Multiple emulsions for confectionery fillings

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Agenda

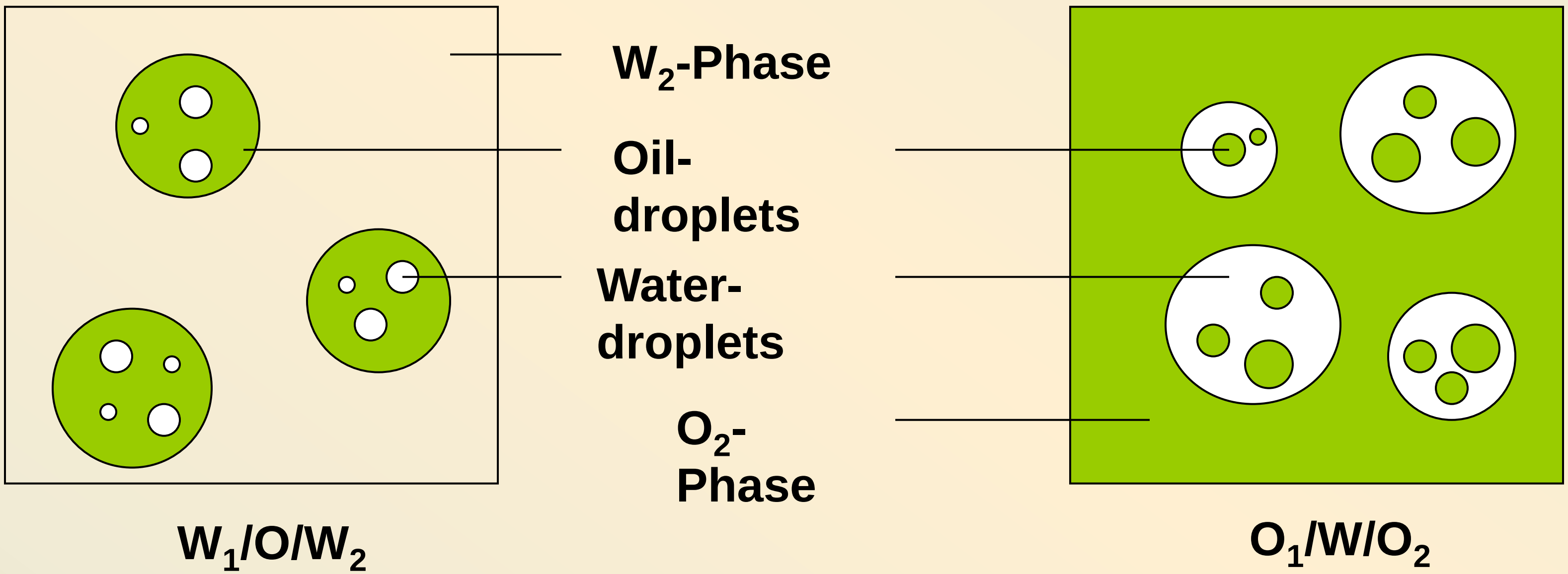
1. **What are multiple emulsions?**
2. **Preparation methods**
3. **Influences on emulsion stability**
4. **Influences on droplet sizes**
5. **Emulsions with high sugar content**
6. **Summary**

What are multiple emulsions?

Multiple emulsions

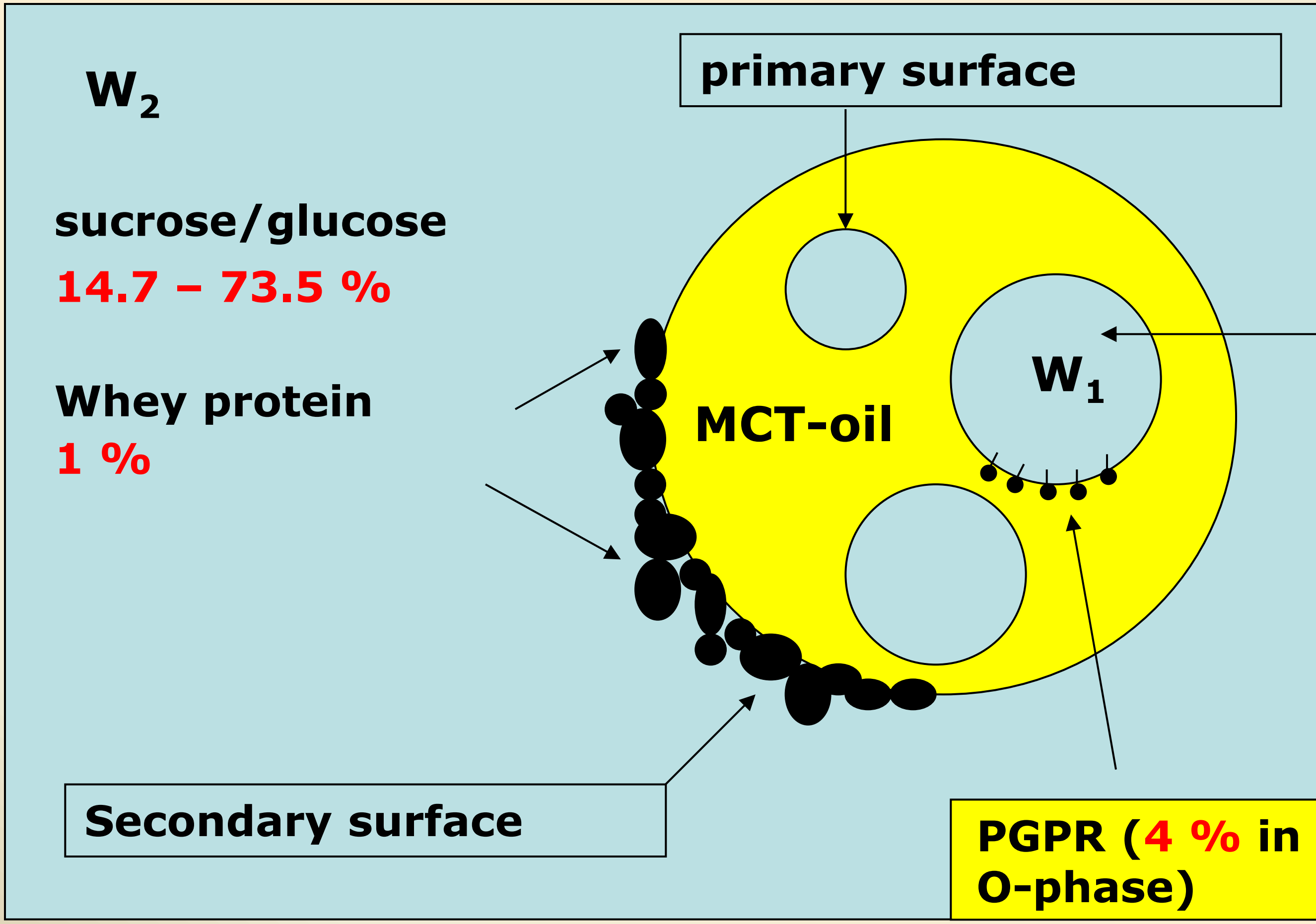
Definition:

Droplets of a dispersed phase (O or W) contain small droplets of another phase



Special types: O/W/O/W/O and W/O/W/O/W

Structure of confectionery W/O/W

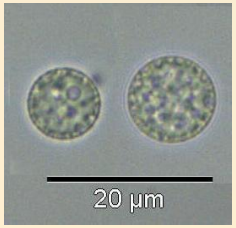


sucrose/glucose
14.7 – 73.5 %

gelatine, Type A
3 %

NaCl
0.6 %

Vit. B_2
0.1 %



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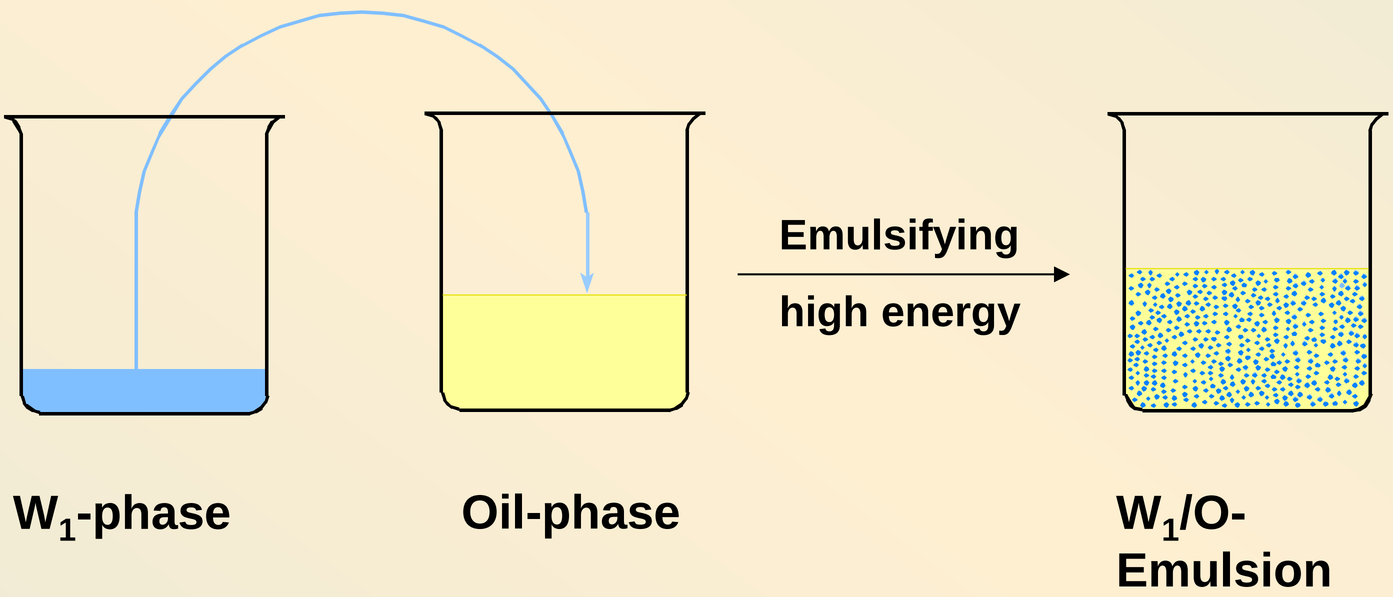
Research questions

- **How can confectionery W/O/W emulsions be prepared?**
- **How influence emulsification conditions the droplet sizes?**
- **Which sugar content (water activity) can be attained in W/O/W emulsions?**
- **What are the encapsulation properties for bioactive substances (e.g.Vit. B_2)?**

Methods of emulsion preparation

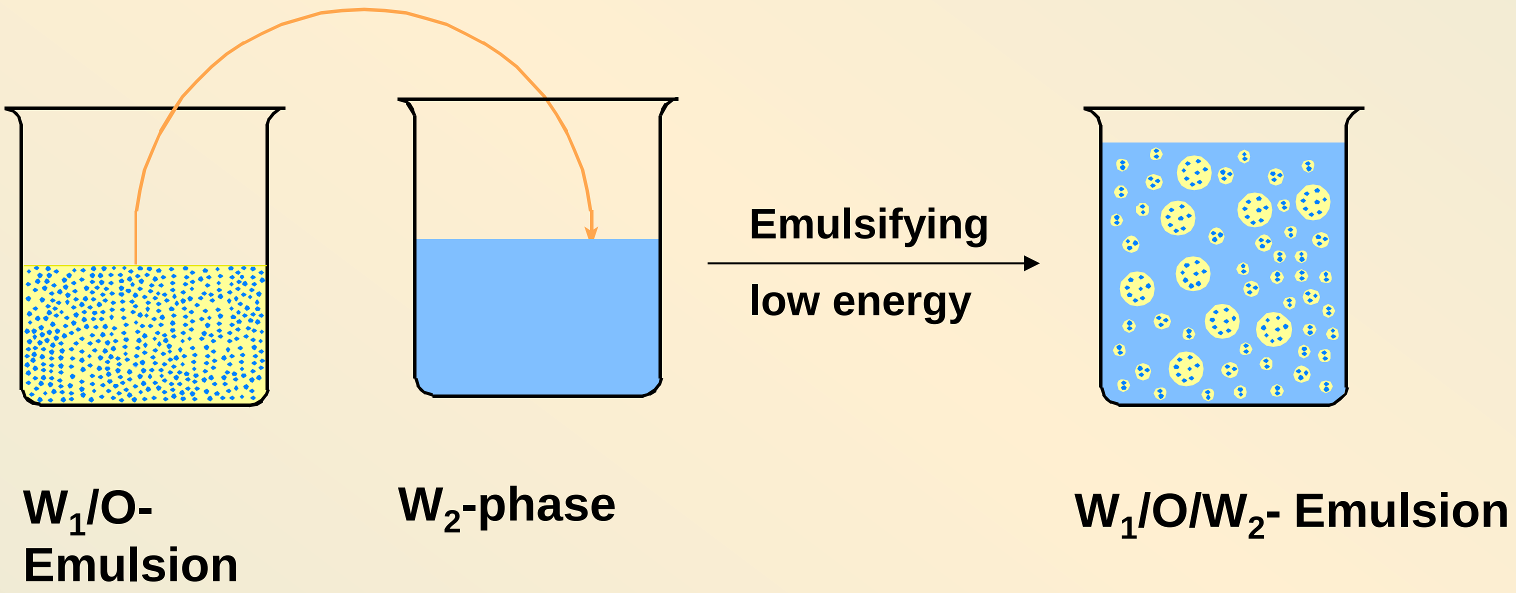
Principle of formation multiple emulsions

1. W_1/O- Emulsion



Principle of multiple emulsion preparation

2. $W_1/O/W_2$- Emulsion



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Methods for emulsion preparation (emulsification of W_1/O in W_2)

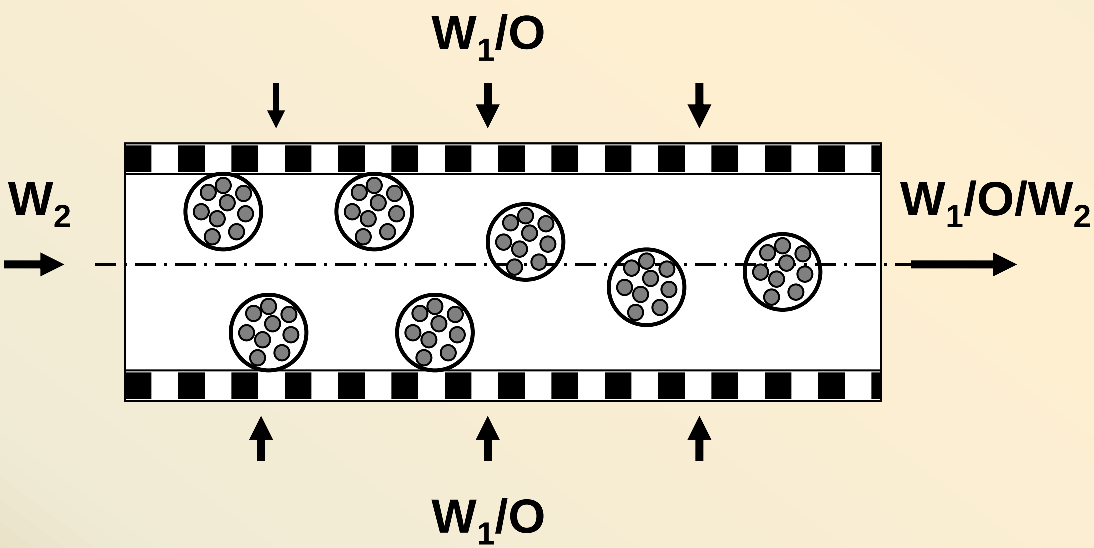
Prevention of:

Disruption of internal emulsion droplets (W_1) and coalescence with the external phase (W_2)

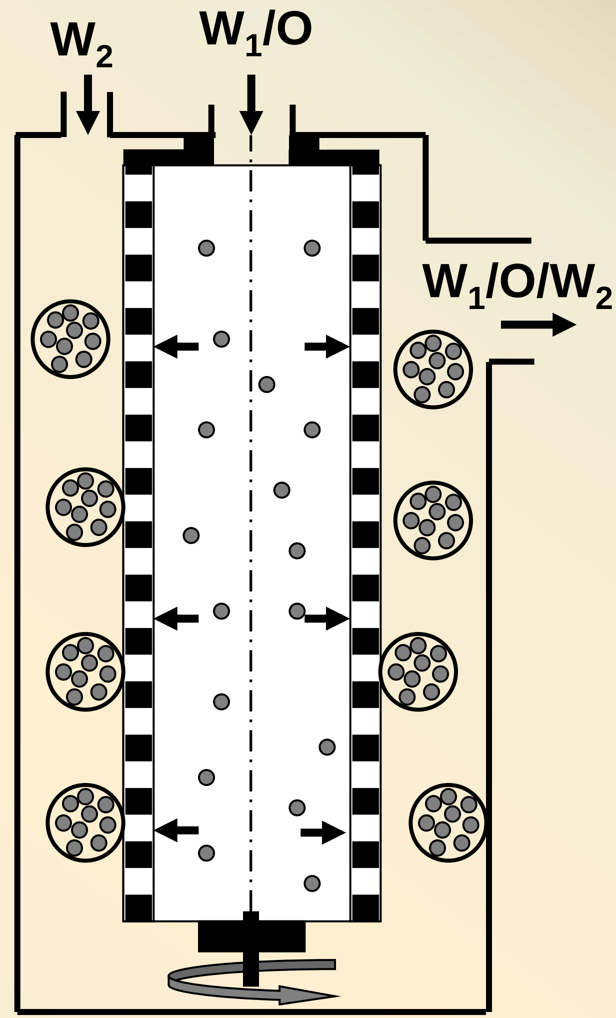
Preferable emulsification methods:

- Membrane emulsification
- Combi-orifice-homogenizer (modified low pressure emulsification)

Membrane emulsification



Fixed membran tube

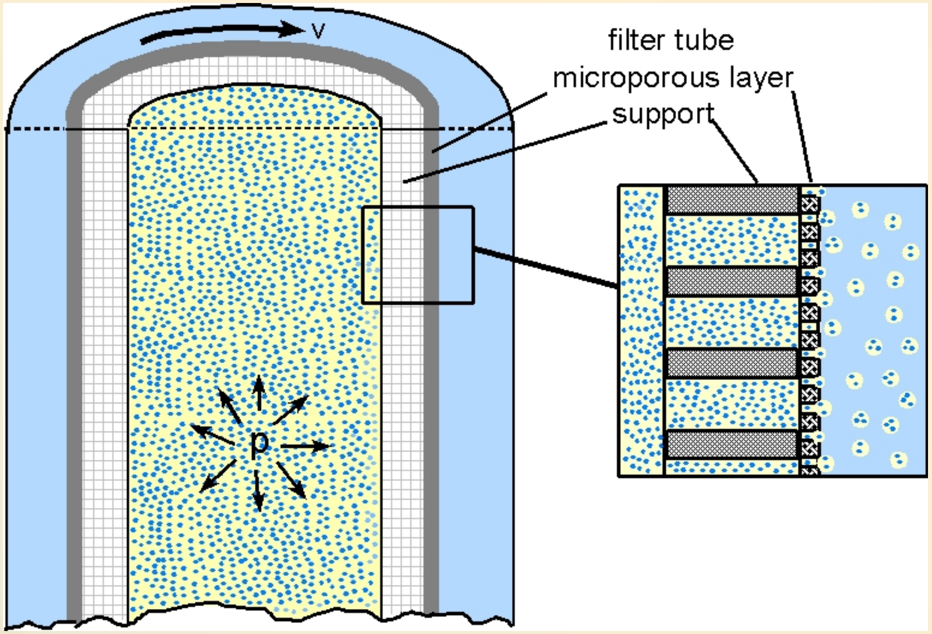


Roating membrane tube

Pilot plant for rotating membrane emulsification
(DIL e.V.)

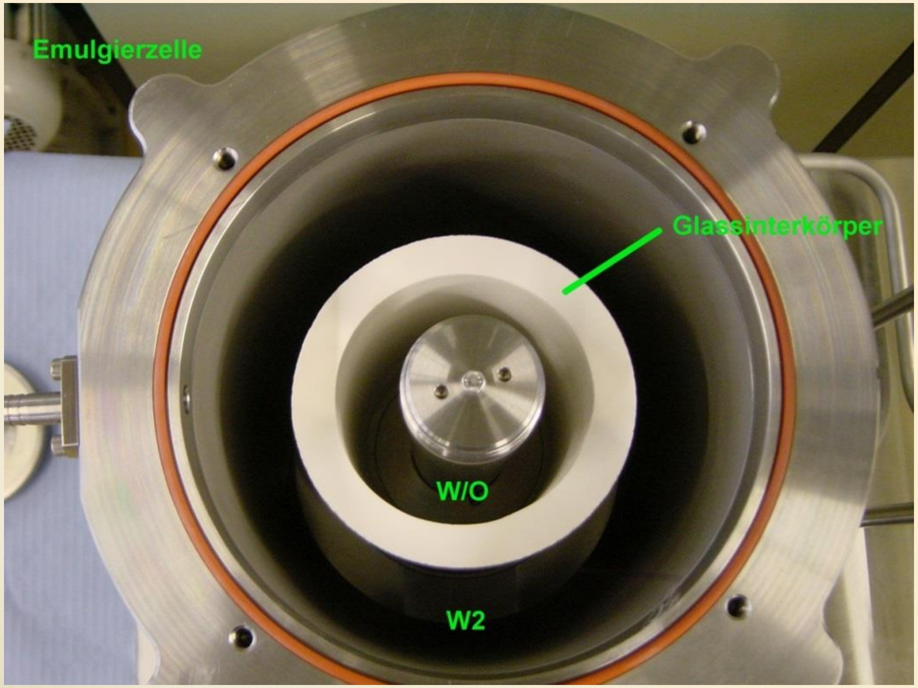
Principle of emulsification:

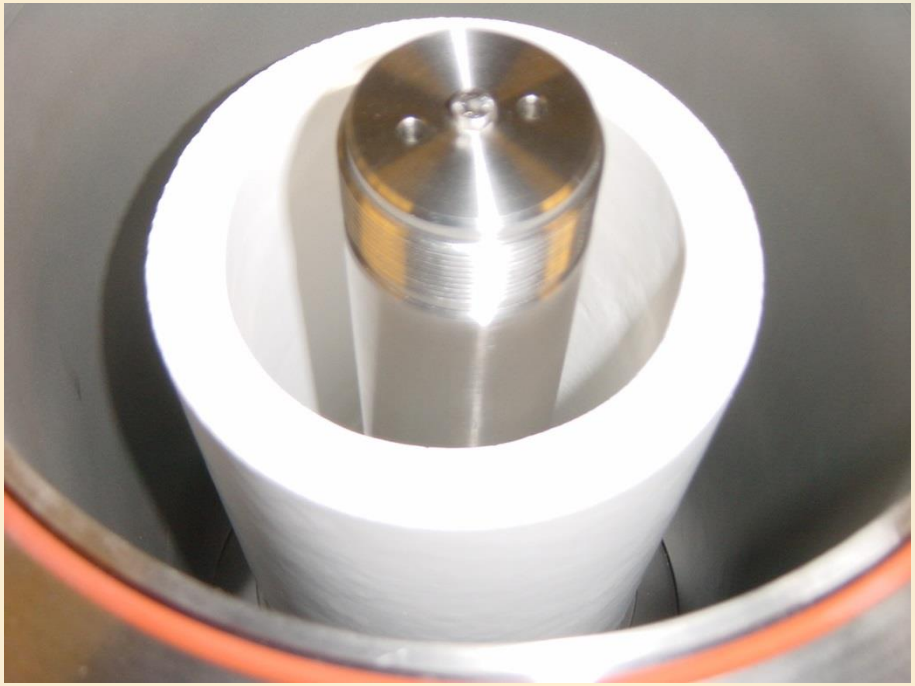
Rotation of sintered glass support with microporous layer outside



DE 103 06 259 A1, 2003

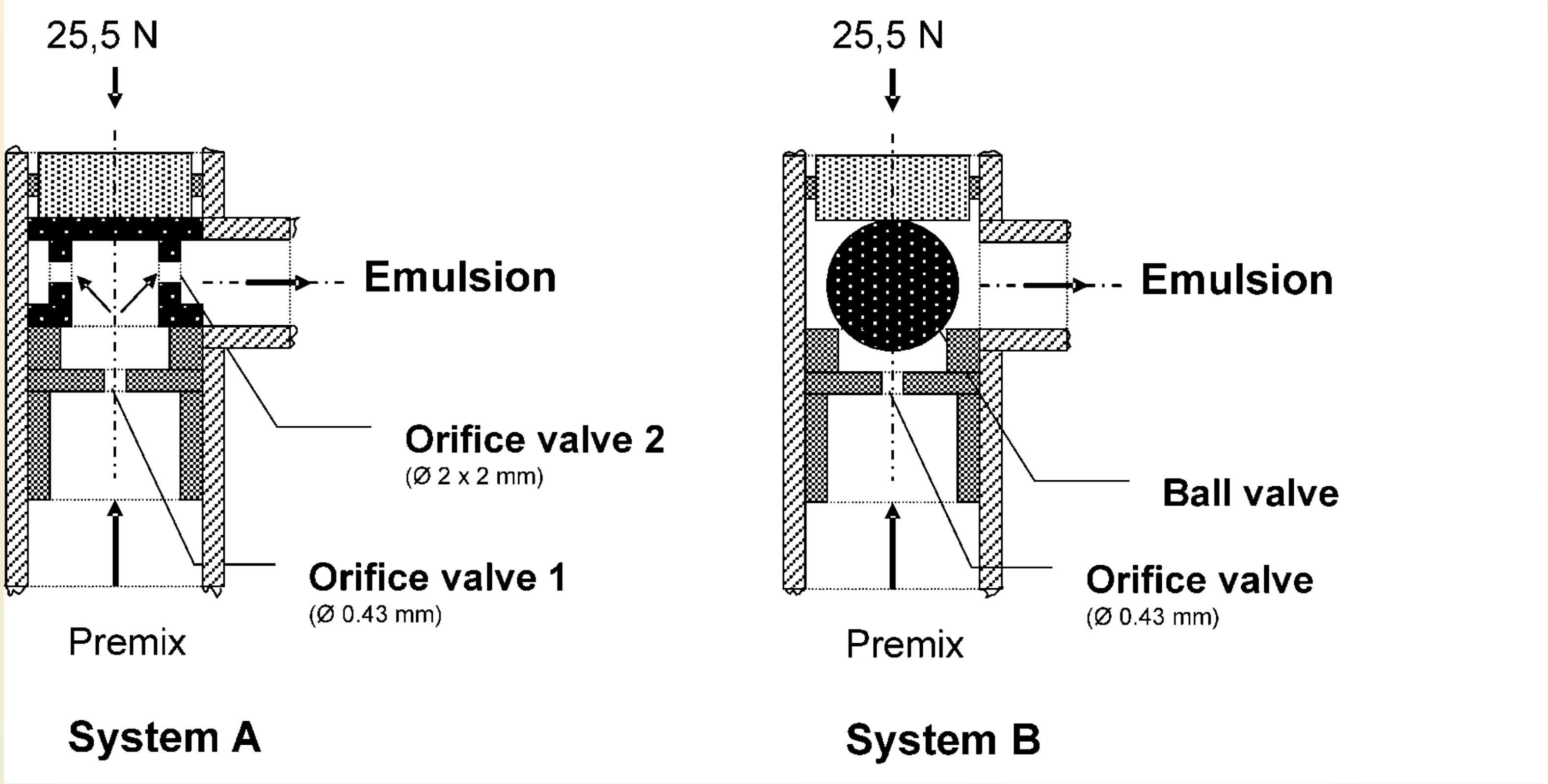
Pilot plant for rotating membrane emulsification
(DIL e.V.)





Modified low pressure homogenizer

Muschiolik et al., 1995



„Combi orifice system“

Premix
W/O/W
0.5-1.0 MPa

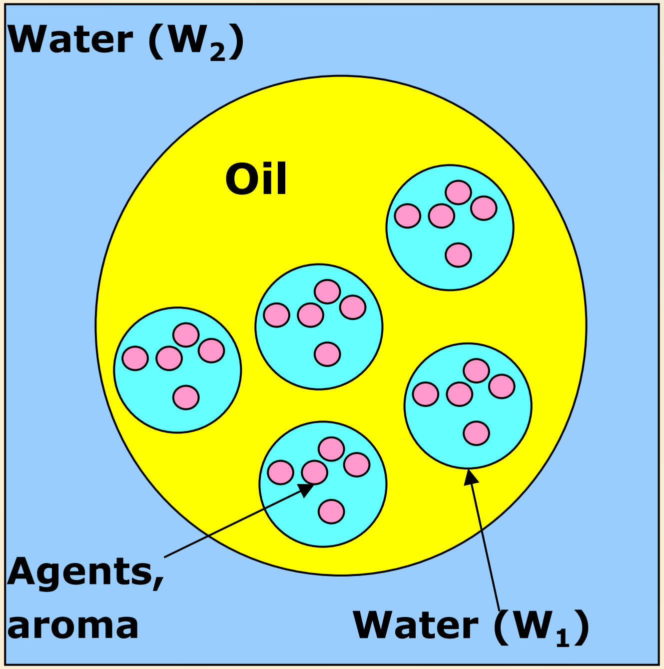
„Orifice-ball-system“

Premix W/O
7 – 8 MPa

Influences on emulsion stability

Stability of W/O/W is influenced by:

- Size of W_1 and W_1-stability
- Size of O and O-stability
- **Osmotic gradient between W_1 and W_2**
- Water flow between W_1 and W_2 (influenced by osmotic gradient)
- Viscosity of the emulsion phases



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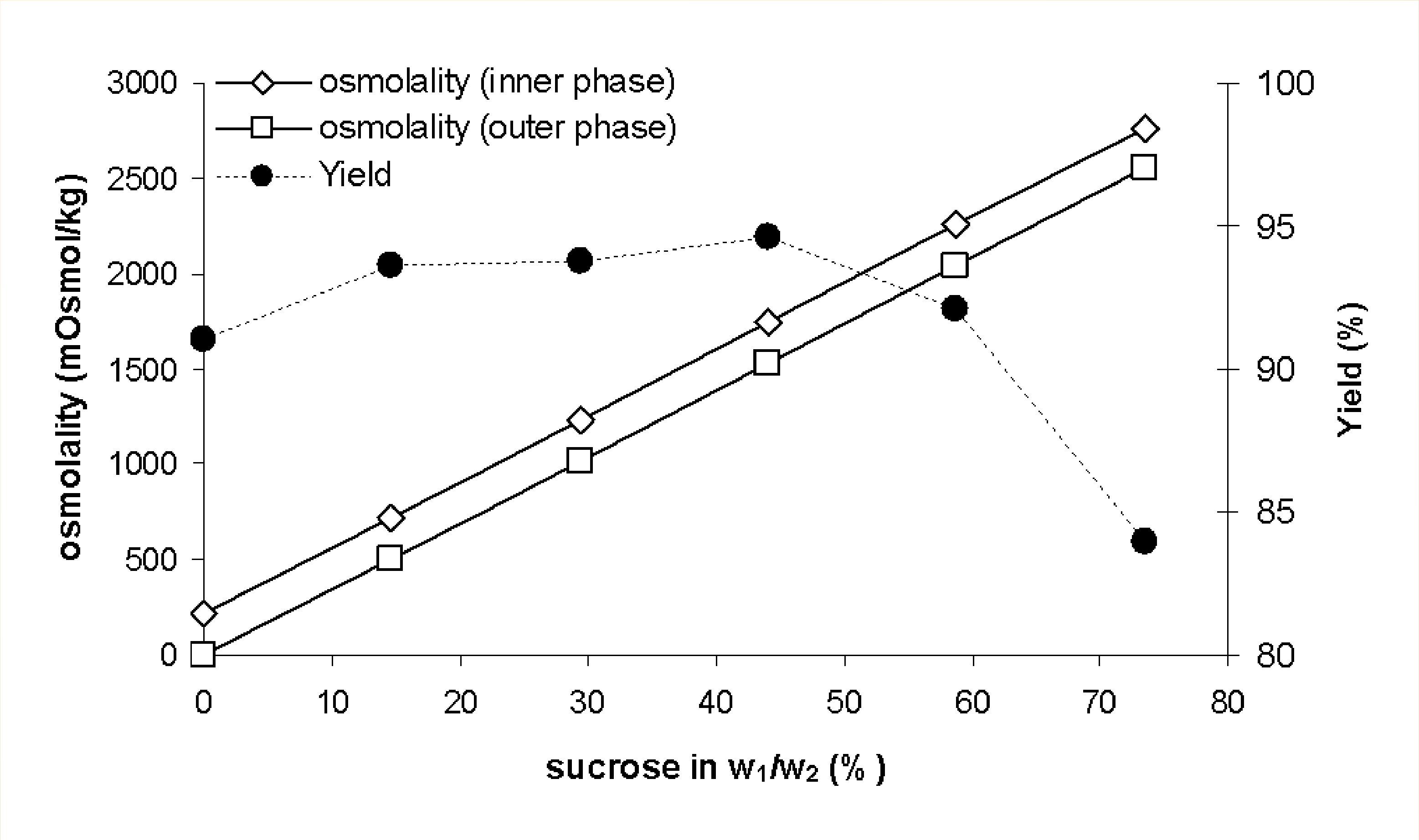
Influence of sugar content on osmotic gradient between the aqueous phases

Yield: encapsulation of Vitamin B_2



The osmotic gradient between W_1 and W_2 should be constant at different sucrose contents (osmolality in the W_1 phase should be higher)

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Stability of W/O/W is influenced by:

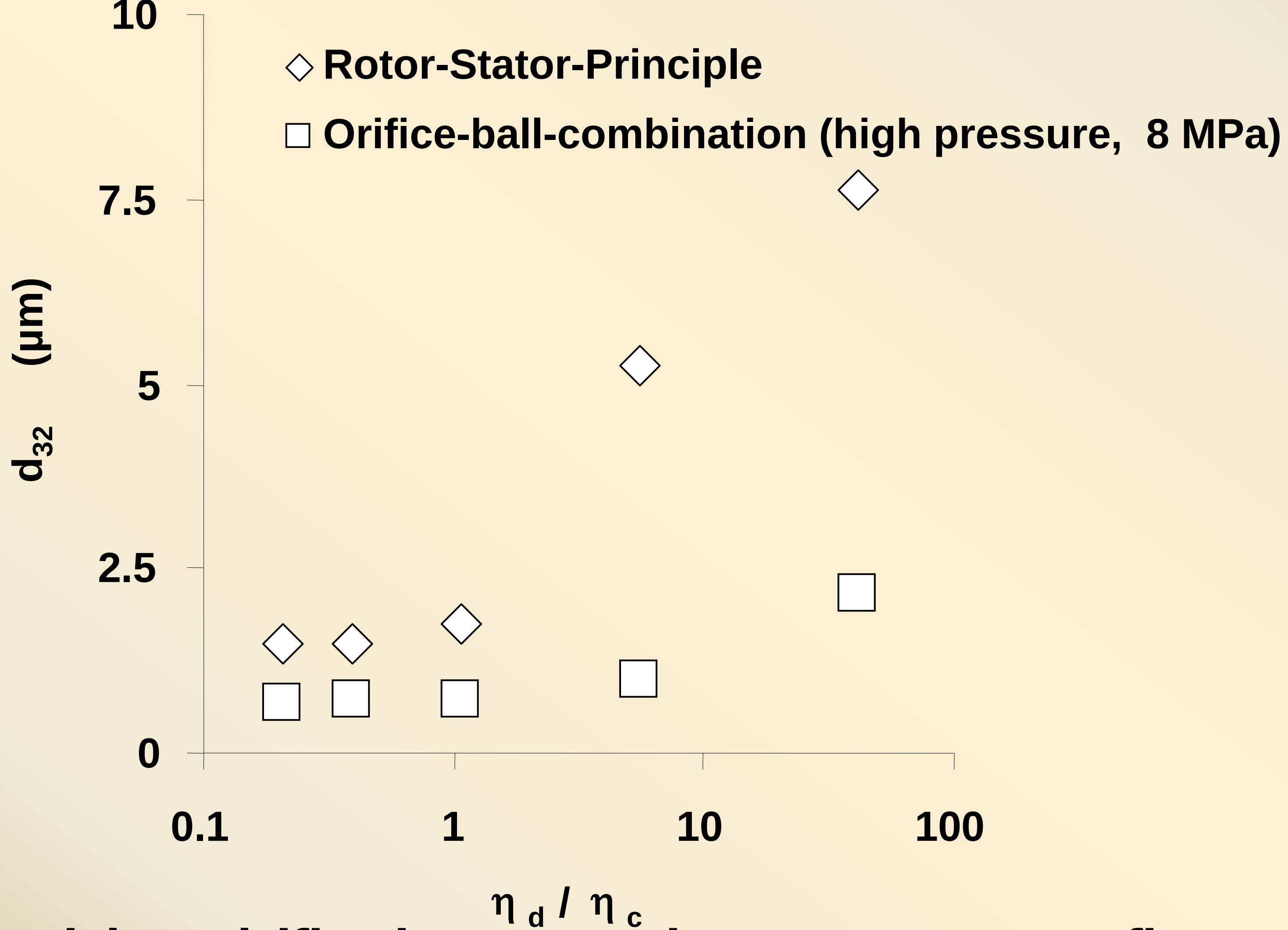
Process conditions:

- Shear force and emulsification pressure (high for W/O, low for W/O in W)
- Temperature (important for phospholipids*)
- pH (important for phospholipids*)

*as W/O-emulsifier

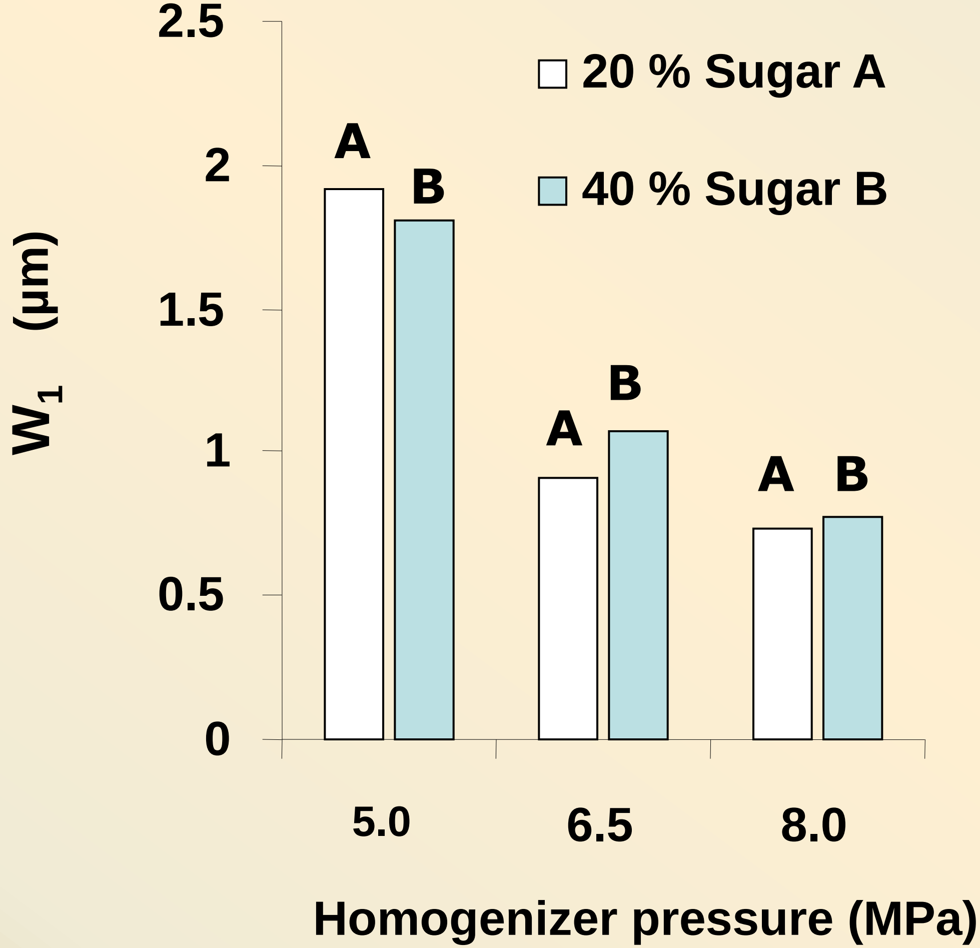
Influences on droplet sizes

Influence of viscosity relation (disperse/continuous phase) on W-droplets (W/O)



A special emulsification system is necessary to get fine W-particles with a high sugar content

Influence of homogenizer pressure (orifice-ball-combination) on W-particles



With the „orifice-ball-homogenizer" can be prepared fine W/O emulsions

Emulsions with high sugar content

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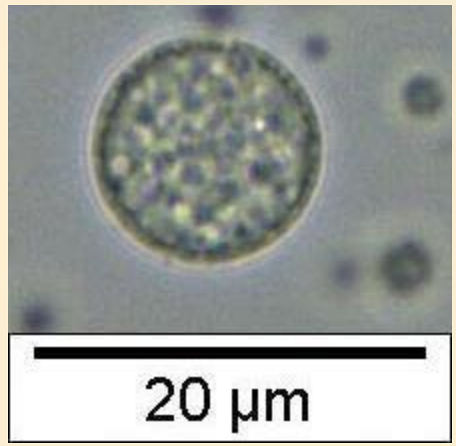
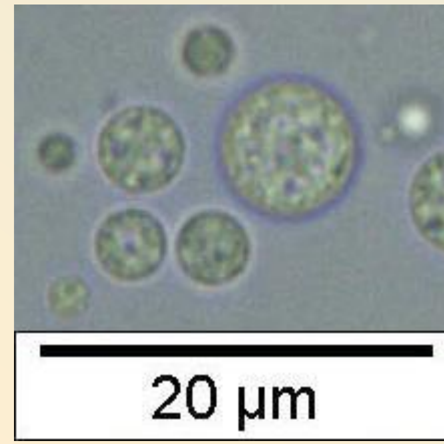
Images of sugar contaning multiple emulsions (O-droplets), diluted

0 % Sucrose

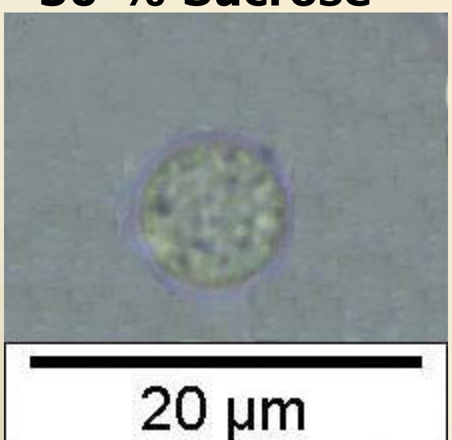
10 % Sucrose



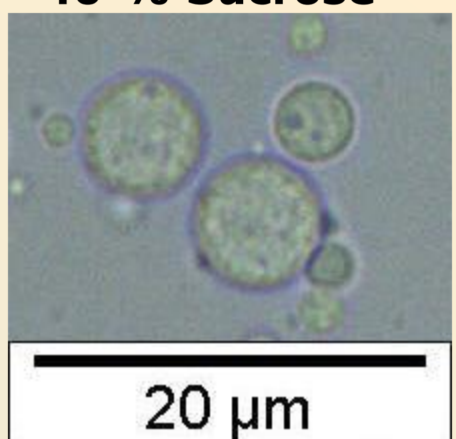
20 % Sucrose



30 % Sucrose



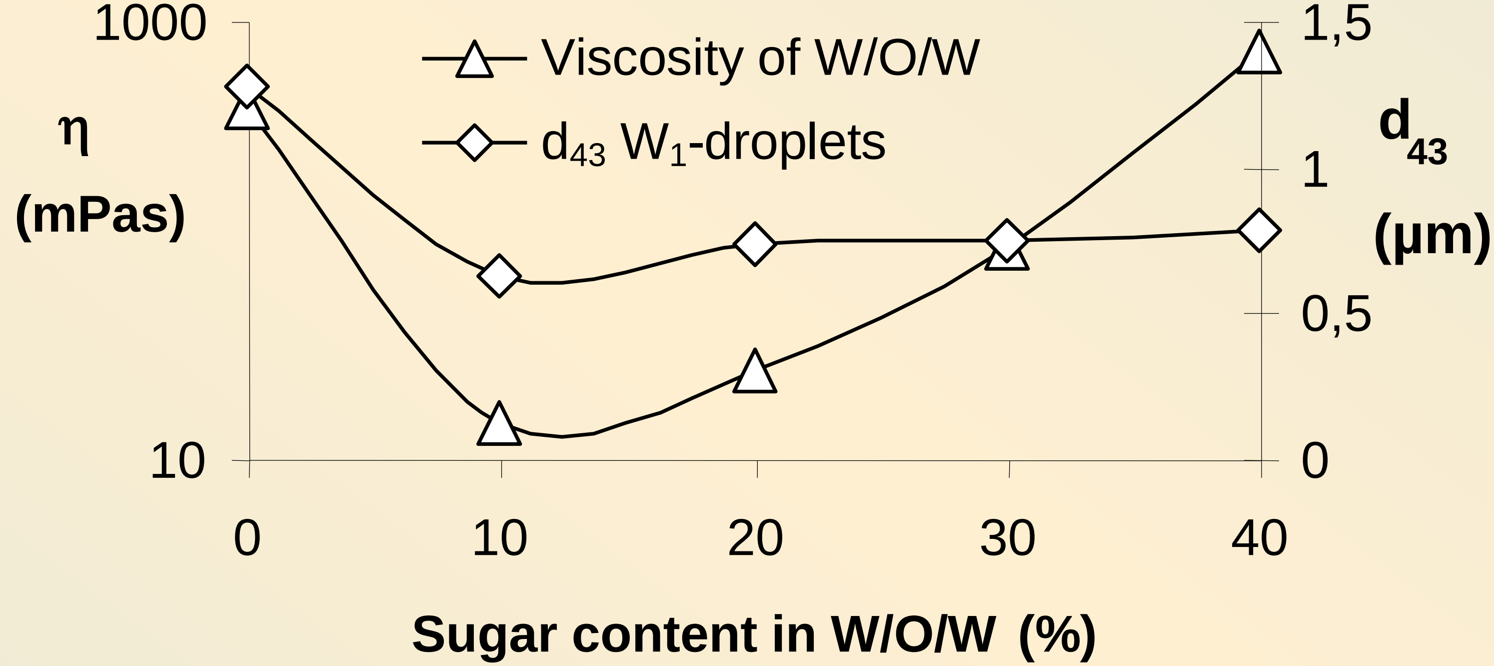
40 % Sucrose



> 50 % Sucrose

Refractive index of oil and sugar solution get similar

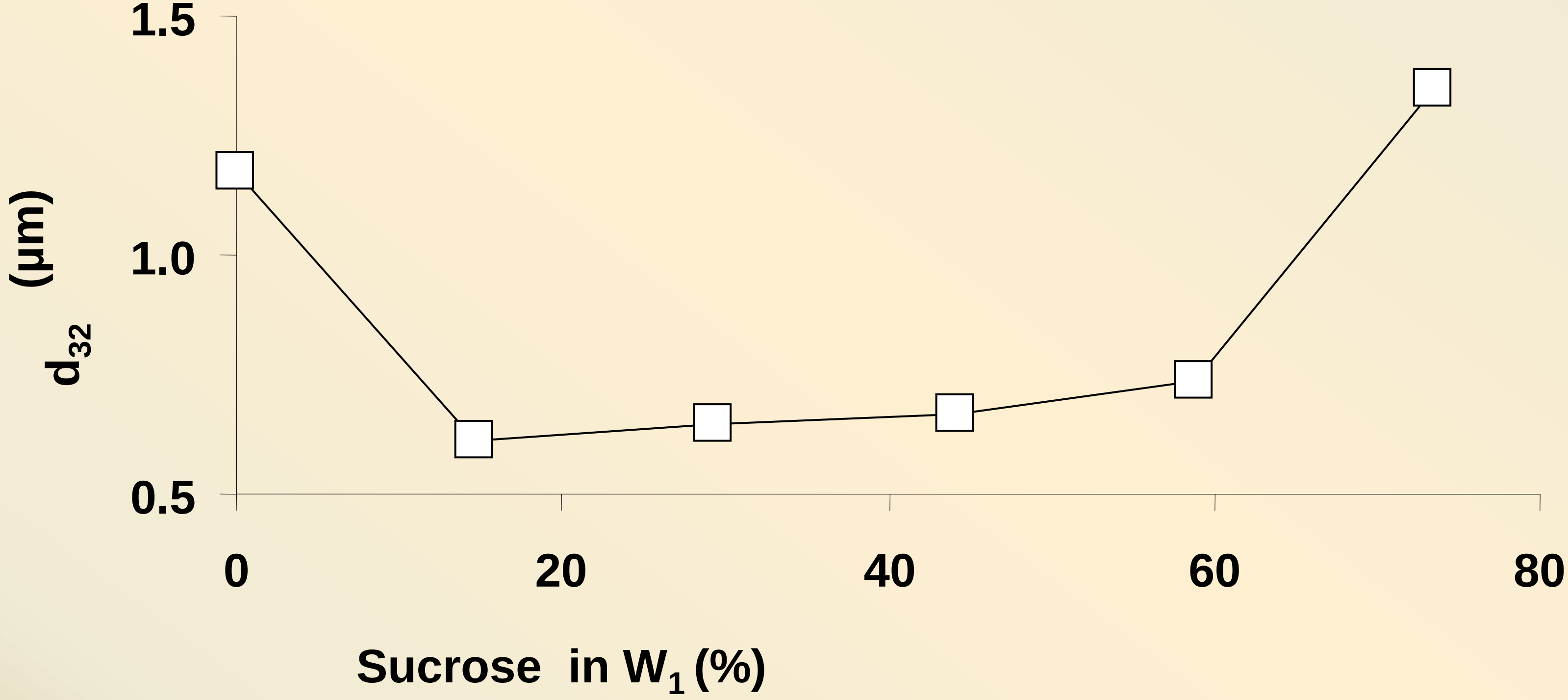
Influence of sugar on W_1-droplets and W/O/W viscosity (100 s^{-1}, 50 °C)



W_1-droplet sizes decrease from 0 to 10 % sugar

The viscosity of W/O/W decreases from 0 to 10 % sugar and increases with higher sugar content

Influence of sugar content on W_1-droplets at ~ 8 MPa



The W_1-droplet size increases rapidly with more than 50 % sucrose in W

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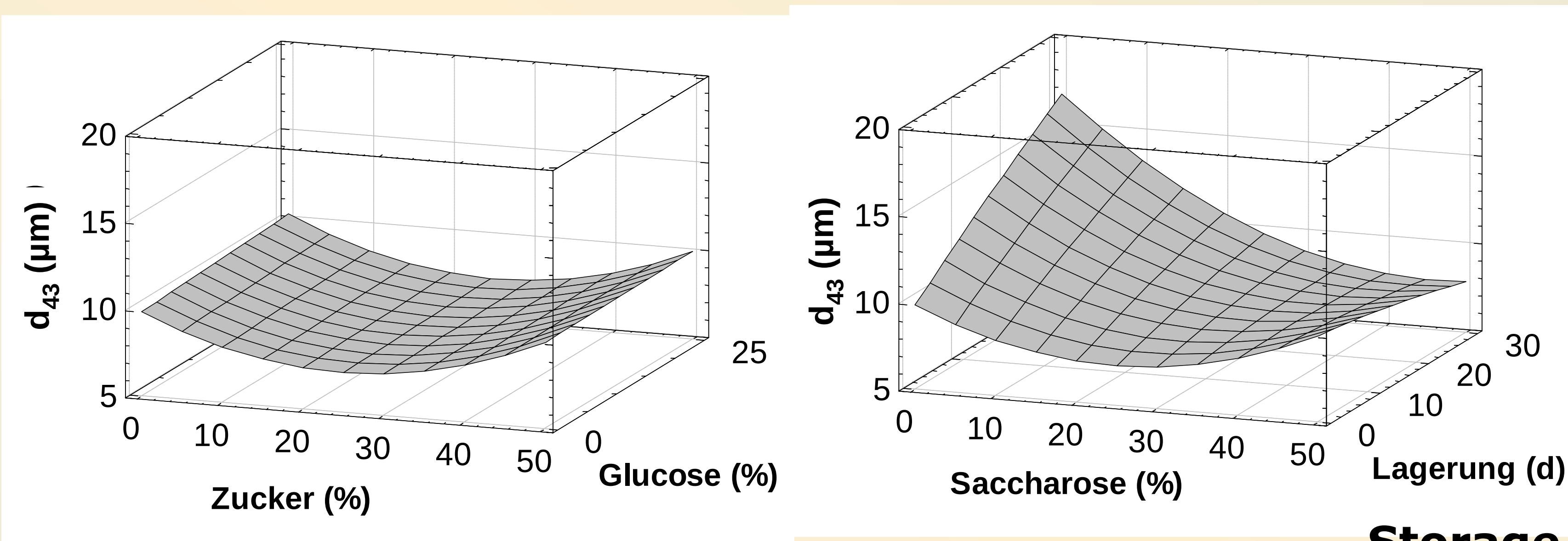
Particle size of O-droplets (d_{43}) depending on sugar content

(W/O/W preparation at ~ 1 MPa)

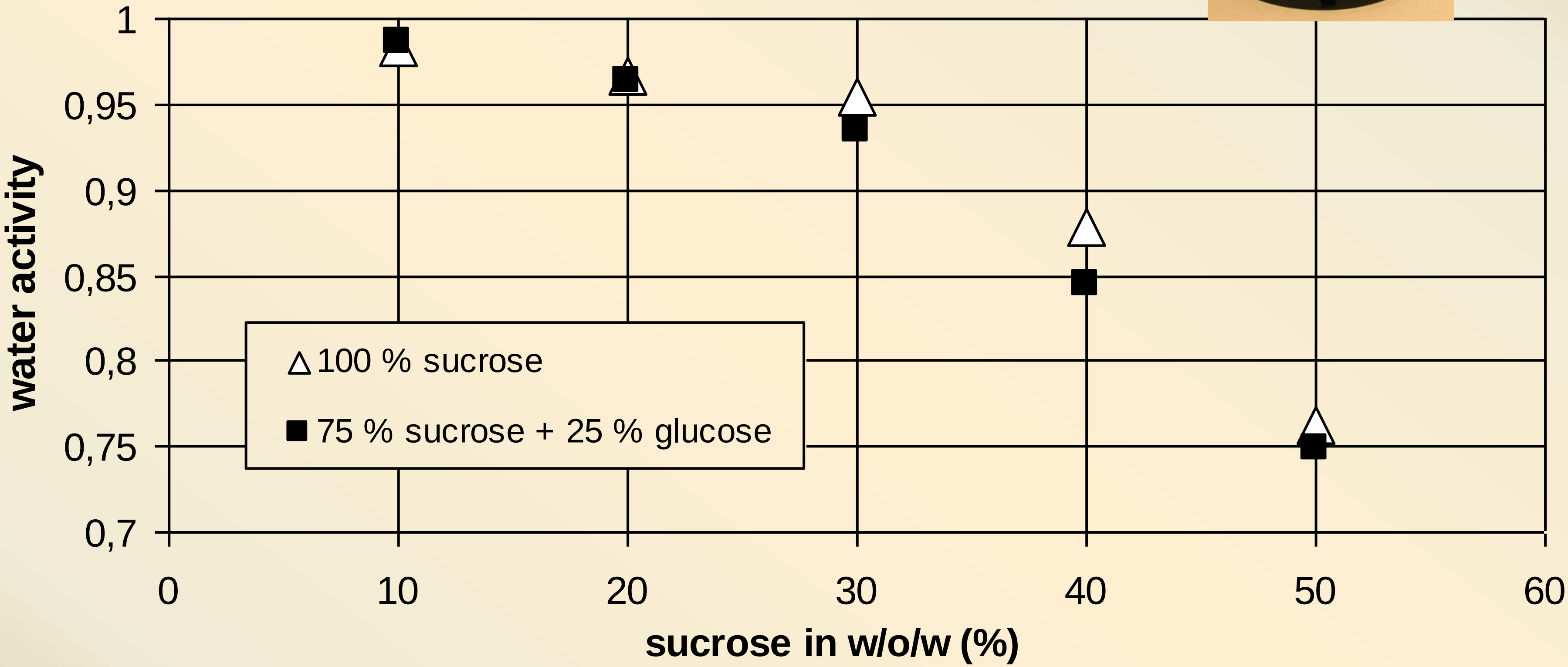


Sugar % **Glucose %** **Sucrose %** **Storage, days**

The storage stability increases up to a sucrose content of ~ 40 %

Multiple emulsions with sucrose
water activity

FA-st,
Fa. GBX



Preparation W/O/W with ~ 59 % sugar in water phases is possible (a_w > 0,75)

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Viscosity of W-phases

Sugar conc. (%)	Sucrose (mPa s)	Sucrose/Gluc. (mPa s)
14.7	3.0 ± 0.06	3.1 ± 0,3
29.4	5.8 ± 0,5	6.8 ± 2.5
44.1	16.0 ± 1.5	21.2 ± 13.7
58.8	83.5 ± 42.,7	44.0 ± 1.8
73.5	626.9	624.7 ± 237.0

O-Phase (continuous phase)

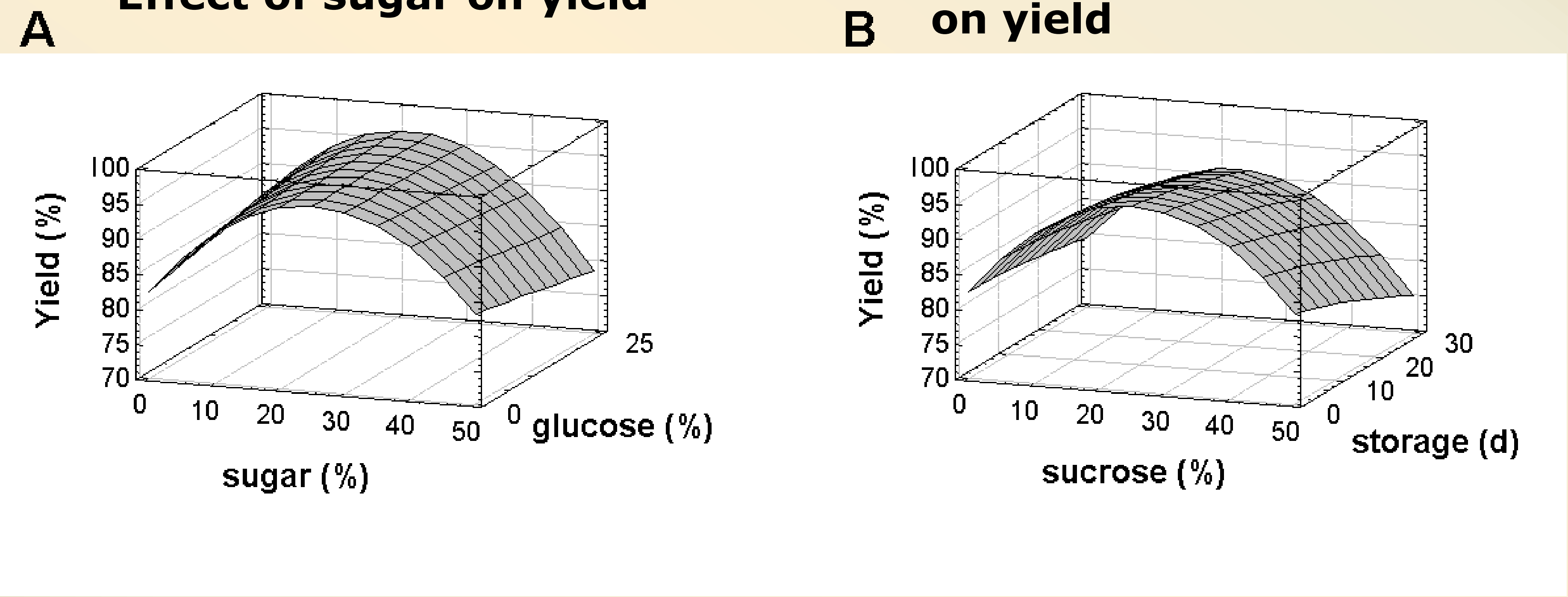
13.5 mPa s

Shear rate: 100 s^{-1}, 60 °C,
Cone-plate 60 mm, 1°

Multiple emulsions with sucrose
Encapsulation behaviour

Effect of sugar on yield

Effect of sugar and storage on yield



Yield: Encapsulation of vitamin B_2 in W_1 > 80 % at a sugar content of 20 – 40 % in W

Sucrose content in $W_1/O/W_2$

(O-phase Miglyol)

Phase relations

W_1 to O = 20/80	W_1/O to W_2 = 40/60

Phases	Sucrose concentration (%)				
W_1 and W_2	14.7	29.4	44.1	58.8	73.5
$W_1/O/W_2$	10	20	30	40	50

Transparency of emulsions increases with sugar content

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Nutritional value of W/O/W

Composition of W/O/W per 100 g 50 % sugar in W-phases (70 % sugar in W-phases)						
W/O	**W/O in W**	**kcal**	**Sugar %**	**Fat %**	**Protein %**	**H_2O %**
20/80	40/60	**439** (495)	34 (47.6)	32	0.68	33
30/70	40/60	**410** (469)	36 (50.4)	28	0.72	34.8

Food calories can be reduced by increasing the W_1-phase

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Conclusions

- W/O and W/O/W phases can be prepared with a high sugar content in W (tested up to 73.5 %)
- Droplet sizes of W/O emulsions containing up to 59 % sugar of < 1 µm ($\eta_d/\eta_c \sim 5$) are possible
- High encapsulation rate (> 90 %) can be realised in emulsions with a sugar content up to 59 %

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Conclusions

- The next research should be concentrated on multiple confectionery emulsions

prepared with

lecithin (PC depleted) or

sugar esters and with

different **fat phases**

Main publications

- Muschiolik/Bunjes,
  Multiple Emulsionen
  Behr´s Verlag, 2007
- Muschiolik, G.
  Multiple emulsions for food use,
  Current Opinion in Colloid & Interface Science 12 (2007) 213-220
- Preissler, P.
  Süßwarenfüllmassen auf Emulsionsbasis
  Logos Verlag Berlin, 2006

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