline.com/x9968.xml

National Statistics (2005). *Product Sales and Trade – Beer (PRA 15960).* London: HMSO. Available at http://www.statistics.gov.uk/downloads/theme_commerce/PRA-20050/PRA15960_20050.pdf

New Mexico State University (1997). *Handling and Cooking Game*. Las Cruces, NM: NMSU. [Online]. http://cahe.nmsu.edu/pubs/_circulars/circ495.pdf

Oat Services Limited (2002). *OATEC Report*, p15-20. [Online]. Cambridge: Cambridge Marketing. Available at http://www.oat.co.uk/pdfs/oatec/oatec_non-food.pdf

Outsider's Guide to Animal Production (1998). Published by Outsider's Guide, Lincoln, 1998 Edition.

Outsider's Guide to Crop Production (1999). Published by Outsider's Guide, Lincoln, 1999 Edition.

Potato Council (2007). Document: *Growing Potatoes*. [Online]. http://www.britishpotatoes.co.uk/growing-potatoes/

Practically Edible – Food Encyclopaedia (2007). Encyclopaedia entries. [Online]. http://www.practicallyedible.com/

Processed Vegetable Grower's Association (2007). Spokesperson [Response to queries on root vegetable harvest and storage]. [Telephone] (Private communication, 30 August 2007).

Prodfact (1988). *A Comprehensive Guide to British Agricultural and Horticultural Produce*, researched and compiled by Daphne MacCarthy, published by Food From Britain.

Purafoods (2001). Steve Trowsdale, Sales Director. *Retail Spreads, Margarines and Bottled Oils*. [Telephone] (Private communication, 2001)

Raffle S (2007). *Shelf-life of Soft Fruits*. Horticultural Development Council. [e-mail] (Private communication, 25 September 2007)

Red Meat Industry Forum (2004). Documents: *FAQs Archive: Who shops at butchers shops these days?* [Online]. http://www.redmeatindustryforum.org.uk/content.output/201/201/On-Farm%20Projects/Facts%20and%20Figures/FAQs%20Archive.mspx#answer4

Red Meat Industry Forum (2007). *Packaging*. [Online]. http://www.redmeatindustryforum.org.uk/supplychain/Packaging.htm

Red Meat Industry Forum (2007b). *Introduction to Beef Production*. [Online]. http://www.redmeatindustryforum.org.uk/supplychain/BeefProduction.htm

Red Meat Industry Forum (2007c). *Introduction to Pig Production*. [Online]. http://www.redmeatindustryforum.org.uk/supplychain/PigProduction.htm

Red Meat Industry Forum (2007d). *Introduction to Sheep Production*. [Online]. http://www.redmeatindustryforum.org.uk/supplychain/SheepProduction.htm

Rhubarb Compendium (2004). *Storing Rhubarb*. [Online]. http://www.rhubarbinfo.com

Ridealgh A (2005). 'The 2005 Malting Barley Crop', *The Brewer and Distiller, Vol 1, Issue 12.* Available at http://www.muntons.com/downloads/Barley_crop.pdf

Royal Horticultural Society (2007). Documents: *Broad Bean; French Beans; Peas; Runner Beans*. [Online]. http://www.rhs.org.uk/vegetables/crops/index.asp

Scott A (2002). PR consultant for Marine Harvest. [Discussion on salmon processing] [Telecon] (Private communication, 16 May 2002)

Scottish Dairy Association (1997). Private Communication.

Sea Fish Industry Authority (2002). *Iced Storage of Fish on Small Inshore Vessels*. Technical Information Sheet No: 1997/02/FT. Hull: SFIA. www.seafish.co.uk

Seafish Education (2002). *Seafood: Shellfish and Packaging*. [Online]. www.seafish-education.org.uk.

Smith K R and Jones A L. (2003). *Generalised habit data for radiological assessments*. Chilton: NRPB-W41.

Statutory Instrument 1995 No. 539 (1995a). *The Fresh Meat (Hygiene and Inspection) Regulations*. London: HMSO.

Statutory Instrument 1995 No. 540 (1995b). *The Poultry Meat, Farmed Game Bird Meat and Rabbit Meat (Hygiene and Inspection) Regulations*. London: HMSO.

Statutory Instrument 2002 No. 843 (2002). *The TSE (England) Regulations*. London: HMSO.

Statutory Instrument 2005 No. 209 (2005). *The Poultry Meat, Farmed Game Bird Meat and Rabbit Meat Hygiene and Inspection) Regulations*. London: HMSO.

Statutory Instrument 2006 No. 14 (2006). *The Food Hygiene (England) Regulations.* London: HMSO.

Stilton Cheesemaker's Association (2004). *The Story of Stilton*. [Online] http://www.stiltoncheese.com/UK/pr/uk.cfm

Tesco Customer Services (2002). Leith J, Customer Service Manager. [Response to queries on fish storage in-store] [Letter] (Private communication, 3 May 2002)

Waitrose (2007). Recipes, Food Glossary. www.waitrose.com/food/cookingandrecipes/cookinglibraries/glossary/food.aspx

Watson J (2007). *An Introduction to Manufacturing Processes for Dairy Products*. [e-mail] (Private communication, 29 October 2007).

Yeo Valley (2007). Documents: *About the manufacture.* [Online]. http://www.foodforum.org.uk/ffiles/Yeo_Valley-Mat+Inn+Man+Sys+Post.shtml