Industrial superchilling, a practical approach

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Abstract

An industrial, automated superchilling process line needs to combine the requirement for gentle handling of a valuable raw material with demands for energy efficiency, high capacity and product quality. The results from the study of three alternative process lines for superchilled processing of fresh cod showed large variations with respect to processing time, need for manual operations, skinning errors and yield. The processing time and need for operators was very high for the Marel superchilling concept, while the quality and yield was high. The alternative involving skinning in a Baader59 unit followed by superchilling in an impingement freezer was very rapid and showed competitive results for quality and yield. Superchilling in the impingement freezer followed by skinning in the Baade59 unit resulted in a substantial amount of skinning errors in spite of very rapid processing. An efficient process presupposes a high yield combined with efficient production, large capacity, few operators, few skinning errors and an end product of high quality. The results from the current experiments indicate that superchilled processing of cod by means of skinning in the Baader59 unit followed by superchilling in the impingement freezer would be the most competitive alternative, taken the above mentioned factors into account. The method implies short processing time, low amount of skinning errors, little manual operation as well as high yield and quality. Superchilling is a robust method for conserving fresh food, and brings along many possibilities due to the extended product shelf-life. In the near future it is considered likely that most industrial processing of fresh fish will be done by means of superchilling, and the pioneer industry currently taking on the method will have a great advantage based on the experience from final development and implementation of the superchilling technology.

Keywords: Superchilling; Atlantic cod; Quality; Impingement freezer

1. Introduction

The results discussed in this paper are based on a series of tests performed in November 2010 at the site of a large Norwegian fish producer. The experiments were performed through two research projects
Superchilling is a well-known method for conserving foods, and was described as early as in 1920. During the recent years research and development has made major progress with respect to establishing superchilling as a technological concept ready for industrial implementation. Equipment enabling several superchilling process concepts is commercially available, however little work has been done to accommodate, investigate and benchmark the different production regimes due to i.e. product quality, yield, capacity and energy use.

Superchilling is a concept where the product temperature is reduced 1-2 °C below its initial freezing point. During processing, a thin layer of ice is produced on the product surface, and during storage, the ice equalizes within the product and the ice serves as a heat sink. The amount and distribution of ice in superchilled products prior to further processing greatly affects the process capacity and yield as well as product quality [1, 2]. Through wide scientific research on superchilling, the positive effect of superchilling and superchilling storage of several food products on microbiological growth have been shown [3, 4, 5], and extended shelf life of fresh food products can be obtained by superchilling.

Production of fresh loins and fillets are based on high quality products. A standardized quality scale range utilized by the Norwegian fish industry is used to evaluate the fresh fish quality. The scale implies ranging of the fillets based on the following grades: 5 (perfect physical appearance), 4A (minor gaping), 4B (little gaping), 3 (some gaping), 2 (much gaping) and 1 (considerable gaping). Fillets graded as 5, 4A or 4B is processed as fresh fillets, and the rest is prepared further as frozen products. The economic difference in selling the fish fresh compared to frozen products is huge for the manufacturer. An increase in amount of fresh fillets is, thus, requested together with extended shelf life of the products.

The main objective of this work is to compare three superchilling process lines measured by means of product quality, yield, capacity and defects during processing and give recommendations for an efficient superchilling process line for white fish, aiming at the best possible utilization of the raw material.

2. Materials & Methods

In the current experiment, three alternatives for superchilled processing of Atlantic cod (Gadus morhua) were tested as shown in Figure 1. Superchilling experiments with the Marel Superchiller concept (Marel, Osnabrück, Germany) process line (Alt. 1 in Figure 1), implies pre-chilling in brine of 2.5 % NaCl at -1.4 ºC for 8 minutes, followed by superchilling in a combined contact blast chiller (CBC) unit at -8 ºC for 8 minutes. The fillets were subsequently skinned by means of Skaginn skinning units. The second process alternative was performed by superchilling of cod fillets in an Impingement Advantec Lab Freezer (JBT Foodtech, Helsingborg, Sweden) at -37ºC for 45 seconds, followed by 10 minutes of equalisation in room temperature at +9 ºC and then skinning in a Baader59 skinning machine for white fish (Baader GmbH, Lübeck, Germany). Finally, the third process alternative involved skinning of the cod fillets in the Baader59 unit followed by superchilling in the JBT Impingement freezer at the same conditions as for the second process alternative.
The experiments were performed on 1-3 kg cod fillets, caught 4-6 days ahead of the experiments. For all process alternatives the cod was pre-chilled in ice-slurry at -1.2 °C, filleted in Baader 184/182 filleting machines for white fish (Baader GmbH, Lübeck, Germany) before the further processing were split in the three mentioned alternatives. The temperature within the cod fillets were registered for all process alternatives from pre-chilling through all manufacturing steps until the superchilled, skinned cod fillets were ready for the final processing. Quality assessment of the fillets was performed shortly after processing of superchilled fillet, and six days after temperature equalization. A standardized quality scale range utilized by the Norwegian fish industry was used to evaluate the superchilled cod fillets. The scale implies ranging of the fillets based on the following grades: 5 (perfect physical appearance), 4A (minor gaping), 4B (little gaping), 3 (some gaping), 2 (much gaping) and 1 (considerable gaping). Based on this a quality score is evaluated by summarising the grades from all fillets with a possible top score of 100 points for 20 fillets (5x20). Additionally the percentage amount of fillets appropriate for fresh end product is estimated based on the fillets with score of 5, 4A and 4B.

3. Results & Discussion

The production time, need for operators and time for each process step for three alternative process concepts is summarised in Table 1.

Table 1. Production flow parameters for alternative superchilling concepts

<table>
<thead>
<tr>
<th>Superchilling concept</th>
<th>Process step</th>
<th>Time at process step</th>
<th>Number of operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt. 1</td>
<td>Pretreatment in 2,5% brine</td>
<td>8 min.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>CBC superchilling-unit</td>
<td>8 min.</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>Skinning</td>
<td>10 sec.</td>
<td>3-5</td>
</tr>
<tr>
<td>Alt. 2</td>
<td>Impingement superchilling-unit</td>
<td>45 sec.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Skinning</td>
<td>10 sec.</td>
<td>1</td>
</tr>
<tr>
<td>Alt. 3</td>
<td>Skinning</td>
<td>10 sec.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Impingement superchilling-unit</td>
<td>45 sec.</td>
<td>1</td>
</tr>
</tbody>
</table>

For each of the three alternatives the possible bottlenecks in the production flow were estimated. For the first alternative, the filleting machines supplied the fillets in an oriented position onto the transport
band. However, when the fillets reached the brine bath this orientation was lost, and the fillets left the brine bath in piles. This involved a need for reorientation before the CBC superchilling-unit and induces a major bottleneck in the production line. Additionally, a reorientation of the fillets on the transport band upstream for the Marell skinning unit was needed, which constitute another bottleneck in the production line.

The second alternative implied no particular bottlenecks in the production line. Superchilling of the fillets in the lab version of the impingement freezer was very quick and agile, and it is considered likely that a continuous large scale impingement freezer would have a large capacity and presuppose minor manual labour. However, the Baader59 skinning machine did not handle the superchilled fillets due to the stiffness of the fillet surface, and rendered a large number of unskinned fillets. The situation did not improve in spite of tests with increased equalisation time for the fillets after superchilling.

The third alternative showed that the Baader59 skinning machine performed very efficient and gentle on the cod fillets before superchilling, rendering high quality fillets with very few skinning errors. In spite of quick superchilling, the skin free fillets easily stuck onto the freezer band, which in turn influenced the physical appearance of the fillets. Both pre treatment in brine and a freezer band covered with non-stick material could solve this issue.

The evaluated physical appearance for the cod fillets after processing by means of the three alternative concepts is presented in Figure 2.

![Fig. 2. Quality score of superchilled cod fillets shortly after processing (Day 0) and after 6 days storage (Day 6)](image)

The figure shows that fillets processed by means the Marell superchilling concept have a higher quality score immediately after production than the other processing concepts. Alternative three implied freezing unto the transport band of the impingement freezer, which gave an evident impact on the physical appearance of the fillets. Consequently optimising experiments should be done to conclude on the quality evaluation without this source of error. After storage the assessment of physical appearance for the three alternative concepts show very similar results, and an expected lower quality score than immediately after production.

The percentual amount of fillets for processing to fresh end product and the number of skinning errors for the three alternative concepts is presented in Table 2.
Table 2 Percentual amount of fillets for processing to fresh end product and number of skinning errors

<table>
<thead>
<tr>
<th>Method</th>
<th>Share for fresh end product [%]</th>
<th>Yield [%]</th>
<th>Skinning defect [%]</th>
<th>Production time [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt. 1 (Ice-slurry/Superchilling-CBC/Skinning Skaginn)</td>
<td>85,6</td>
<td>92</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Alt. 2 (Superchilling Impingement/ Skinning Bader59)</td>
<td>80,6</td>
<td>95</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Alt. 3 (Skinning Baader59/ Superchilling Impingement)</td>
<td>81,9</td>
<td>91</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

As for the assessment of physical appearance, the fillets processed by means of alternative one give a higher share of raw material for fresh end product than the other process alternatives. Again, the source of error induced by freezing of the fillets unto the impingement transport band must be considered, and could change the amount of raw material appropriate for fresh end product for the third alternative. This fact is also likely to be a drawback with respect to yield from processing by means of alternative three. The highest yield (based on the weight of skinned, superchilled fillets compared to the weight of the raw material fillets) was seen for fillets processed through alternative two, while the other two alternatives resulted in similar levels for the yield. The results on skinning errors show a very high amount of skinning errors for the second processing alternative, while the third alternative imply a considerable lower skinning error than the first alternative.

The temperature levels in the fillets through the three alternative process lines are shown in Figure 3, and results from temperature logging of the fillets during distribution from Norway to France is presented in Figure 4.

![Fig. 3. Temperature levels within the cod fillets during processing through three alternative process lines](image-url)
Figure 3 reveals that the temperature fluctuations are least for cod processed by means of alternative 1 or 2, the temperature varying between -0.7 °C (after superchilling) and 0.8 °C (after filleting). For alternative 3 the temperature variation is somewhat higher, with a peak after filleting at approximately 2.2 °C. However, due to the short timeframe for the processing (20 minutes) a temperature variation between -0.7 °C and 2.2 °C is not considered to have significant impact on the end product quality. As shown in Figure 4, the temperature variations during transport from Norway to France, keep the product at a very uniform temperature, safeguarding the quality until the recipient.

4. Conclusion

Based on the results above superchilled processing of cod is considered most feasible by means of alternative 1 or alternative 3. An efficient process presupposes a high yield combined with efficient production, large capacity, few operators, few skinning errors and an end product of high quality. Of the three alternatives tested, processing by means of skinning of filets in the Baader59 unit followed by superchilling in the impingement freezer seems to be the most promising alternative due to the short processing time, low amount of skinning errors, the need for few operators as well as high yield and quality. The method presupposes that the superchilling step can be handled automatically, and that the fillets don’t stick unto the transport band during chilling.

Superchilling is a robust method for conserving fresh food, and brings along many possibilities due to the extended product shelf-life. This involves i.e. increased production capacity, simplified production planning as well as opening up for new kinds of product and the ability to reach new markets. Automatization is very important also for the fish industry and superchilling as a rapid and repeatable production method is very suitable for automated processing. In the near future it is considered likely that most industrial processing of fresh fish will be done by means of superchilling, and the pioneer industry
currently taking on the method will have a great advantage based on the experience from final development and implementation of the superchilling technology.

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References


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