DryingMate A/S

Energy aspects and practical challenges

Ebbe Nørgaard, Director.

DryingMate A/S

Content (21 slides)

DryingMate A/S

- Who/what is DryingMate A/S?
- Energy consumption in Drying
- Business case / payback
- Practical challenges
- Summary / Conclusions

Who/what is DryingMate A/S?

DryingMate A/S

- Mechanical Engineer
- 13 Years at the Energy division – Refrigeration and Heat Pump centre, Danish Technological Institute
- Courses, projects, etc. within Drying - 6 Years
- DryingMate A/S, 2½ Years old – started with a partner
- Business plan – Energy efficient drying systems for temperature sensitive products
- Vacuum drying combined with Heat Pump

Energy consumption in Drying

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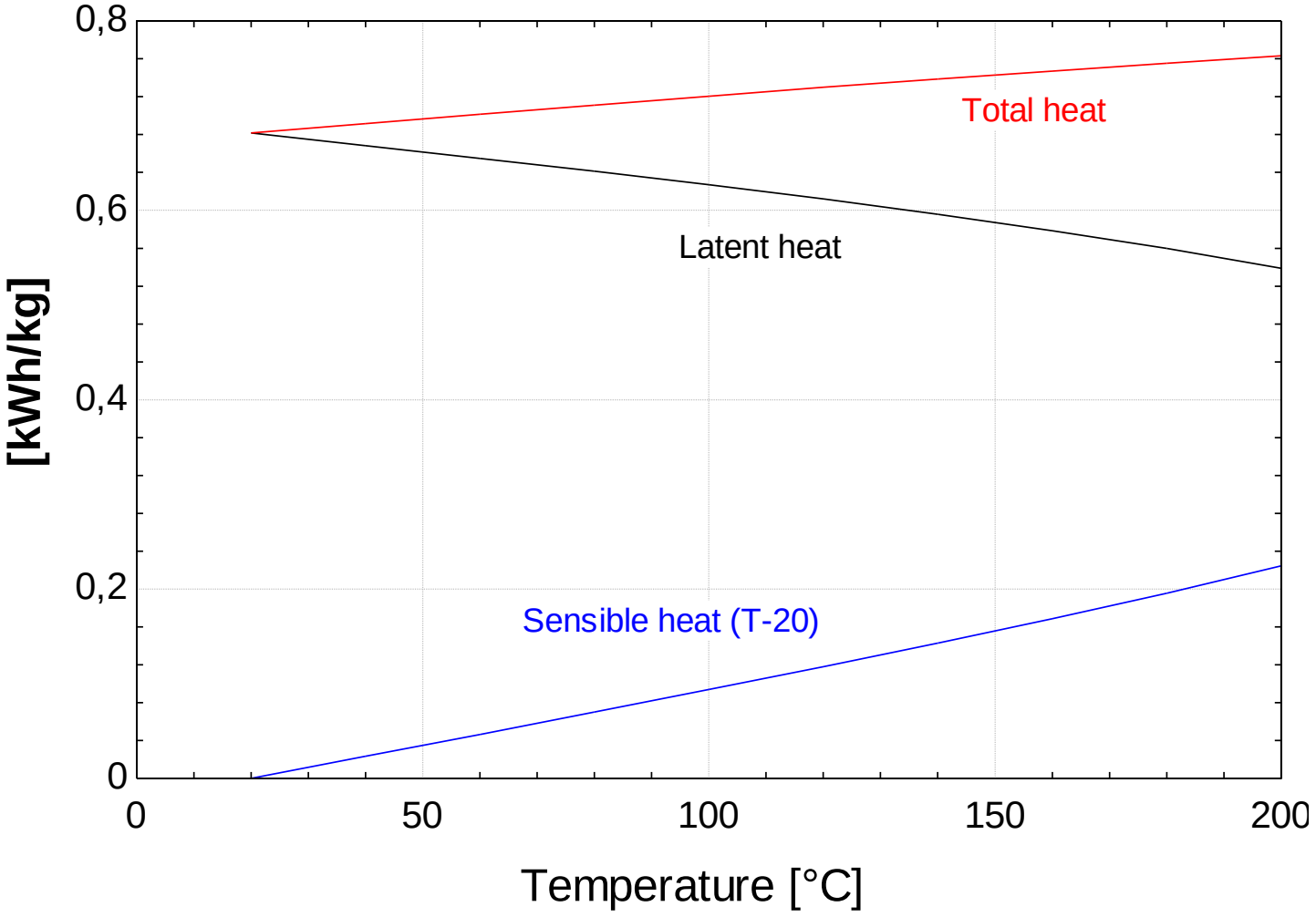
Specific energy for water



Drying is very energy intensive – in comparison

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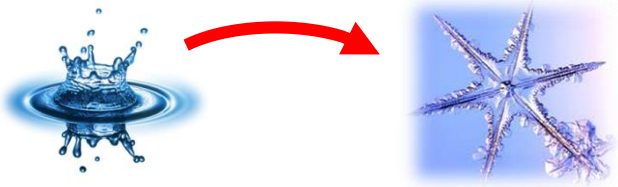
Evaporation of 1 kg water

~ 0,7 kWh/kg

Freezing 1 kg water

0,1 kWh/kg



Relative: 7

Drying efficiency

If: kWh/kg = 0,7 then $\eta = 1$

If: kWh/kg > 0,7 then $\eta < 1$

If: kWh/kg < 0,7 then $\eta > 1$

Evaporation of water cools well

Typical specific energy consumption for industrial drying processes in Denmark

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Dryer types	Typical energy consumption		
	[kJ/kg water]	kcal/kg water	[MWh/ton]
Convection dryers			
Conveyer dryers	4000-6000	957-1435	1,1-1,7
Tunneldryers	5500-6000	1316-1435	1,5-1,7
Owens	5000-5800	1196-1388	1,4-1,6
Rotorowen	4500-9000	1077-2153	1,3-2,5
Fluid bed	4000-6000	957-1435	1,1-1,7
Flash	4500-9000	1077-2153	1,3-2,5
Spray	4500-11500	1077-2751	1,3-3,2
Steam			
Vacuum	2900-4600	694-1100	0,8-1,3
Atmospheric	2500	598	0,7
High pressure	2500	598	0,7
Heat pump	500-1100	120-263	0,1-0,3
Contact dryers			
Drum	3200-6500	766-1555	0,9-1,8
Roller	2900-5700	694-1364	0,8-1,6
Spiraltube	3400	813	0,9
Screw	3400-5600	813-1340	0,9-1,6
Gas based infra red dryers	3500-9500	837-2273	1,0-2,6
Radiant dryers			
Radiofrequency	5300	1268	1,5
Microwave	6400	1531	1,8
Freeze drying	10000	2392	2,8
Infrared	3300-5600	789-1340	0,9-1,6

If: kWh/kg = 0,7 then $\eta = 1$

If: kWh/kg > 0,7 then $\eta < 1$

If: kWh/kg < 0,7 then $\eta > 1$

SHS: $\eta \approx 1$

SHS + heat pump: $\eta \approx 2,5 - 7$

Energy used for

1. Water heating / evaporation
2. Solids heating
3. Auxilary equipment
4. Heat loss
5. Exhaust waste heat

Source: Danish Energy agency (1998)

Simple pedagogical/banal example

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Q_spec = 2,8 kWh/kg
100 g
1900 g water evaporated
5,3 kWh
=
60 W light bulb on for 89 hours (3,7 days)

Declaration of energy consumption!!

DryingMate drying concept
Business cases / payback

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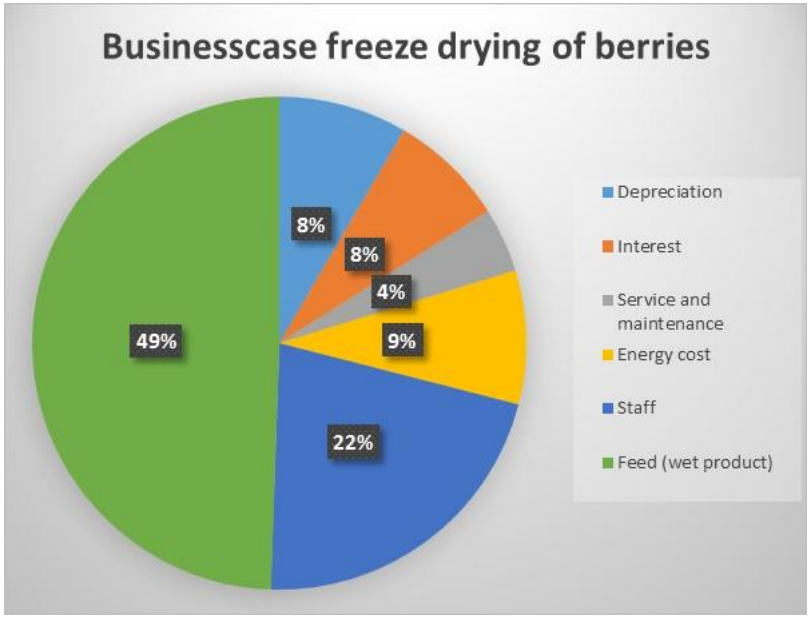
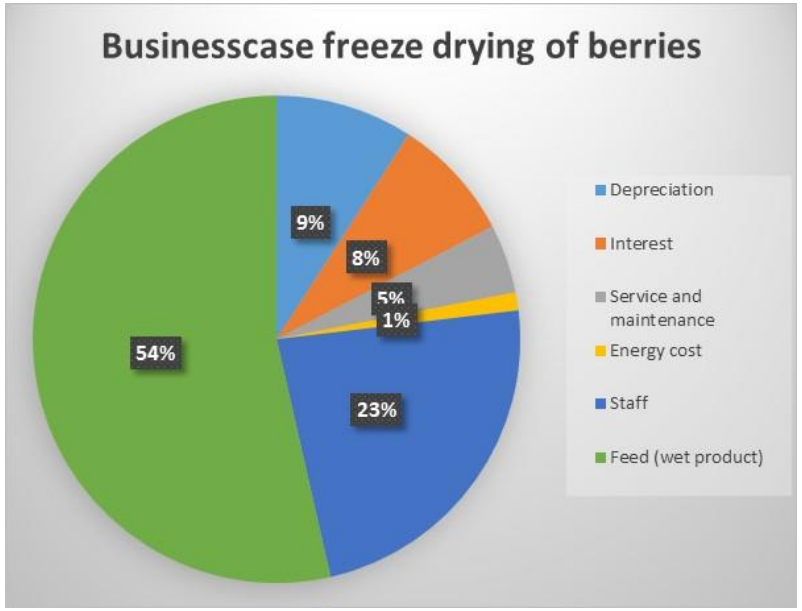


- Depreciation period 10 Years
- Interest 10 %
- Service and maintenance 5 % of investment
- Energy cost 100 Euro/MWh (0,75 kr/kWh)
- Specific energy consumption **2,8 kWh/kg**
- Yearly energy cost **63.000 Euro/Year**



- Depreciation period 10 Years
- Interest 10 %
- Service and maintenance 5 % of investment
- Energy cost 100 Euro/MWh (0,75 kr/kWh)
- Specific energy consumption **0,35 kWh/kg**
- Yearly energy cost **8.000 Euro/Year**

Business cases / payback

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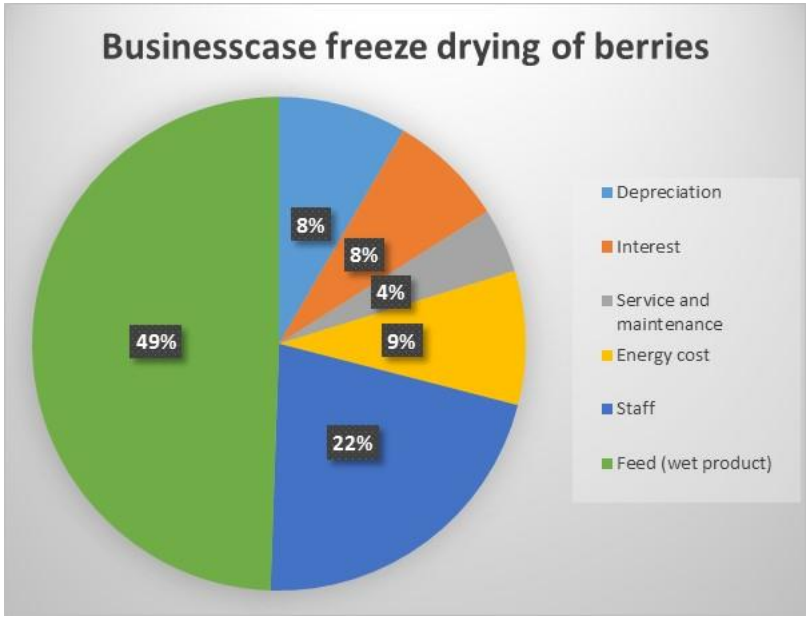
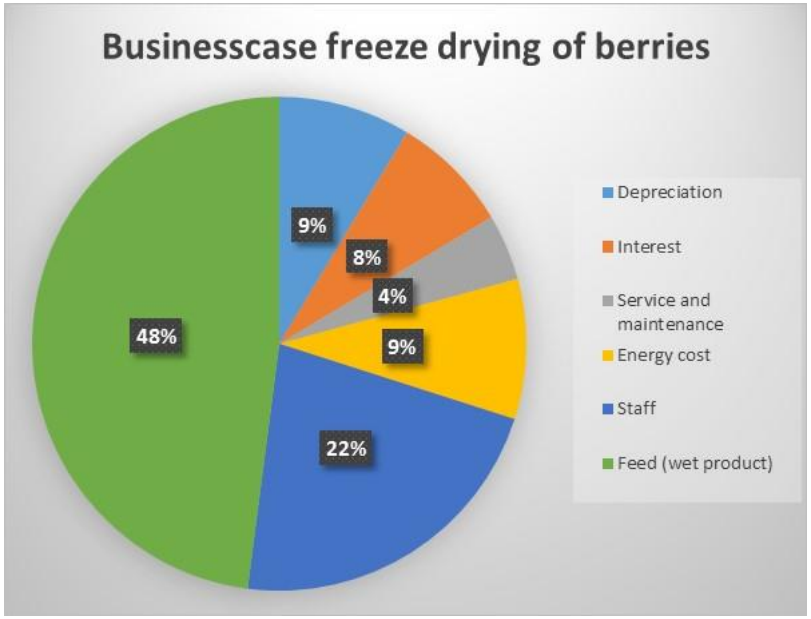


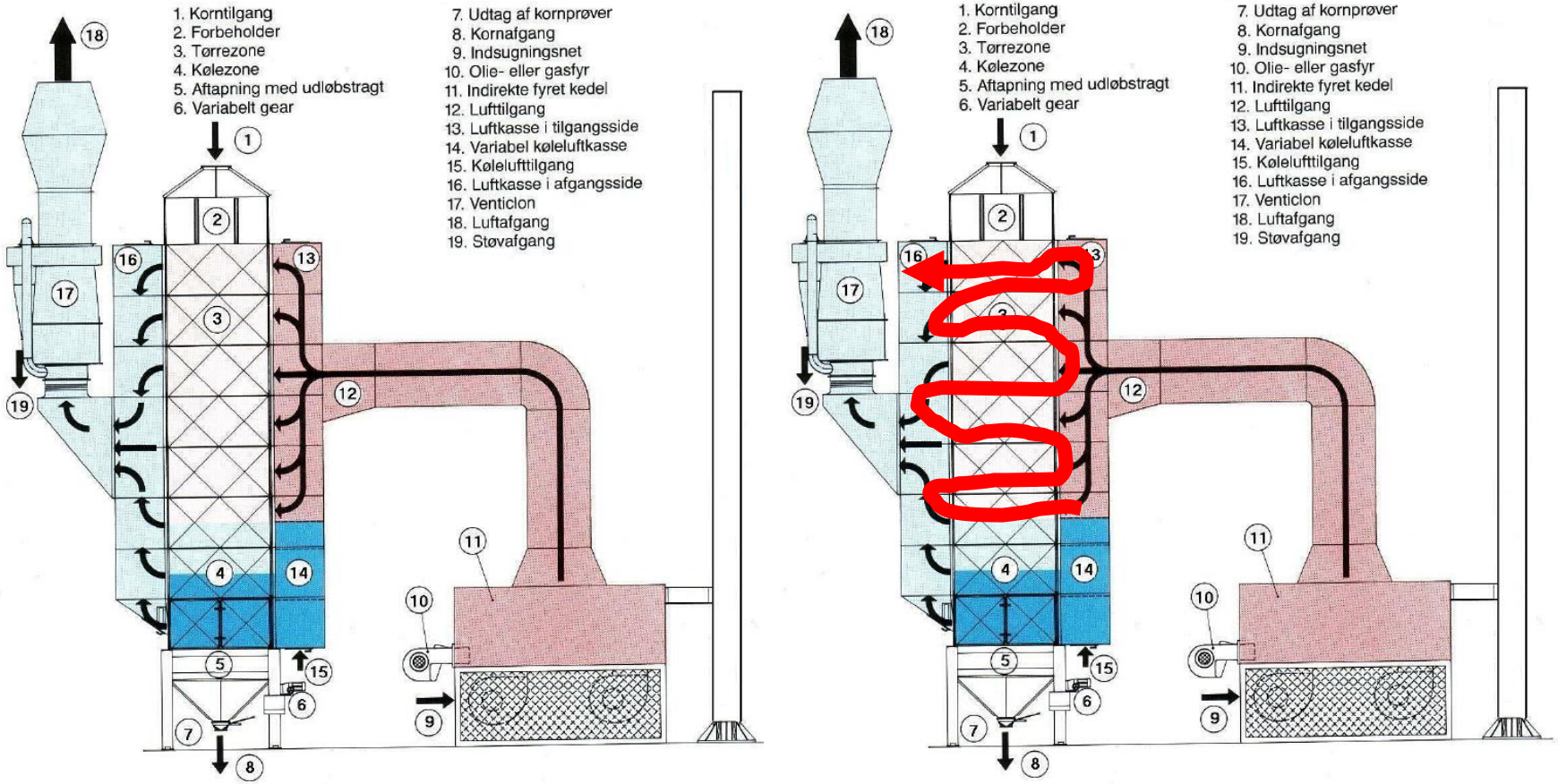
- Water content init 80% (wet basis)
- Water content end 15% (wet basis)
- Specific energy consumption **2,8 kWh/kg**
- Yearly energy cost **63.000 Euro/Year**
- Bottom line **328.000 Euro/Year**



- Water content init 80% (wet basis)
- Water content end 10% (wet basis)
- Specific energy consumption **2,8 kWh/kg**
- Yearly energy cost **64.000 Euro/Year**
- Bottom line **288.000 Euro/Year**

Drying of grain – business case

DryingMate A/S



Importance of water measurement varies a lot – depending on type of dryer

Drying of grain

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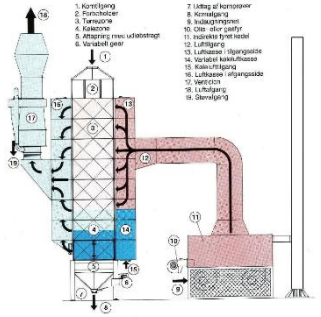
Annual production	kg	32.000.000
Initial moisture, avg	%	22,00
Final moisture, avg	**%**	**16,00**
Annual, dry mass		24.960.000
Initial water content	kg	7.040.000
Final water content	kg	4.754.286
Differnce, water	kg	2.285.714
Spec energy	kJ/kg	7.500
Evaporation energy	kJ	17.142.857.143
Evaporation energy	kWh	4.761.905
Energy price	EUR/kWh	0,04000
Annual price	EUR	190.476

Annual production	kg	32.000.000
Initial moisture, avg	%	22,00
Final moisture, avg	**%**	**15,50**
Annual, dry mass		24.960.000
Initial water content	kg	7.040.000
Final water content	kg	4.578.462
Differnce, water	kg	2.461.538
Spec energy	kJ/kg	7.500
Evaporation energy	kJ	18.461.538.462
Evaporation energy	kWh	5.128.205
Energy price	EUR/kWh	0,04000
Annual price	EUR	205.128

Annual production	kg	32.000.000
Initial moisture, avg	%	22,00
Final moisture, avg	**%**	**13,00**
Annual, dry mass		24.960.000
Initial water content	kg	7.040.000
Final water content	kg	3.729.655
Differnce, water	kg	3.310.345
Spec energy	kJ/kg	7.500
Evaporation energy	kJ	24.827.586.207
Evaporation energy	kWh	6.896.552
Energy price	EUR/kWh	0,04000
Annual price	EUR	275.862

Difference/Year	
Energy	**366.300 kWh**
Economy	**14.652 EUR**
Dif, product mass	**175.824 kg**

Difference/Year	
Energy	**1.768.347 kWh**
Economy	**70.734 EUR**
Dif, product mass	**848.806 kg**



Barriers for doing it better.

- Energy cost is forwarded to the customer
- Extremely busy – no time for second chance

Practical challenges

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- **Many different drying methods / conditions and products**
- Inline measurement vs. laboratory measurement
- Harsh environment – dust, deposits, temperature etc.
- **Drying kinetics – unsteady state**
- Biological products can behave differently during drying
  - Ex. Wood from Westend of forrest vs. Eastend
- **DryingMate challenge**

Practical challenges

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Different type of dryers

- How is the heat transferred?
  - Convection
  - Conduction
  - Infrared (IR)
  - Dielectric (microwaves, radiofrequency)

- How is the product handled?
  - Fluid bed
  - Spray
  - Continuous
  - Batch
  - Band
  - Drum
  - Many others

- What is the condition of the environment?
  - Media (gas, liquid)
  - Pressure
  - Temperature
  - Partial pressure of water

Practical challenges - Drying Kinetics

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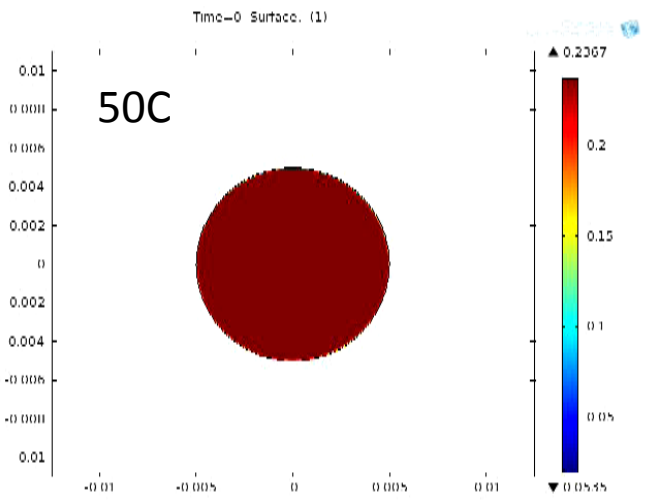
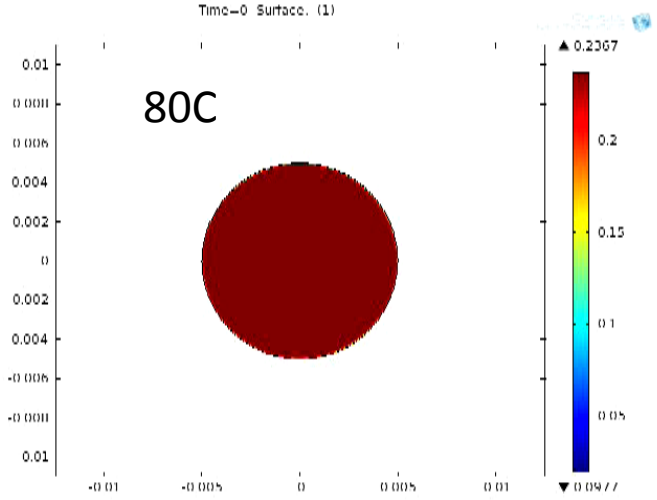
- How fast does heat and mass transfer occur?
- Non equilibrium state





Source: Teknologisk Institut

Drying Kinetics

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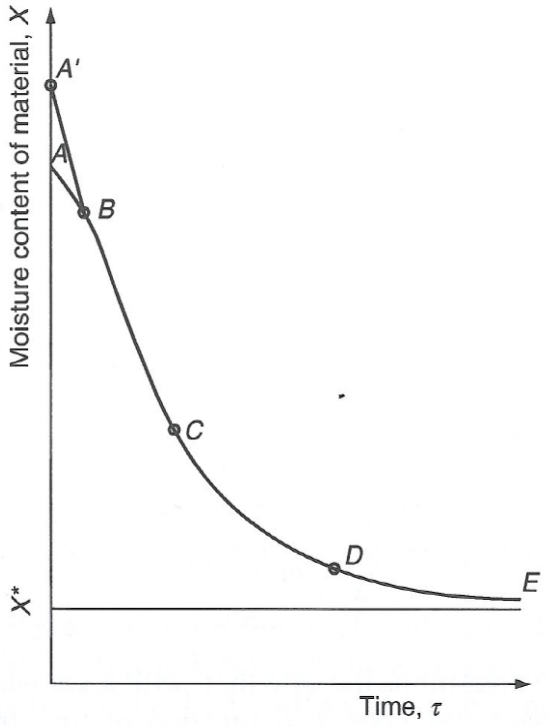
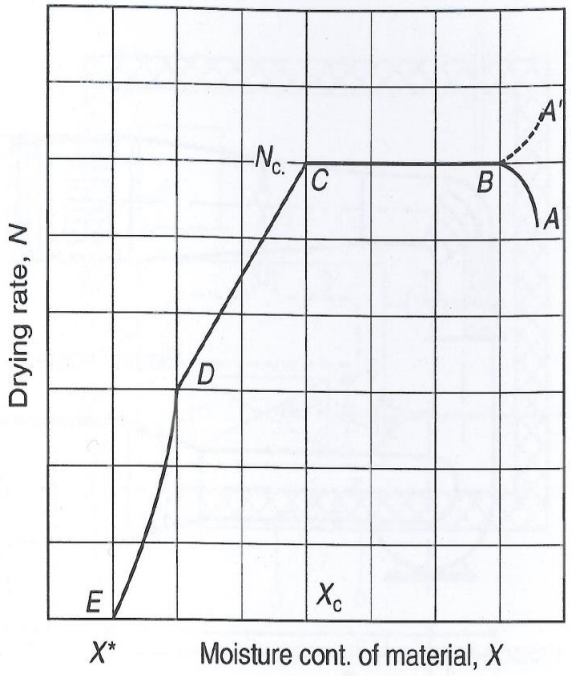
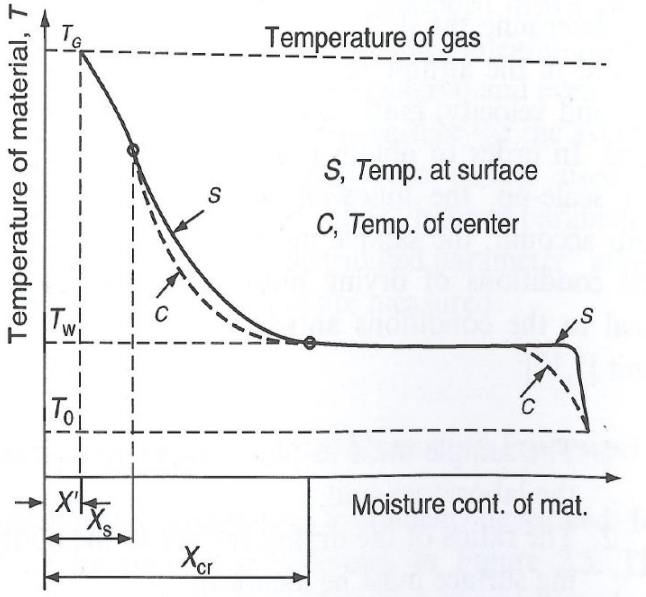
- A-B: warming up
- B-C: Constant rate period, evaporation of free moisture from surface
- C-D og D-E: Falling rate period, dry spots on the surface, diffusion of moisture from centre towards surface







Drynetics™ (Niro)

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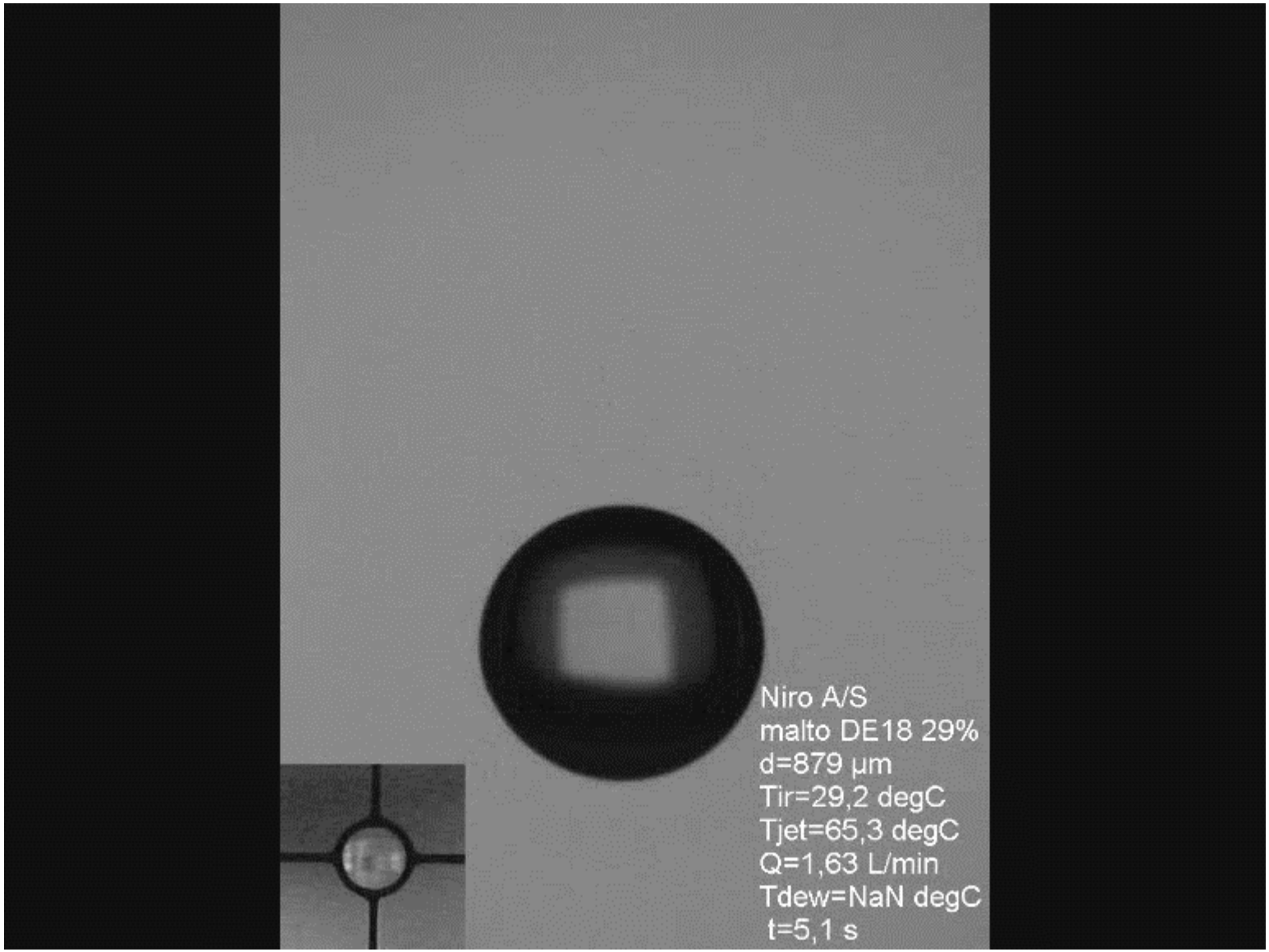

Equilibrium moisture content

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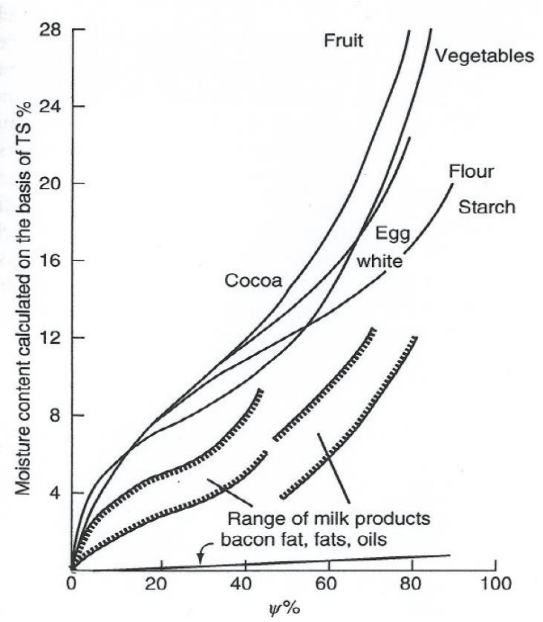
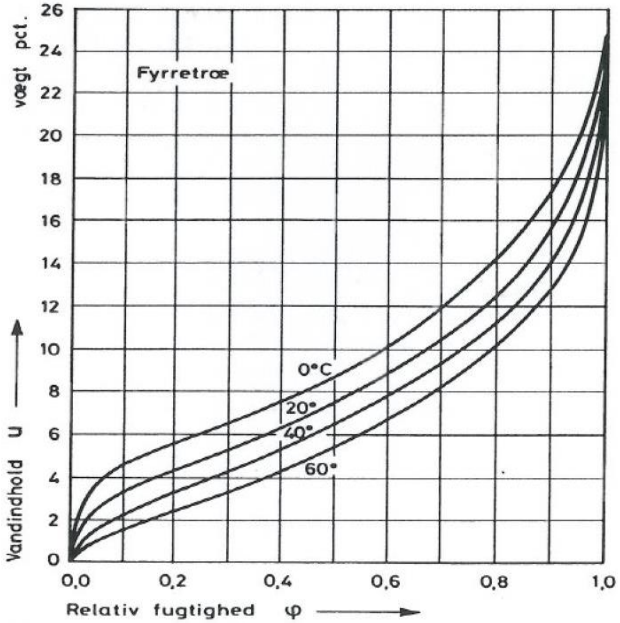
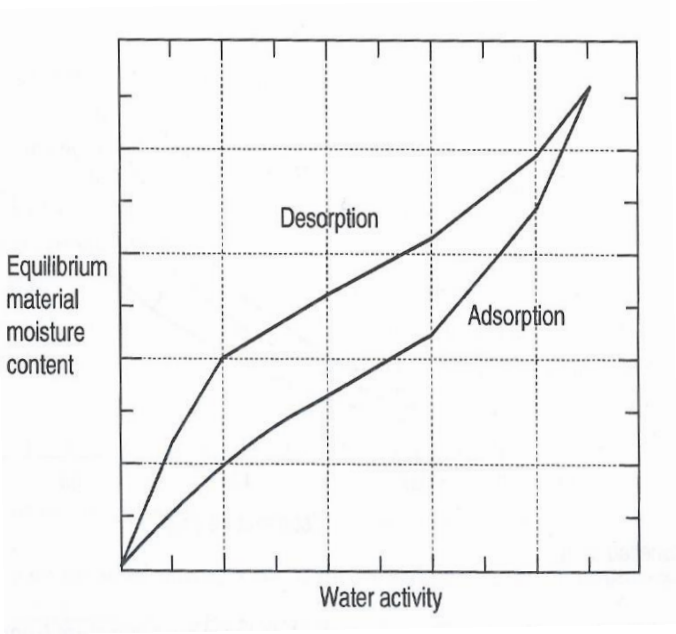




Figur 6.13 *Sorptionskurver for træ i afhængighed af temperaturen.*



Potential temperature dependency

Potential hysteresis

Diffusion coefficient

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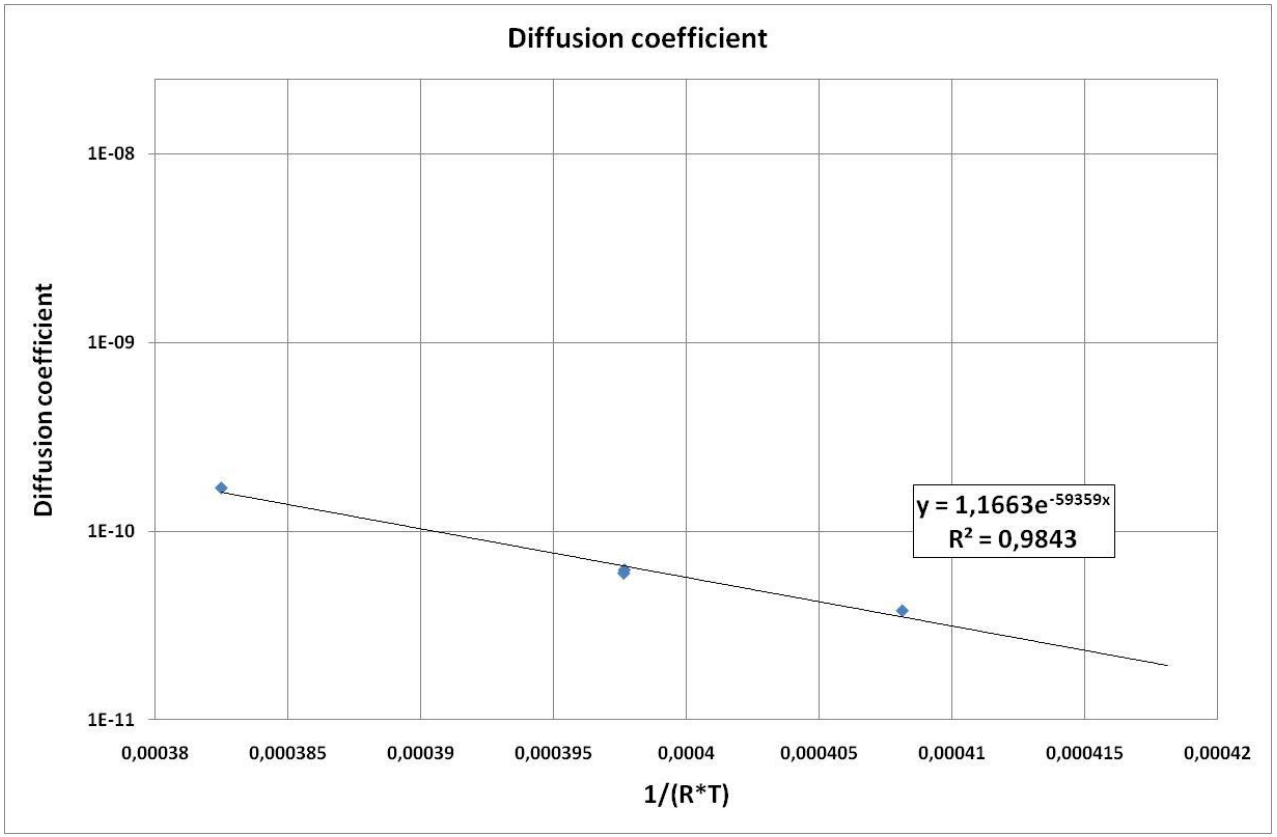
Temperature dependency



Source: Teknologisk Institut

Summary / conclusions

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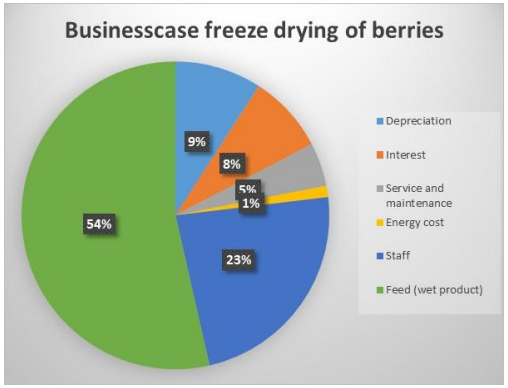
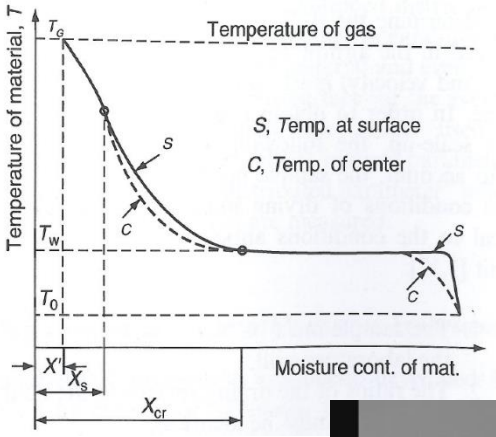
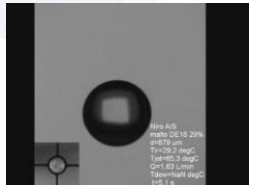
- Yes drying is energy intensive and costly, but -
- Product quality and weight of dried product has a larger impact on the users business case
- In-line measurement must take drying kinetics into account







DryingMate A/S

Thanks for the attention!

Questions?

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100 g:
60 W light bulb
must burn for 89 hours

DryingMate challenge

DryingMate A/S

- Temperature 60° C
- Pressure 1 – 20 mbar (freeze drying / vacuum drying)
- Products: mainly berries and fruit (80 % → 10 % moisture)
- Continuous drying on 600 x 400 mm trays
- Conductive and convective heat transfer
- Product weight init. per tray 1,8 kg
- Product layer 5-10 mm
- Drying time 5 – 24 hours

- How to, which accuracy, cost?