ICE REQUIREMENT GUIDELINES FOR FISH PACKED IN SÆPLAST 460 AND 660 AND NORDIC 660 CONTAINERS DURING INDOOR STORAGE

Figure 1. Insulated Sæplast 460 (above) and Sæplast 660 (below) fish containers shown without lids.

Author

Björn Margeirsson, Ph.D.
Research Manager at RPC-Sæplast / RPC-Tempra and
Assistant Professor at University of Iceland
E-mail: bjorn.margeirsson@saeplast.com
Tel: +354 8984901

Date

31 Jan 2017

Introduction

It is a well known fact that maintaining a perfect temperature control in the chill chain of perishable, fresh food can be a difficult task (Mai et al., 2012; Margeirsson, 2012). Food packaging can play a considerable role in protecting the perishables, especially at high temperature conditions. The importance of containers in fish handling has been described by Brox et al. (1984) by the following functions:

- ease the handling of small and large quantities of fish;
- simplify and increase the speed of unloading/loading and transportation of raw material;
- protect the fish against physical damage contamination and other deteriorating factors;
- offer a suitable packing unit for fish and ice;
- contain the fish under such conditions that it reaches the buyer in the best possible condition;
- help to protect the raw material against natural deteriorating effects;
- help to make maximum utilization of resources and to achieve optimum economical results through the whole system of handling from harvest to consumption.

Figure 2. Three types of single walled fish boxes with volume capacity of around 70 L.

Insulated plastic containers (also called tubs or bins, see Figure 1) outperform single walled fish boxes (Figure 2) with regard to many of the functions above. Therefore the insulated containers have replaced the fish boxes in many fish industries throughout the world. One of the main benefits is the superior thermal insulation, which results in slower ice melting, better fish temperature control and slower fish deterioration (Seafish, 2013; Margeirsson, 2016). Considerable effort has been put in studying the insulative properties of 340–660 L containers manufactured by Sæplast (Snorrason, 2014a,b).

The aim of this study is to compare the ice required using different insulated containers, with and without lids, for storage and transport of fish. These containers include the types Sæplast 460 PE, Sæplast 460 PUR, Sæplast 660 PE, Sæplast 660 PUR and 660 Nordic. This is done by means of ice-melt tests and analytical heat transfer modelling.

Figure 3. Nordic 660 container.

Figure 4. The same lid fits on Sæplast 340, 460 and 660 containers. Here it is shown on a Sæplast 340 PE container.

Figure 5. Sæplast 460 PUR (left) and Sæplast 460 PE (right) containers filled with ice at the beginning of an ice-melt test.

Figure 6. Sæplast 460 PE containers in a wetfish trawler hold, some packed with ice.

Materials and Methods

Both thermal load experiments with ice, as described by Burgess (1999), Singh et al. (2008) and Margeirsson (2016), and fish packed in ice and heat transfer modelling have been used to prepare the results presented in this document. Bulk densities of 550 kg/m^3 and 992 kg/m^3 are assumed for ice and fish, respectively.

The R-value for each container is calculated from ice-melt tests or estimated as an area weighted R-value average of the bottom, walls and lid. The R-value for the bottom, walls and lid is calculated as the sum of the conductive resistances of the PUR/PE-foam and PE skin layers and the convective thermal resistance due to a constant convection coefficient of 6 W/m^2/K.

The weights and dimensions of the packaging are presented in Table 1.

Table 1. Weights and dimensions adopted in the heat transfer model of the insulated containers under consideration.

	Sæplast 460 PE	Sæplast 460 PUR	Sæplast 660 PE	Sæplast 660 PUR	Nordic 660
Weight without lid* (kg)	50	41	60	52	70
Container contents (L)	420	420	615	615	615
L = inside length (m)	1.15	1.15	1.15	1.15	1.15
W = inside width (m)	0.95	0.95	0.95	0.95	0.95
H = contents depth (m)	0.39	0.39	0.57	0.57	0.57
A_{in} = Inside area, (m^2)	3.82	3.82	4.58	4.58	4.58

* The weight of PUR-foamed lid for Sæplast 460/660-PE/PUR is 12.5 kg

* Taking into account the volume capacity decrease due to lid

The heat transfer rate from the ambient air to the container load can be described by the following equation (Holman, 2002):

$$q_{amb} = UA\Delta T = UA(T_{amb} - T_{load}) \tag{1}$$

where q_{amb} denotes heat transfer rate [W], U is overall heat transfer coefficient between the ambience and the container load [W/m^2/K], A is surface area [m^2] and ΔT denotes the temperature difference between the ambient air (T_{amb}) and the container load (T_{load}). This heat transfer rate can be connected to the ice melting rate as follows:

$$q_{melting} = \dot{m}_{ice} L_{ice} = UA\Delta T = q_{amb} \tag{2}$$

where $\dot{m}_{ice}$ represents ice melting rate [kg/s], L_{ice} is latent heat of fusion (melting) [J/kg]. The surface area and the overall heat transfer coefficient can be seen as constants in the temperature range applied in the current study and thus, the ice melting rate will increase approximately linearly with ΔT according to the following equation:

$$\dot{m}_{ice} = UA\Delta T / L_{ice} \tag{3}$$

Equation (3) can also be written in the following way:

$$\dot{m}_{ice} = A\Delta T / (RL_{ice}) \tag{4}$$

where R is the reciprocal of U (R=1/U) and represents the thermal resistance (R-value) of the container [m^{2}K/W]. From the ice-melt tests the R-values are calculated as follows:

$$R = A\Delta T / (\dot{m}_{ice} L_{ice}) \tag{5}$$

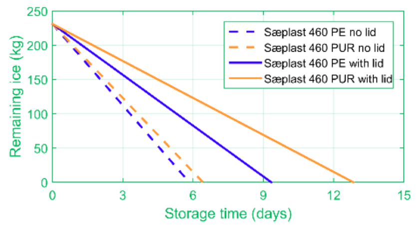

Figure 7. Remaining ice during storage in Sæplast 460 PE/PUR containers at 20 °C.

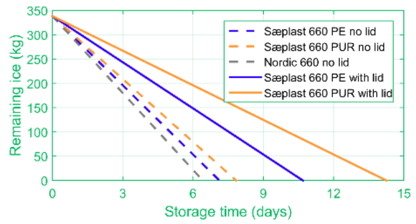

Figure 8. Remaining ice during storage in Sæplast 660 PE/PUR and Nordic 660 containers at 20 °C.

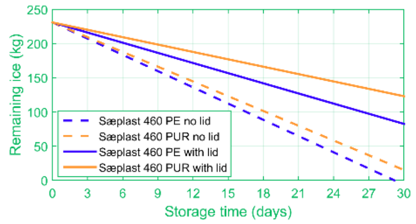

Figure 9. Remaining ice during storage in Sæplast 460 PE/PUR containers at 4 °C.

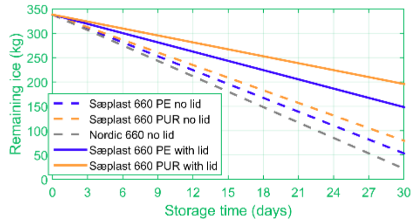

Figure 10. Remaining ice during storage in Sæplast 660 PE/PUR and Nordic 660 containers at 4 °C.

Results and Discussion

The R-values obtained from ice-melt tests and/or calculations from the thermal properties of the packaging materials are presented in Table 2. Note that a high R-value represents a well insulated container, which is suitable for minimizing heat transfer between the ambience and the container contents and thereby minimizing ice melting or food product temperature changes. As can be seen from the table, the insulation performances of the PUR containers are considerably better than of the PE containers. Without a lid, the PUR containers have around 8–10% higher R-value, which can result in around 7–9% slower ice melting according to Equation (4).

The results also show that using a lid is even more important for the insulation than the choice of PUR vs. PE. Applying a lid on top of a container can increase the R-value of the container by around 30–80%, resulting in around 25–45% slower ice melting.

Table 2. Thermal insulation performance (R-value) of Sæplast 460/660-PE/PUR and Nordic 660 containers.

Container type	With / Without lid	R-value (m^2K/W)
Sæplast 460 PE	Without	0.50
Sæplast 460 PE	With	0.80
Sæplast 460 PUR	Without	0.55
Sæplast 460 PUR	With	1.10
Sæplast 660 PE	Without	0.50
Sæplast 660 PE	With	0.75
Sæplast 660 PUR	Without	0.55
Sæplast 660 PUR	With	1.00
Nordic 660	Without	0.45

The R-values from Table 2 and Equation (4) are adopted to estimate ice melting rate in different containers under different ambient temperatures, see Figure 7–Figure 14.

Figure 7–Figure 10 can be used to estimate the remaining ice in different containers with or without lids during up to 15-day storage at 20 °C and up to 30-day storage at 4 °C. The containers are assumed to be almost filled with ice in the beginning, i.e. with 231.0 kg in the 460 types and 338.25 kg in the 660 types.

Firstly, it should be noted that ice melting is slow in all of those insulated container types, at least compared to single walled packaging (Margeirsson, 2016). As an example, it can be seen that storing 338.25 kg of ice for three days in 660 types at ambient temperature as high as 20 °C should result in remaining ice of around 180 kg and 267 kg in the worst and best cases, respectively. These worst and best cases are a Nordic 660 container without a lid and a Sæplast 660 PUR with a lid, respectively.

Comparable numbers for a 3-day storage at 20 °C in the 460 types are ice weights from 231 kg initially to between 112 kg (worst case, Sæplast PE without a lid) and 177 kg (best case, Sæplast PUR with a lid).

The ice melting is of course much slower at 4 °C than at 20 °C. In fact, according to the linearity of Equation (4) it is around 5-times faster at 20 °C as compared to 4 °C.

In order to estimate the daily ice weight required for a typical fish weight in each container stored at different temperatures, Figure 11–Figure 14 can be used. Comparison of both Figure 11 to Figure 12 and of Figure 13 to Figure 14 clearly indicates the importance of precooling the fish before it is packed into the containers. As an example, around 33 kg of extra ice is needed to chill 300 kg of fish from 10 °C to 0 °C, which must be added to the ice required to counteract the heat from the ambience during storage.

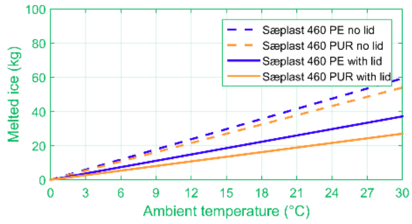

Figure 11. Daily ice melting during storage in Sæplast 460 PE/PUR containers assuming 300 kg of fish is packed at 0 °C into each container.

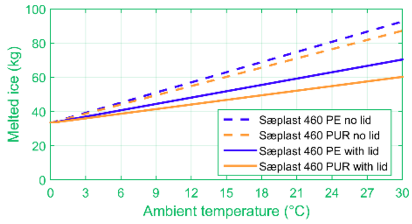

Figure 12. Daily ice melting during storage in Sæplast 460 PE/PUR containers assuming 300 kg of fish is packed at 10 °C into each container.

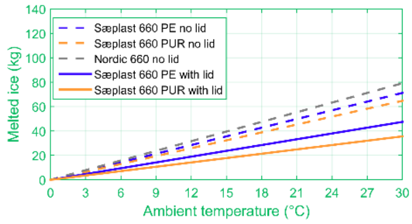

Figure 13. Daily ice melting during storage in Sæplast 660 PE/PUR and Nordic 660 containers assuming 430 kg of fish is packed at 0 °C into each container.

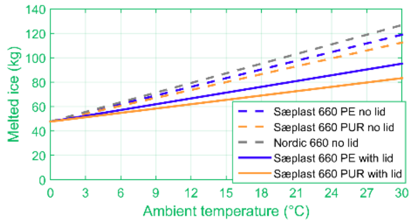

Figure 14. Daily ice melting during storage in Sæplast 660 PE/PUR and Nordic containers assuming 430 kg of fish is packed at 10 °C into each container.

Conclusions

The results from the current study have shown that lids are very important for the insulation performance of insulated containers, such as Sæplast 460/660-PUR/PE containers. Adding a lid to an insulated container can decrease the daily ice requirement by around 33–50%.

The choice of PUR vs. PE does not seem to be as important as using lids, at least with regard to insulation performance. The ice requirement using PE containers is around 10% higher.

With regard to ice requirements, fish temperature at the time of packing it into an insulated container can be just as important as the insulation properties of the container.

Finally, it should be noted that the results presented in this study assume that the insulated containers are stored indoors. This means that neither direct sun radiation nor high wind speed are taken into account. Storing the containers outdoors could easily result in around 20–70% faster ice melting, but this is left for future studies. Furthermore, the effect of existence and fastening of drainage plugs should be investigated.

References

Brox, J., Kristiansen, M., Myrseth, A., Aasheim, P.W. 1984. Planning and engineering data. Containers for fish handling. FAO. Available at http://www.fao.org/docrep/003/r1263e/r1263e03.htm.

Burgess, G. 1999. Practical thermal resistance and ice requirement calculations for insulating packages. Packaging Technology and Science 12, 75–80.

Holman, J., 2002. Heat Transfer, ninth ed. McGraw-Hill, New York.

Mai, N.T.T, Margeirsson, B., Margeirsson, S., Bogason, S., Sigurgísladóttir, S., Arason, S. 2012. Temperature Mapping of Fresh Fish Supply Chains – Air and Sea Transport. Journal of Food Process Engineering 35(4):622–656.

Margeirsson, B. 2012. Modelling of temperature changes during transport of fresh fish products. Doctoral thesis. University of Iceland, Reykjavík, Iceland. Main supervisor: Dr. Halldór Pálsson.

Margeirsson, B. 2016. Thermal Performance of 70 L single walled fish boxes and Sæplast insulated Fish containers. Technical report. RPC-Sæplast.

Seafish. 2013. Improving catch quality on inshore vessels. Industry fact sheet. Available at http://www.seafish.org/media/Publications/FS76_ImprovingCatchQualityonInshoreVessels_201311.pdf.

Singh, S., Burgess, G., Singh, J. 2008. Performance comparison of thermal insulated packaging boxes, bags and refrigerants for single-parcel shipments. Packaging Technology and Science 21, 25–35.

Snorrason, S.G. 2014a. Numerical analysis of heat transfer in fish containers. Masters thesis. University of Iceland.

Snorrason, S.G., Margeirsson, B., Pálsson, H., Arason, S. 2014b. Heat transfer modelling of fish containers – Final report. Promens, University of Iceland, Matís.