Melons: Health Hazard through Contamination with Pathogenic Bacteria

BfR opinion 021/2013, 09 August 2013

Melons can come into contact with bacteria, viruses or parasites at any stage of the food supply chain from production and transport to preparation in private households. Pathogens can be transferred from the skin to the flesh of the fruit when the melons are cut. At warm temperatures, in particular *Salmonella*, *Listeria* and EHEC can easily multiply on the flesh which is low in acidity. Accordingly, outbreaks of illness have in the past been triggered by the consumption of melons contaminated with these pathogens.

In order to avoid illness, the rules of personnel and kitchen hygiene should be strictly adhered to during the preparation of melons. For example, it is important to ensure sufficiently large and clean working areas, clean hands and to use thoroughly cleaned knives and chopping boards. These rules of hygiene are all the more important in view of the fact that a small infection dose suffices to cause an infection from pathogens such as campylobacter, EHEC and norovirus.

In addition, the Federal Institute for Risk Assessment (BfR) recommends to food retail stores, catering businesses and community institutions only to cut up small quantities of melons which can be sold to customers within about two hours. Consumers should eat cut up melons quickly or refrigerate them as soon as possible. Pieces of melons which have been kept unrefrigerated for several hours or exposed to high temperatures (e.g. through sunlight), should, as a precaution, be disposed of. To protect themselves against infections, especially vulnerable people should, to be on the safe side, refrain from eating cut melons which have been stored at room temperatures for several hours. Risk groups include pregnant women, small children as well as elderly and sick persons. These groups should think carefully before eating cut-up melons, if they do not know whether the fruit has been kept unrefrigerated for lengthy periods of time.

1 Subject of the assessment

All over the world, melons are a popular fruit which is predominantly eaten raw. Typically, they reach consumers as a whole or cut into pieces (half or quarter melons). Alternatively, the precut fruit is sold in plastic containers. Due to cultivation conditions, melons can come into contact with pathogens which survive on the skin. Especially to melons with a rough skin such as cantaloupe germs can adhere easily. Melons do not go through a production step that is suitable to kill off pathogenic germs.

Scientific studies confirm that germs present on the surface are transferred to the flesh when the melon is cut. Under favourable temperature conditions, they can multiply quickly. This means that by eating melons consumers run the risk of infecting themselves with germs that are pathogenic to humans, notably *Salmonella*, *Listeria monocytogenes* or Enterohemorrhagic *Escherichia coli* (EHEC).

BfR	BfR risk profile: Pathogenic bacteria on melons (Opinion No. 021/2013)				
A Groups affected	1) General population 2) Pregnant women, small children, the elderly and weak				
B Probability of health problems resulting from the consumption of melons contaminated with pathogenic bacteria	Virtually impossible	Unlikely	Possible	Probably	Validate fact
C Severity of health problems resulting from the consumption of melons contaminated with pathogenic bacteria	None Problems	Slight Problems [reversible/irreversible]	Moderately severe Problems [reversible/irreversible]	Severe Problems [reversible/irreversible]	
D Informative value of the available data	High: The most important data are available and free of contradictions	Medium: Some important data are missing or contradictory	Low: Numerous important data are missing or contradictory		
E Controllability by consumer	Control not necessary	Can be controlled by taking precautions	Controllable by refraining from consumption	Not controllable	

Fields shaded in dark blue designate the properties of the risk assessed in this opinion
(for more detailed information, see the text of BfR Opinion No. 021/2013, 9 August 2013).

Explanations

The risk profile aims to visualise the risk described in the BfR opinion. It is not intended for the purpose of comparing risks. The risk profile should only be read in the context of the opinion.

[Line B – The probability of health problems
[1] – The probability of health problems can vary. It depends, among other things, on the type and quantity of pathogens and on the individual state of health of the consumer.

Line C – Severity of health problems:
[1] – The severity of health problems can vary. It depends, among other things, on the type and quantity of pathogens and on the individual state of health of the consumer.

Line E - Controllability by the consumer
[1] – In its opinion, the BfR recommends preventive measures: In order to avoid illness, the rules of personnel and kitchen hygiene should be strictly adhered to during the preparation of melons. Consumers should eat cut up melons quickly or refrigerate them as soon as possible. Melon pieces which have been left unrefrigerated for several hours should be disposed of for safety reasons. Pregnant women, small children as well as old and sick people should, to protect themselves against infection, refrain from eating cut melons which have been stored at room temperature for several hours. These groups should think carefully before eating cut-up melons, if they do not know whether the fruit has been kept unrefrigerated for lengthy periods of time.

In the past, reports have repeatedly appeared on food-borne outbreaks following consumption of contaminated melons, sometimes with serious health consequences for those infected. For example, at least 147 people became ill with an infection caused by *Listeria monocytogenes* in the USA in 2011 after eating cantaloupe melons. 33 people died as a result of the infection and one pregnant woman suffered a miscarriage.

In Germany, an outbreak was linked to the consumption of watermelons for the first in time at the beginning of 2012. It was part of a national salmonella outbreak affecting at least five federal states. Cases of illness were also reported in Great Britain and in the Republic of Ireland. Watermelons imported from Brazil were identified as the food that had caused the outbreak. Contaminated with *Salmonella* Newport, the melons were predominantly sold to consumers as cut-up pieces.

Against this background, the BfR conducted an analysis of the available information on the presence and growth behaviour of salmonella, *Listeria monocytogenes* and Enterohemorrhagic *Escherichia coli* on melon pieces. The aim of the analysis was to characterise the risk of illness resulting from the consumption of melons and to recommend preventive measures to minimise that risk.

The BfR chose the above-mentioned types of pathogens for the analysis, because these bacteria can multiply on the melons and because they have caused melon-associated outbreaks of illness in the past. For the same reason, available scientific investigations on the survival and growth behaviour on melons for the most part focus on these pathogens.

2 Findings

Melons can come into contact with bacteria, viruses or parasites at any stage of the food supply chain from production and transport to preparation in private households. Pathogens can survive on the surface of melons and subsequently be transferred from the skin to the flesh when the fruit is cut. When preparing (i.e. cutting) melons, it is therefore imperative to adhere to the rules of personnel and kitchen hygiene. Observing the rules of hygiene is very important because the dose required to contract an infection is very low for some pathogens (e.g. campylobacter, EHEC, hepatitis A virus, norovirus). For example, it is important to ensure sufficiently large and clean working areas, clean hands and to use thoroughly cleaned knives and chopping boards. Because the flesh is low in acidity, pathogenic bacteria (e.g. *Listeria monocytogenes*, *Salmonella*) can easily multiply at warm temperatures, further boosting the risk of infection. The recommendation for food retail stores, restaurants and eateries and community institutions is therefore to cut melons only in small quantities which can be sold to customers within about two hours. Cut-up melons should be eaten or refrigerated as quickly as possible. Pieces of melon which have been kept unrefrigerated for several hours or exposed to high temperatures (e.g. through sunlight) should, as a precaution, be disposed of. To protect themselves against infection, the BfR recommends that pregnant women and persons with an undeveloped or weakened immune system in particular (small children, elderly and sick people) refrain, as a precaution, from eating cut melon pieces which have been stored at room temperature for several hours. These groups should think carefully before eating cut-up melons, if they do not know whether the fruit has been kept unrefrigerated for lengthy periods of time.

3 Statement of Reasons

3.1 Risk Assessment

3.1.1 Potential Source of Danger

A report written for the Codex Committee on Food Hygiene (FAO/WHO, 2011) contains information on 85 melon-associated outbreaks which have occurred worldwide between 1950 and May 2011. As the report states, the consumption of melons has in the past led to outbreaks caused predominantly by salmonella and norovirus. In addition, several EHEC and listeriosis outbreaks occurred in that time period. These pathogens cause particularly severe illness. In some cases, the consumption of melons caused campylobacter and shigella outbreaks. In Germany it has so far been possible to link only one salmonella outbreak to the consumption of melons. A special threat is posed by *Salmonella*, *Listeria monocytogenes* and enterohaemorrhagic *Escherichia coli* (EHEC), because these bacteria can, in favourable temperatures, quickly multiply on the melon flesh.

Salmonella are common in nature and can stay alive for long periods of time. They are detected in many cold and warm-blooded animals and are among the most common pathogens causing diarrhoea in humans. Foods can be contaminated with *Salmonella* through direct or indirect contact with the faeces of infected animals or humans at any stage of the process chain. The pathogens can survive in or on different foods for up to several months, and freezing does not kill them. Compared to other bacteria, their requirements for growth are modest. They multiply between temperatures of +7 to +45 °C; the higher the temperature the faster they multiply. Their optimal multiplication temperature is around +37 °C. Only in temperatures above +60 °C do they begin to die off. Multiplication is still possible in slightly sour environments (pH 4 to 5).

Listeria monocytogenes is the most important representative of the *Listeria* genus. *Listeria* are very common in the environment and can be found in the soil, in surface waters, waste water, on plants and in the digestive tract of animals. They either already come into contact with food at the production stage, for example during milking, slaughtering or harvesting of vegetables, or contamination occurs during production and processing of foods. An increased risk is therefore posed by raw and ready-to-eat foods which after processing do not generally undergo any germ-killing treatment. *Listeria* can survive and grow in wide temperature, pH and salt concentration ranges, and they are considered resilient in terms of environmental conditions. They can multiply in temperatures from -0,4 °C to +45 °C and at pH-values between 4.3 and 9. In addition, they can grow in salt concentrations of up to 13 % (Walker et al., 1990; Khelef et al., 2006; Shabala et al., 2008). Tolerance to pH and osmotic stress largely depends on the sequence and combination in which the bacteria are exposed to stress and whether they have previously had a chance to adapt to sub-lethal conditions (Skandamis et al., 2008; Tiganitas et al., 2009). Optimal growth conditions for *Listeria* are temperatures between +30 °C and +37 °C, a neutral to slightly alkaline environment and salt contents of about 0.5 % (McClure et al., 1991).

A EU regulation lays down that the concentration of *Listeria monocytogenes* in ready-to-eat foods in retail must not exceed a certain limit value (100 colony-forming units [CFU] per gram) during the food's shelf life [1].

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[1] Regulation (EC) No. 2073/2005 of the Commission from 15 November 2005 on microbiological criteria for foods: ABl. No. L 338 from 22 December 2005, p. 1 (last updated by Regulation (EU) No. 209/2013 from 11 March 2013)

Enterohemorrhagic *Escherichia coli* (EHEC) are *Escherichia* (*E.*) *coli* bacteria with the ability to form shigatoxins which can cause bloody diarrhoea in humans. *E. coli* O157:H7 is globally the bacteria that is most frequently associated with outbreaks of illness. Shigatoxin-forming *Escherichia coli* (STEC) are naturally found in the intestine of ruminants (cattle, goats, sheep, roes etc.) and they are excreted with the faeces of the animals. EHEC are resistant to dehydration, freezing and acidification, meaning that they can survive in the environment (soil, water, faeces) for weeks or even months. Through direct or indirect contact with the faeces of infected animals or humans, foods can be contaminated with STEC at any stage of the process chain. At temperatures of between +8 °C to +45 °C, STEC multiply; multiplication rates increase as the temperature rises. Their optimal multiplication temperature is +37 °C. Experiments on decontamination of foods contaminated with *E. coli* O157:H7 involving 0.5-, 1.0- and 1.5 per cent organic acids underline the acid tolerance of this pathogen (Brackett et al., 1994). In the laboratory, it can be shown that cultures with 3.0 x 10^4 CFU/ml *E. coli* O157:H7 are stable after a 24-hour incubation, both at +4 °C and +24 °C with a pH 3.4 and pH 11. A pH of 2, only leads to a slight reduction (0.5 – 1 log) of the number of germs (Miller and Kaspar, 1994). Experiments with artificial gastric juice indicate that not only do *E. coli* O157:H7 survive at a pH of 1.5 but other pathotypes (such as enteropathogenic *E. coli)* too are extremely acid-tolerant (Arnold and Kaspar, 1995). EHEC can still multiply at low pH values. In a study conducted by Zweifel et al. (2009), the minimum pH values were, depending on the acid tested and the pathogen strain, between pH 4.5 and pH 6.1.

3.1.2 Hazard potential / Hazard Characterisation

Humans typically contract **Salmonella** infections by eating contaminated foods of animal or plant origin. However, infection is also possible through direct contact with infected animals or humans. The infection dose for healthy adults is thought to be between 10^4 and 10^6 salmonella. Depending on the fat content of the food matrix and the immune status of the exposed persons, even an infection dose of less than 100 salmonella can lead to illness. After an average incubation time of 12 to 36 hours, the first symptoms can appear. Salmonellosis in humans usually manifests itself as diarrhoea which may be accompanied by abdominal pain, nausea, vomiting and fever. In rare cases, especially among the risk groups specified below, this results in severe general infections and death. According to the Robert Koch Institute (RKI), during the outbreak caused by *Salmonella* Newport after consumption of watermelon which occurred at the beginning of 2012, eight out of the 17 reported cases of illness required hospitalisation. Especially at risk are persons whose immune system is not fully developed yet (children under five) and persons whose immune defence is weakened, for example due to old age, previous illnesses or medication.

Salmonellosis in humans must by law be reported in Germany. The number of infections has decreased significantly in Germany in the time period from 2007 to 2011. For the year 2011, the Robert Koch Institute only recorded 24,512 cases of salmonellosis and 24 confirmed casualties (RKI, 2012). Back in 2007, the numbers were 55,408 reported cases of salmonellosis and 40 confirmed casualties (RKI, 2009). Despite the dwindling number of reported cases, salmonellosis is still, after campylobacteriosis, among the most common food-borne bacterial infectious diseases.

Listeria monocytogenes are predominantly transferred to humans through the consumption of contaminated foods. The infection dose to a large extent depends on the state of health of the affected person. According to EU law, ready-to-eat foods are considered safe if the concentration of *Listeria monocytogenes* does not exceed a predefined limit value of 100 colony-forming units [CFU] per gramme. Healthy persons usually do not become ill or only experience flu-type symptoms or a self-limiting gastroenteritis. However, people with weakened immune defence can develop severe illness following an incubation period of several weeks. Listeriosis can lead to blood poisoning, encephalitis or meningitis and not infrequently results in death. Infections in pregnant women can lead to miscarriage or premature birth and can cause irreversible damage in infants.

Listeriosis in humans too must by law be reported in Germany. For the year 2011, the Robert Koch Institute recorded 337 cases of listeriosis and 23 fatalities (RKI, 2012). Apart from newborns, those over 60 - in this group especially men - were notably affected. Due to the possibility of irreversible health damage and the high case fatality rate (7 %), listeriosis is, despite comparatively low number of cases, among the most significant food-borne diseases.

In 2011, a major listeriosis outbreak in the USA made international headlines: At least 147 people were taken ill, and 33 persons died as a result of the infection. *Listeria monocytogenes* was detected, as part of the investigation, in various samples which had been taken from the producer of suspicious melons. The US-American Food and Drug Administration (FDA) acts on the assumption that the melons were contaminated during production and that the germs were subsequently transferred from the skin to the flesh when the fruits were cut in consumer households (FDA, 2011).

EHEC can be transmitted through direct contact with infected animals or humans or indirectly via the consumption of contaminated foods. At less than 100 EHEC germs, the infection dose is very low. The incubation period is 2 to 10 days (3 to 4 days on average), this data being based for the most part on investigations into EHEC of serogroup O157. The majority of the illnesses caused by EHEC manifest themselves as typically watery diarrhoea without blood. In some cases, patients develop haemorrhagic colitis with spasmodic stomach pains, bloody stool and, in some cases, fever. However, infections may take an unapparent and hence unnoticed course. Small children especially are at risk of developing haemolytic-uraemic syndrome (HUS). The full clinical picture of HUS is characterised by acute renal failure in some cases including anuria, haemolytic anaemia and thrombocytopenia (low level of blood platelets). This severe complication occurs in approximately 5 to 10 % of symptomatic EHEC infections. It frequently leads to short-term dialysis dependency and more rarely to an irreversible loss of renal function with chronic dialysis dependency. During the acute phase, the fatality rate of HUS is approximately 2 % (RKI, 2011).

In Germany, it is compulsory to report EHE infections and cases of HUS. Between 2007 and 2010, about 900 EHEC cases and 40 to 70 HUS cases were reported per year. A sprout-associated EHEC outbreak in 2011 led to a significant increase in the number of reported cases. In the year 2011, a total of 4,904 EHEC and 877 HUS cases were reported. 58 persons died as a result of EHEC and / or HUS (RKI, 2012).

3.2.3 Exposure

Production and import of melons

Melons are berry fruits and belong to the gourd family (cucurbitaceae). They are usually classified into water melons (*citrullus lanatus*) and musk melons (*cucumis melo*), musk melon being a generic term covering a wide range of different types, including cantaloupe, galia and honeydew melons. The Federal Office for Agriculture and Food (BLE) distinguishes trade types of melons on the basis of their different characteristics such as fruit shape (round or oblong), skin colour, flesh colour and netting (BLE, 2006).

Worldwide, every year more than 100 million tons of melons are cultivated (2011: 131,768,261 tons), of which approximately 80 % in Asia. The majority of melons produced are water melons. The main producer is China with over 60 % of worldwide melon production in the years 2009 to 2011. However, Chinas export volume in the same time period was, at 0.13 % of production, still very low (FAOSTAT, 2013). The main exporters of melons are Mexico, Spain, the USA and Brazil (FAO/WHO, 2011).

In the EU, melons are predominantly produced in southern countries such as Spain, Portugal, Italy and Greece. But even Austria and the Netherlands produce several hundred tons of melons per year. In the EU, about 3 million tons of water melons and 2 million tons of other melons (including cantaloupe) were cultivated per year between 2009 and 2011 (FAOSTAT, 2013).

No melons are produced in Germany. In the time period from 2008 to 2010, an annual average of roughly 230,000 tons of water melons and 111,000 tons of other types of melons were imported into Germany (FAOSTAT, 2013). The main share both of water and other melons came from Spain (64 and 54 %, respectively). Germany also imports large quantities of water melons from Italy (13 %) and other types of melons from the Netherlands (28 %). The statistics do not reveal, however, whether and to what extent the melons are imported as whole fruits or pre-cut. Additionally, Germany annually imports more than 1,000 tons of melons from Costa Rica and Brazil (FAOSTAT 2013, figures from the years 2008 to 2010).

Contamination of melons

Melons grow on vines close to the ground. They prefer a warm and sunny climate and moist soil. Due to the size and weight of the fruit, melons are in touch with the ground, meaning that they can easily be contaminated, either from the soil or through contaminated water (FDA, 2009; FAO/WHO, 2011). Studies on cantaloupe farms in the USA and Mexico show that the used irrigation water can constitute a significant path of contamination for micro-organisms (Castillo et al., 2004). A study conducted in Texas shows a *Salmonella* prevalence in the irrigation water of 9.4 % (Duffy et al., 2005). Pests too are important vectors (FDA, 2009; FAO/WHO, 2011). Lopez-Velasco et al. (2012) tested whether *Salmonella* can enter the plant through its roots. They came to the conclusion that such a path of contamination is very unlikely and that contamination of the skin is the most significant factor.

The so-called "ground spot", i.e. the area where the fruit touches the ground is especially susceptible to fungal and bacterial growth. In order to minimise the risk of contamination, the ground is often covered with plastic, or the fruits are put on plastic containers (especially smaller types such as cantaloupes). One way to avoid ground spots is to turn melons regularly during their growth phase. This procedure must be done by hand and poses further contamination risk through inadequate personnel hygiene (FDA, 2009; FAO/WHO, 2011).

Contamination of the melons can also occur during harvest and transport, for example through asymptomatically infected people. After the harvest, the melons are usually refrigerated to extend their shelf life. This can be done either by air or water cooling, with both methods posing the risk of spreading any existing pathogens (FDA, 2009). Especially if a water basin is used to cool or wash the melons, there is a danger of further spreading the germs from contaminated to non-contaminated surfaces (Parnell et al., 2005). In a study by Duffy et al. (2005), both unwashed cantaloupes from the field and washed fruit from the packing station were tested. *Salmonella* were detected only on washed cantaloupes. Contaminated surfaces, for example in packing stations or transporters too can constitute a source of contamination. Castillo et al. (2004) found *Salmonella* in two environmental samples from the cold storage room of a cantaloupe packing station.

In order to keep the temperatures low during transportation, the fruits are often covered with ice which typically melts during transport and distribution. This can contribute to cross-contamination when the melting water flows between the melons and transport boxes, thereby spreading any existing germs (FDA, 2009).

Melons are not subject to a production stage which completely eliminates human pathogenic germs. Microorganisms can survive on the skin (Parnell et al., 2005; Richards and Beuchat, 2004), especially the rough skin of netted melons such as cantaloupes makes it easy for them to adhere to the surface and offers some protection from washing procedures and disinfectants (Parnell et al., 2005). The germ contents on the skin of cantaloupe melons is higher than that of honeydew and watermelons (Ukuku and Sapers, 2007). The FDA emphasises that a significantly larger number of outbreaks are caused by melons with rough than melons with smooth skin. 13 outbreaks in the time period from 1996 to 2008 with a total of 500 affected persons occurred in the USA following consumption of melons. 10 of these outbreaks were caused by cantaloupe melons (FDA, 2009).

Treatment and consumption of melons

Melons can be grown outdoors or in greenhouses. After harvest, they are either packed directly on the field or initially chilled in a packing station and then packed for transport. In dry cultivation areas, packing straight on the field is more common than in humid cultivation areas where, due to heavier soiling (e.g. through frequent rainfall) it is necessary to wash the melons (FAO/WHO, 2011).

Melons are either sold to the market as whole fruits, or they are processed first. When they are processed, they are, for example, pre-cut or prepared as an ingredient for fruit salad, meaning that they enter the food trade as a ready-to-eat product. Cutting up and packaging of melons can also be done directly by the retailer before the goods are displayed for sale. Figure 1 shows the process chain for melons in a simplified flow chart.

The fruit is sold to the consumer either as a whole or as segment wrapped in plastic foil (half or quarter melons). In addition, melons are sold as cut-up and ready-to-eat fruit, sometimes mixed with other types of fruit, in plastic containers. Since cooling of cut-up melons is currently not a legal requirement in Germany, the melon pieces are predominantly offered for sale uncooled.

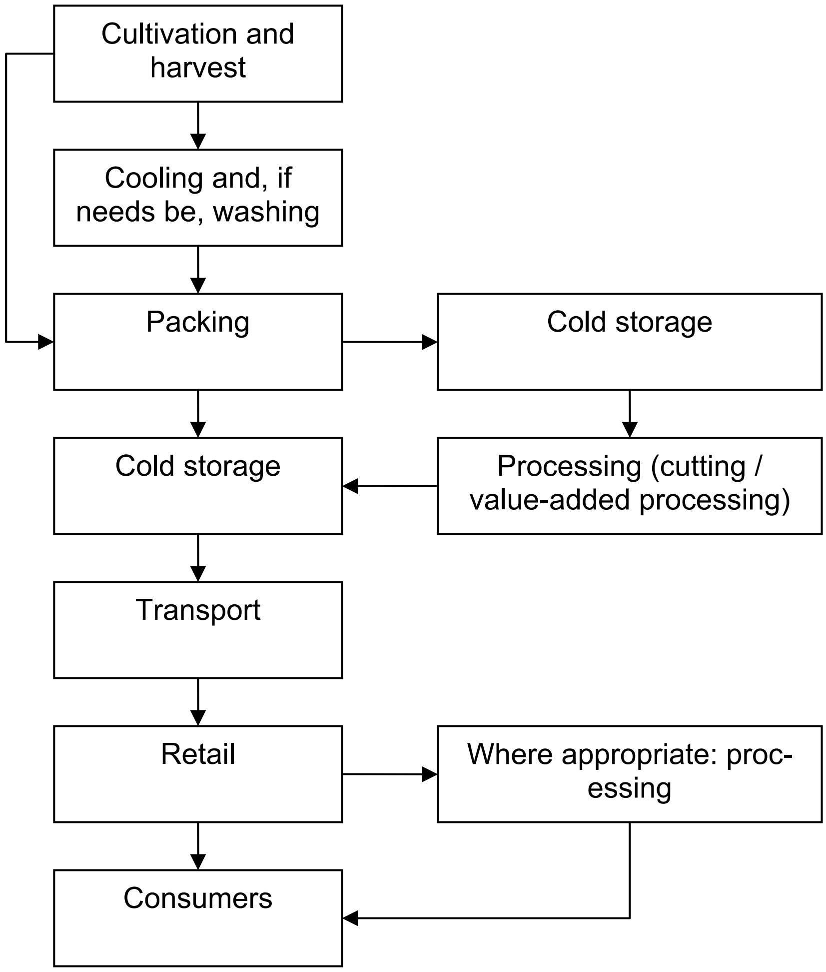
The flesh of the melons is typically eaten raw. According to a recent assessment of consumption data collected by the European Food Safety Authority (EFSA), about 7% of the population in the EU (3,640 out of 52,852 surveyed persons) eat melons (EFSA, 2013). The BfR acts on the assumption that melon flesh, due to its sweet taste and soft consistency, is eaten by all age groups, including risk groups such as small children and very old persons.

Presence of pathogenic bacteria on melons

As part of a major study on microbiological testing of fruit and vegetables, the FDA analysed a total of 366 cantaloupe melons between 1999 and 2001. In 16 cantaloupe samples, pathogens were detected. *Salmonella* were detected in eight samples and *Shigella* in four samples. *E. coli* O157:H7 were not found (FDA, 2001 and 2003). The report does not specify whether the pathogens were detected on the skin, the flesh or both.

A literature analysis conducted by the Austrian Institute of Technology GmbH (AIT) shows that *Salmonella* prevalence on melons can vary to a large extent (AIT, 2013). In Mexico, 12 out of 55 (22 %) melons were contaminated with *Salmonella*. In Malaysia too cut-up melons obtained from retailers were frequently contaminated with *Salmonella*. *Salmonella* were detected on 6 of 20 samples of water melon (30 %) and on 5 of 20 samples of honeydew melon (25 %). In Nigeria, *Salmonella* were found in three of 50 tested water melon samples (6 %). Apart from *Salmonella*, additional types of germs were found on the melons (*Staphylococcus aureus, Enterobacter aerogenes*, *Klebsiella pneumoniae*).

Figure 1: Schematic representation of the process chain of melons



In the year 2000, Castillo et al. (2004) tested cantaloupe melons from farms in Texas (950 samples) and Mexico (300 samples). They found *Salmonella* prevalences of 0.5 % and 0.3 %, respectively. As part of an additional study by Duffy et al. (2005), the surfaces of a total of 200 cantaloupe melons were tested fro the presence of *Salmonella*. *Salmonella* were detected only on three washed cantaloupe melons.

Within the framework of the European Rapid Alert System for Food and Feed (RASFF), reports on *Salmonella*-contaminated melons have only appeared infrequently in recent years. The ones that did appear concerned water melons from Costa Rica (April 2013) and Brazil (December 2011 and February 2012). In March 2008, the member states were informed of suspected *Salmonella* in fruit salad containing cantaloupe melons from Honduras. In March 2007, a notification appeared in RASFF about *Salmonella*-contaminated cantaloupe melons from Costa Rica.

As part of the federal monitoring plan, the microbiological state of pre-cut fruit and vegetables was determined all over Germany in 2007. It was not possible to cultivate *Salmonella* from 391 tested samples. *Listeria monocytogenes* was qualitatively detected in three of 406 tested samples, including two samples of "Melon / Honeydew Melon" (BVL, 2008).

Survival and growth of pathogenic bacteria on the skin and the flesh of melons

Pathogenic bacteria can survive and multiply on the skin of melons (Annous et al., 2004 and 2005). At +25 °C, the population of *E. coli* O157:H7 on the skin of cantaloupe and water melons increased by more than one log per cm² (Del Rosario and Beuchat, 1995) within four days. Especially the rough skin of cantaloupe melons makes it easy for germs to adhere to the surface (Annous et al., 2004; Richards and Beuchat, 2004). In addition, the fissured net-like structure of the skin offers the germs protection against external influences such as washing and treatment with disinfectants (Richards and Beuchat, 2004; Annous et al., 2013). For *Salmonella*, it has been shown that they can multiply on the skin of cantaloupes and that at +20 °C they form biofilm structures after only two hours (Annous et al., 2005 and 2013). *Salmonella* Poona multiplied, at room temperature, in 24 hours by more than two logs per cm² (Annous et al., 2013).

Studies of Ukuku and Sapers (2007) showed that the total aerobic counts on the flesh of freshly cut cantaloupe was higher than on the flesh of water or honeydew melons. Micro-organisms present on the skin can be transferred from the skin to the flesh when the fruit is cut (Ukuku and Fett, 2002; Ukuku et al. 2004; Ukuku and Sapers, 2007; Vadlamudi et al., 2012). Because the flesh is low in acidity, bacteria can survive and, depending on storage conditions, quickly multiply. For *Salmonella* and *Listeria monocytogenes*, generation times of approximately two hours were determined at room temperature (20 °C) (Penteado and Leitão, 2004a and 2004b). As a general rule, the higher the storage temperature, the shorter the lag phases and generation times.

Table 1: Lag phases and generation times of *Listeria monocytogenes* and *Salmonella* Enteritidis on water melons and cantaloupes (Penteado and Leitão, 2004a and 2004b)

Pathogen	Temperature (in °C)	Water melon		Cantaloupe	
		Lag phase (in h)	Generation time (in h)	Lag phase (in h)	Generation time (in h)
Listeria monocytogenes	10	24	13.03	24	7.12
	20	18	2.17	6	1.72
	30	4	1	4	0.84
Salmonella Enteritidis	10	24	7.47	24	7.31
	20	none	1.6	none	1.69
	30	2	0.51	2	0.69

Other studies on the growth of *Listeria monocytogenes* on cut cantaloupe showed short to no lag phases at all at a temperature of +4 °C to +40 °C (Fang et al., 2013). Starting with a contamination of log 3.3 to 3.6 *Listeria monocytogenes* per gramme, the maximum population of approximately log 8 cfu/g was, in dependence of temperature, reached at different speeds: after about eight days at +8 °C, approximately 60 hours at +16 °C and about 35 hours at +20 °C.

Studies by Li et al. (2013) on the growth of *Salmonella* and *E. coli* O157:H7 on different cut melon types (cantaloupe, honeydew and water melon) showed that at +4 °C no bacterial growth took place, irrespective of the type, and that growth rates rapidly increased at temperatures of +15 °C and above. *E. coli* O157:H7 multiplied on the flesh of all melon types slightly faster than *Salmonella* at room temperature (+23–25 °C). Contrary to expectations, similar growth rates were observed on water melons (pH 5.1 – 5.6) and cantaloupe (pH 6.1 – 6.6) despite their different pH values. However, the growth rates on honeydew melons were somewhat lower (log 0.19 cfu/h for *Salmonella* and log 0.28 cfu/h for *E. coli* O157:H7) than on the other types (log 0.26 cfu/h for *Salmonella* and log 0.4 cfu/h for *E. coli* O157:H7).

If cut melon pieces are stored unrefrigerated for lengthy periods of time before they are taken to the cold storage room, the risk of germ growth increases (Ukuku and Sapers, 2007; Ukuku et al., 2012). Storage at +22 °C notably boosted *Salmonella* growth on cut cantaloupe and honeydew melons. On cantaloupes, the *Salmonella* population increased, after 5 hours, by approximately log 1.3 cfu/g and on water melons by approximately log 0.2 cfu/g (Ukuku and Sapers, 2007). On cut cantaloupe pieces which were stored for four hours or more at +20 °C before being chilled (+5 °C), Ukuku et al. (2012) detected *Listeria*, but not on immediately chilled melon pieces. The authors conclude that storing melon pieces at room temperature even for just a few hours can boost the growth of *Listeria monocytogenes*.

3.1.4 Risk Characterisation

Little is known in Germany about the frequency of pathogenic bacteria on melons, since melons have not so far been tested for pathogens on a regular basis. Even the RASFF rarely received notifications in recent years about melons contaminated with *Salmonella*. Studies in other countries have shown that the prevalence of pathogenic bacteria varies greatly depending on type and origin of the melons. For this reason, it is not possible to reliable assess the probability of occurrence for melon-associated infections.

In Germany, cases of illness following consumption of melon have only once been known to occur. However, the reason for this could be that national outbreaks are difficult to detect, and their causes are hardly ever determined. Nevertheless, the outbreak with *Salmonella* Newport clearly showed that melons distributed in Germany too can be externally contaminated with pathogenic bacteria and that pathogenic bacteria are transferred to the flesh when the fruits are cut. In addition, it is possible that pathogens come into contact with melon pieces through cross-contamination or inadequate personnel hygiene.

According to scientific studies, washing melons with water does not lead to a significant reduction in the number of germs on the skin (Ukuku and Fett, 2002; Ukuku, 2004; Ukuku et al., 2012; Vadlamudi et al., 2012). A three-minute washing procedure of cantaloupe melons did not lead to a reduction in the population of *Salmonella* Poona and *E. coli* (Annous et al., 2004). The authors on the one hand attribute this to the net structure of the surface which offers protection to the bacteria and, on the other hand, to the formation of biofilms.

In order to reduce the germ count on the skin, the melons must additionally be thoroughly scrubbed with a clean brush. A study by Parnell et al. (2005) showed that scrubbing of smooth melon skins for 60 seconds (honeydew melons) lead to a reduction in *Salmonella* concentration by more than four logs and of rough melon skins (cantaloupe) by 1.6 logs. However, the experiments also show that the pathogens are spread through the washing process.

While treating the skin of whole melons with a 2.5 % hydrogen peroxide solution did lead to a reduction in the number of germs on the surface in a study, *Listeria monocytogenes* was still detected on the flesh after the fruit had been cut up (Ukuku et al., 2012).

Experimental studies with *Salmonella*-contaminated cantaloupe showed that peeling the skin off before cutting the fruit led to significantly lower germ counts on the flesh than cutting with subsequent removal of the skin (Vadlamudi et al., 2012).

In some countries outside of Europe (e.g. USA, Canada, Australia / New Zealand), recommendations for cooling melons as soon as possible after cutting and for disposing of melons after they have been stored unchilled for more than two or four hours are already in place (FDA, 2009; FSANZ; Health Canada, 2009; Food and Environmental Hygiene Department Hong Kong, 2006).

In the view of the BfR, Germany's population is not sufficiently aware yet that uncooled melon pieces potentially pose a health risk. Since the melon pieces are usually offered for sale unrefrigerated and do not come with instructions for cooling, this leads consumers to believe that this type of food is safe without refrigeration.

Depending on the pathogen and the immune status of the exposed persons, illness can take a wide variety of forms. Severe illness is notably to be expected in small children, pregnant women and persons whose immune defence is weakened on account of old age, previous illness or medication. The sprout-associated EHEC O104:H4 outbreak in early summer 2011 showed, however, that especially virulent pathogens can cause severe illness even in healthy adults. Notably as part of listeriosis and EHEC infection, irreversible damage and death are possible.

Below the consumer risk is characterised posed by cut-up melons contaminated with *Salmonella*, *Listeria monocytogenes* or EHEC bacteria.

Situation 1: Cut-up melons are stored at room temperature for several hours before consumption.

If melon pieces contaminated with *Salmonella*, *Listeria monocytogenes* or EHEC bacteria are stored at room temperature, the above-mentioned pathogenic bacteria will multiply on the flesh; the higher the storage temperature, the faster the multiplication rates. In addition, the type of germ and type of melon appear to have an influence on the multiplication rate. Germ multiplication would increase the risk of an infection after consumption of contaminated fruit, because melons are typically eaten raw.

Food business operators can minimise the risk of consumers by refrigerating cut-up fruit and by making sure that pieces of melon which have been stored at room temperature for several hours or which have been exposed to high temperatures are no longer sold to customers. Consumers can minimise their risk of infection by refrigerating cut-up melons and by refraining from eating melon pieces which have been stored at warm temperatures over lengthy periods of time including during outdoor events (picnic, barbecue party).

Situation 2: Cut-up melons are eaten within a short time after cutting.

If melons are eaten shortly after they have been cut, infections caused by *Salmonella* and *Listeria monocytogenes* are unlikely, because the germs have not had a chance to multiply in the flesh yet and the relevant infection doses are therefore probably not reached. Due to their low minimal infection dose, infections with EHEC cannot be completely eliminated even if the melon pieces are eaten immediately. The reason is that the required quantity of germs is probably already transferred to the flesh during cutting, if the melons are contaminated. Multiplication of EHEC bacteria is probably not necessary for causing an infection.

Situation 3: Melons are sufficiently cooled after cutting.

Provided that melons are stored at fridge temperatures (+4-6 °C) a short time after cutting, infections with *Salmonella* and *Listeria monocytogenes* through consumption are unlikely, because any existing *Salmonella* cannot multiply at all, whereas *Listeria monocytogenes* can only multiply very slowly. This means that the necessary infection doses are probably not reached. In contrast, EHEC infections can probably not be prevented altogether through refrigeration, since sensitive persons only require low germ quantities which can be transferred to the flesh through cutting.

3.2 Framework of Action / Measures

To protect consumers from melon-associated infections, the BfR makes the following recommendations for risk minimisation:

- The BfR recommends to take special hygienic precautions when cutting melons (e.g. a sufficiently large and clean work surface, clean hands, clean knives and clean chopping boards), in order to prevent contamination of the flesh with pathogens. Observing the necessary rules of kitchen and personnel hygiene is especially important, because the infection dose is very low for EHEC. In addition, ensuring strict hygiene minimises the risk of infections with other pathogens such as *Campylobacter*, hepatitis A virus or norovirus.

- The recommendation for food retail stores, restaurants and eateries and community institutions to prevent the growth of pathogenic bacteria is therefore to cut melons only in small quantities which can be sold to customers within about two hours. Pieces of melon which have been kept unrefrigerated for several hours or exposed to high external temperatures (e.g. through sun light) should, as a precaution, be disposed of to prevent food-borne infections.

- The BfR recommendation for consumers is to eat cut-up melons quickly or to refrigerate them as soon as possible, preferably at + 4-6 °C in order to minimise germ multiplication. To protect themselves against infection, the BfR recommends that in particular pregnant women and perons with an undeveloped or weakened immune system (small children, elderly and sick people) refrain, to be on the safe side, from eating cut melon pieces which have been stored at room temperature for several hours. Such persons should think carefully before eating melons, if they do no know whether the fruit has been left unrefrigerated for a long period of time.

- As part of risk-oriented sampling, the BfR recommends that unrefrigerated melons offered by retail shops are tested more frequently.

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