THERMAL COMPARISON BETWEEN 70 PUR AND 100 PUR SÆPLAST CONTAINERS

Author

Björn Margeirsson, Ph.D.
Research Manager at RPC-Sæplast/RPC-Tempra and Lecturer at University of Iceland
E-mail: bjorn.margeirsson@saeplast.com
Tel: +354 5205410 / +354 8984901

Date

19 February 2016

Introduction

The aim of this study is to compare the thermal performance of two Sæplast container types containing frozen fruit juice:

- 70 PUR
- 100 PUR

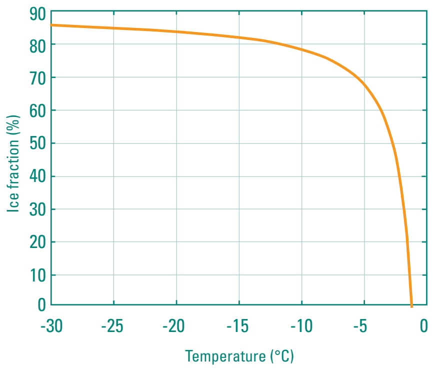

Figure 1. Ice fraction (ratio of frozen water) in fruit juice as a function of temperature.

Materials and Methods

The assumed composition of the fruit juice is as is shown in Table 1.

Table 1. Composition (%) of fruit juice (http://www.matis.is/ISGEM/en/search/).

Water	Carbohydrates	Fat	Protein	Fiber	Ash
89.2	9.5	0.1	0.7	0.1	0.4

From the composition data the following thermal properties (shown in Figures 1-4) are calculated with the methods of Choi and Okos (1986) and Wang and Weller (2011). An initial freezing point (T_f) of -1.2 °C is adopted for the fruit juice.

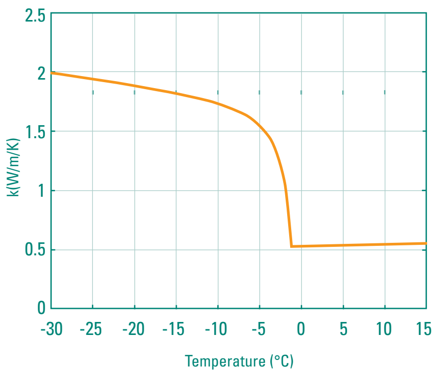

Figure 2. Temperature dependent heat conductivity (k) of fruit juice.

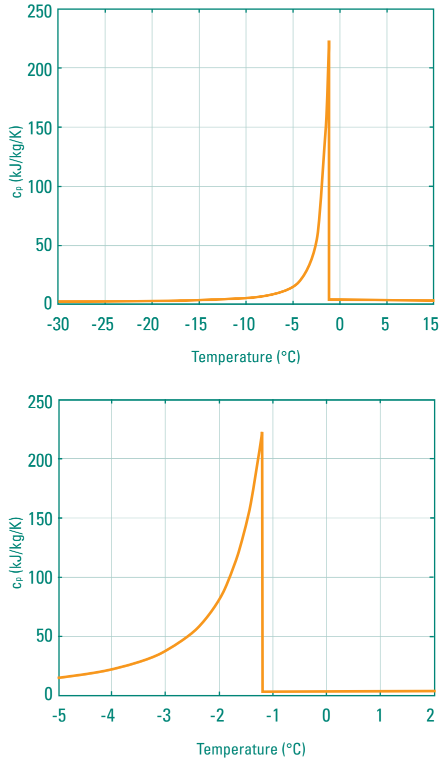

Figure 3. Apparent specific heat capacity (c_p) of fruit juice for wide (above) and narrow (below) temperature ranges.

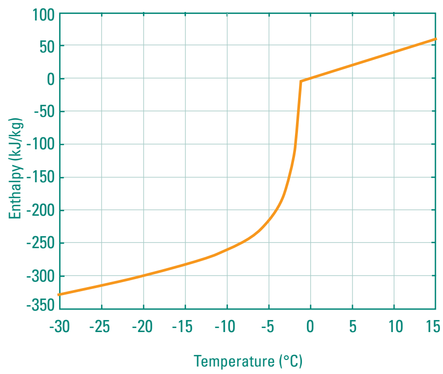

Figure 4. Enthalpy of fruit juice as a function of temperature. The enthalpy is set at 0 at 0 °C.

In order to raise the temperature of the fruit juice from -24 °C to -8 °C, heat must be transferred from the ambience to the fruit juice in such amount that the enthalpy of the juice increases by around 63.7 kJ/kg. The specific heat capacity is relatively close to being constant between -24 °C and -8 °C (Figure 3 and also seen in almost linear increase of the enthalpy in Figure 4). Thus, in the analytical model a mean apparent specific heat capacity of 3.974 kJ/kg/K is adopted for the temperature range between -24 °C and -8 °C.

The analytical model used for estimating the temperature rise from -24 °C to -8 °C in the two containers under consideration is as follows:

$$T = T_{amb} - \frac{T_{amb} - T_{init}}{\exp\left(\frac{3.6 A_{in}}{m \cdot c_p \cdot R_{total}}\right)}$$

where T_{amb} is the constant ambient temperature of 30 °C, T_{init} is the initial juice temperature, A_{in} is the inside surface area of the container, m is the mass of the juice, c_p is the specific heat capacity of the juice and R_{total} is the thermal resistance (R-value) of the container. The R-value for each container is estimated as an area weighted R-value average of the bottom, walls and lid, also taking into account results from an ice-melt test (Margeirsson, 2015). The R-value for the bottom, walls and lid is calculated as the sum of the conductive resistances of the PUR foam and PE skin layers and the convective thermal resistance due to a constant convection coefficient of 6 W/m²/K.

The R-value is lower for the 100 L container than the 70 L container mainly due to lower wall, bottom and lid thicknesses.

Table 2. Dimensions of the 70 PUR and 100 PUR containers under consideration.

	70 PUR	100 PUR
L = length inside (m)	0.66	0.73
W = width inside (m)	0.40	0.46
H = height inside (m)	0.28	0.32
Area inside, A_{in} (m^2)	1.13	1.43
Calculated volume capacity, LxWxH (L)	74	107
Volume capacity with lid (L)	70	102
Density of frozen juice (kg/m^3)	950	950
Mass of frozen juice inside container (kg)	66.5	96.9
Average wall thickness (mm)	38	36
Average bottom thickness (mm)	43	39
Average lid thickness (mm)	37	35
R-value (m^2K/W)	1.10	1.02

Results and Discussion

The warm up times from -24 °C to -8 °C are predicted to be **25.2 hours** and **26.8 hours** for the 70 PUR and the 100 PUR containers, respectively (Figure 5).

These values can easily vary by up to 10%, mainly depending on the type of juice and thereby the water content of the juice. It should also be noted that the containers are assumed to be filled. Partly filling the containers will decrease the warm up time, see Figure 6.

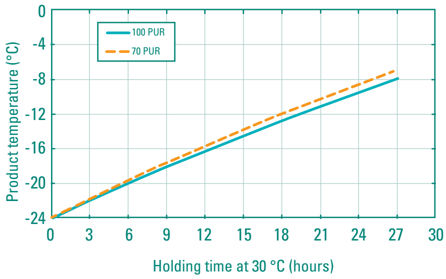

Figure 5. Predicted mean temperature evolution of fruit juice stored in Sæplast 70 PUR and 100 PUR containers at ambient temperature of 30 °C. The 70 PUR and 100 PUR containers are assumed to be filled with 66.5 and 96.9 kg of frozen fruit juice, respectively.

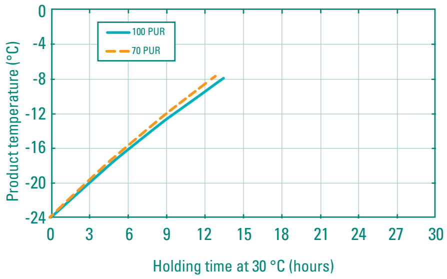

Figure 6. Predicted mean temperature evolution of fruit juice stored in Sæplast 70 PUR and 100 PUR containers at ambient temperature of 30 °C. The 70 PUR and 100 PUR containers are assumed to be half-filled with 33.3 and 48.5 kg of frozen fruit juice, respectively.

References

Wang, L., Weller, C.L. 2011, in Da-Wen Sun (Ed.), Handbook of Frozen Food Processing and Packaging, 2nd edition. CRC Press. London, UK. pp. 101–125.

Choi, Y., Okos, M.R., 1986. Effects of temperature and composition on the thermal properties of foods, in: Maguer, M., Jelen, P. (Eds.), Food Engineering and Process Applications. Elsevier Applied Science, London, UK, pp. 93–101.

Margeirsson, B. 2015. Experimental investigation of thermal performance of 70 L PUR Sæplast Containers. Technical report. Promens.