Distribution of superchilled meat

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Introduction

Superchilling is a process where a minor part of a food product's water content is frozen. During superchilling, the temperature of the foodstuff is lowered, often 1-2 °C, below the initial freezing point of the product. After initial surface freezing, the ice distribution levels out to a predefined value and the product obtains a uniform temperature at which it is maintained during storage and distribution. With superchilling technology, cold is accumulated within the product and serves as a heat sink for eventual ambient heat load. The necessary holding time inside the chilling equipment is shortened compared to traditional chilling, as the ice formed under the surface accumulates heat from the interior of the products after leaving the equipment. At superchilling temperatures, most microbial activity terminates or is inhibited. The main benefit for implementing the technology are shelf-life prolonging for superchilled food of at least 1.4-4 times compared to traditional chilling (Einarsson, 1988, Duun *et al.*, 2008). The ice-forming and recrystallization can cause microstructural changes to foods tissue during freezing, resulting in cell dehydration, drip loss and tissue shrinkage during thawing (Magnussen *et al*., 2008). To maintain the ice content achieved by superchilling, the mean storage temperature must be adjusted to a level corresponding to a defined optimal ice content. Temperature variations must be limited to avoid recrystallization. Improved air-flow control, stacking in storage units, improved evaporator temperature control and a reduction of fluctuations in refrigeration temperatures and refrigeration loads are therefore required. A complete implementation of superchilling technology requires an improved cold chain adjusted to superchilled distribution requirements.

The first Norwegian meat processing plant base on superchilling was build in 2006, The Norwegian distribution chain for the superchilled products is however still based on temperature requirements of 0-4 °C. A national superchilled distribution chain for meat cuts is going to be developed, based on cooperation between the meat producer, their cooperation transport company, their wholesaler and retailers and refrigeration and logistic research groups. The objective of this work was to perform a descriptive study to map the today's situation in one selected distribution route of interest. The specific aims were to map the temperature history of superchilled products in an ordinary distribution chain, to analyse the driploss of the superchilled products after distribution as well as an analysis of the mercantile quality of the products et the end store. In the second phase 4 different superchilled meat cuts where tested for microbiology, sensory and physically differences at 3 different temperature levels, where one of the temperature levels correspond to the desire superchilled temperature.

Materials and Methods

Four cuts of pork; packed rib, sirloin steak, loin and legs were superchilled in a Advantec Impingement freezer from JBT Foodtech. The air temperature was fixed at -33ºC while the holding time was varying dependent on product. Thermocouples were installed in the core and the surface of superchilled, packed pork rib, pork sirloin, pork loin and legs of pork. Thermocouples were in addition placed in the air above the products. After the superchilling process the products were stored in a superchilled storage room (-1.1°C) for 6 days before they were transported on trucks and reloaded at intermediate storage sites. After 8 days the products was transported to the end grocery store and placed in a refrigerated counter for 3 days. Drip loss, water holding capacity (WHC).

In the second phase, still focusing on pork, four different cuts were selected for testing, including pork rib, pork sirloin, pork loin and leg of pork. 160 packed samples, superchilled to -1.1°C, were randomly collected from the production line at the production plant. Thermocouples (ibutton – TMEX from Dallas Semiconductor) were installed in the core and at the surface of the samples and also in the air above the products. The temperature in the storage compartments was controlled to ±0.1°C. During sampling the temperature at the production plant were recorded in the production room, the shell freezer and the superchilling unit.

The samples were stored at superchilled conditions (-1.1°C) for 14 days and then transported on trucks to the test laboratory and split into three for storage at different temperatures (-1.1, 4.0 and 8.0°C). One batch was sent to a grocery store (wholesale dealer) and placed in a refrigerated counter.

The laboratory testing comprised sensory, physical and microbiological analyses. **Sensory tests** were carried out using a trained panel focusing on smell, taste, appearance and texture of raw material. A minimum of five persons evaluated the samples. The sensory evaluation was rated on a scale from 1 to 10, where 10 indicate the highest score.

The physical tests included measurement of pH, water holding capacity (WHC) and drip loss. The microbiological analyzes included total colony forming units (CFU) and psycotrophic bacteria. Samples (3) stored in the laboratory at three different temperatures, were tested at laboratory storage days 0, 4, 8, 12, 14, 16, 20 prior to 14 days superchilled storage.

Controls were samples collected from the production line prior to superchilling, and samples after superchilling at the production plant. The laboratory test period lasted 20 days after arrival of the samples. Table 1 is a summary of the test programme.

Table 1: Time schedule second test for laboratory storage, sampling and testing.

Storage conditions		Storage days								
		Ref.[1]	S.k.[2]	0[3]	4	8	12	14	16	20
-1.1°C				x	x	x	x	x	(x)	x
4.0°C				x	x	x	x	x	x	x
8.0°C				x	x	x	x	x	x	x
Test parameters	Number of samples									
CFU	3	x	x	x	x	x	x	x	x	x
Psycothropic	3	x	x	x	x	x	x	x	x	x
Drip losses	3	x		x		x		x	(x)[4]	x
WHC	3	x		x		x		x	(x)	x
pH	3	x		x		x		x	(x)	x
Sensory	2[5]			x		x	x	x	x	(x)[4]

1) Samples collected before superchilling
2) Samples taken after one day at superchilling
3) Starting time for laboratory testing (after one day storage in the laboratory =day 15 after collecting samples at the production plant)
4) Samples collection provided final analyses.
5) Samples evaluated by a minimum of five persons

Collecting data on drip loss and water holding capacity (WHC) started on day 15 after processing.

The temperature was recorded inside the sample, at the sample surface and in the air just above the samples. The temperature recording devices followed the products through the whole distribution line and the laboratory tests.

pH value was measured using an instrument from MeterLab, Standard pH meter PHM 210.

Microbiological growth during storage was measured by method 3M Petrifilm for CFU and NMKN74 for psycotrophic bacteria. The measurement was performed bye Analysesenteret (www.trondheim.analysenter.no/analysesenteret)

For quantification of **drip loss**, the sample was removed from the wrapping, thawed at 10ºC for approximately 10 hours and then weighed. Calculation of the drip loss was based on the initial sample weight directly after superchilling. Mean values were calculated from three replicates.

The **water-holding capacity** (WBC) was determined on meat muscle tissue cut from the centre of the product. Cylinders of meat tissue were extracted using a steel cone, sliced and weighed. A cylindrical slice of approximately 10 g (approximate measures: 0.10 cm^2 * 1 cm) was then placed between two filter papers (Schleicher & Schuell 597 Roundfilter, 90 mm) and a weight of approximately 1kg (1.0087 kg) applied for 60 seconds. The final weight of the meat slice was compared to the weight before the pressure was applied and the water holding capacity was calculated. Mean values were calculated from three replicates (Hemmingsen, 2002).

Results from test 1

Figure 1 show the temperature history of the superchilled products from the first test during a local distribution route of 11 days. Table 1 show the results of the quality analysis after 11 days.

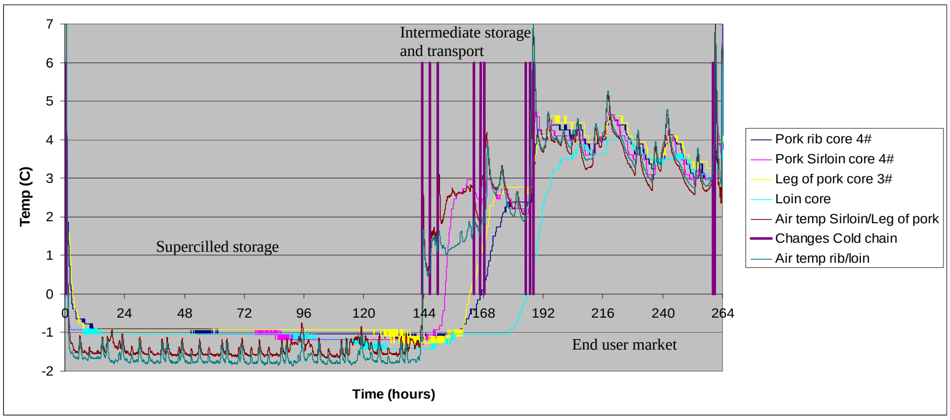

Figure 1a: Core temperature of superchilled products in distribution

Figure 1a shows a stable air temperature of about -1.5°C during storage in the superchilled storage rooms at the production plant. During intermediate storage and transport the air temperature rises to about 3°C and during storage in a refrigerated counter at the grocery store (end destination) the air temperature rises to about 4 °C. A fluctuating air temperature is also seen after the products leave the production plant.

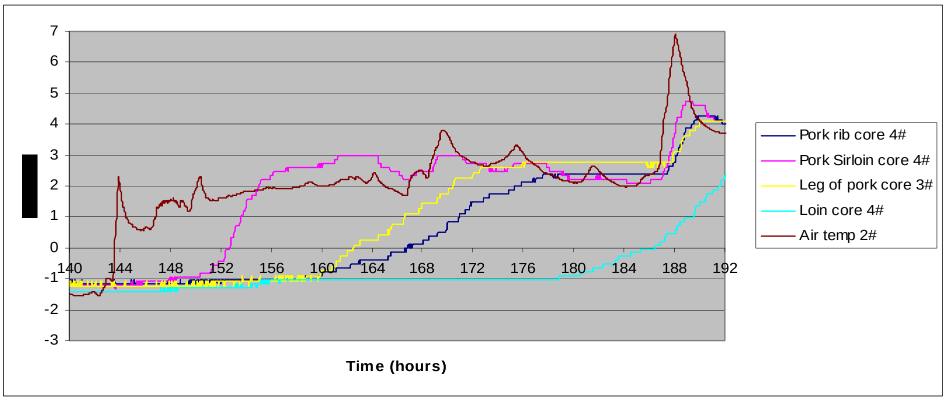

Figure 1b: Core temperature as product ice is melting.

Figure 1b shows that the products ice content delays product temperature rise for up to two days.

Table 2: Driploss and WHC of superchilled products 11 days after initial superchilling

Product	Drip loss [%] n=4	WHC [%] n=9
Pork rib	1.27	97.80
Pork sirloin	8.33	97.56
Pork loin	3.63	97.92
Leg of pork	10.71	98.73

The driploss of the superchilled products after distribution and thawing was high for pork sirloin and legs of pork. The process conditions for these products should be optimized to avoid this. Visually, there was more water in the superchilled pork packages at day 11 than of ordinary chilled products. The mercantile quality judged bye the wholesaler was elsewhere as for ordinary chilled products.

Results from test 2

Sensory quality

A common finding was a significant reduction in sensory quality for all products 28 days after production. This reduction was experienced at all storage temperatures.

After 34 days all superchilled products (-1 ºC) maintained better sensory quality than samples stored at 4 and 8 ºC. Figure 2 shows the result for taste of sirloin steak as an example.

The appearance of the samples did not change during the test period, regardless of storage temperature.

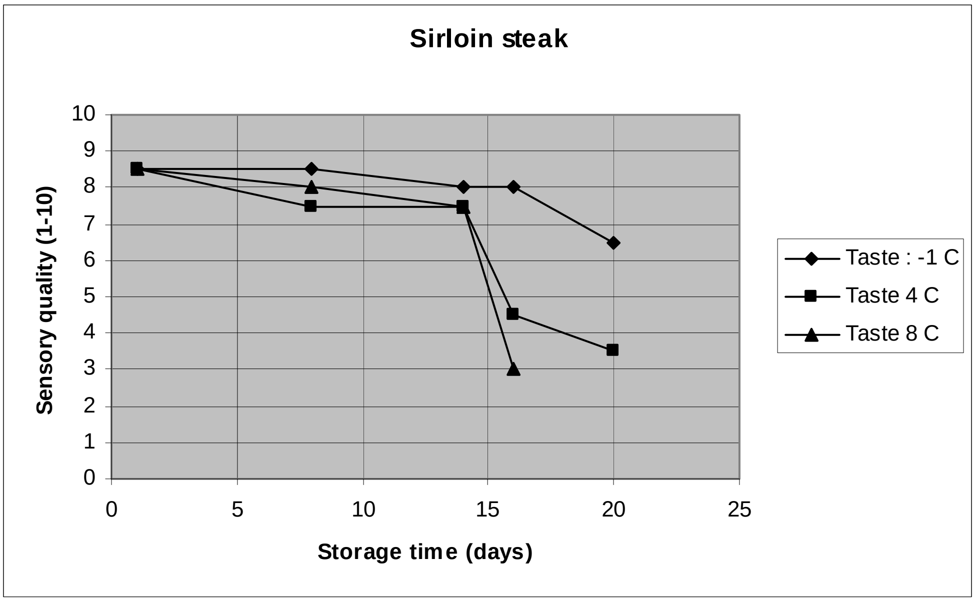

Figure 2. Taste response curves for sirloin steak, representing typical curves for other pork cuts

Samples stored at traditional chilling conditions after an initial superchilling period, did not receive an inferior sensory rating than samples that remained supercilled through the entire test period.

Physical quality

Low drip loss was recorded for all test conditions. Generally, a good physical quality was maintained through the storage cycle for all conditions. No negative impacts on drip loss caused by defrosting from superchilled condition were identified, until 15 days of storage.

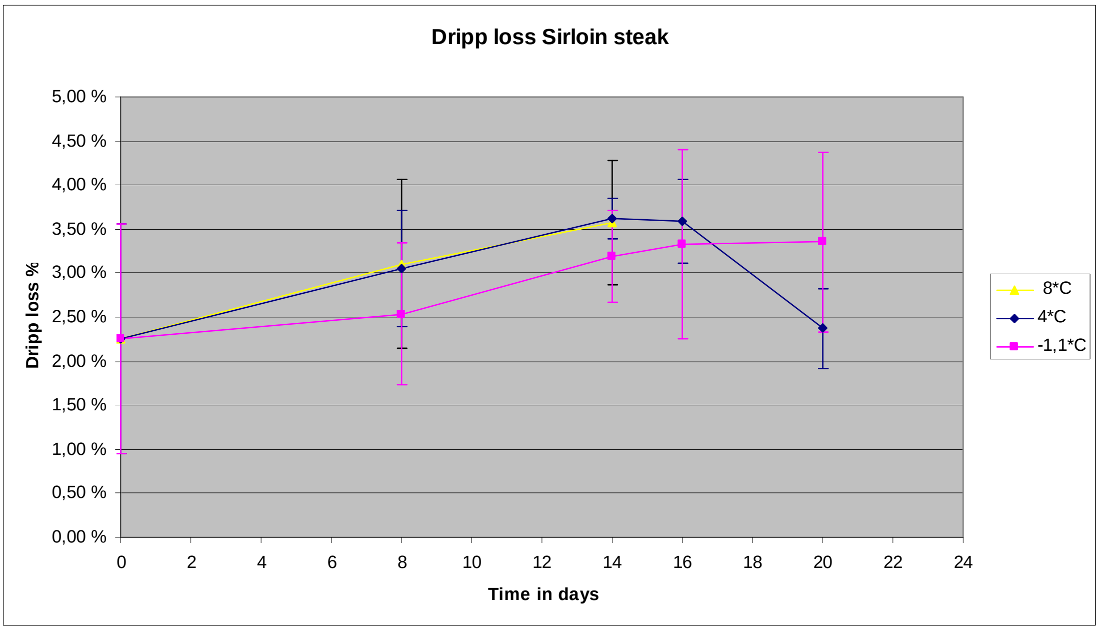

Figure 3: Physical quality(dripp loss) for pork sirloin steak

Figure 3 shows that for pork rib there were no significance differences between the storage temperatures when comparing drip loss. The same result where obtained for WHP and pH. The same result where found for the other cuts.

Storage temperature

The storage temperatures at the production site were recorded using two data loggers in each room. All recordings indicate stable temperature conditions.

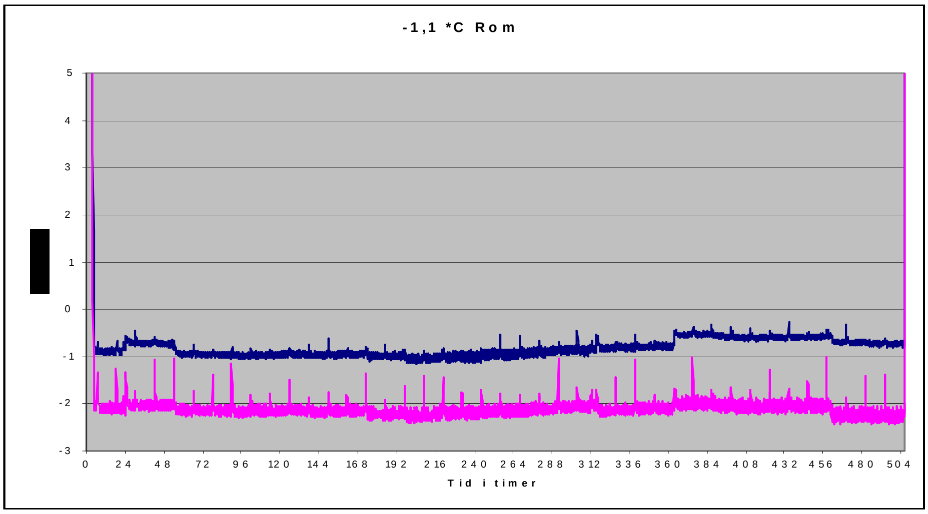

Figure 4. Temperature storage stability. The graph represents the temperature in the – 1.1°C room .

Microbiological quality

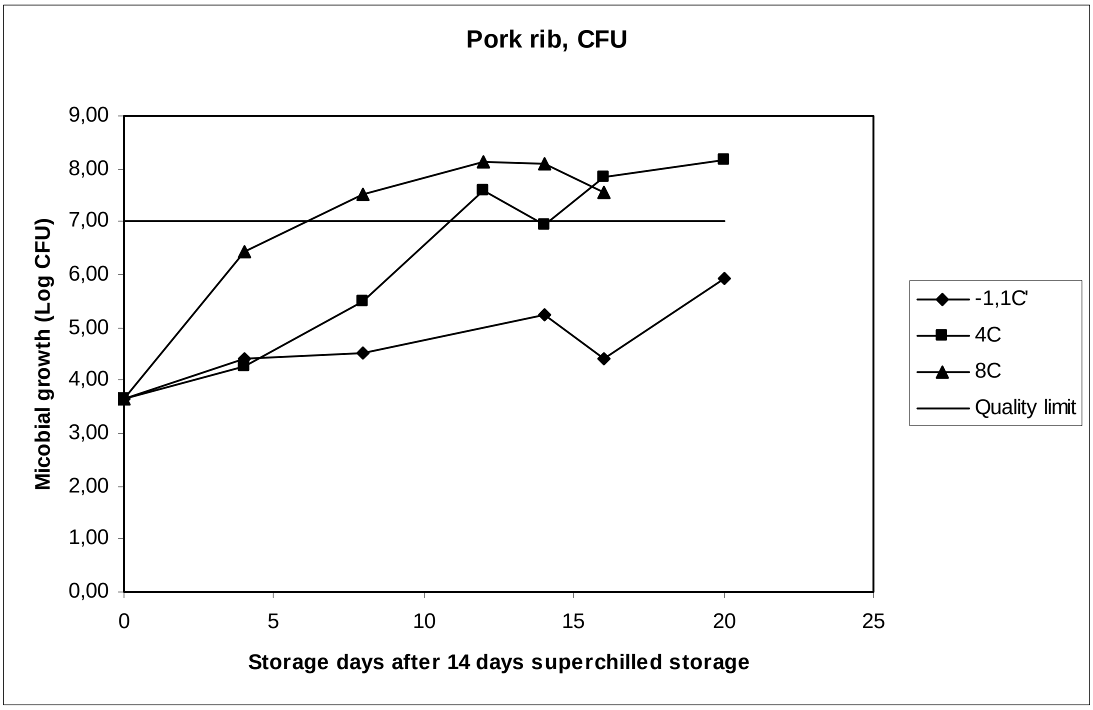

Figure 5. Total CFU of pork rib presented as a function of storage time.

In figure 5 the horizontal line represents the limit value for acceptance; log CFU should not exceed 7.0. Test results for psychotropic micro organisms showed similar graphs.

Samples of pork rib and pork sirloin did not show significant differences between the counting of total CFU and psychotropic bacteria. For samples from leg of pork and pork rib the counts showed a somewhat higher growth for total CFU compared to psychotropic micro organisms. In general, a relatively high level of micro organisms was identified during packing. Reducing these concentrations may imply a great potential for increased shelf life.

The microbiological testing conducted during this study showed that the shelf life for samples stored at superchilled conditions (-1.1ºC) was longer than for ordinary cooling (at least 34 days) and that the shortest shelf life, approximately 19 days, was experienced for samples stored at 8ºC. Samples stored at 4ºC showed shelf life in the range 24 to 19 days. In this study pork sirloin had the lowest potential for microbiological growth. No significant differences in microbiological growth represented by CFU and psychotropic bacteria were identified for the different products and environmental conditions.

DISCUSSION

The results clearly indicate that superchilled storage and distribution of pork meat cuts meet all quality requirements, even after prolonged storage time compared to products cooled to 0 – 4 ºC. The results show that an extended shelf life of fresh meat will be obtained.

Another benefit using superchilling seem to be that pork meat cuts keep their core temperature below 0 ºC from 12 hours to a couple of days even if the air temperature rises by several degrees. The cooling potential present in the product ice will maintain quality during transport even if the cooling facilities are not working properly or other logistic problems should occur in the supply chain. One the other hand, to achieve longest possible shelf life it is necessary to lower the temperature during transport and distribution compared with today's cold chain. This is not a technical barrier since most of the equipment used in the cold chain is designed for temperatures below 0ºC. The barriers are how to change the standard conditions currently used in the cold chain.

The product quality of superchilled pork meat has been assessed through temperature monitoring and analysis of samples from distribution line as well as laboratory testing.
One major finding is that the shelf life of superchilled meat will be significantly longer compared to traditional cooling techniques.

Superchilled storage followed by supercooled or cooled distribution of selected pork meat products like leg of pork, pork rib, pork loin and pork sirloin, can be recommended with respect to sensory quality as well as physical and microbiological quality.

Acknowledgment

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