HOW COULD A LOWER TEMPERATURE IN THE COLD CHAIN AFFECT FOOD WASTE?

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1. ABSTRACT

This paper presents the results of an investigation into where and how food waste at the retail and consumer levels would be affected by a lower temperature in the cold chain for chilled food. A lower temperature means that shelf life will be longer. If, for example, milk, ready meals and sandwich spreads were stored at 4 °C instead of 8 °C, it would extend product shelf lives by up to weeks in some cases.

A lower temperature in the cold chain could allow food producers to extend the expiry date on their products. Longer shelf life, combined with extended expiry date on products, could reduce the in-store waste of foods having a date indication. A lower temperature in the cold chain in combination with extended shelf life marking could reduce food waste for those consumers who do not eat foods past their expiry dates.

A project to study the effects on food waste by lowering the temperature in the cold chain was performed by SP Technical Research Institute of Sweden (Jensen and Båth, 2013). The project was initiated by the Swedish National Food Agency and the Swedish Environmental Protection Agency. In addition to a literature review, the project included two parts presented in this paper: an analytical model and an interview study. Producers and store managers have given their views on how they think a lower temperature in the cold chain would affect the amount of waste of chilled foods.

If the results indicate that the temperature in the cold chain should be lower, further work should be carried out to investigate where and how the temperature should be reduced. Investment costs should also be considered, along with other potential working areas, such as improved knowledge. This paper discusses these issues.

2. INTRODUCTION AND LITERATURE REVIEW

The main objective of this paper is to better understand how food waste in the retail system and in households could be affected by a lower temperature in the cold chain.

Two parts of a recent study *(i.e. in addition to the literature review)*, are presented in this paper: an analytical model and an interview study.

Energy use depends on the particular methods of cooling, i.e. refrigeration, and on temperature requirements for the different steps along the cold chain. Each step has an environmental impact, an energy footprint and a water footprint, and will provide input for a better understanding of the complete chain. Lower temperatures basically require more refrigeration and therefore also increase energy consumption.

There is a close connection between food waste and the presence of unwanted microorganisms causing food-borne disease or food spoilage. Some examples of unwanted waste include food waste due to expired dates and labelling with inaccurate expiry dates, while waste of chilled products in customer households has a significant additional impact. Preventing waste at the consumer level saves resources earlier in the chain.

The EU is making extensive efforts to reduce energy use. The Ecodesign and Energy Labelling Directive is an essential tool in the EU's efforts to achieve a 20 % reduction in energy use from certain energy-using products by 2020. Ecodesign means that products, including refrigeration equipment, in the future must have

certain energy and resource efficiencies when in use. The EU's ambitious objective (European Comission, 2008) is to decrease emissions of greenhouse gases by 30 %, while simultaneously improving European food security and quality by 2020. The work of these directives is not only crucial in energy work, but also important for the EU's climate and environmental work.

Many products are distributed cold, as they are temperature-sensitive: a reliable cold chain is required In order to maintain the quality and safety of storage, handling and transport. About 360 million tonnes of food are lost annually worldwide due to poor refrigeration. A change in temperature provides many effects throughout the chain, both technical and non-technical, and also related to investment costs.

Current legislation in Sweden requires food producers to label their products with 'Best-before' dates or expiry dates, and with appropriate storage temperatures. Product temperatures must never, throughout the cold chain, exceed the temperature specified on the date label. However, several studies have shown that the cold chain is often broken, with the weakest links often being at the different transfer points along the chain. During transportation from the shop to the domestic refrigerator, for example, the temperature often exceeds the value printed on the date label. More research is necessary to assess and encourage measures to reduce food waste upstream, such as by dual-date labelling ('Sell by' and 'Use by'), and the discounted sale of foods close to their expiry date and of damaged goods (the minimum -durability 'Best before' date is related to quality, while the 'Use by' date is related to safety) (Caronna, 2011).

There is a significant increase in electricity consumption towards the final stages of the chain. Up to 30-50 % of energy can be saved by introducing display cabinets with doors instead of open cabinets (Estrada-Flores, 2007) (Kauffeld *et al.*, 2008) in supermarkets . This means that energy-saving technologies that target retail and domestic refrigeration can significantly decrease the financial and environmental impacts of energy usage worldwide (Gheewala *et al.*, 2011). Open display cabinets without doors are still commonly seen in supermarkets. In supermarkets, especially in open chilled cabinets, it can be difficult to maintain an even temperature for the chilled food, and there is a risk that the chilled foods are actually at a different temperature from that shown by the temperature monitoring system. Measurements of smoked and marinated salmon conducted in Sweden in 2010 indicated that many stores keep these products at a higher temperature than that specified by the food manufacturers on the product labels. In the study, all cabinets except one were equipped with doors or lids on the cabinet (Larsson and Kallberg, 2010). Several other studies (Omberg, 2011) (Lindblad and Boysen, 2004) have shown higher temperatures than recommended in cabinets and freezers. A report (Omberg, 2011) based on interviews with twelve major supermarkets in the Östersund area of Sweden shows that a majority of the stores found that the benefits of lower temperature in cabinets for meat are more important than any increase in energy consumption.

It has been concluded that more knowledge is needed for households. A Swedish study (Marklinder *et al.*, 2004) of temperatures under domestic conditions found that half of the households stored their goods at temperatures higher than the recommended temperatures on the packages. Many consumers do not know the temperature in their refrigerator, or that the temperature varies between shelves, or the best way to store food in the fridge.

3. PRODUCERS – SUPERMARKETS – HOUSEHOLDS

The most important factors to influence the level of microorganisms in foods are the temperature of the cold chain, including domestic refrigerators, and for how long the goods are stored at this temperature (Landfeld *et al.*, 2011).

Following the directive on waste, all EU member states should have their own waste management plans. The Swedish national waste plan presented in 2013 (Swedish Environmental Protection Agency, 2013) aims to have reduced food waste by at least 20 % by 2020, as compared with the quantity of waste in 2010. This includes the entire food chain other than primary production

In addition, it is estimated that this should result in an overall socio-economic benefit of between SEK 3.2 – 5.7 billion per year (Kock and Andersson, 2012). There are therefore benefits in both environmental and economic terms of reducing food waste.

Although there are considerable uncertainties in the assumptions of the effects, costs and value and calculations of the environmental benefit based on EcoValue, EcoTax and ASEK, it is clear that the benefits from achieving the interim target of reduced food waste by at least 20 % by 2020 are substantial.

3.1. Producers and retailers

Food law is decided at EU level. In Sweden, the legislation is interpreted in a guide (National Food Agency, 2014). Under current law, the food producer or the company packing or repacking the food is obliged to label the product with a Best-before date or an expiry date on a printed label. The product should also be labelled with a storage temperature.

Indirect and overall temperature requirements for food can be found in EC Regulation 178/2002, 852/2004 and 853/2004. The Swedish Frozen & Chilled Food Association refers to them in its industrial practices, where it writes that fresh fish and fish products must be stored at a maximum of +2 °C. Perishable products such as ground beef, vacuum-packed smoked or marinated fish, raw sausage and chicken should be stored at no higher than 4 °C. Producers may choose to label their products with a storage temperature lower than the statutory maximum temperatures to ensure a longer shelf life. In this case, the product temperature must never exceed the temperature stated on the label. (Djupfrysningsbyrån, 2007).

3.2. Households

The Waste and Resources Action Programme (WRAP) (George *et al.*, 2010) has commissioned an assessment to measure temperature changes in refrigerated foods, from when the goods were picked out from the cabinets of the store, were packed in bags and transported back to the consumer's domestic refrigerator. The measurement showed that the temperature of the products may be higher than the desired storage temperature (in the UK, 0-5 ºC) for a longer time than the actual transportation time to the home. The temperature of some products had not fallen to the desired temperature even after a period of three hours in the refrigerator.

A Swedish study (Marklinder *et al.*, 2004) of domestic refrigerator temperatures in a hundred households was performed in 2004. Selected groceries (the same products for all households) were brought home from the supermarket to the households, and the consumers were told to store the grocery in their refrigerators. The temperature in the products was measured next day. The study showed that 40 % of the consumers stored food at a temperature above the recommended temperature. Interviews carried out showed that most people did not know what the temperature should be in a domestic refrigerator (most chilled products should not be stored in temperatures above 4-8 °C), while only a quarter of the respondents knew or regularly measured the actual temperature.

In a study (Brown and Evans, 2013) based on published storage lives of foods which are currently refrigerated and UK waste statistics, it is suggested that reducing fridge temperatures from 7 to 4 °C should be recommended to consumers as an approach to improve shelf lives.

The problem of leftovers discarded from dishes or pots cannot be tackled through better storage of refrigerated food: this aspect of the waste problem requires efforts to change consumer behaviour.

4. METHODS

The project financed by the Swedish National Food Agency and the Swedish Environmental Protection Agency (Jensen and Båth, 2013) included an analytical model that highlighted the impact on shelf life depending on temperatures, and an interview study with food producers and representatives of supermarkets, to find out what they think would be the impact of a lower temperature in the cold chain. The project does not consider the effects on food waste for the producers. No interviews were conducted with consumers or households.

The questions were based on the following four refrigerated products:

Green salad - ready to eat in a bag, shelf life about 6-9 days
Packed cooked meat – producer-packed sliced ham, shelf life about 30 days
Mincemeat – producer-packed, shelf life about 4-5 days
Milk – not UHT, shelf life about 7 days

4.1. Analytical model

A predictive model (García-Gimeno and Zurera-Cosano, 1996) was used for calculating the growth of spoilage as indicated by the increase of lactic acid bacteria in a ready-to-eat (RTE) salad consisting of shredded cabbage, shredded carrots and green salad. This type of RTE product is sensitive: in Sweden, it is recommended that it should be stored at a temperature not exceeding 4-5 °C. The model shows how storage temperature affects the shelf life. Producers, retailers, etc. blame consumers for poor transportation conditions from the supermarket to the domestic refrigerator. The predictive model illustrates the impact of transportation in temperatures up to 19.6 °C and for up to eight hours.

4.2. Interview study

The interviews aimed at finding out how the Swedish food producers and representatives in supermarkets would utilize a lower temperature in the cold chain and potentially extended expiry dates. The interviews also investigated where in the chain the prolonged shelf life could be useful (producer, retailer or consumer).

Seven producers and eight store representatives answered questions about 1) storage of the chilled food, 2) how much waste they have, and 3) how they think a lower temperature could affect waste. The questions related to the above four refrigerated products.

4.2.1. Supermarkets

A total of eight stores participated in the interview study. This is not sufficient to provide statistically significant results, but the results from this study are indications of the situations in stores today. Representatives of the stores were interviewed to obtain their views on how storage temperatures and food waste are linked.

Two main questions were put in the interviews:
• Would a lowered temperature in the cold chain reduce the store's food waste *('food waste' being defined as food that has been discarded instead of being sold or eaten)*?
• Would extended expiry dates on the products (due to lower storage temperatures) reduce the store's food waste?

4.2.2. Producers

Interviews with quality managers (or equivalent) at seven major food companies with production in Sweden were conducted. Three of the companies were meat producers, two producers of dairy products, and two produced washed leaves or chopped salad mixes (RTE).
Two main questions were put in the interviews:
• Are there any hot spots in the cold chain, and do you trust the temperature along the cold chain?
• How could a lower temperature along the chain be used; what would be the consequences of a lower temperature?

5. RESULTS

The predictive model calculation shows that a constant storage temperature of 4 °C gives RTE salad a shelf life of 12-13 days. A transportation time (from the store to the domestic refrigerator) of eight hours at 19.6 °C (worst-case scenario (Landfeld *et al.*, 2011)) shortens the shelf life by one day, to 11-12 days. The average transportation time of 1 h and 15 min at 11.9 °C does not have any detectable effect on shelf life.

The calculation also highlights the fact that a constant storage temperature of 6 °C would shorten the shelf life to 8-9 days, and constant storage at 8 °C would further shorten the shelf life to 6-7 days (see Figure 1).

This means that the overall storage temperature (local transportation, producer, retailer and consumer) has a significantly greater effect on durability than has consumer transportation to the home.

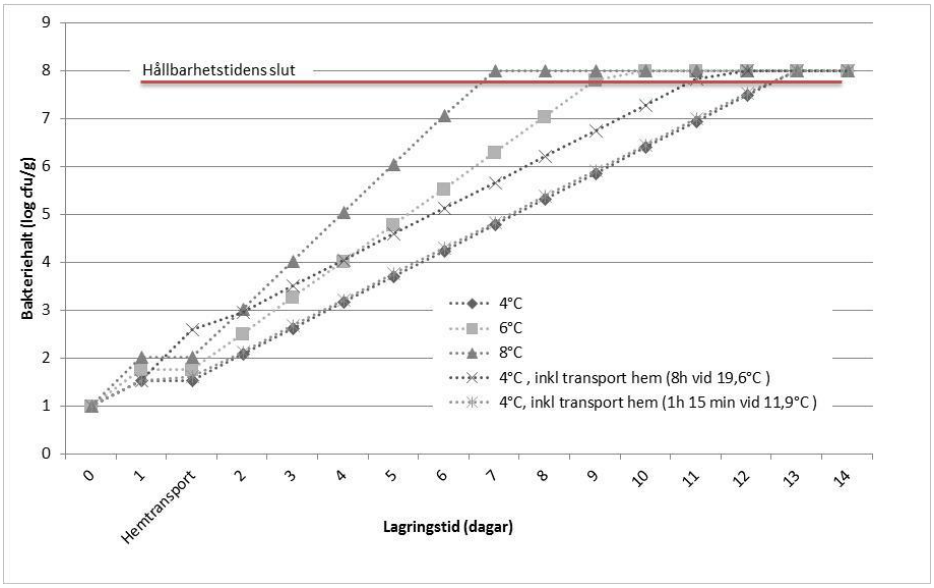

Figure 1. Bacterial growth of lactic acid bacteria vs. days of storage for RTE salad. The calculation is based on a model by (García-Gimeno and Zurera-Cosano, 1996).

5.1 Supermarkets

One of the most important reasons for food waste, according to the representatives of the stores, was poor planning for ordering the food, with the result that the products were not sold before their expiry date. Even if the product had a longer shelf life, due to lower storage temperatures, the store cannot sell products past their expiry dates.

Lower temperatures alone make no difference to the amount of waste of the four chosen products. The majority of the store respondents thought that the extra shelf life resulting from a longer shelf life label would particularly benefit retailers and consumers.

The store representatives believed that longer shelf life in combination with extended expiry dates, resulting from lowered temperatures, would reduce food waste in the stores. Packed cooked meat products are the refrigerated product of which shops have minimum waste: the explanation for this that was given is that these products have the longest shelf life dates.

5.2 Producers

When the producers were asked if they thought that there were any hot spots in their cold chains, or if they had margins for possible departures along the chain, they all responded that they do not have safety margins. The producers monitor the cold chain by installing temperature loggers at varying intervals. Temperature checks are performed anywhere from twice a year to, in some cases, at each delivery. Checks are carried out primarily between the producer and the customer's distribution centre (wholesaler), i.e. rarely all the way to the store. It is unusual for every delivery to be checked unless it is an explicit requirement from the producer's customer, e.g. a grocery store. The interviewed producers all have similar procedures for predicting dual date labelling. Storage study (under controlled conditions in a laboratory environment) is performed at the temperature for which the product is supposed to be labelled.

Producers who already mark their products with 4 °C believe that if the temperature of all foods were lowered to the same level, their products would benefit. Many distributors and retailers are not in the habit of keeping such low temperatures today, and so the quality of refrigeration varies, but if all products were to be stored at 4 °C the retailers would have to improve their cooling equipment to meet the new standard. If the temperature drops below 4 °C, it also takes longer to cool down the products, which can cause reduced

efficiency and increased energy consumption. Another disadvantage of longer shelf life (due to the lower temperature), as several producers emphasise, is loss of consumer confidence. Many consumers do not understand the relationship between lower temperatures and longer shelf life, but believe that the producers extend shelf life through the use of additives. The producers agree that a lower temperature in the cold chain means safer food and better quality of their products; see Figure 2.

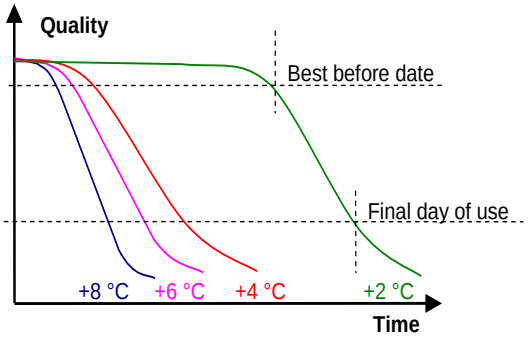

Figure 2. Food's quality as a function of time (Best before or Use by) and temperature

6. DISCUSSION

In order to lower the temperature of the cold chain, all parties in the cold chain - from producers and transporters to stores and consumers - must first be sure that they are measuring the temperature correctly and that the temperature range does not allow certain food to be too warm while other food is freeze-damaged. It is, for example difficult to maintain an even temperature in refrigerated open cabinets without doors or covers: temperatures can vary by several degrees depending on where in the open refrigerated display case temperature is measured. The unit's operation, such as defrosting, also affects the temperature of the cabinet.

Measurements, day and night conditions, have been performed under controlled conditions of the temperatures in a six-shelf cabinet without doors, loaded with test packages (Lindberg *et al.*, 2010). Results from the measurements are shown in Figure 3 and Figure 4. Note that only the temperature of the test packages on the bottom shelf is shown in the figures. Measurements 12 h day following 12 h night.

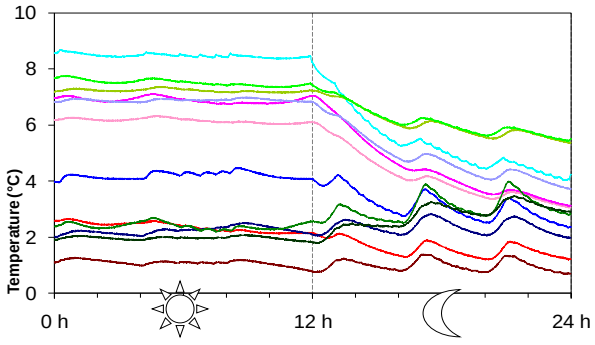

Figure 3. Temperatures in twelve of the M-test packages on the bottom, base, shelf in a cabinet without doors (and night curtains).

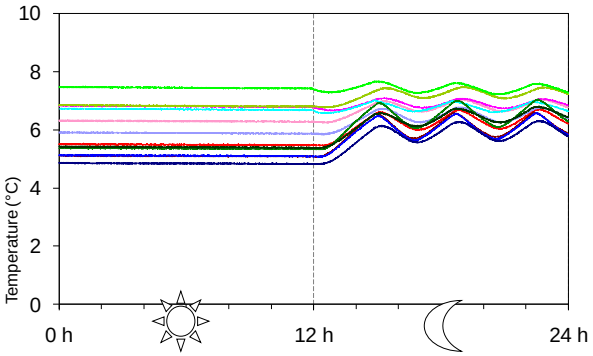

Figure 4. Temperatures in twelve of the M-test packages on the bottom, base, shelf in a cabinet with doors.

Figure 3 clearly shows the difficulty in lowering the temperature in an open refrigerated display. When no doors are installed the temperature distribution varies significantly, both over time and in different locations in the cabinet. Although all of the measured product packages were on the bottom shelf, the temperature differed by almost eight degrees between the warmest and the coldest package during daytime. During the night, a curtain was installed in front of the opening of the cabinet, which reduced some of the variation. Lowering the temperature in this open cabinet would probably mean that some of the goods would freeze. Figure 4 shows temperatures in the same test packages on the bottom shelf. The cabinet is fitted with doors, and the incoming brine temperature is 10 K higher in the 'With Doors' cabinet (Figure 4) than in the

'Without Doors' cabinet (Figure 3). With doors fitted, the temperature variations between different positions on the shelf are smaller, and the temperature is more even compared with without doors.

Retrofit installation of doors on display cabinets will reduce the cooling demand and reduce the temperature differences in the cabinets (Lindberg *et al.*, 2010).This gives better control of the products' quality, and also improves thermal comfort in front of the cabinet. However, for the energy-saving potential to be maximised, the entire refrigeration system must be considered and modified to suit the lower cooling demand. It has been estimated in a pre-study that after installation of doors the cooling demand can decrease by more than 30 %. Modification of the refrigeration could reduce cooling demand even more (Rolfsman, 2012).

Consumers believe that a longer expiry date also means more additives. However, it could be solved bv labelling products with "Additive-free".

7. CONCLUSIONS

7.1 Supermarkets

- It is difficult to maintain an even temperature in refrigerated cabinets without doors or lids. The temperature can vary by several degrees depending on where in the cabinet the temperature is measured.
- Reducing the temperature in a chilled food refrigerated cabinet with uneven temperature distribution could lead to frost-damaged food.

Store managers expressed themselves;

- expiry date is the biggest reason for food waste in the stores.
- food waste in their stores would probably decrease if product expiry dates were extended as a result of a lower temperature in the cold chain.
- a lower temperature in the cold chain, if not accompanied by extended products' expiry dates, would not reduce food waste in stores.

7.2 Producers

Producers should be aware of, and learn more about, the temperature variations that occur in different cabinets and storage areas in stores.

Producers expressed themselves;

- some products, such as cheese and yoghurt, are microbiologically stable, and their shelf lives would not necessarily be extended with a lower temperature in the food chain.

Seven Swedish food producers were asked if their expiry dates have margins for probable hot spots along the cold chain e.g. when being taken home from the shop. None of the interviewed producers takes this into account when predicting the expiry date: they all assume an unbroken cold chain right up to the time when the product is to be used.

Both store managers and producers to whom we talked said that ;

- extended expiry dates of products could result in products remaining longer in producers' and retailers' store rooms and on store shelves, instead of in consumers' refrigerators, so that food waste by consumers would remain unaffected.
- some consumers do not trust products with extended expiry dates, because they believe that they contain more additives.

7.3 Households

- The overall storage temperature (during transportation, in stores and at home) has a significantly greater effect on life length than the consumer's transportation of the product from the store to home.
- Extended expiry dates in combination with lower temperatures for the cold chain could reduce food waste for those consumers who do not eat date-expired food.
- Lower temperatures in the cold chain, but with the same expiry date on products, could reduce food waste for consumers who make their own judgment about the quality of the product, even though the best-before date has expired.

- Consumers' lack of knowledge on how chilled foods should be stored, and high temperatures in domestic refrigerators, causes the product quality to deteriorate more quickly.
- Consumers should be made aware of how much the temperature of refrigerated products can increase during the time they are in the shopping cart and being transported home to the domestic refrigerator.

If the temperature in the cold chain ought to be lower, further investigation is needed in order to find where and how this can best be done. In addition, investment costs need to be considered. However, for the part of the cold chain for which retailers are responsible, it has been shown that fitting doors to cabinets permits a more even and lower storage temperature than without doors.

8. ACKNOWLEDGEMENTS

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