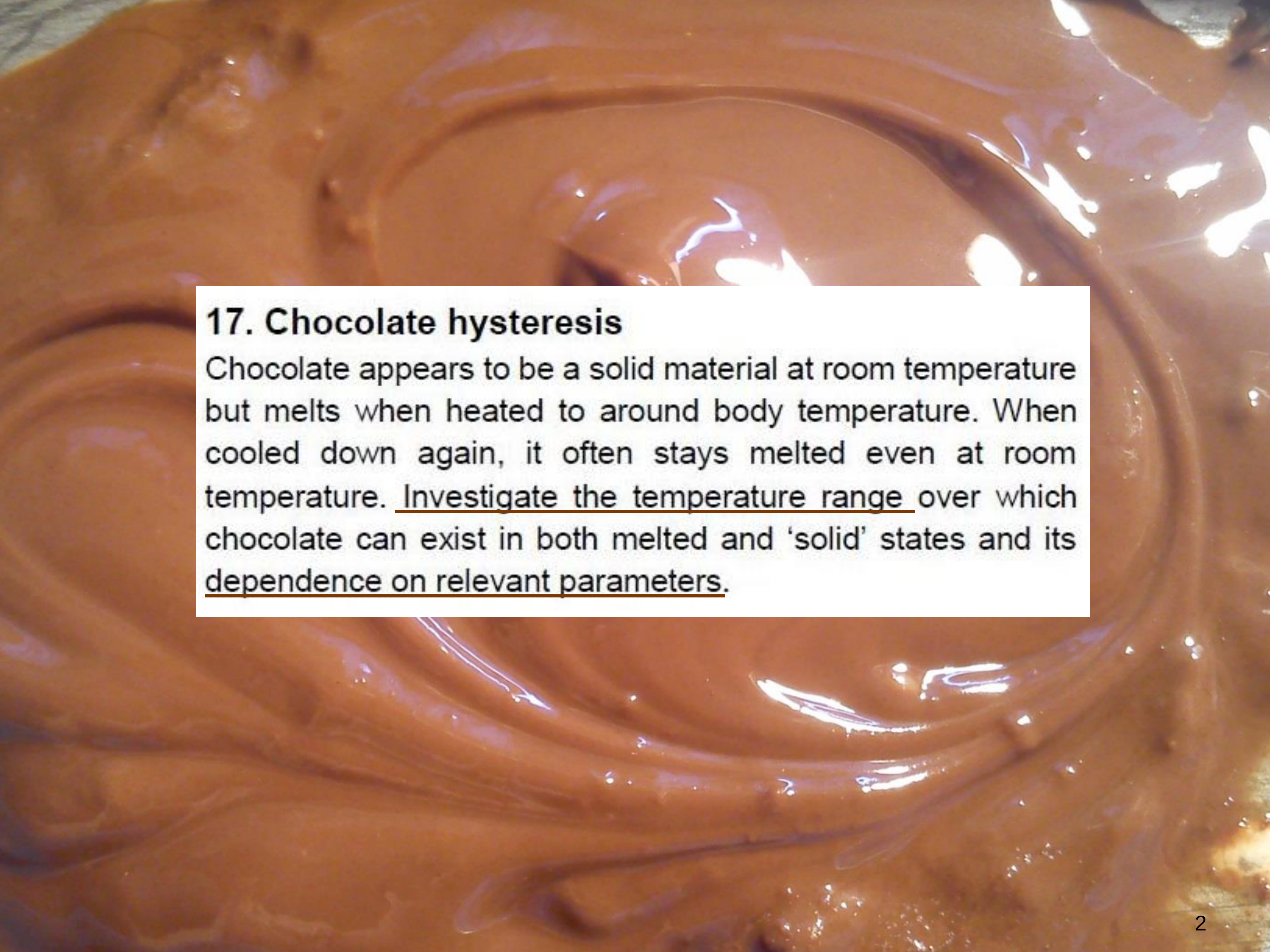
CHOCOLATE HYSTERESIS

IYPT 2014.

Team Croatia
Reporter: Ilona Benko



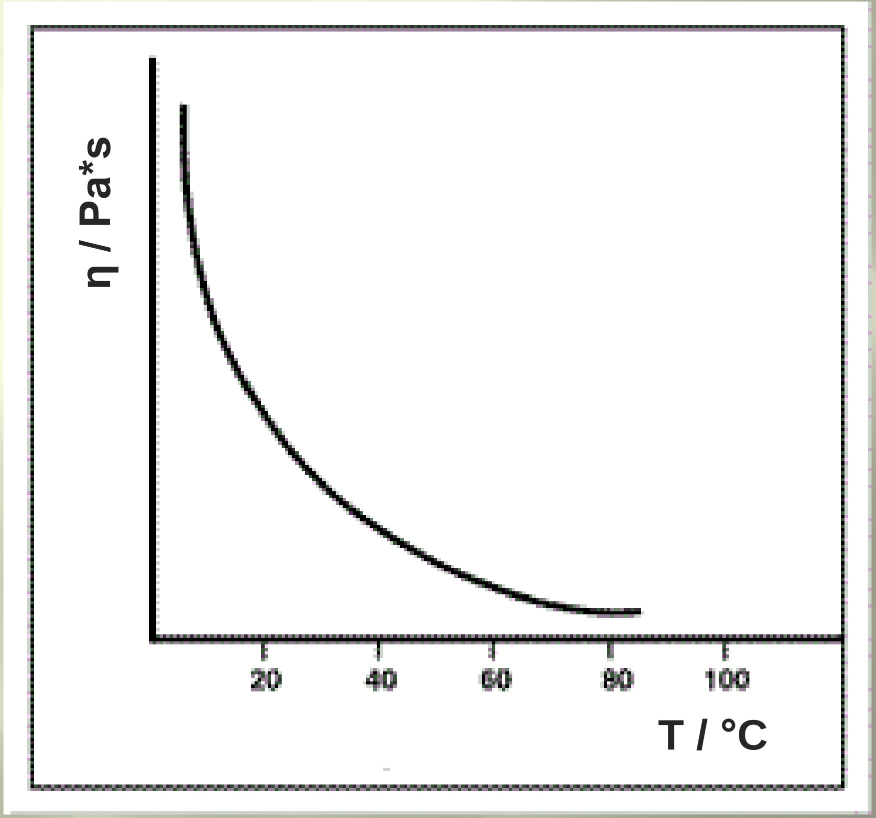
17. Chocolate hysteresis

Chocolate appears to be a solid material at room temperature but melts when heated to around body temperature. When cooled down again, it often stays melted even at room temperature. Investigate the temperature range over which chocolate can exist in both melted and 'solid' states and its dependence on relevant parameters.

Chocolate properties

- solid material
- melts at around body temperature
- has high viscosity when it is in liquid state
- sometimes, it takes a long while before it transists back from liquid into solid state
- properties and behaviour of milk and dark chocolate are different, and for our measurements dark chocolate samples were used

Chocolate viscosity



$\eta(T) = a^{T-24}$

$0 < a < 1$

At 24°C cristalization and viscosity rapidly increases.

$\eta(T) = 1{,}5 – 3{,}5$ Pa*s

Range of viscosity depends on:

- fat content 25 – 30%
- size of particles (< 30 μm)

References: Sandra Mary Rutson: Rheology of chocolate,
M. Gresham: Viscosity: A fluid’s resistance to flow

Strucure

- every chocolate is consisted of cocoa butter, sugar, cocoa dust and milk

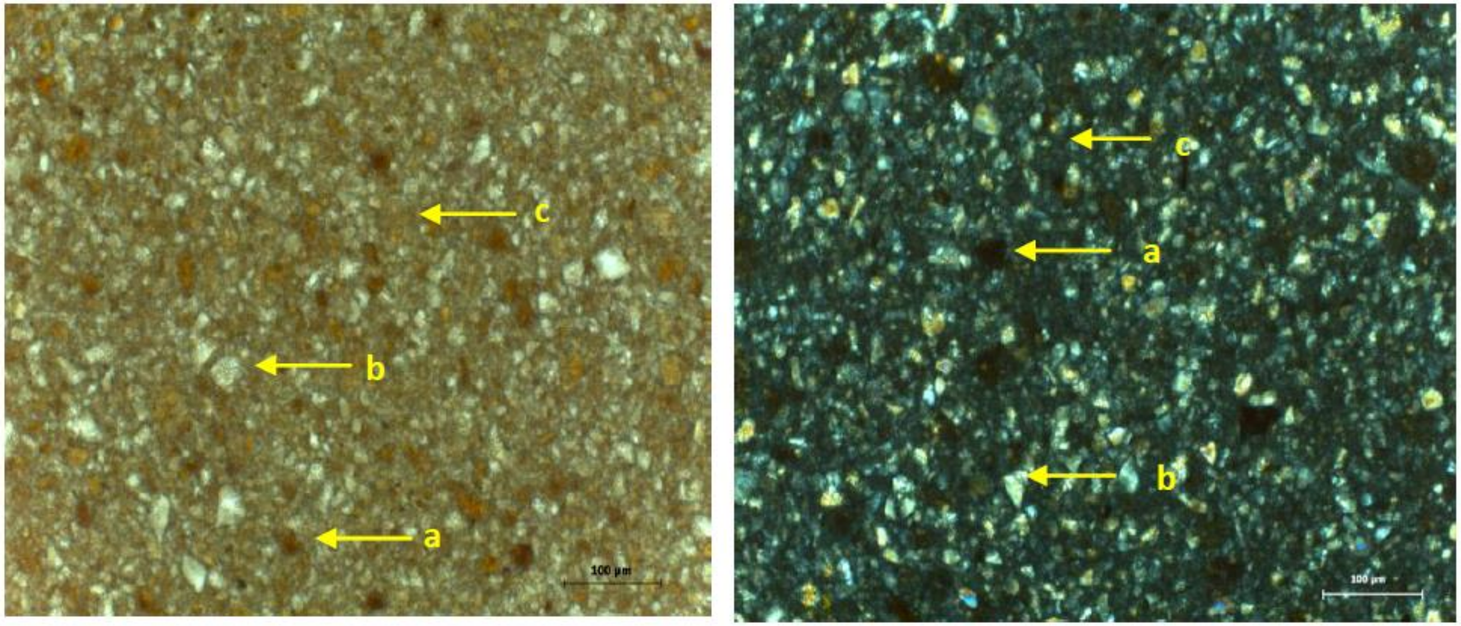
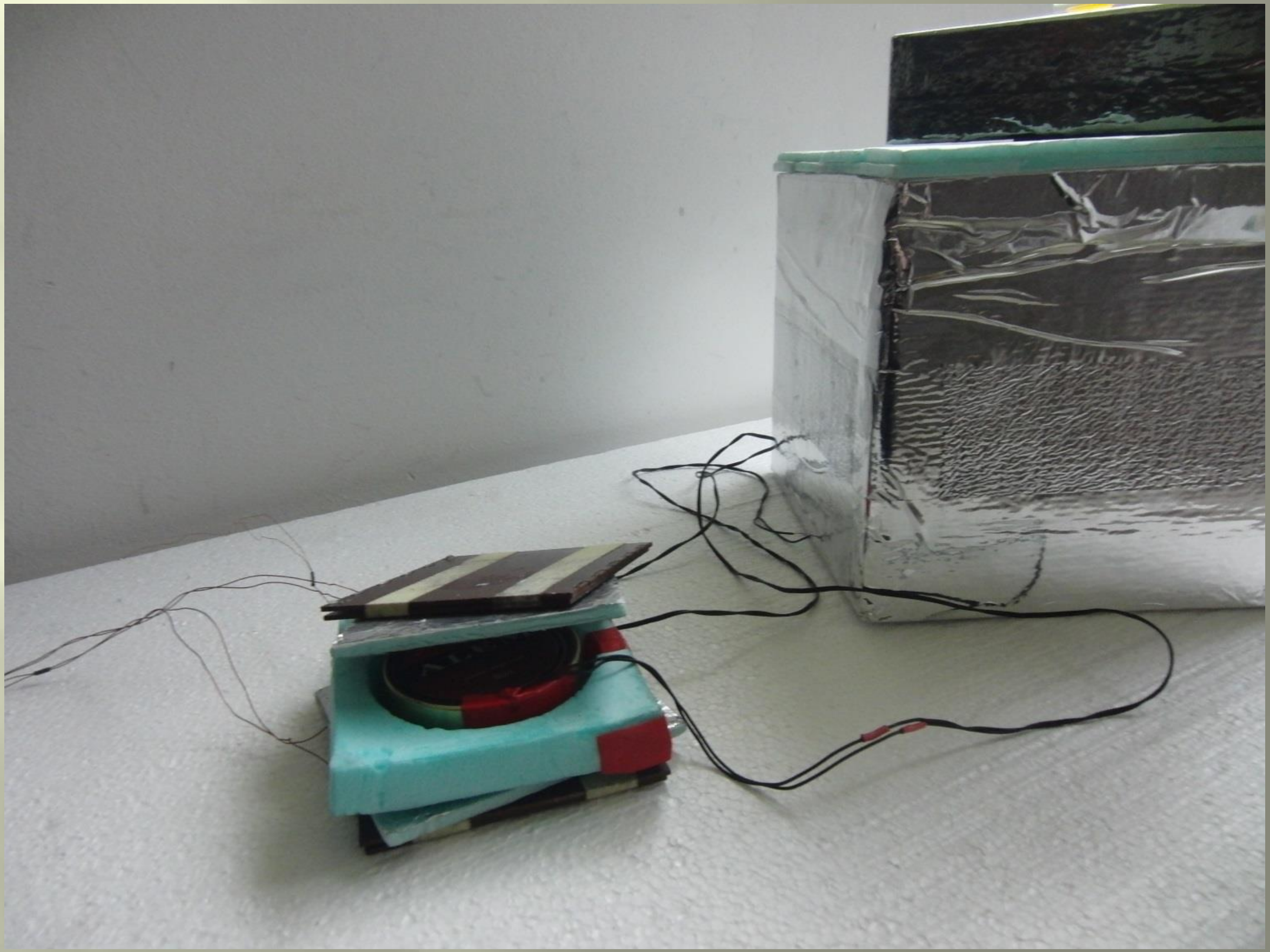


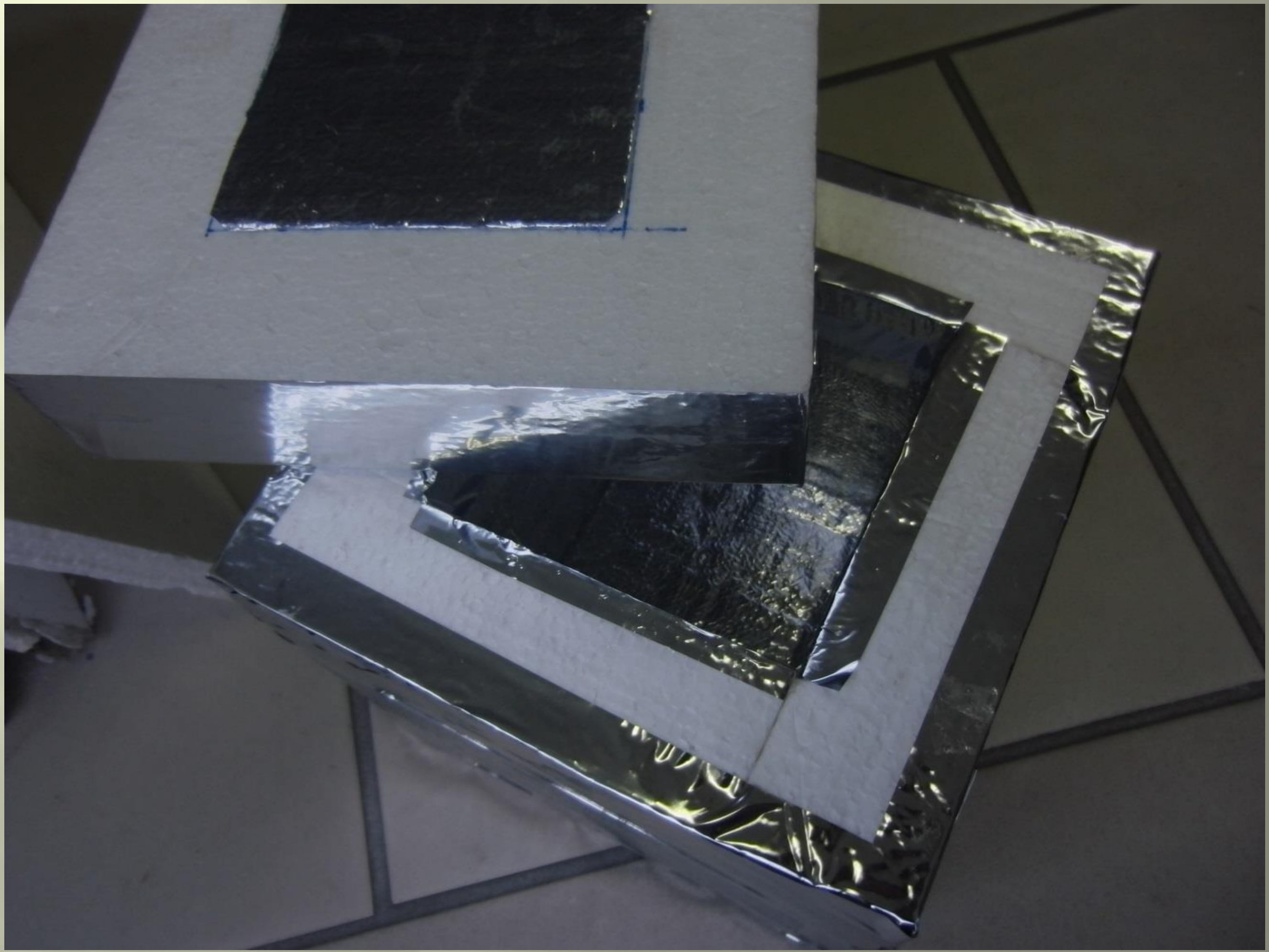
Figure 3-12 Dark chocolate microstructure viewed using bright field microscopy (left) and differential interference contrast (right) mode at 20X magnification. Cocoa particles (a); and sugar crystals (b) are indicated embedded in continuous fat phase (c).

References: Vish Gaikwad: Oral processing of dark and milk chocolate, New Zeland, 2012.

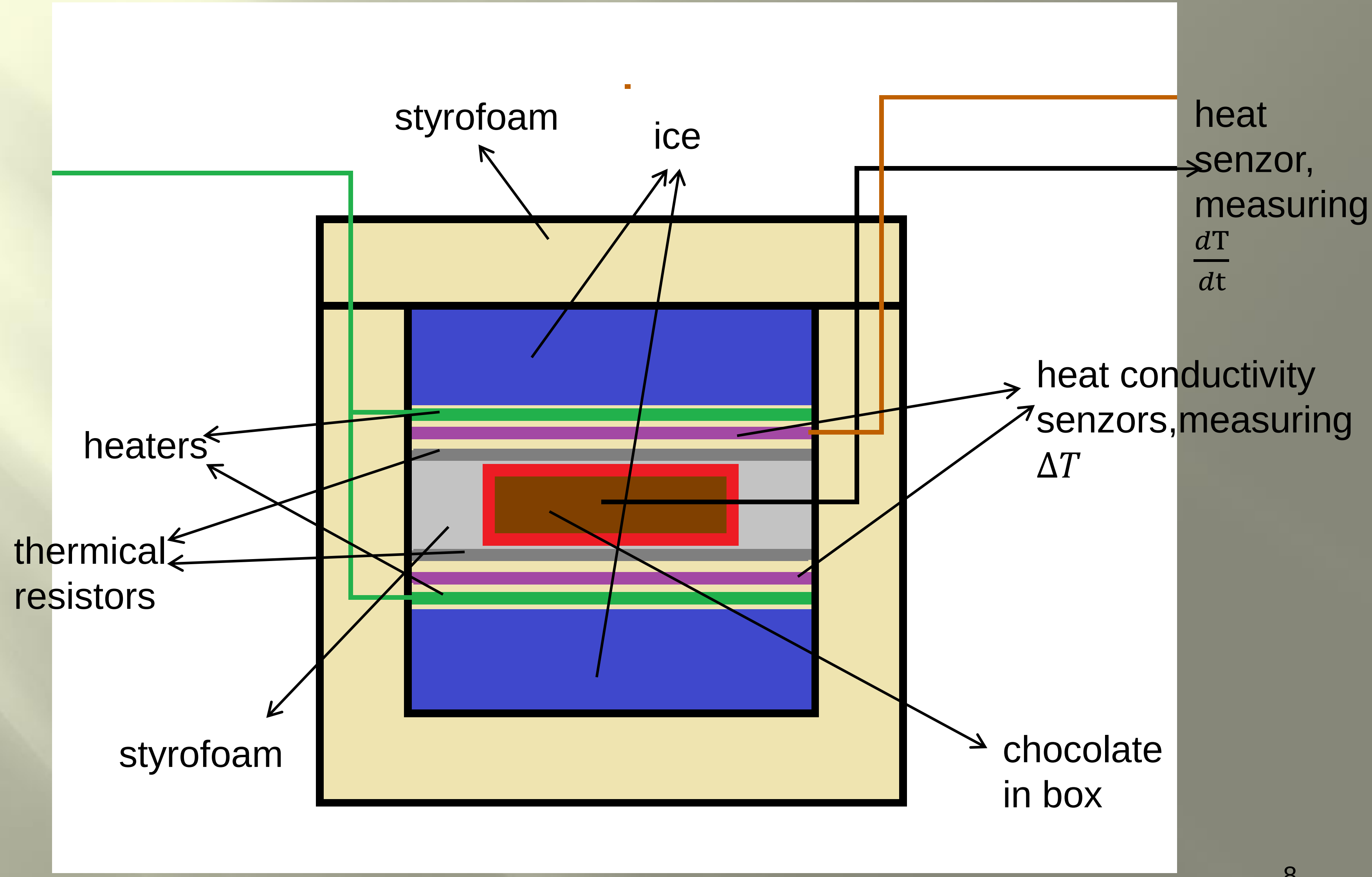
Calorimeter



Calorimeter

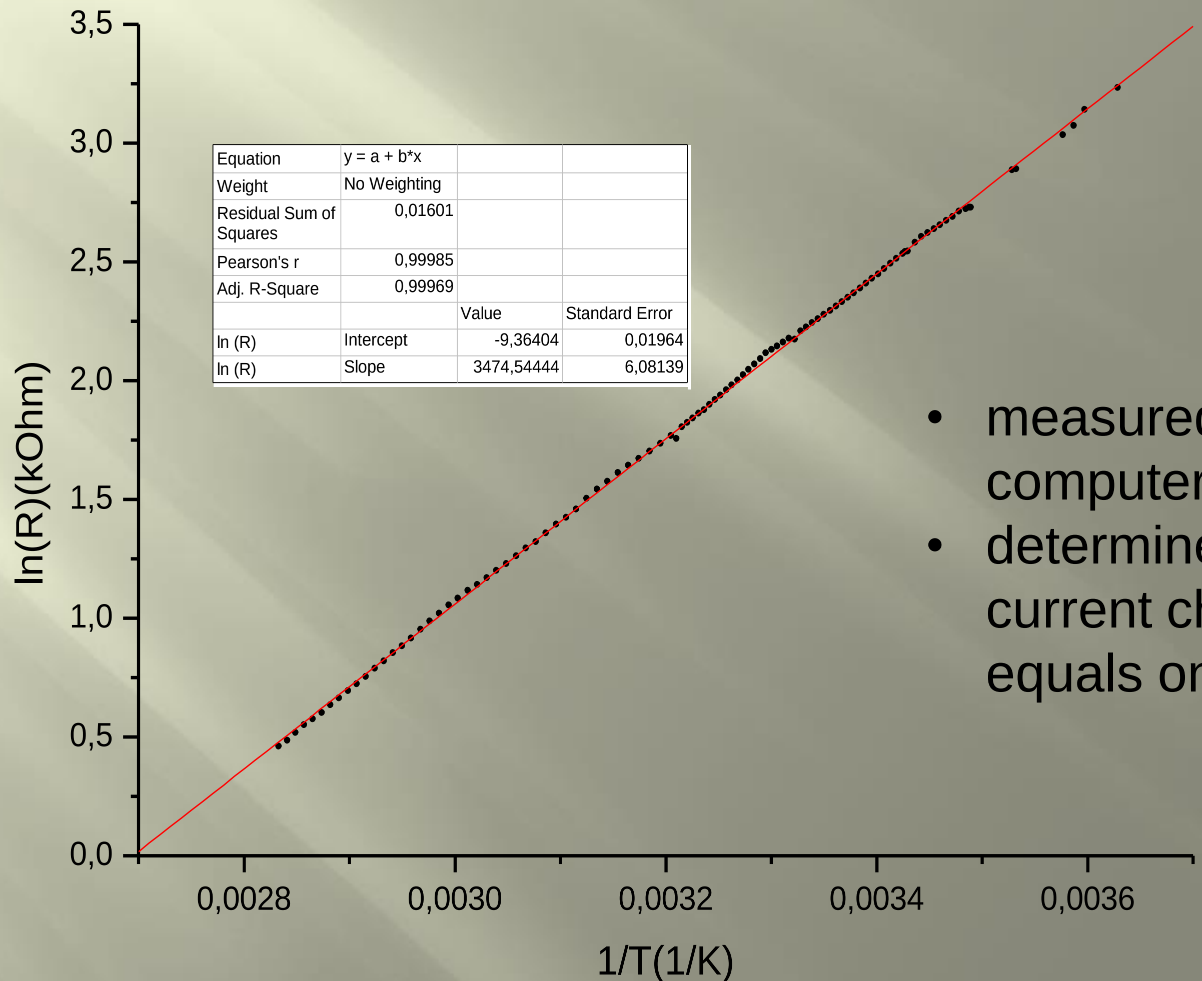


Calorimeter



Changes of resistance measured with computer

Calibration of termometer



Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	0,01601		
Pearson's r	0,99985		
Adj. R-Square	0,99969		
		Value	Standard Error
ln (R)	Intercept	-9,36404	0,01964
ln (R)	Slope	3474,54444	6,08139

- measured with computer
- determined which current change equals one Ohm

Mathematical model

Starting equasions:

$$Q = k\frac{S}{2d}\Delta T$$

$$Q = mC_p\frac{dT}{dt}$$

$$\Rightarrow \quad k\frac{S}{2d}\Delta T = mC_p\frac{dT}{dt}$$

Determinated function F:

$$F = \frac{\Delta T}{\frac{dT}{dt}} \text{ [s]}$$

Q - heat

k – heat conductivity

S – contact surface

d – thickness of conductivity senzors

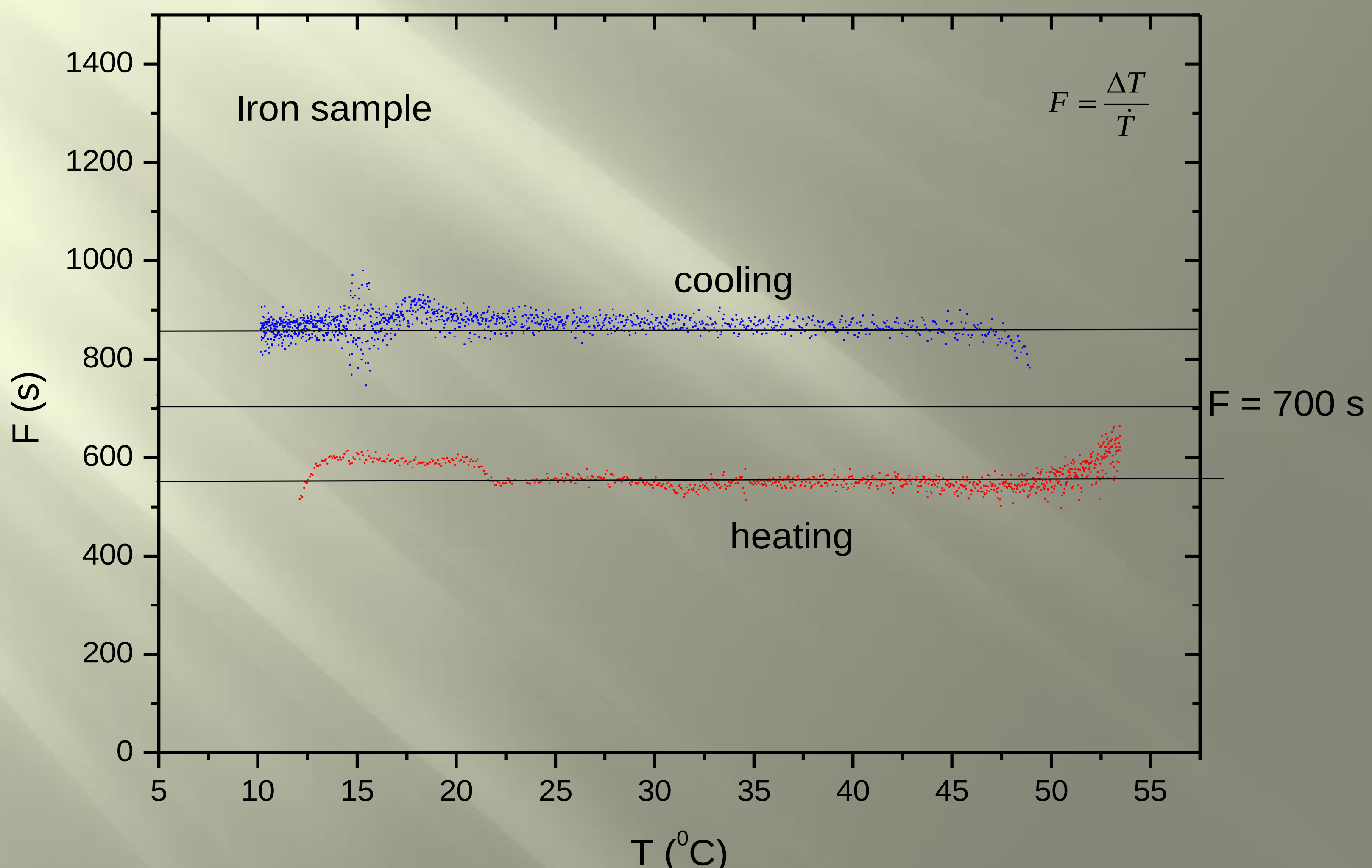
ΔT – change of tepmerature flow

dT/dt – change of temperature in time

m – mass of sample

C_p – heat capacity

Graph: heating and cooling iron sample



First measurment was done with an iron sample to determine which influence does the container have on our measurments and also to callibrate calorimeter.

m(Fe container) = 24 g

m(Fe sample) = 131 g

m(Fe total) = 155 g

C_p(Fe) = 450 J/kgK

mC_p (Fe) = 69.75 J/K

S = 0.0041 m^2 - contact surface

d = 0.005 m – thickness of conductivit senzor

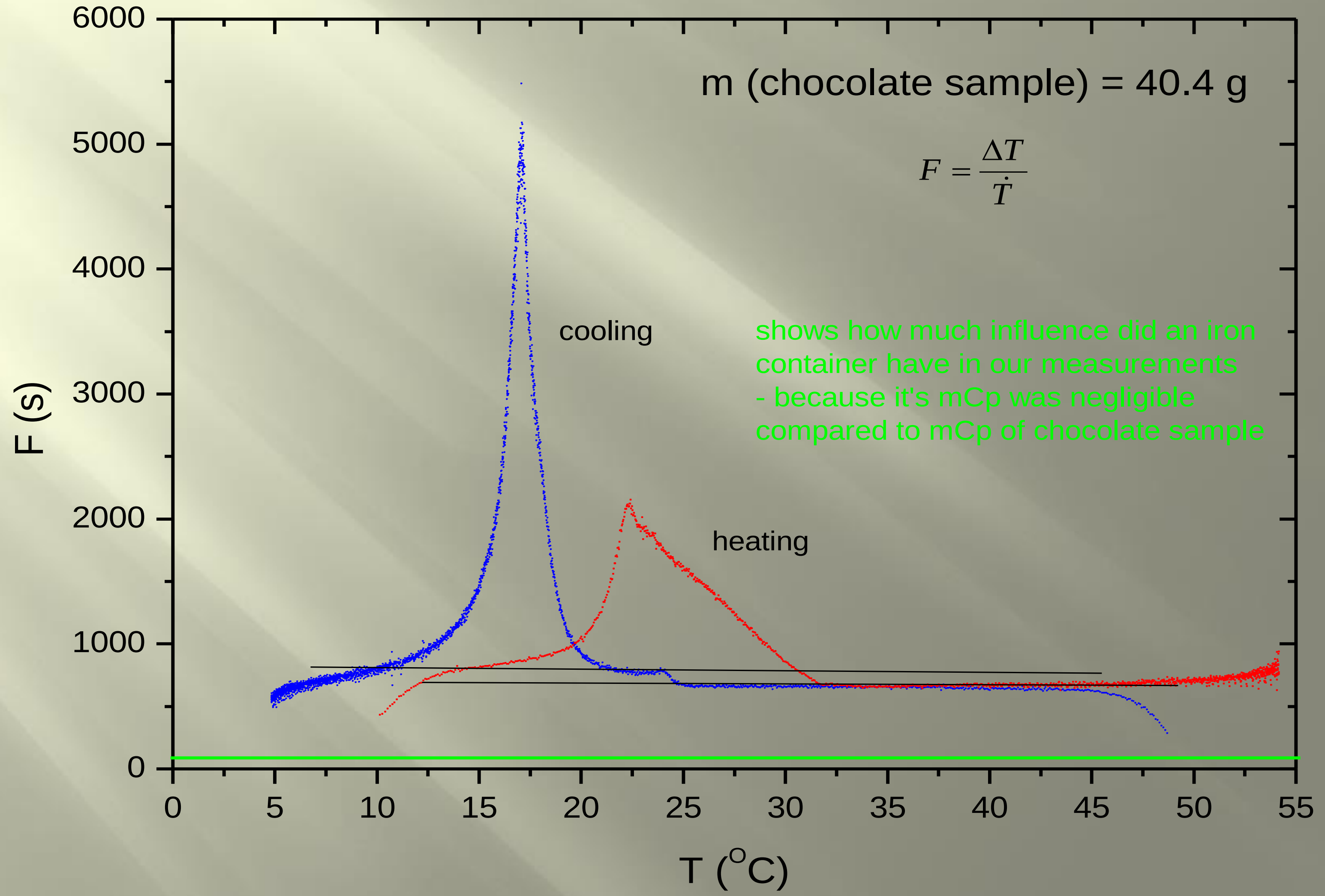
F = 700 s – for iron

Result:
k = 0.061 Watt/kgK

$$mC_p = k \frac{S}{2d} * F$$

for thermical resistors used in calorimeter

Graph: heating and cooling chocolate sample

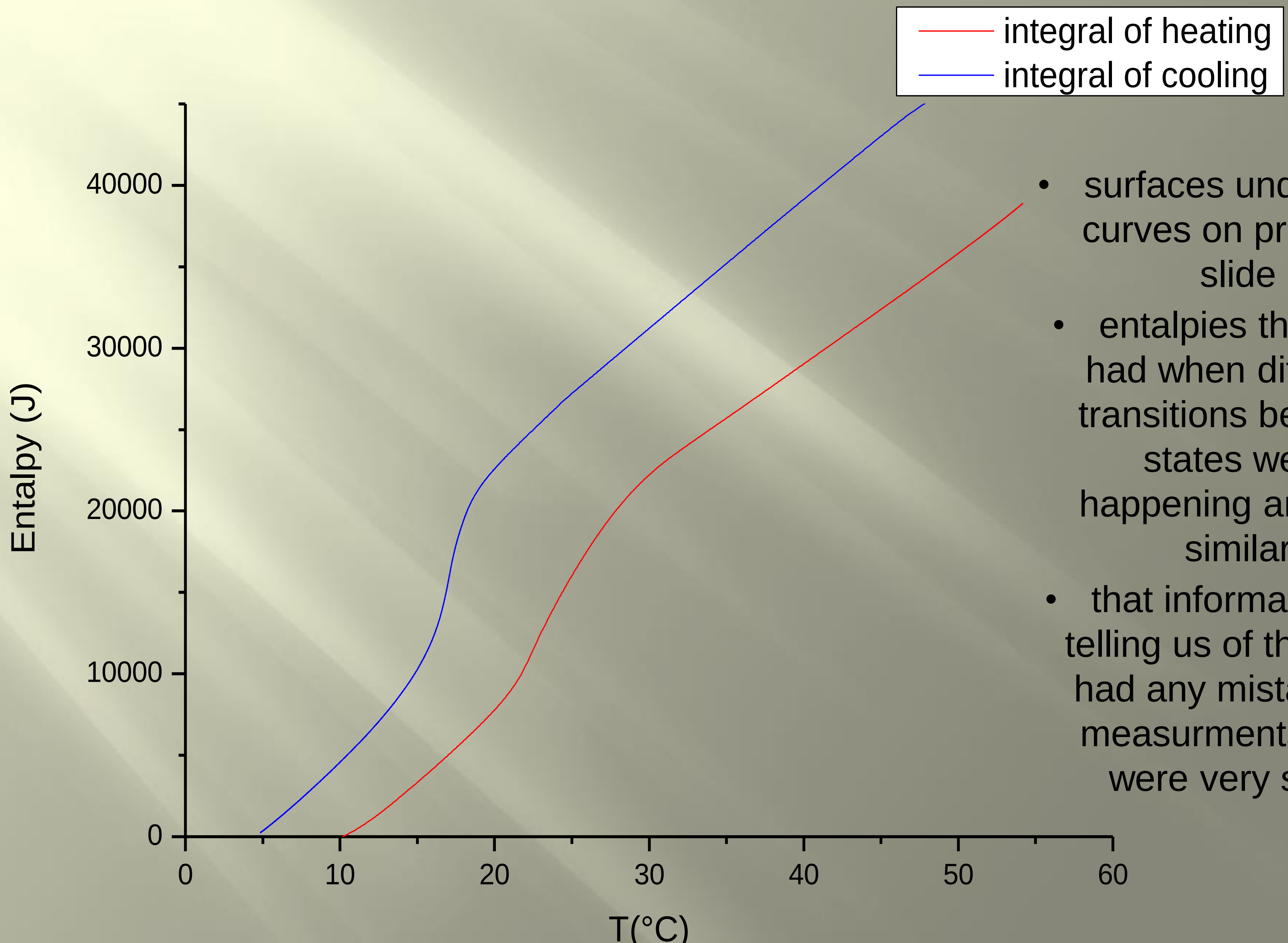


After we have determined k of our thermical resistors (which were the same for all measurements), we determined F from cooling and heating chocolate sample.

Then we were able to calculate thermal capaticity of our chocolate sample:

$$C_p(\text{chocolate}) = 1810 \text{ J/kgK}$$

Analysing entalpies



- surfaces under the curves on previous slide
- entalpies that we had when different transitions between states were happening are very similar
- that information is telling us of that if we had any mistakes in measurments, they were very small

Determinating ranges

- the same sample was heated and cooled in calorimeter five times

Results:

- **lowest temperature of chocolate in liquid state:**
  - last cooling of the same sample
  - at **12°C** we had highest entalpy
- **highest temperature of chocolate in solid state**:
  - at **23°C** we had highest entalpy
    - that means that process of transition started

Picture of our chololate sample when it was taken from our container and was heated and cooled for the sixth time. ‘Blooming’ of fat and sugar particles.

Conclusion

- we determinated highest temperature at which our sample could exist at solid state and lowest temperature at which it can exist at liquid state and measured chocolate hysteresis and determined on which parameters does it depend and how
- hysteresis shows how some systems can ‘remember’ states in which they had existed before
- chocolate hysteresis happens because of aglomeration of sugar and cocoa butter particles when it transists from solid into liquid state

Literature list

- Messtecnik: Introduction to rheology
- Vish Gaikwad: Oral processing of dark and milk chocolate
- Sandra Mary Rutson: Rheology of chocolate - Rheological studies of chocolate in relation to their flow and mixing properties
- Gebhrad Schramm: A practical approach to rheology and rheometry
- Radosavljevic, Schlunk: Melting chocolate
- M. Anandha Rao: Rheology of fluid and semisolid foods
- M. Gresham: Viscosity: A fluid's resistance to flow

Thank you for your attention!

Calibration of thermometer