

### Module Title:

Freezing of ice cream: how freezing progresses with time and how composition affects freezing time

### Module Goal:

Learn the impact of composition on ice cream freezing

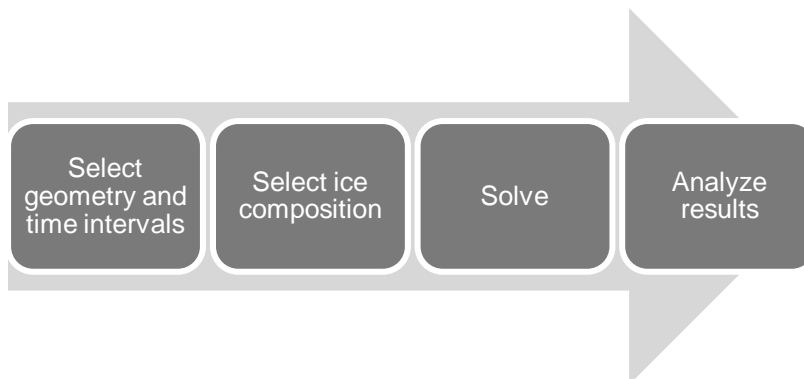
### Module Learning Outcomes:

1. Know the effect of overrun on the freezing time of ice cream
2. Know the effect of different ice cream composition on freezing time
3. Understanding how extent of freezing varies over the thickness of food being frozen

### Problem Details

Slabs of ice cream with different compositions are being frozen from both sides. They are 2 cm thick (half thickness 1 cm) and being frozen with coolant that is  $-10\text{ }^{\circ}\text{C}$ . Their initial temperature is  $2\text{ }^{\circ}\text{C}$ .

### Module Step by Step Procedure



### Model Set-up

1. Double Click on "CU\_IceCreamFreezing.xls"
2. Click cell A1 and click "open" on the COMSOL Ribbon
3. Select the file "CU\_IceCreamFreezing.mph" and click open
4. In the Excel spreadsheet (see below),
  - a. Enter ice cream composition in cells B12-B18 and B22-B28.
  - b. On the COMSOL ribbon, click the arrow under "Update" and click "update all"
  - c. On the COMSOL ribbon, click Compute
  - d. **When updating anything, you must click "update all" again before clicking "compute" again**

**Student Instructions for Simulation Module**  
(Intended for use by Undergraduate or Graduate Food Science and Engineering students)

The screenshot shows an Excel spreadsheet with two tables. The first table is titled 'Initial Product Composition of Mixture 1' and the second is 'Initial Product Composition of Mixture 2'. Both tables have three columns: Name, Expressions, and Description.

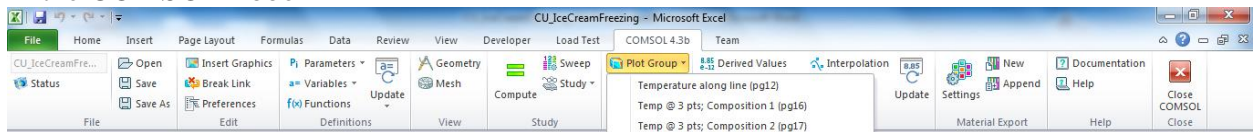
Initial Product Composition of Mixture 1		
Name	Expressions	Description
wt_Fat		0 Wt % of milk fat
wt_MSNF		0 Wt % of MSNF
wt_Sugar		21 Wt % of sugar
wt_CornSolid		1 Wt % of cornsolids
wt_Stab		0.5 Wt % of stabilizers
wt_Water		77.5 Wt % of water
overrun		50 % overrun

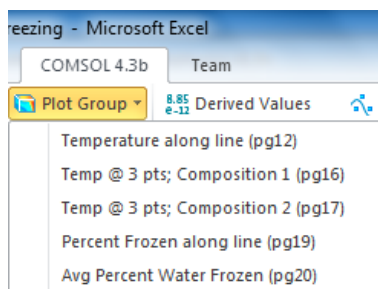
Initial Product Composition of Mixture 2		
Name	Expressions	Description
wt_Fat		0 Wt % of milk fat
wt_MSNF		7 Wt % of MSNF
wt_Sugar		14 Wt % of sugar
wt_CornSolid		1 Wt % of cornsolids
wt_Stab		0.5 Wt % of stabilizers
wt_Water		77.5 Wt % of water
overrun		50 % overrun

## Results

### 5. In the COMSOL ribbon



- a. To see a plot, click 'Plot group' and the plot you would like. It will appear in the COMSOL window then
- b. A list of plots is below. A description and picture of each is in the Appendix. There are 5 total.
- c. If you would like the plot, click 'insert graphics' on the COMSOL ribbon. The plot will be inserted into the Excel sheet



**Module Questions and Activities**

1. Using the weight composition of ice cream listed below:
  - a. how does the freezing time change between ice cream with 50% overrun and 100% overrun?
  - b. does the freezing time change by the same factor as the overrun (i.e. does the freezing time double as the % overrun is doubled)?
  - c. How does the percent frozen vary over the thickness of slab?

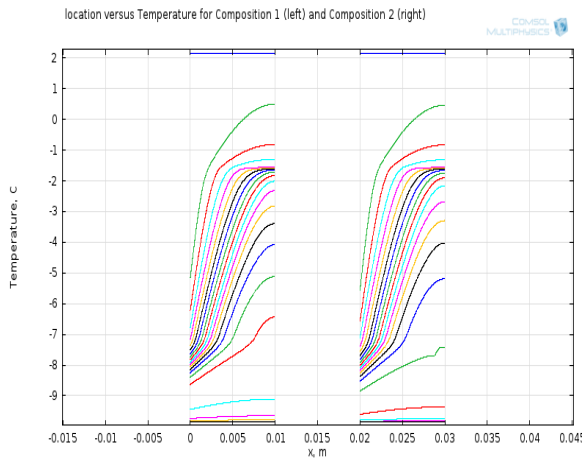
Components	Wt % of Ice Cream
<b>Milk Fat</b>	12
<b>MSNF</b>	11
<b>Sugar</b>	14
<b>Corn Solids</b>	1
<b>Stabilizer</b>	0.5
<b>Water</b>	61.5

2. How does the composition of ice cream (50% overrun) affect the freezing time and percent water frozen? What is the most important component? Use the following 4 ice cream combinations.

Components	Wt % of Ice Cream A (similar to ice/dessert cream)	Wt % of Ice Cream B (similar to milk ice)	Wt % of Ice Cream C	Wt % of Ice Cream D (similar to sorbet)
<b>Milk Fat</b>	12	5	0	0
<b>MSNF</b>	11	11	7	0
<b>Sugar</b>	14	21	14	21
<b>Corn Solids</b>	1	1	1	1
<b>Stabilizer</b>	0.5	0.5	0.5	0.5
<b>Water</b>	61.5	61.5	77.5	77.5

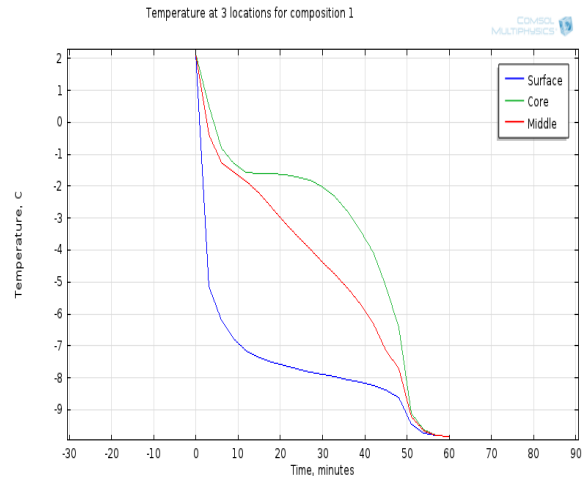
## Appendix

**The following are example plots for comparing freezing of sorbet at 2 different overrun (30% composition 1 and 50% composition 2)**



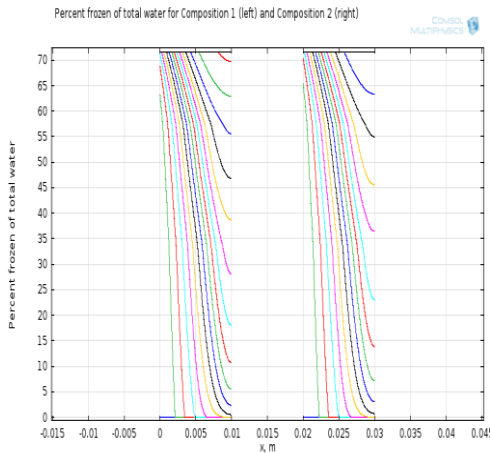
**Temperature along line (pg12)**

Composition 1 is left and Composition 2 is right. Temperature versus thickness (each line represents 5 minutes)



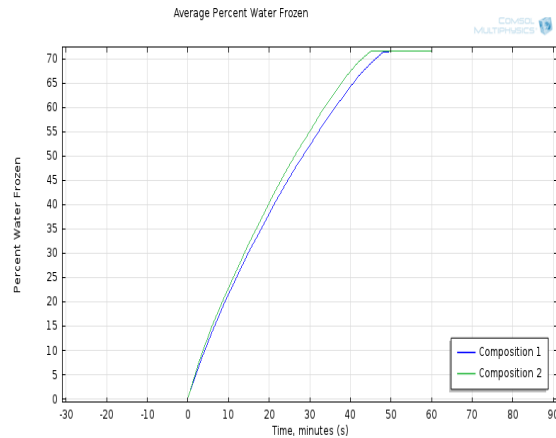
**Temp @ 3 pts; Composition 1 (pg16)**

Temperature versus time at 3 points for composition 1



**Percent Frozen along line (pg19)**

Composition 1 is left and Composition 2 is right. Percent frozen versus thickness (each line represents 5 minutes)



**Avg Percent Frozen Water (pg20)**

Average percent of frozen water for composition 1 and 2 versus time