

Storage of food

Fact sheet

Storing food properly brings many benefits. Products last longer, you have to throw less away, and bacteria grow less quickly, so they don't make you ill. The best way to store products depends on the type of food involved. Some products should be stored in the refrigerator, while others do not need to be refrigerated, and in some cases it is actually better not to do so.

Better food storage ensures that products spoil less quickly. Spoilage can occur in several ways:

- Microbiological. Here, bacteria, moulds and yeasts damage the product.
- Chemical. This involves chemical reactions, caused by various substances coming into contact with each other. A pack of butter may become rancid because oxygen in the air reacts with fat. A peeled apple turns brown from exposure to oxygen.
- Physical. This involves changes to the structure of the product. Some examples of this are fruit drying out, or curd cottage cheese, where a thin layer of water appears on the surface after some time.

Spoilage can often be seen, smelled or tasted. Most people will not consume spoiled products, such as sour milk, because they think these will make them ill. Yet, if you do eat them, most spoiled products will not make you ill. On the other hand, products that still look fine can contain harmful microorganisms. While it is not always the case, these can make you ill.

In this fact sheet, we show what is meant by 'store properly', and provide practical recommendations on how to do this. In drawing up our storage advice, we have sought to maintain a balance between food safety, sustainability and health.



For whom is it relevant?

This fact sheet can be used by professionals and businesses to educate consumers about how products can best be stored. One goal is to prevent food waste by spoilage, another is to prevent foodborne infections.

What issues are involved?

The Netherlands Nutrition Centre first published the Foodkeeper (Bewaarwijzer in Dutch) guide back in 1950, and it has been revised many times since then. The Foodkeeper traditionally focused on food safety. However, sustainability and particularly food waste are issues that have become increasingly important in recent years. Consumers throw away an average of 47 kilograms of food a year. The most common reason for throwing away food is that the expiration date had passed.¹ It is often not necessary to throw away a product with a 'best before' date immediately after that date has passed.²

When products are stored for longer periods of time, this can sometimes run counter to food safety. Every year, 700,000 people become ill after eating contaminated food.³ Storing food incorrectly is a major cause of this. If you store highly perishable food for too long, or at too high a temperature, pathogens can multiply. Whether or not people become ill depends on the number and type of pathogens involved, and on whether the consumer in question is a member of a 'vulnerable group'. Vulnerable groups (pregnant women, young children, the elderly, and immunocompromised individuals) are most at risk of foodborne infections. For this reason, the recommendations that apply in their case differ from those that apply to non-vulnerable groups (see the 'Hygiene and Foodborne Infection' fact sheet).

There has to be a balance: food must be safe for everyone but, at the same time, the aim is to keep food good for as long as possible. To this reason we have formulated a number of practical guidelines.

Scientific state of the art

Many factors determine how long a product remains of good quality. These include temperature, humidity, kind of packaging, as well as the characteristics of the food itself. Is it dry or raw, has it been heated, it is acidic or not?

The term 'food spoilage' refers to any unwanted change in the composition of a food. This might involve a change in its appearance, its taste, its smell and/or its consistency, making it less attractive to eat. Spoilage can be caused by chemical processes. For example,

a product may become rancid when fat reacts with air (in a process known as oxidation), producing free fatty acids such as butyric acid. This makes butter smell and taste bad. Another example of chemical spoilage is when bread becomes stale and dry. Spoilage can also be caused by microorganisms. Bacteria, moulds and yeasts may produce changes in products which, in some cases, are undesirable and in others, desirable. Compare, for example, blue cheese with mouldy cheese, or yogurt with sour milk. All of these changes are caused by microorganisms.⁴

A common form of spoilage is mould growth. This is often visible, because part of the mould develops on the surface of the food. Most moulds look like a fluffy white or dark-coloured tarnish. Moulds often produce an abnormal smell and a musty taste. Yet moulds can also produce dangerous toxins (mycotoxins). You cannot always see, smell, or taste these toxins. As a general rule, if there is mould on a product, you should throw the entire product away. For example jam (and diet jam), bread, biscuits or meat. There is a significant risk that the mould will have penetrated the entire product. An exception is hard cheese. Cut out patches of mould plus an additional 1 to 2 cm of the surrounding material. For hard fruit or hard vegetables, such as carrots and cabbage, cut out the mouldy parts plus a very wide margin of surrounding material. The remainder of the product is safe to eat, as long as it still looks and tastes good. If the taste is not quite right, then you should throw the product away.⁵

Is spoiled food dangerous?

It could be, but that is not necessarily the case. Food that looks spoiled, or that smells or tastes strange, will not necessarily make you ill. The problem is that, with some products, you do not see, smell or taste anything different. This is because you cannot always see, smell or taste harmful microorganisms on products, but these can still make you ill. Some examples of pathogens are Salmonella, Listeria, or viruses such as norovirus or hepatitis A virus.³ Some products are more likely to contain pathogens, especially raw meat and raw fish. These products should, therefore, be processed in the right way. They must be handled hygienically, and it is very unwise to eat or drink such products after their 'use by' date. This is because the safety of the product is guaranteed until that date, but no later than that.

Expiration date

The text printed on product packaging often includes a 'best before' date or a 'use by' date. There is an important distinction between the two (see the 'Food Waste by Consumers' fact sheet).


Many products with a 'best before' date can still be eaten without any problems after that date has passed, although there may be some loss of quality. If you carefully examine, smell and taste the product, you will be able to determine whether it is still edible. This is not possible in the case of perishable products with a 'best before' date, such as processed meats, smoked fish and soft cheese (from unpasteurised milk). In products such as these, *Listeria* can multiply to numbers which can make you ill.⁶ You cannot smell them, taste them or see them, and these bacteria can multiply at refrigerator temperatures, which is why you are advised not to eat these products after the 'best before' date. Pregnant women, young children, the elderly, and immunocompromised individuals, in particular, are advised to eat these refrigerated products before the expiration date has passed, and within four days of after opening them (see the 'Diet and Pregnancy' fact sheet).

The 'use by' date is the last day on which you can still use the product safely. This is because, after that date

has passed, the product may contain pathogenic bacteria at levels that can make you ill. Thus, once the 'use by' date has passed, you should throw the product away. Alternatively, you can extend the shelf-life beyond the indicated 'use by' date by freezing the product shortly after purchasing it, or by preparing it.⁷

According to the Dutch food legislation (warenwet-besluit Bereiding en behandeling levensmiddelen), the text printed on packaging must include a 'use by' date if the product has to be stored at a temperature between 0°C and 6 °C, or if there are 5 days or less until the expiration date. The text printed on packaging must also include details of storage instructions, including a maximum storage temperature.

Important: The 'best before' date and the 'use by' date apply only to unopened products. Once the product has been opened, those dates no longer apply. Different storage terms will then apply. There are also foods for which, according to the law, no expiration date is required. These include vinegar, sweets, wine, salt and fresh vegetables (European Regulation (EC) 1169/2011). If you carefully examine, smell and taste the product, you will be able to determine whether it is still edible.

	What does it stand for?	For which products?	Use after the date has passed?
Use by	Indicates the date until when the food can be eaten safely.	Highly perishable food such as fresh fish, fresh meat (including minced meat), pre-cut vegetables and chilled meals.	No. After this date has passed, the product is no longer safe. You can extend the shelf-life beyond the indicated 'use by' date by freezing it shortly after purchasing it, or by preparing it.
Best before	Indicates the date until when the food retains its expected quality.	Non-refrigerated products such as dried pasta, and rice, flour, coffee, sweets, soft drinks and preserves.	Yes. If you carefully examine, smell and taste the product, you will be able to determine whether it is still edible.
		Refrigerated products such as milk, yoghurt and hard cheese.	Yes. If you carefully examine, smell and taste the product, you will be able to determine whether it is still edible.
		Refrigerated perishable products, such as processed meats, smoked fish and soft cheese (from unpasteurised milk).	No. After this date has passed, the product may no longer be safe. This is particularly important for pregnant women, young children, the elderly, and immunocompromised individuals, known as YOPI's.

Opened products

In the case of opened products, it is important to follow the storage instructions on the package. If a product's label bears the phrase 'Store in a cool place', then, after opening the product, you should store it in a cool, dark and dry place. In a basement or a cool larder, for example. Ideally, the temperature should be below 15 °C. If there is no suitable place in the house and it's warm outside, then these products can temporarily be stored in the refrigerator. If the label bears the words 'Store chilled', then the product should always be stored in the refrigerator.

Packaging

The text printed on packaging informs consumers about various characteristics of the product, and the packaging extends the products shelf life. In addition, the packaging protects vulnerable products against damage. The development of new materials has made it possible to create the correct air composition and humidity, thereby extending the product's shelf life. Shrink wrap, for example, extends the shelf life of cucumbers. Also, modifying the composition of the air can significantly extend the shelf life of pre-cut vegetables (Modified Atmosphere Packaging).⁸

Packaging and the environment

The manufacturing of packaging has an environmental impact, as energy and raw materials are used in the process. Sometimes, packaging is not considered to be environmentally friendly. Yet, packaging accounts for just 10% of a household's total food-related environmental impact. Food loss accounts for another 15%, and the remainder is associated with the food production chain. So focusing on food waste can deliver greater environmental benefits than the elimination or modification of packaging.²

Temperature

In the case of perishable products: the higher the temperature, the faster the product spoils. On the other hand, some products that are stored under excessively cold conditions can undergo cold decay. Also, the development of bacteria is highly dependent on the temperature. Every one degree Celsius rise in temperature accelerates their multiplication rate, which causes spoilage to occur more quickly, making it more likely that the product will make you ill. One of the most effective ways to prevent a foodborne infection is to store high-risk products at a low temperature (4 °C), in a refrigerator.^{9, 10} For this reason, perishable products should be returned to the refrigerator as soon as possible after being used.

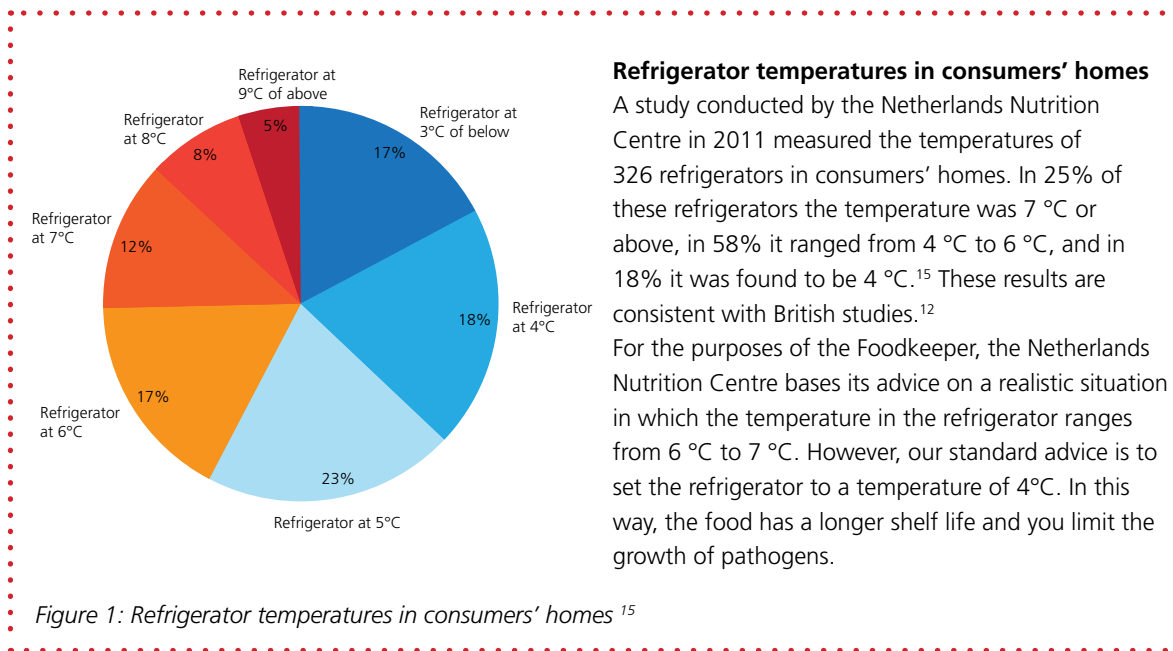
One important pathogen that must be taken into account is *Listeria monocytogenes*. Unlike many other harmful microorganisms, this bacterium can multiply at the low temperatures found in refrigerators. Nevertheless, the general rule still applies - the lower the temperature, the slower it will multiply. A computer model created by Wageningen UR shows that *Listeria* multiplies almost three times faster at 7 °C than it does at 4 °C (and almost eight times as fast at 12 °C).

The temperature can vary from one part of the refrigerator to another. As cold air is heavier than warm air, the temperature at the top of the refrigerator is often higher than it is at the bottom. Indeed, it can vary by several degrees.¹¹ The temperature in the vegetable drawer is often slightly higher, due to the lack of ventilation. The warmest part is usually the door of the refrigerator. The extent of these temperature differences is highly dependant on the type of refrigerator and the way it is used (e.g. if the refrigerator is frequently opened). Some of the newer, more expensive models can regulate temperature and humidity per compartment.¹²

The temperature differences measured in the air are much greater than those measured in the product. So the best way to check the temperature in the refrigerator is to place a refrigerator thermometer in the refrigerator (preferably in a glass of water) for at least 8 hours.

Refrigerator temperature and its effect on the environment

In a survey of 21 different refrigerators, the Consumers' Association (Consumentenbond) found that energy consumption at 4 °C is more than 20% higher than it is at 7 °C.¹³ Milieu Centraal (a public information organisation that helps consumers make sustainable choices) has calculated that, at a temperature setting of 5 °C, the annual energy consumption of a new A+++-label fridge freezer costs € 30. The equivalent amounts for an 8-year-old and a 20-year-old fridge freezer are € 70 and € 100, respectively.¹⁴ If you were to change your refrigerator's setting from 7 °C to a new permanent setting of 4 °C, this would cost you € 7 a year more for a new refrigerator, € 14 more for an 8-year-old fridge, and € 20 more for a 20-year-old fridge (also about 20%). On the other hand, products will remain safe for longer, and you will not have to throw away so much food due to spoilage. Much more energy is required to make that food than to refrigerate it. Therefore, it is advantageous to set the refrigerator to 4 °C.



Humidity in the refrigerator

One major factor that shortens the period for which fresh foods can be stored is dehydration. The lower the temperature, the less moisture the air can hold. For many foods, humidity in the refrigerator is often below the ideal level.

Thus, humidity inside the fridge can be 70%, but fruit and vegetables require a humidity of around 90%.¹⁶ The quality of eggs, cheese and processed meats can also be impaired by dehydration. As a consumer, you can boost humidity by placing moist products in tightly sealed containers. The vegetable drawer is designed to ensure that its internal humidity is higher than in the rest of the refrigerator. Sealing cheese and processed meats in a separate container, and storing eggs in their original packaging, creates higher humidity. However, this approach involves a risk of condensation, which is detrimental to quality. Another disadvantage of condensation and high humidity is that bacteria, moulds and yeasts can grow more rapidly under these conditions. You can prevent dehydration by wrapping products properly. For example, you can wrap them in a damp tea towel or paper bag, or you can cover a dish with cling film. One way to prevent condensation is to include a sheet of paper towel in the packaging.

Having weighed up all these factors, the Netherlands Nutrition Centre has drawn up an ideal division for refrigerators. It should be noted that the location of the coldest zone may differ from one refrigerator to another. So it pays to read the refrigerator's manual (see Figure 2).

Freezing

Freezing is a good way to store perishable products for several weeks or months. Bacteria cannot multiply at a temperature of -18°C. They can survive at this temperature, however, which is why it remains important to safely thaw frozen products (in the refrigerator or, in the case of small pieces, in the microwave). However, storing products in the freezer does result in some loss of quality. This is because freezing breaks the product's cells open, causing it to dry out. You can prevent dehydration by wrapping products properly. To preserve quality, the general advice is to freeze products as rapidly as possible and to thaw them as slowly as possible, in the refrigerator.

The freezer section in a domestic refrigerator is a lot less cold than a separate freezer. Accordingly, the freezer section is only suitable for storing frozen food for a few days. The star rating is a useful guide here.

Star rating	Temperature	Maximum storage time
*	- 6 °C or lower	a week
**	-12 °C	a month
***	-18 °C	three months or longer, depending on the type of product
****	-18 °C or lower	three months or longer, depending on the type of product

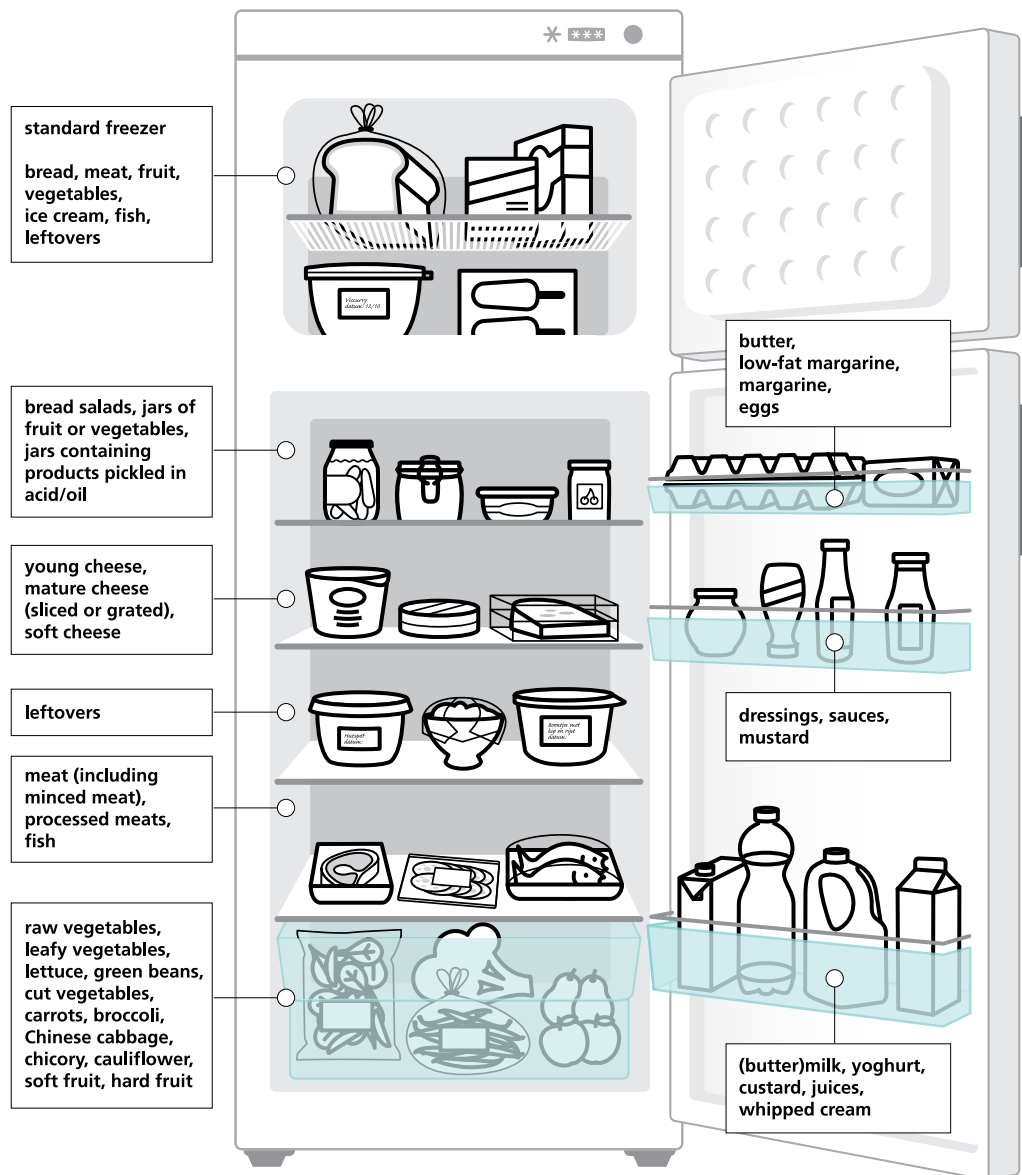


Figure 2: Refrigerator layout

Meat

Meat's shelf life can be prolonged by freezing it immediately after it has been purchased. However, even this method has its limits as meat loses quality when frozen. This is because, as the water crystallises it breaks open the cell walls, causing the product to dry out. A general rule for the freezer is that the larger the piece of meat, the longer it will remain good. More fatty types of meat cannot be stored for very long, as they tend to become rancid over time. Processed products to which salt has been added (such as hamburgers, stuffed beef rolls, fresh sausages and other products that can be prepared quickly) turn rancid faster, thus they have a shorter shelf life (one month).¹⁷

Besides freezing, frying is an excellent way to extend the shelf-life of meat. Accordingly, roasted meat can

be kept for a few days in the refrigerator, especially if it is stored beneath the layer of solidified fat from the gravy.¹⁷

Loss of vitamins due to incorrect storage

Incorrect storage leads to a substantial loss of vitamins. This is mainly due to moisture loss and to the breakdown of vitamin C under the influence of heat, light and oxygen.¹⁸ In fact, food always loses vitamins when stored for longer periods of time, even when stored at the right temperature, in the fridge. However, fewer vitamins are lost than at room temperature. Exposure to light can also lead to a loss of vitamins, as in the case of potatoes.

Consumers who want to store their vegetables at home for longer and who want to limit the loss of colour,

smell, taste, texture and vitamins should blanch (boil briefly 1 or 2 minutes) the vegetables, rinse them with cold water and immediately freeze them to a temperature below -18 °C.¹⁹ While this does not stop the loss of vitamins, it does limit it. That certainly applies to modern freezers, which freeze food quickly when you hit the 'fast freeze' button. Even shop-bought frozen vegetables are a good alternative to fresh ones. Their vitamin levels are often higher than those in fresh vegetables which have been stored for a while.¹⁹

Leftovers

We use the term 'leftovers' to refer to the remnants of a meal, which can be reused without any problems at all. If leftovers are stored out of the refrigerator for extended periods of time, bacteria can multiply. Two hours is a safe limit. Leftovers should, therefore, be allowed to cool rapidly, and must always be placed in the refrigerator within two hours.²⁰

As a general rule, according to the Netherlands Nutrition Centre, leftovers should be stored in the refrigerator for no more than two days. The temperature of the refrigerator is, of course, important. At a maximum of 7 °C, the leftovers of a meal can often be stored for two days, at 4 °C this can be extended to three days.²¹ Two days allows a margin of safety. When freezing leftovers, it is important to cool them down thoroughly before placing them in the freezer.

Cold damage to fruit

Some types of fruit are not fully ripe when you buy them. These include peaches, nectarines and kiwis. These products can best be stored outside the

refrigerator, at room temperature. Under these conditions, the acid breaks down and the sweet taste emerges. If post-ripening fruit is stored at too low a temperature, it will not ripen properly. Post-ripening fruit such as avocados, bananas, mangoes, melons, papayas and tomatoes can also suffer cold damage.

Many tropical (and sub-tropical) fruits such as lemon and banana can be damaged if they are cooled to between 0 °C and 10 °C. Bananas, for example, turn black if you put them in the refrigerator.^{22,23}

Details of the best way to store fruit and vegetables can be found in the online Foodkeeper.

See www.voedingscentrum.nl/bewaarwijzer

Maturation

Some types of fruit, such as apples, bananas, pears and peaches, release a gas (ethylene) when ripening.^{22, 23} Certain types of fruit and vegetables may be susceptible to ethylene, which causes them to spoil more rapidly. Lettuce, for example, develops brown spots on the veins, potatoes and onions sprout, while broccoli, various types of green cabbages, parsley and cucumber turn yellow.^{22, 23}

Some types of fruit may, in fact, benefit from the presence of ethylene in their physical environment. This is fruit that is normally sold before it is ripe, and where ripening significantly improves its quality. One example is an immature kiwi (see Table 1).

		Ethylene sensitive		
		High	Medium	Low
Ethylene producing	High	Apple, kiwi, pear	Avocado, melon, passion fruit	
	Medium	Apricot, banana, mango	Nectarine, papaya, peach, plum, tomato	
	Low	Various types of cabbage, carrot, cucumber, lettuce, potato	Asparagus, celery, citrus, aubergine	Artichoke, berries, cherries, grapes, pineapple, sweet pepper

Green: can be stored in combination with any colour category
Pink: do not store with orange and yellow
Orange: accelerates ripening when stored with orange and yellow

Table 1: fruit and vegetables that produce ethylene and that are sensitive to this gas.²³

Looking to the future

Detailed, specific information printed on the packaging informs consumers how to store food properly. Certain details must be provided, as a legal requirement.

These include the expiration date and specific storage instructions. In practice, we see wide variety in the use of the 'best before' and 'use by' dates on products.

For example, one brand of smoked salmon will carry a 'best before' date, while another will bear a 'use by' date. Consumers find this confusing. The business community would be well advised to introduce more uniformity, in cooperation with the government. In addition, terms such as 'perishable' are not sufficiently specific for consumers. Manufacturers and supermarkets can help consumers by printing specific storage advice on the packaging and food labels. However, it is important that the dates involved are not too tight. Allowance must be made for food safety, sustainability and common sense.

In the future, there will be new initiatives to help consumers store food properly. Specific sensors are already commercially available. These include the CheckPack sensor and the Pasteur chip, which give a warning if a product has spoiled or if it has been stored at too high a temperature. These techniques, which can be of genuine help to consumers, will be further developed in the future. 'Smart' packaging also has an important part to play in this regard. Nevertheless, consumers' senses are still an important factor. Consumers should re-acquaint themselves with their senses and learn how to use sight, smell, and taste to determine whether a product bearing a 'best before' date is still edible. The nose is often a very good indicator. Reliable, detailed consumer information from the Netherlands Nutrition Centre, as well as from the business community, is essential in this regard.

The following experts were consulted in the course of drafting this document:

Mr R.R. Beumer, Ph.D., food microbiologist, Wageningen UR

Mr J. Dijksterhuis, Ph.D., senior scientist, Applied and Industrial Mycology, CBS-KNAW Biodiversity Centre

Ms K. van Hoeij, MSc., food technologist/microbiologist

Ms G. Mittendorff, BSc., coordinating specialist inspector, The Netherlands Food and Consumer Product Safety Authority

Mr L. van Nieuwland, MSc., Nutrition expert

Ms J. Snoek, MSc., researcher, Milieu Centraal

Mr P. van Trigt, consultant, consultancy and training agency for sausage-making and meat preparation

Mr R. Wessels, MSc., Head of Research & Development, Bakker Barendrecht

Mr P. van der Wilt, BSc. BA, energy expert, Consumers Association

Referenties

1. van Westerhoven, M., *Bepaling voedselverliezen in huishoudelijk afval in Nederland, Vervolgmeeting 2013, 2013, CREM: Amsterdam.* p. 17.
2. Sevenster, M.N., H. Blonk, and S. van der Flier, *Milieuanalyses Voedsel en Voedselverliezen, 2010, CE Delft, Blonk Milieu Advies: Delft.* p. 78.
3. Bouwknegt, M., et al., *Disease burden of food related pathogens in the Netherlands, 2014, RIVM: Bilthoven.* p. 44.
4. Ummeayman, R., *Biochemistry of Food Spoilage, PFDNAI, 2009: India.*
5. *USDA. Molds On Food: Are They Dangerous? www.fsis.usda.gov; bezocht 8 maart 2016.*
6. Friesema, I.H.M., et al., *Surveillance van Listeria monocytogenes in Nederland, 2014, in Infectieziekten Bulletin 2016, RIVM: Bilthoven.* p. 8.
7. Soethoudt, J.M., et al., *Houdbaarheidsdatum, verspilde moeite?, 2012, Wageningen UR: Wageningen.* p. 58.
8. Bergsma, G.C., et al., *Verkenning van een nieuwe milieumethodiek voor verpakkingen en integratie met productbeleid, 2004, CE Delft/ KPMG: Delft.* p. 156.
9. *FDA, Refrigerator Thermometers: Cold Facts about Food Safety, FDA, 2011: Washington, USA.* p. 2.
10. *USDA, Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans – Part D. Section 8: Food Safety and Technology, 2010, United States Department of Agriculture: Washington, DC.*
11. Kandhai, M.C., *Detection, occurrence, growth and inactivation of Cronobacter spp. (Enterobacter sakazakii), 2010.*
12. George, R.M., P.J. Burgess, and R.D. Thorn, *Reducing food waste through the chill chain 2010, WRAP: UK.* p. 95.
13. Wilt, P. v.d., *Vier graden, 2015, Consumentenbond: Den Haag, persoonlijke mededeling.*
14. MilieuCentraal. *Koelkasten en vriezers. 2016; https://www.milieucentraal.nl/energie-besparen/apparaten-en-verlichting/huishoudelijke-apparaten/koelkasten-en-vriezers/.*
15. Temminghoff, M.B.M., *Koelkasttemperatuur in huishoudens, 2011, GfK: Dongen.* p. 19.
16. Lobitz, R., *Lebensmittelhygiene, Praxishandbuch zur Lebensmittellagerung im Haushalt, 2013, AID infodienst: Bonn.* p. 108.
17. Beumer, R. en P. van Trigt, *persoonlijke mededeling, 2015.*
18. Lee, S.K. and A.A. Kader, *Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biology and Technology, 2000.* 20(3): p. 207-220.
19. Dewettinck K, A.K., Verbeken D, Van Camp J, Huyghebaert A., *Literatuurstudie over de voedingswaarde van verwerkte groenten., 2005, OEITFL (Organisation of European Industries Transforming Fruit and Vegetables): Brussel.*
20. Ministerie VWS, *Kamerbrief over de tijdsduur van ongekoolde presentatie van levensmiddelen, in Tweede Kamer, 2015: Den Haag.* p. 2.
21. *Voedingscentrum, Hygiënecode voor de voedingsverzorging in zorginstellingen en Defensie, 2014, Voedingscentrum: Den Haag.*
22. Wang, C.Y., *Chilling and Freezing Injury. 2004, USDA Agricultural Reserach Centre: Beltsville Area.* p. 8.
23. *Watkins, C.B. and J.F. Nock, Production Guide for Storage of Organic Fruits and Vegetables, 2012, Cornell University: Cornell, USA.* p. 67.

Authors: ms Wieke van der Vossen, MSc. and mr Corné van Dooren, MSc.

May 2016 / Translated July 2016

www.voedingscentrum.nl