

6-23-2016

# How to reduce the energy costs of food and dairy products to spray drying?

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## Recommended Citation

Pierre Schuck, Anne Dolivet, Serge Méjean, and Romain Jeantet, "How to reduce the energy costs of food and dairy products to spray drying?" in "5th International Congress on Green Process Engineering (GPE 2016)", Franco Berruti, Western University, Canada Cedric Briens, Western University, Canada Eds, ECI Symposium Series, (2016). <http://dc.engconfintl.org/gpe2016/55>

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# How to reduce the energy costs of food and dairy products to spray drying ?

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# STLO

## Science & Technology of Milk & Egg

# A multidisciplinary and multiscale approach, reinforced by two high-calibre facilities:

### Dairy Platform

### Biological Resource Centre



80 standing fellow workers  
25 PhD students



- ❑ **Structuration / destructuration mechanisms of food matrix:** *from structural characterisation to digestion*
- ❑ **Dairy processing and cheese making:** *toward sustainable dairy systems*
- ❑ **Microbial interaction:** *food matrix and host cell*

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# Backgrounds & Objectives



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# Introduction (1)

① Spray drying is a useful technique for water evaporation using hot air, but **very black box in nature**.

② So the question is “how to anticipate the behaviour of dairy products to drying ?”

③ To date, there are 4/5 methods available to determine precisely the parameters of spray drying for food products before drying.

④ The first way to determine *a priori* & precisely the parameters of spray drying for food products is via pilot / plant experiments  
→ **expensive, time consuming, empirical & sometimes unreliable.**

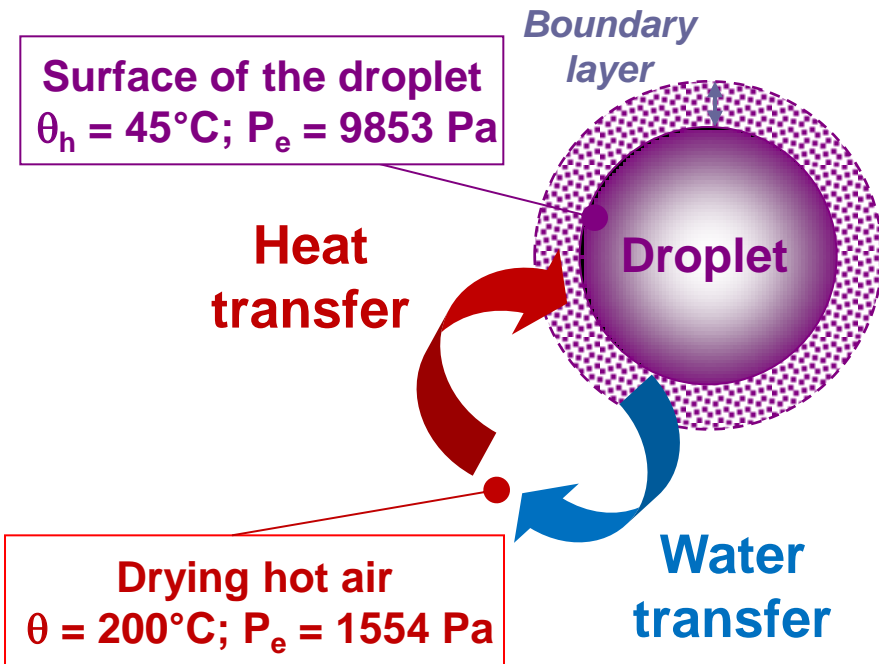
⑤ **The other ways are** ⇒ spray drying modeling based on drying physics (transport phenomena, fluid mechanics, heat and mass transfer, reaction engineering, particle engineering as well as material science )

# Introduction (2)

⑥ One difficulty remains  $\Rightarrow$  taking into account water availability =  $f(\text{product})$

## ⑦ Why ?

- Kinetics of mass / heat transfer phenomena and drying behaviour depend on the water availability  $\Rightarrow$  needs extra energy to overcome binding of water



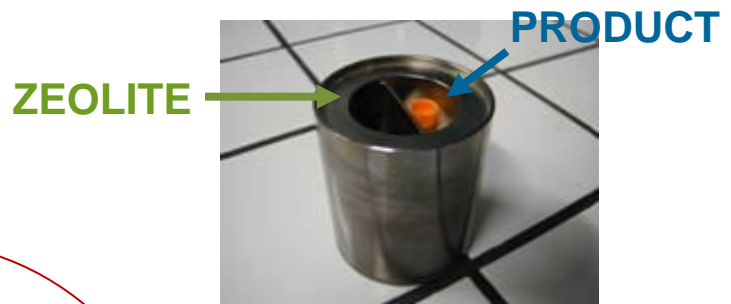
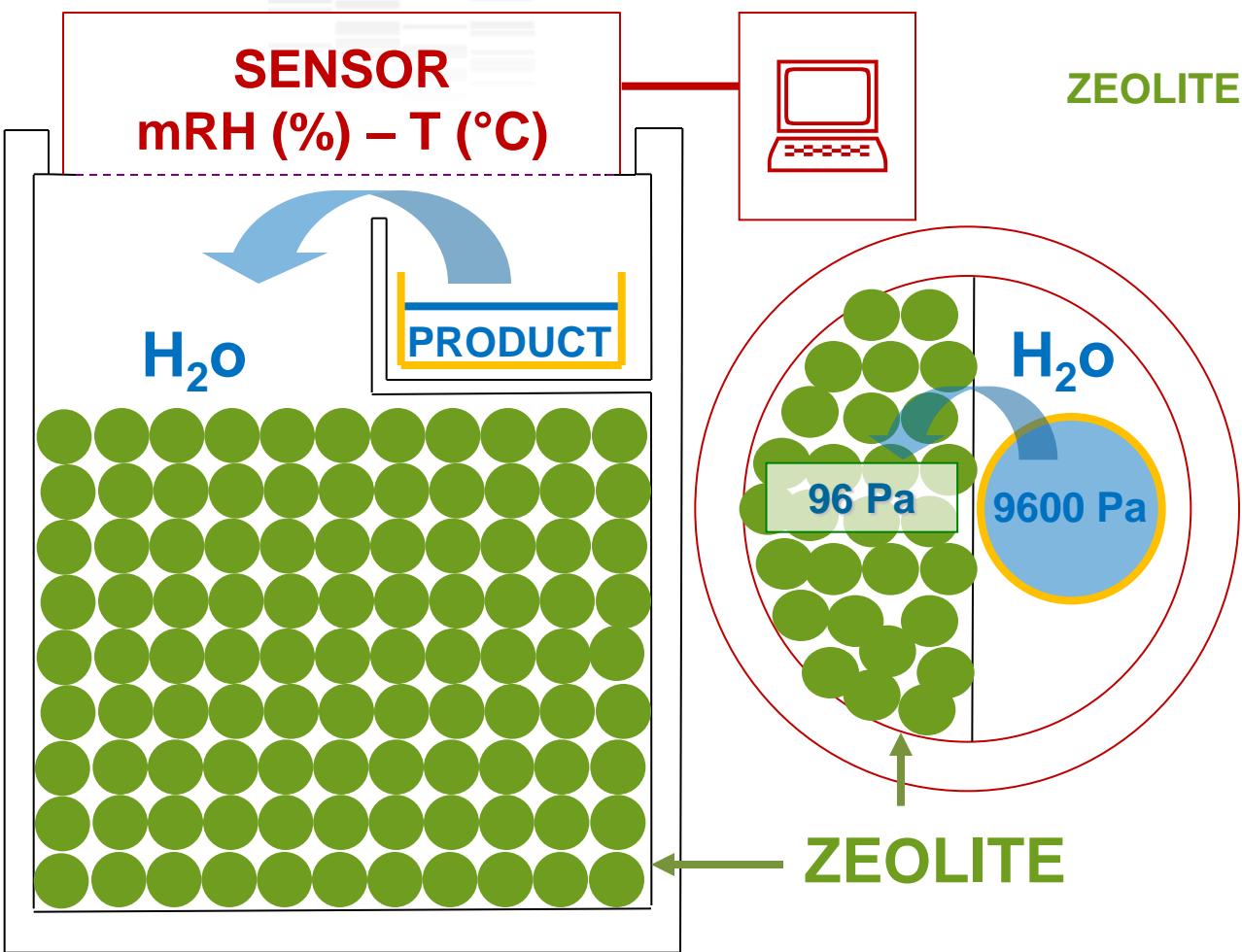
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# Drying by desorption



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# Step ①: Concentrate desorption by $a_w$ -metry

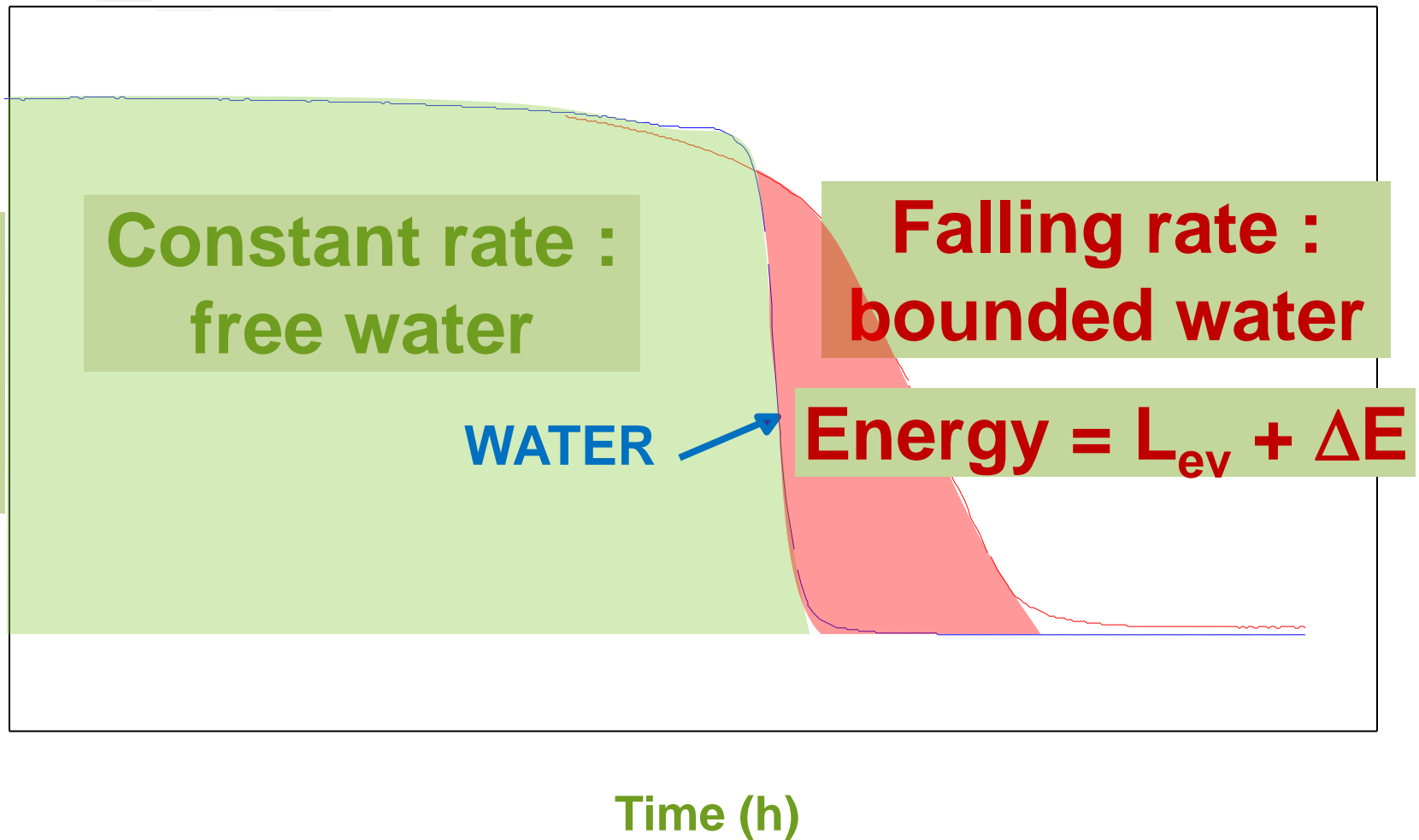


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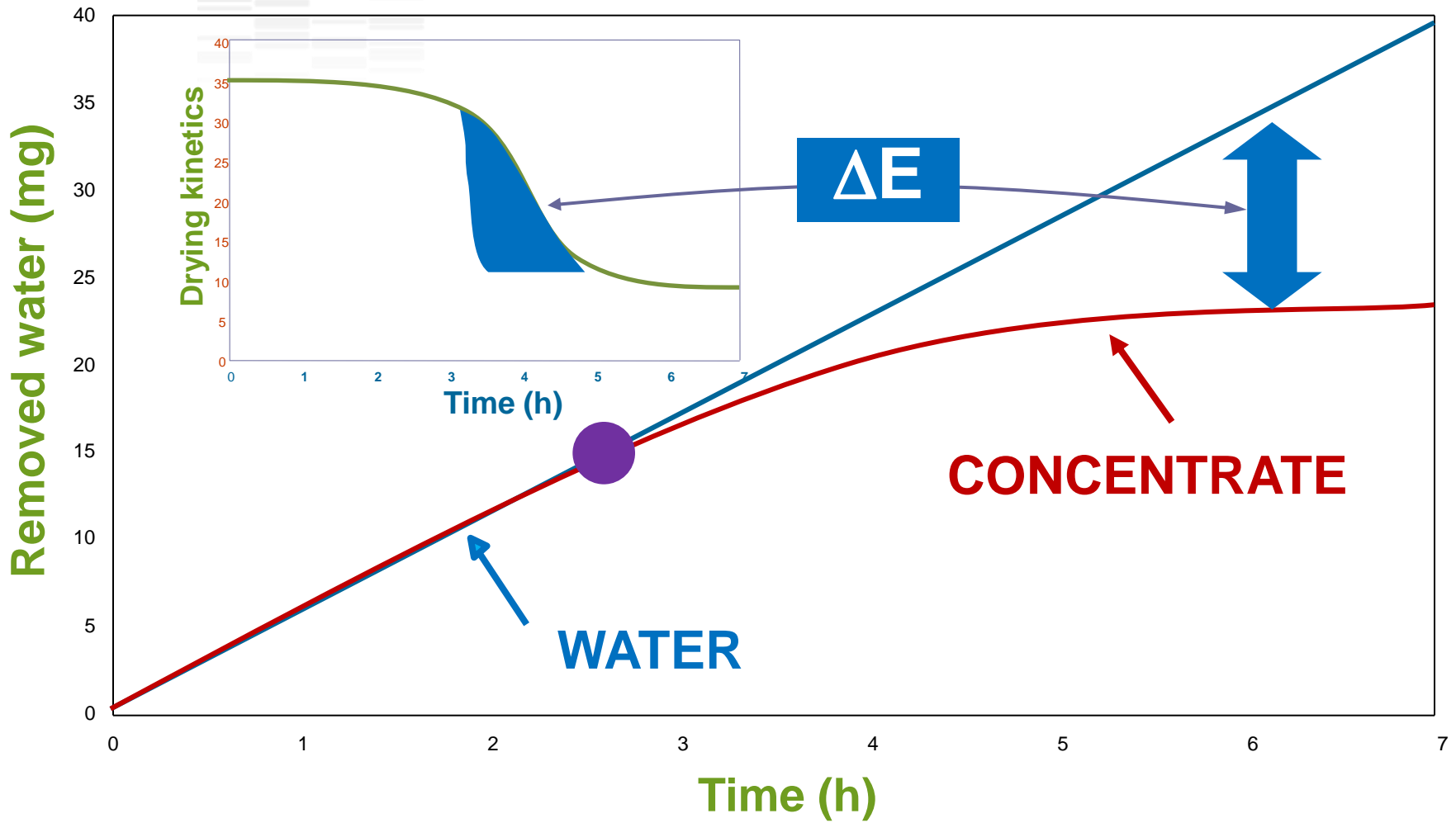


# Step ②: Desorption curve vs. time

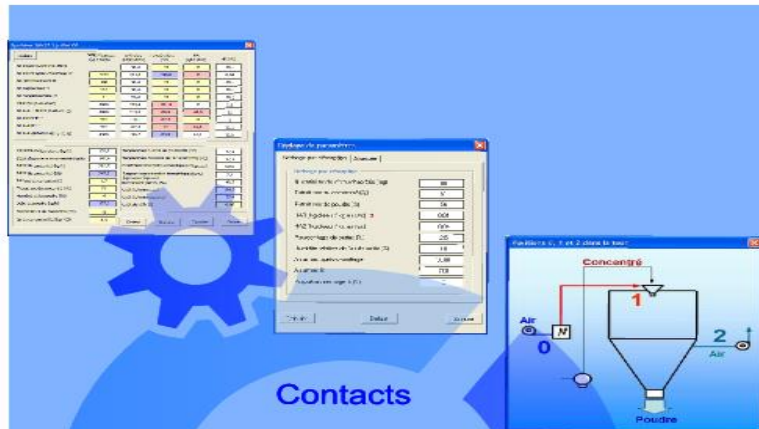
Drying  
kinetics



# Step ③: Desorption curve vs. time



# Step ④: Calculation by INRA Software SD<sup>2</sup>P<sup>®</sup> integrating the ratio of bound and unbound water.



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SD2P  
Spray Drying Parameters  
Simulation & Determination

# SD2P

Spray Drying Parameters  
Simulation & Determination



Version 5.0 2010

IDDN.FR.001.480002.002.R.P.2005.000.30100

Le logiciel SD2P (Drying), enregistré à l'APP sous le n° IDDN.FR.001.480002.002.R.P.2005.000.30100, est un programme informatique développé par l'INRA servant à déterminer les paramètres de séchage à priori en intégrant la disponibilité de la matrice à sécher et les caractéristiques de l'équipement. Son utilisation est régie par une licence sur logiciel concédée par INRA Transfert. Le fait que vous puissiez accéder à cet en-tête signifie que vous avez pris connaissance de cette licence et que vous en avez accepté les termes.



# Skim Milk Concentrate @ 50% TS



Reduce	Settings	Mass flow rate (kg DA/h)	Enthalpy (kJ/kg DA)	Temperature (°C)	AH (g/kg DA)	RH (%)
			38	20	7	47,8
	Inlet air after heating 'I'	75000	248	225.2	7	0,04
	Cooling air 'C'	2000	38	20	7	47,8
	Recirculation air 'R'	2000	38	20	7	47,8
	Complementary air 'C'	0	17,5	0	7	183,3
	Air mix (I+C+R+C)	79000	237.4	214,2	7	0,05
	Outlet air 1 stage (I+C+R+C)	79000	213,2	89,8	45,8	10
	IFB inlet air before heating		37,8	20	7	47,8
	IFB inlet air after heating 'B'	15000	118,2	98.4	7	1,2
	IFB outlet air 'B'	15000	86	56.8	11	10,2
	Overall outlet air (I+C+R+C+B)	94000	192,9	84.8	40,2	10,7

Evaporation capacity (kg/h)	3125,2
Water flow rate in concentrate (kg/h)	3250,2
Concentrate flow rate (kg/h)	6500.4
Concentrate flow rate (l/h)	5417
Concentrate density (-)	1,2
Concentrate dry matter (%)	50
Powder moisture (%)	4
Powder flow rate (kg/h)	3385.6
Concentrate temperature (°C)	45
Concentrate Cp (kJ/(kg.°C))	3,5

Wet bulb temperature of overall outlet air (°C)	47,6		
Dew temperature of overall outlet air (°C)	36,8		
Energy balance (kJ/kg water)	5426		
Energy consumption ratio (60°C) (kg vapour/kg water)	2,3		
Yield (60°C) (%)	43,5		
Cost (\$/ton water)	90.4		
Cost (\$/ton powder)	83.5		
kWh cost (\$)	0,06		
Corresponding standard breakpoint (%)	100		
Default	Print	Export	Quit



# Materials

Pilot workshop : Research and development for evaporation / drying

"MSD type" drying tower  
80 kg of water evaporated per hour

B  
I  
O  
N  
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V



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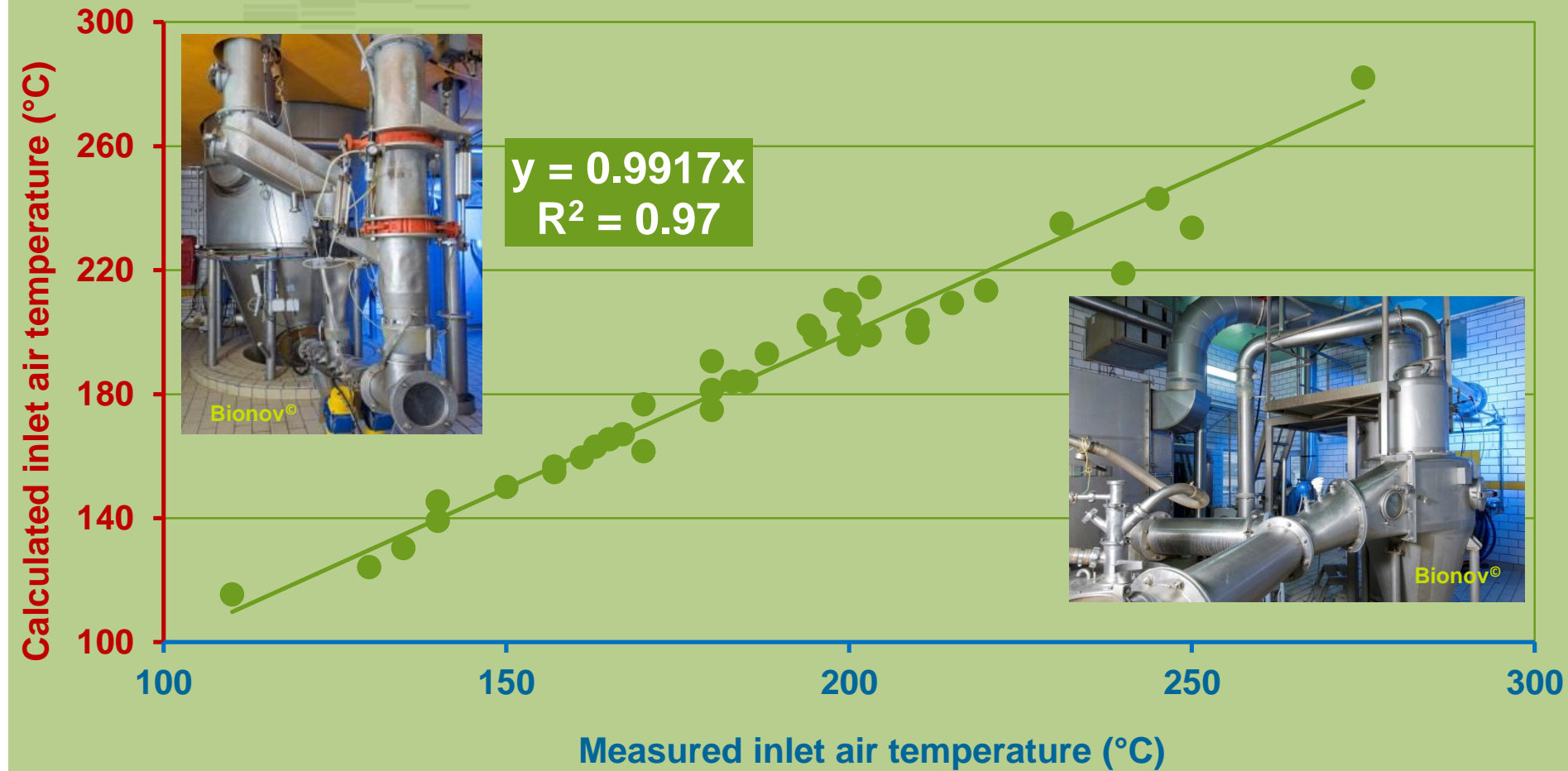
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# Results



Schuck P. et al. Drying by desorption: a tool to determine spray drying parameters. *J Food Eng.* 94,199–204 (2009),

Patel K. et al. One-dimensional simulation of co-current, dairy spray drying systems – pros and cons. *Dairy Sci Technol.* 90, 181-210 (2010),

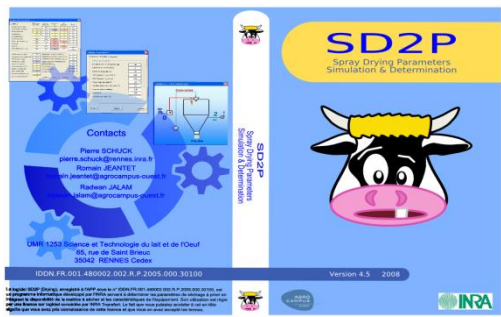
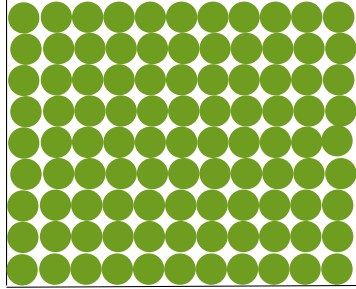
Zhu P., et al. Simulating industrial spray drying operations using a reaction engineering approach and a modified desorption method. *Drying Technol.* 29, 419-428 (2011).

Zhu P. et al. Prediction of dry mass glass transition temperature and the spray drying behaviour of a concentrate using a desorption method. *J Food Eng.* 105, 460-467 (2011).

**SENSOR**  
mRH (%) – T (°C)

H<sub>2</sub>O

PRODUCT



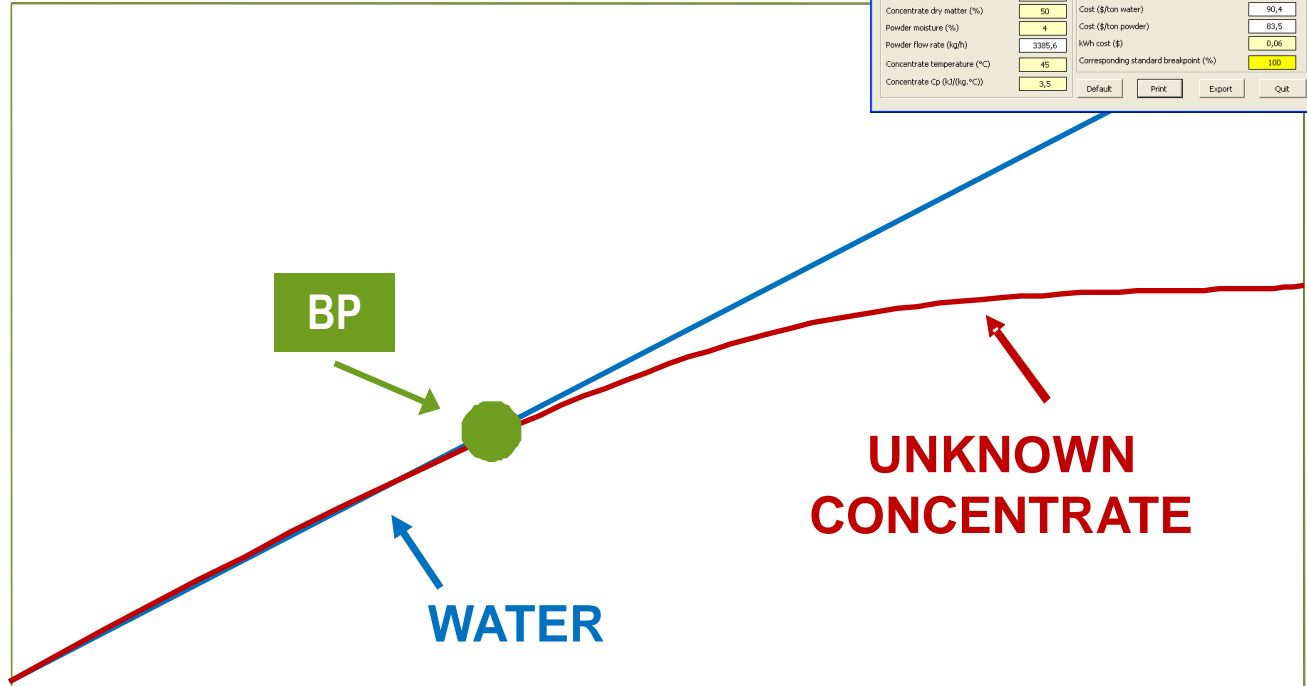
SD2P Spray Drying Parameters Simulation & Determination

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		2000	38	20	7	47,8
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		0	17,5	0	7	183,3
		79000	237,4	214,2	7	0,05
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			37,8	20	7	47,8
		15000	118,2	95,4	7	1,2
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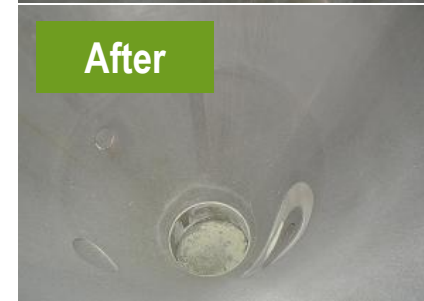
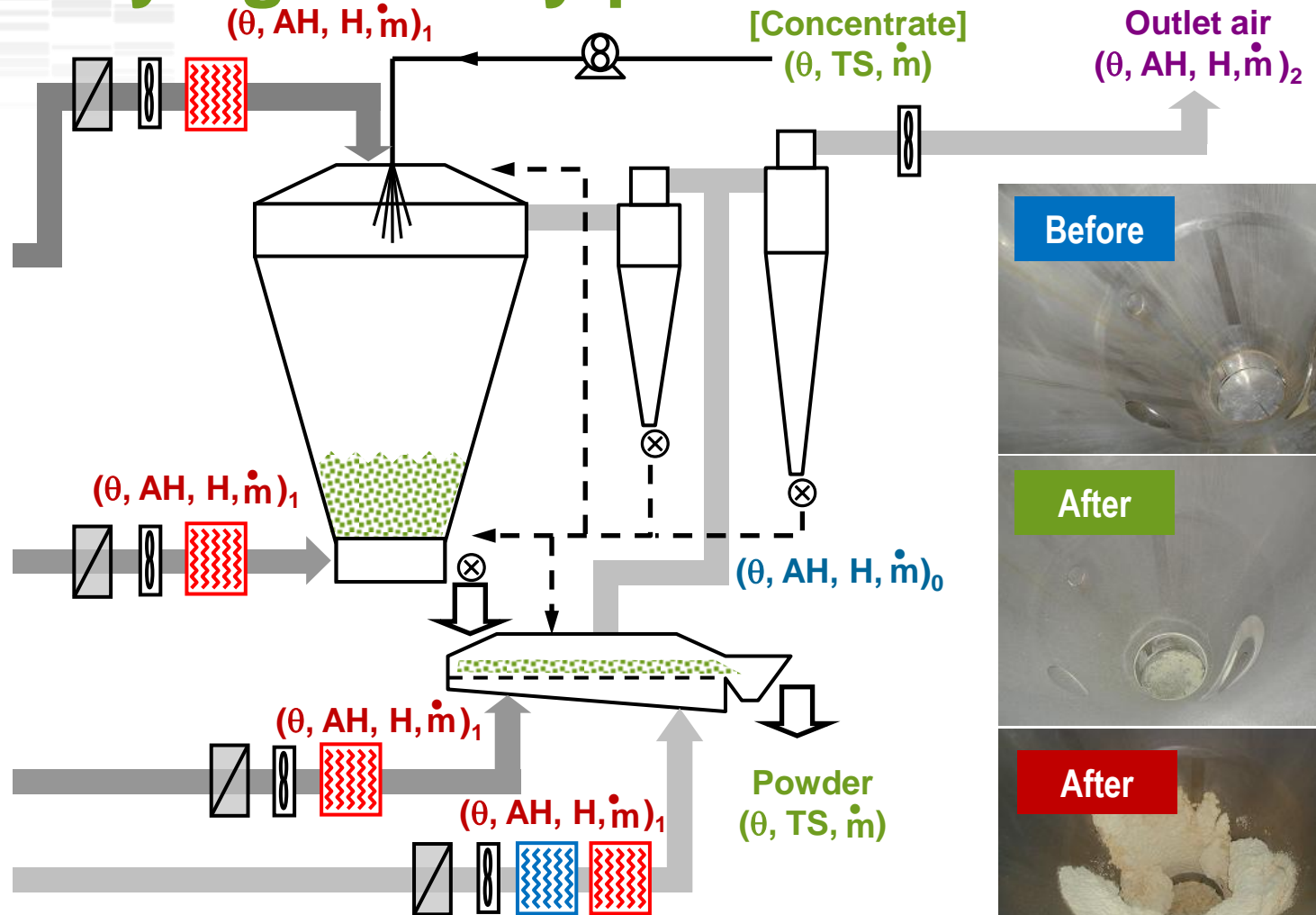
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Powder flow rate (kg/h)	3385,6	kWh cost (\$)	0,06
Concentrate temperature (°C)	45	Corresponding standard breakpoint (%)	100
Concentrate Cp (kJ/kg °C)	3,5		

Removed water (mg)



Time (h)

# How to optimize the energy cost of spray drying of dairy products ?



Index	Settings	Flow Rate (kg/h)	Enthalpy (kJ/kg)	Temperature (°C)	AH (kg/h)	SH (kJ/h)
Inlet air before heating	2000	20	20	7	42.8	0.0
Outlet air after heating	2000	20	20	7	42.8	0.0
Concentration at 1 <sup>st</sup> stage (D-C4-C4)	2000	20	20	7	42.8	0.0
Outlet air 1 stage (D-C4-C4)	2000	20	20	7	42.8	0.0
Overall outlet air (D-C4-C4)	2000	20	20	7	42.8	0.0

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Schuck P. et al. Thermohygrometric sensor: a tool for optimizing the spray drying process. Innov. Food Sci. and Emerg. Technol. 6, 45-50 (2005)





# How to optimize the energy cost of spray



## drying of dairy products ?

By variation of drying parameters and concentrate parameters with the help of the INRA software (SD<sup>2</sup>P<sup>®</sup>) for prediction.

→ High interest to increase, the TS of the [C] and the T°C of the inlet air before heating,

→ High interest of the IFB for easy (drying) or difficult (cooling) product to spray dry,

→ Interest of the dehumidification the air ✓ To increase the production ✓ To have regular spray drying parameters (Major air) and ✓ To decrease the powder temperature (IFB).

But to optimize, don't forget to take into account the cost of the investment that you have to realize and the quality of the dairy powder too.

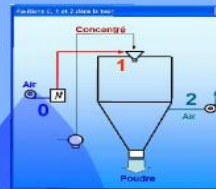
# SD2P

Spray Drying Parameters  
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Spray Drying Parameters  
Simulation & Determination

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# CONCLUSIONS

❖ With this method, it is possible to predict and optimize the **spray drying parameters** ( $\pm 1-5\%$ ) for food products in relation to their desorption behavior

❖ **Validation tests** (>100 products) indicate that this method could be applied to a large range of food products & spray dryer types.

❖ For reasons of calculation speed and reliability, the method has been computerized.  
**Spray Drying Parameters Simulation & Determination Software (SD<sup>2</sup>P®)**  
[N° IDDN.FR.001.480002.003.R.P.2005.000.30100](http://www4.rennes.inra.fr/stlo)

❖ Up-to-date, 31 licenses have been sold at 24 factories [80% Dairy (4 of the Top 5 and 9 of the Top 25) – 20% Non Dairy], from 8 different countries:



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YOUR ATTENTION**



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