# An integrated process for utilization of unused chokeberries

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# Chokeberry

- *Aronia* is a member of the *Rosaceae* family
- Two species can be distinguished:
- ✓ *Aronia melanocarpa* (black chokeberry)
- ✓ *Aronia arbutifolia* (red chokeberry)

The most important growing regions are:

- ➢ North America
- ➢ East Canada
- ➢ Germany
- ➢ Russia

# Composition-Polyphenol Content of Chokeberry

| Component | Content (%) |
|---|---|
| Total solids | 25.60 |
| Moisture | 74.40 |
| Total sugars | 10.00 |
| Proteins | 0.70 |
| Crude Fiber | 5.60 |
| Fat | 0.15 |
| Ash | 1.30 |
| Total phenolics | 7.85 |

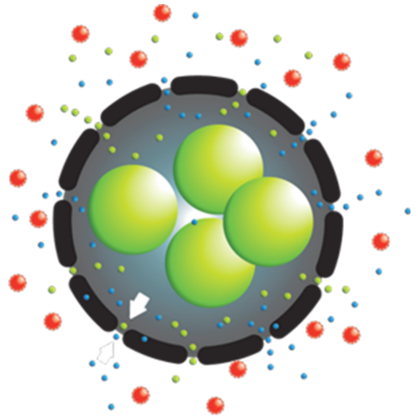
| Phenolic compound | Content (mg/100g dry matter) |
|---|---|
| Procyanidins | 5,182 |
| Anthocyanins | 1,959 |
| Quercetin | 101 |
| Catechin | 15.4 |
| Chlorogenic acid | 302 |
| Neochlorogenic acid | 291 |

- Antioxidant activity
- Anti-mutagenic activity
- Anti-hypertension activity
- Anti-inflammatory activity
- Anti-atherosclerotic activity

*Kulling & Rawel, 2008*

# Applications of chokeberry


# Encapsulation of phenolic compounds

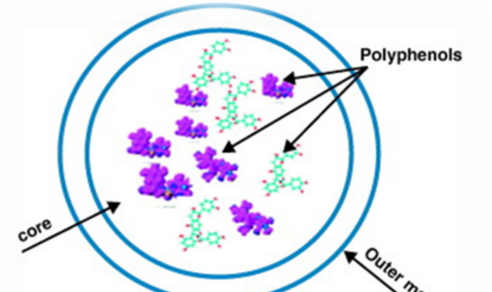


1 Masking of astringency

2 Improvement of color

3 Suitability for use as an additive in functional foods

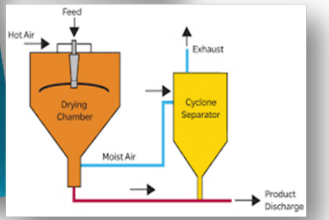
4 Increase of their stability during storage and passage through the gastrointestinal tract




*Shahidi & Han, 1993*

# Encapsulation methods

| Encapsulation method | Encapsulation efficiency (%) | Reference |
|---|---|---|
| Spray drying | 99.8 | Kaderides et al., 2015 |
| Freeze drying | 97.22 | Saikia et al., 2015 |
| Spray chilling | 91.3 | Sukransik et al., 2018 |
| Rotating disk | 80.0 | Akhtar et al., 2014 |
| Yeast encapsulation | 70.0 | Gonzalez et al., 2019 |
| Emulsions | 86.6 | Guldiken et al., 2019 |



# Wall material characteristics

1. Good rheological properties at high concentration
2. Ability to disperse or emulsify the active material and stabilize the emulsion produced
3. Non reactivity with the material to be encapsulated
4. Ability to provide maximum protection to the active material against environmental conditions (e.g., heat, light, humidity)
5. Chemical non reactivity with the active material
6. Ability to seal and hold the active material within its structure during processing or in storage

*Shahidi &Han, 1993*

# Wall materials used for encapsulation of phenolic compounds

| Phenolic extract | Encapsulation method | Wall material | Reference |
|---|---|---|---|
| Pomegranate peel extract | Spray drying | Maltodextrin; Whey protein;Skim milk powder | Kaderides et al., 2015 |
| Blueberry juice | Spray drying & Freeze drying | Cyclodextrins | Wilkowska et al., 2016 |
| *Hibiscus sabdariffa* L. extract | Spray drying | Fruit fibers | Chiou & Langrish, 2007 |
| Olive leaf extract | Spray drying | Sodium caseinate; Lecithin | Kosaraju et al., 2008 |
| Yerba mate extract | Co-crystallization | Sucrose | Deladino et al., 2007 |
| Red wine | Freeze drying | Maltodextrin DE10 | Sanchez et al., 2011 |
| *Rubus chamaemorus* extract | Freeze drying | Maltodextrin DE 5-8 & DE18.5 | Laine et al., 2008 |

# Objective

**The exploitation of chokeberry wastes** based on:

- ➢ Ultrasound & microwave-assisted extraction of phenolic compounds from chokeberries
- ➢ Encapsulation of extract by spray drying using maltodextrin; skim milk powder and whey protein concentrate as wall material

❖ **Optimization**:

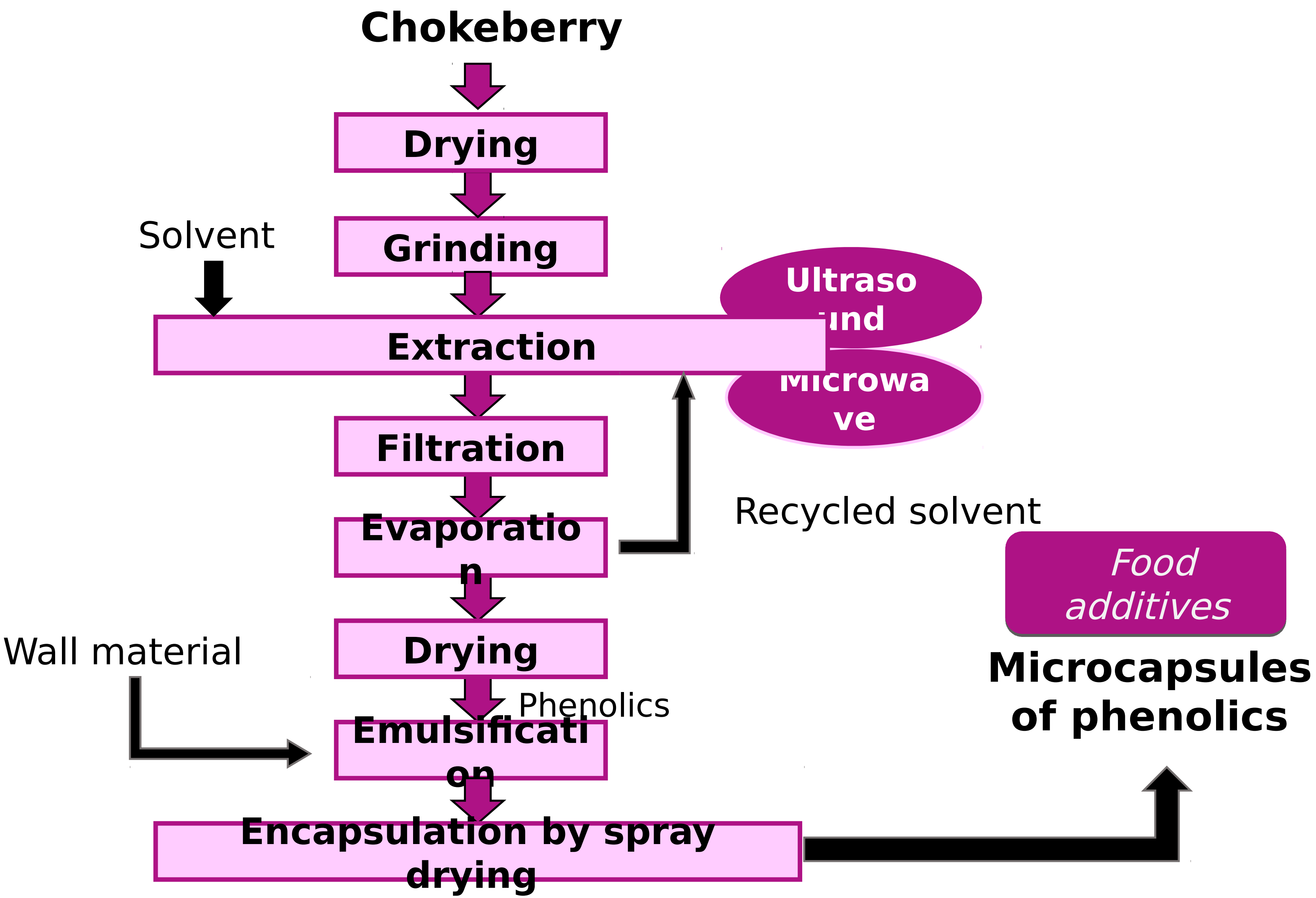
1. *Ultrasound & microwave-assisted extraction of phenolic compounds*
2. *Encapsulation by spray drying of phenolic compounds*

❖ **Study of:**

1. *Encapsulation efficiency*
2. *Physical properties of microcapsules (moisture content, bulk density, rehydration ability and solubility)*

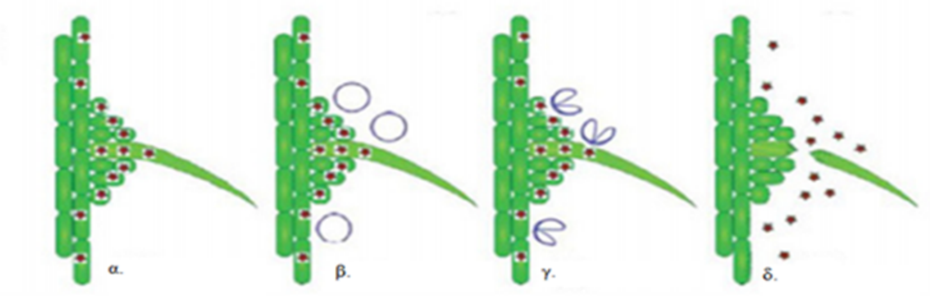
# Materials & Methods

# Proposed process for chokeberry Application in food industry



# Factors affecting the Ultrasound-assisted extraction

1. Extraction temperature
2. Solvent type
3. Liquid/Solid ratio
4. Amplitude level
5. Pulse duration/Pulse interval ratio
6. Extraction time





130 W, 20 kHz VCX-130 Sonics and Materials (Danbury, CT, USA) με Ti–Al–V probe (13 mm)

# Experimental design for optimization of Ultrasound-assisted extraction of phenolic compounds from chokeberry

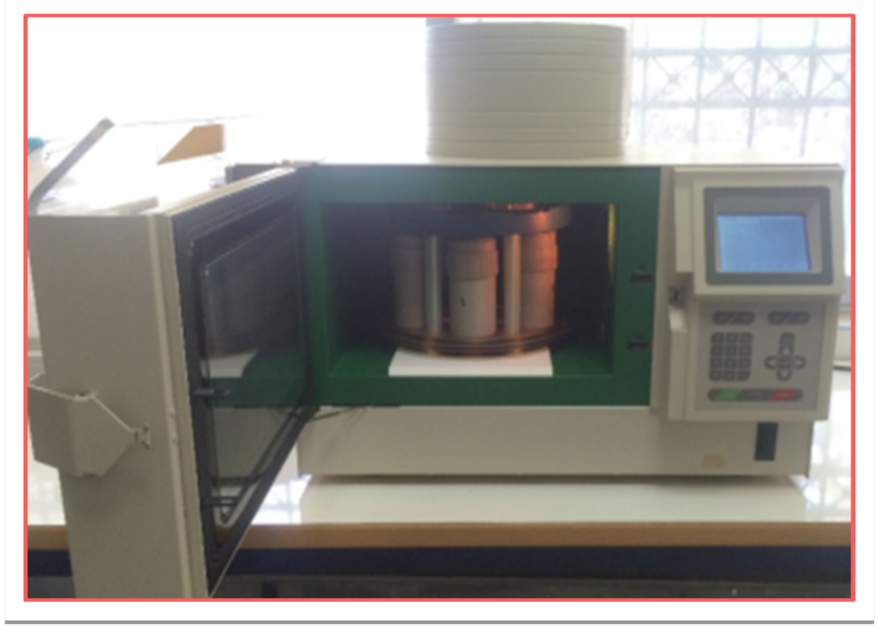
- Response Surface Methodology: **31 experiments**

| Parameters | Levels | | | | |
|---|---|---|---|---|---|
| **Solvent type (% ethanol)** | 0 | 25 | 50 | 75 | 100 |
| **Extraction temperature (T, °C)** | 20 | 30 | 40 | 50 | 60 |
| **Amplitude level (A, %)** | 20 | 30 | 40 | 50 | 60 |
| **Liquid/solid (mL/g)** | 8 | 12 | 16 | 20 | 24 |

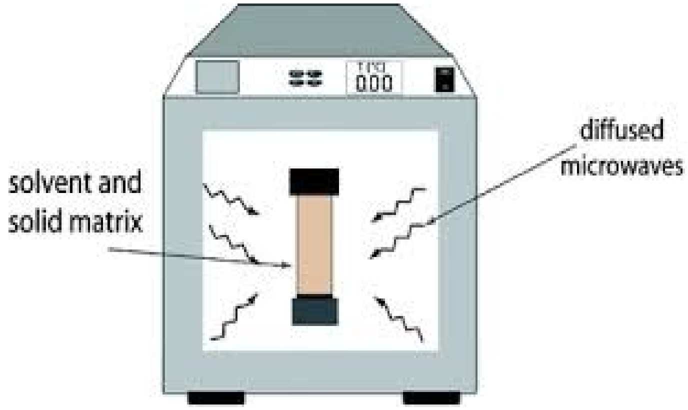
- Each experiment in **2,5,10,20,30 min**

# Factors affecting the Microwave-assisted extraction

1. Power
2. Solvent type
3. Liquid/Solid ratio
4. Extraction time



Microwave system (MultiwaveB30MC030A) (Anton Paar, Austria)



# Experimental design for optimization of Microwave-assisted extraction of phenolic compounds from chokeberry

- Response Surface Methodology: **20 experiments**

| Parameters | Levels | | | | |
|---|---|---|---|---|---|
| **Solvent type (% ethanol)** | 0 | 25 | 50 | 75 | 100 |
| **Power (W)** | 100 | 200 | 350 | 500 | 600 |
| **Liquid/solid (mL/g)** | 8 | 12 | 16 | 20 | 24 |

- Each experiment in **1,2,3,4,5,6 min**

# Factors affecting the spray drying encapsulation process

1. Inlet air temperature
2. Feed solids concentration
3. Ratio of core to wall material
4. Drying air flow rate
5. Drying air humidity


Buchi, B-191,
Buchi Laboratoriums-Technik,
Flawil, Switzerland

# Experimental design for optimization of spray drying encapsulation of phenolic compounds from chokeberry

- Response Surface Methodology: **20 experiments x 2 wall materials**

| Parameters | Levels | | | | |
|---|---|---|---|---|---|
| **Ratio of wall to core material (w/c)** | 2.3 | 3.7 | 5.6 | 7.3 | 1/9 |
| **Inlet air temperature ($T_i$, ºC)** | 150 | 158 | 170 | 182 | 190 |
| **Drying air flow rate ($Q_a$ %)** | 50 | 53 | 57.5 | 62 | 65 |

**Wall material:**

- Maltodextrin/SMP: 50/50
- Maltodextrin/WPC: 50/50

- *SMP: Skimm milk powder*
- *WPC: Whey protein concentrate*

# Yield and Efficiency of microencapsulation

❖ **Microencapsulation efficiency (E)**

$$E_{ff} = \left(1 - \frac{\text{Phenolics on microcapsule surface}}{\text{Total phenolics of microcapsule}}\right) * 100$$

❖ **Microencapsulation yield (Y)**

$$\Upsilon = \frac{\text{Mass of microcapsules (g)}}{\text{Total mass of initial substances (g)}} * 100$$

Solids feed collected in product container

# Physical properties of microcapsules

1 Moisture content

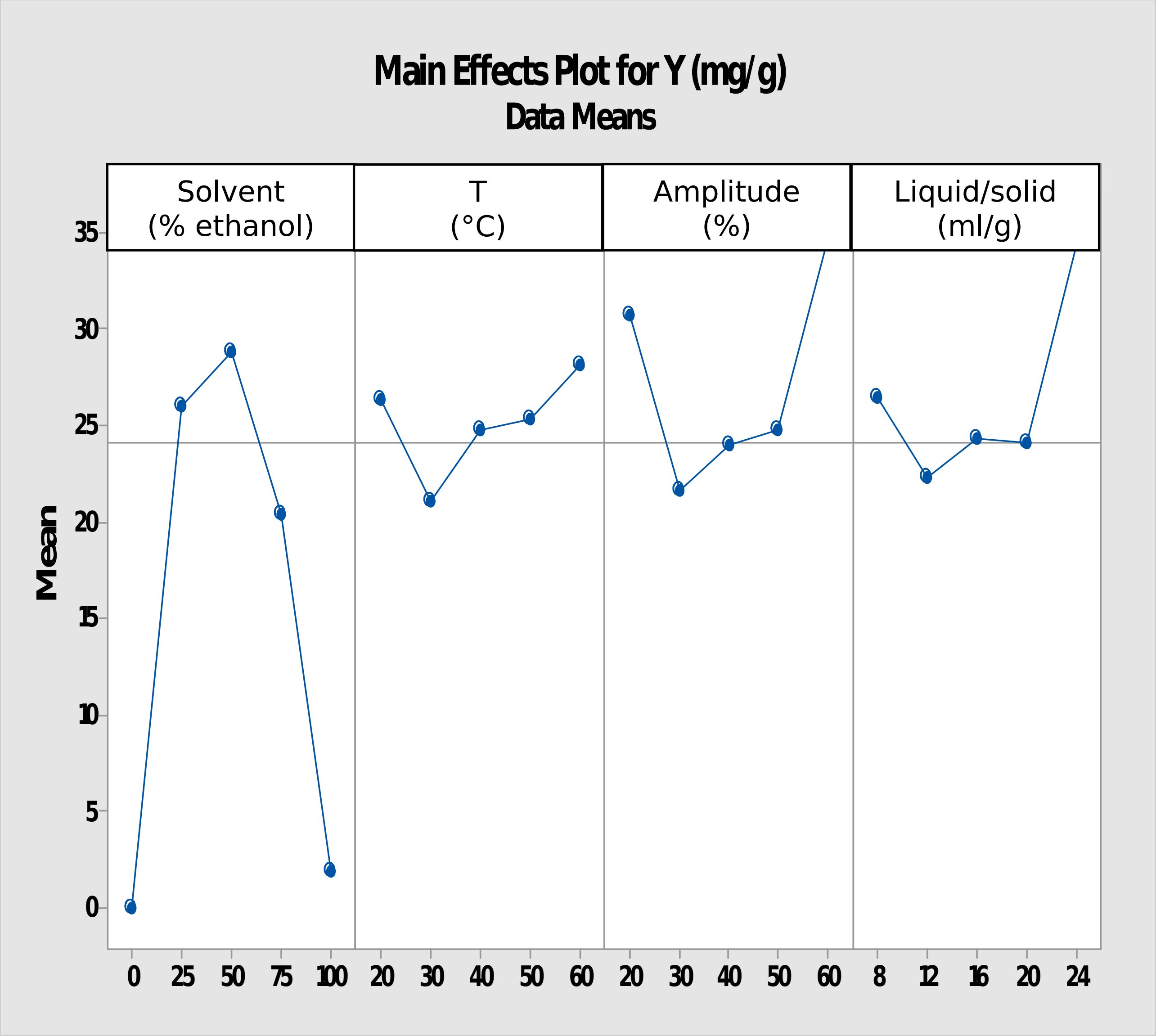
2 Bulk density

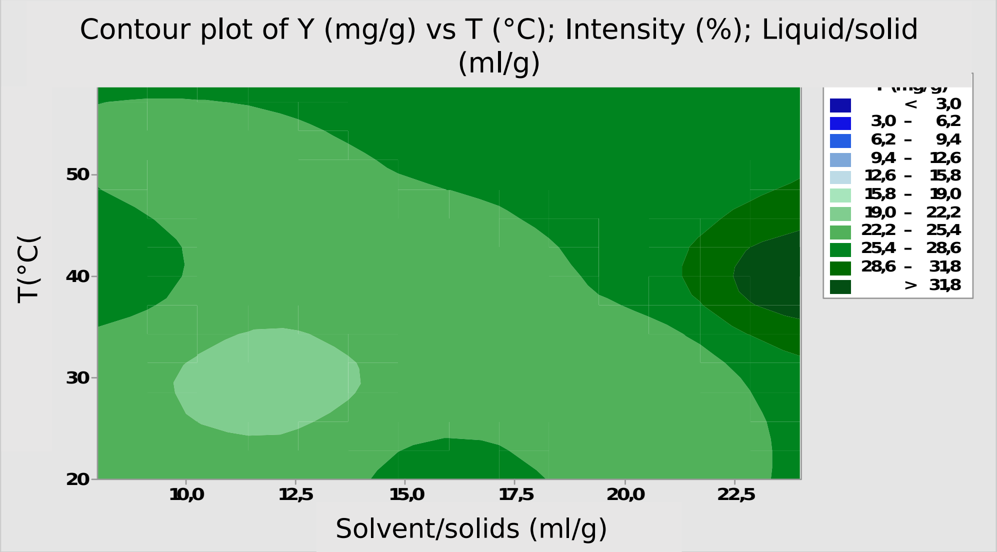
3 Rehydration ability

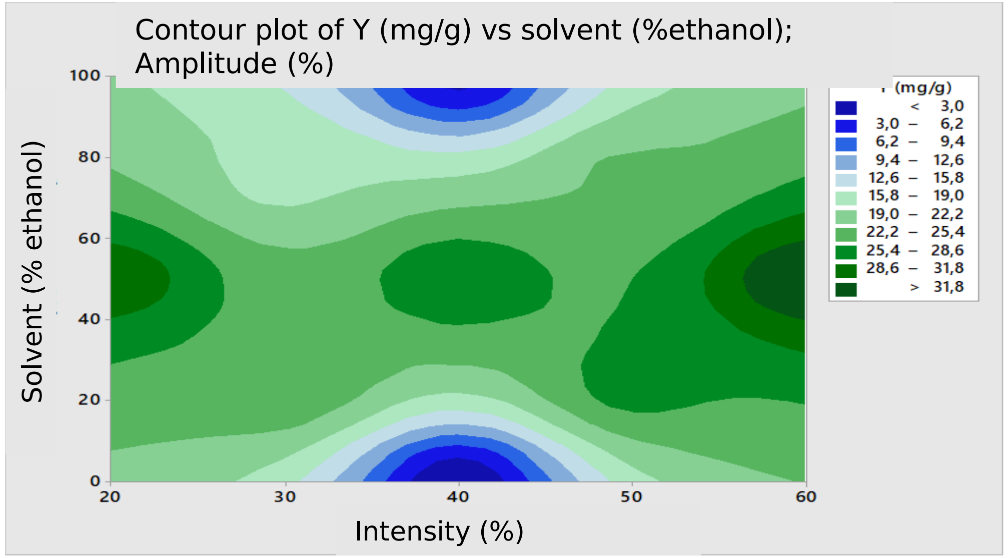
4 Solubility

# Results

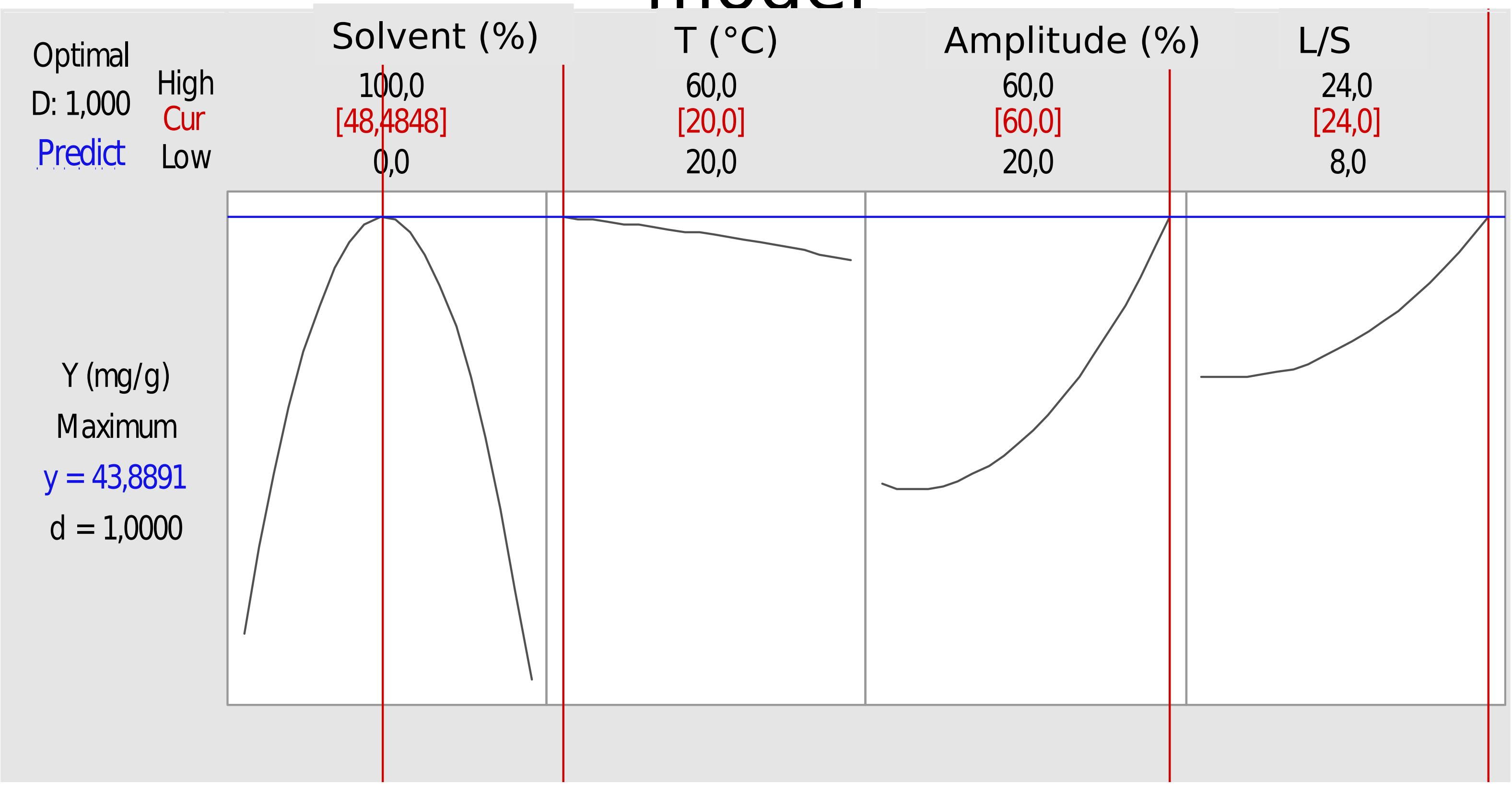
# Ultrasound-assisted Extraction Yield-Effects of various parameters



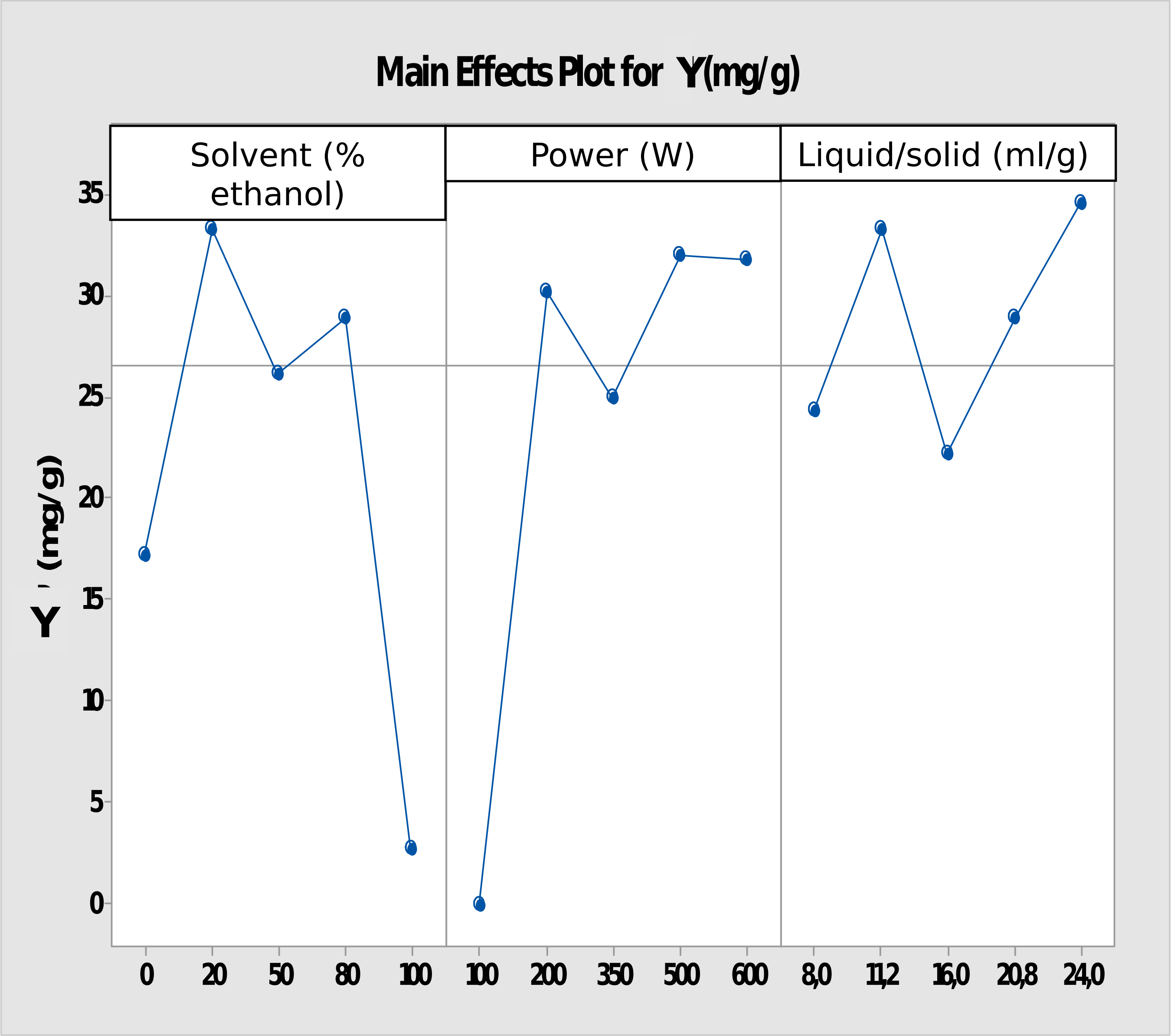
# Extraction Yield-Optimization-Empirical model

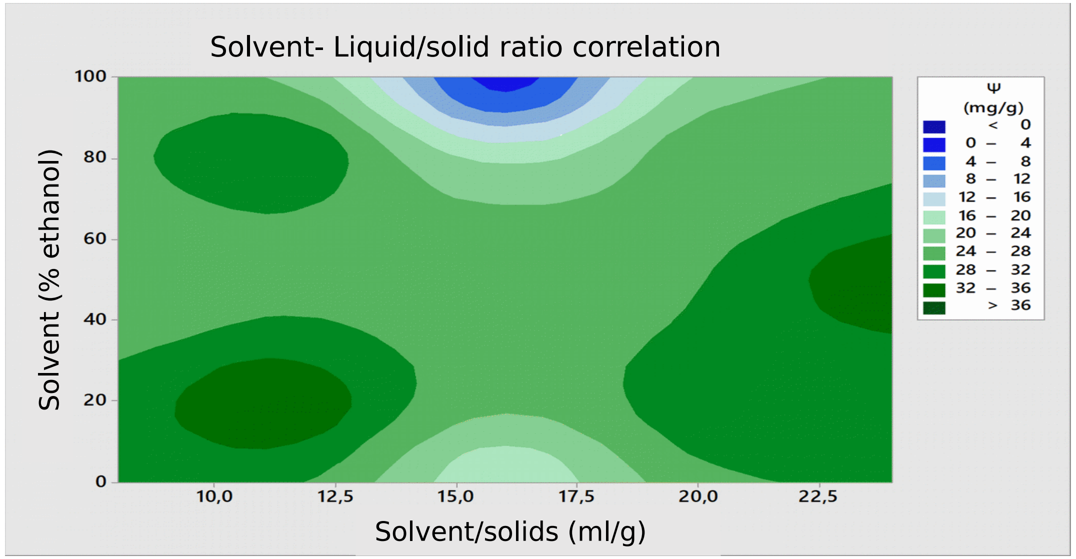


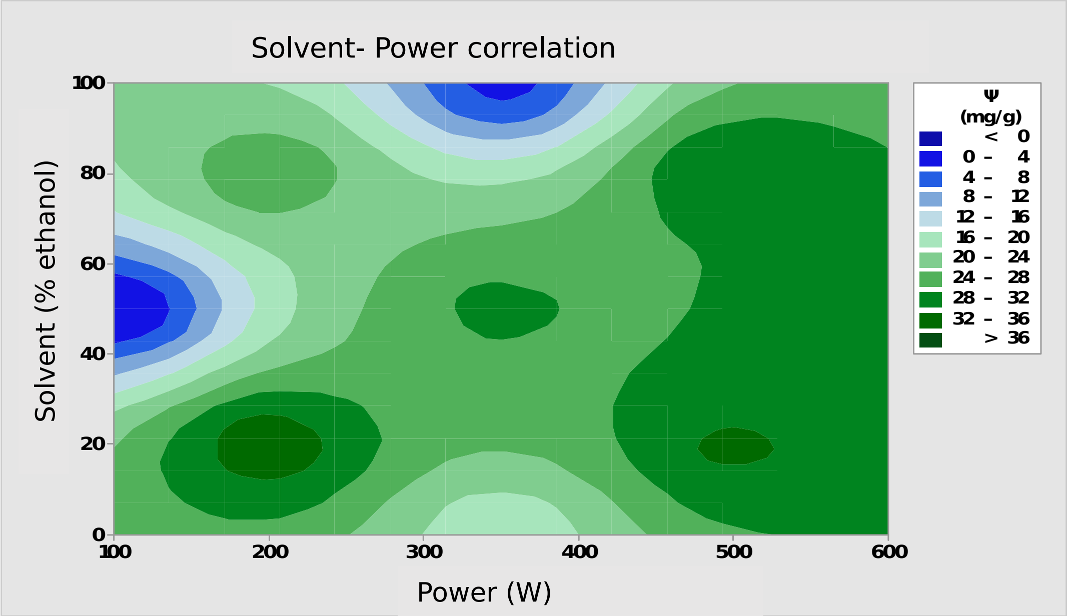

***Empirical model of extraction yield:***

$$Y (\%) = 20.9+0.748*S+0.543*T-0.841*A-1.58*s/s-0.0106*L^2-0.00061*T^2+0.0304*A^2+0.0469*(L/S)^2+0.00204*L*T+0.00294*S*A+0.00282*L*L/S-0.0946*T*A-0.038*T*L/S+0.0104*A*L/S$$

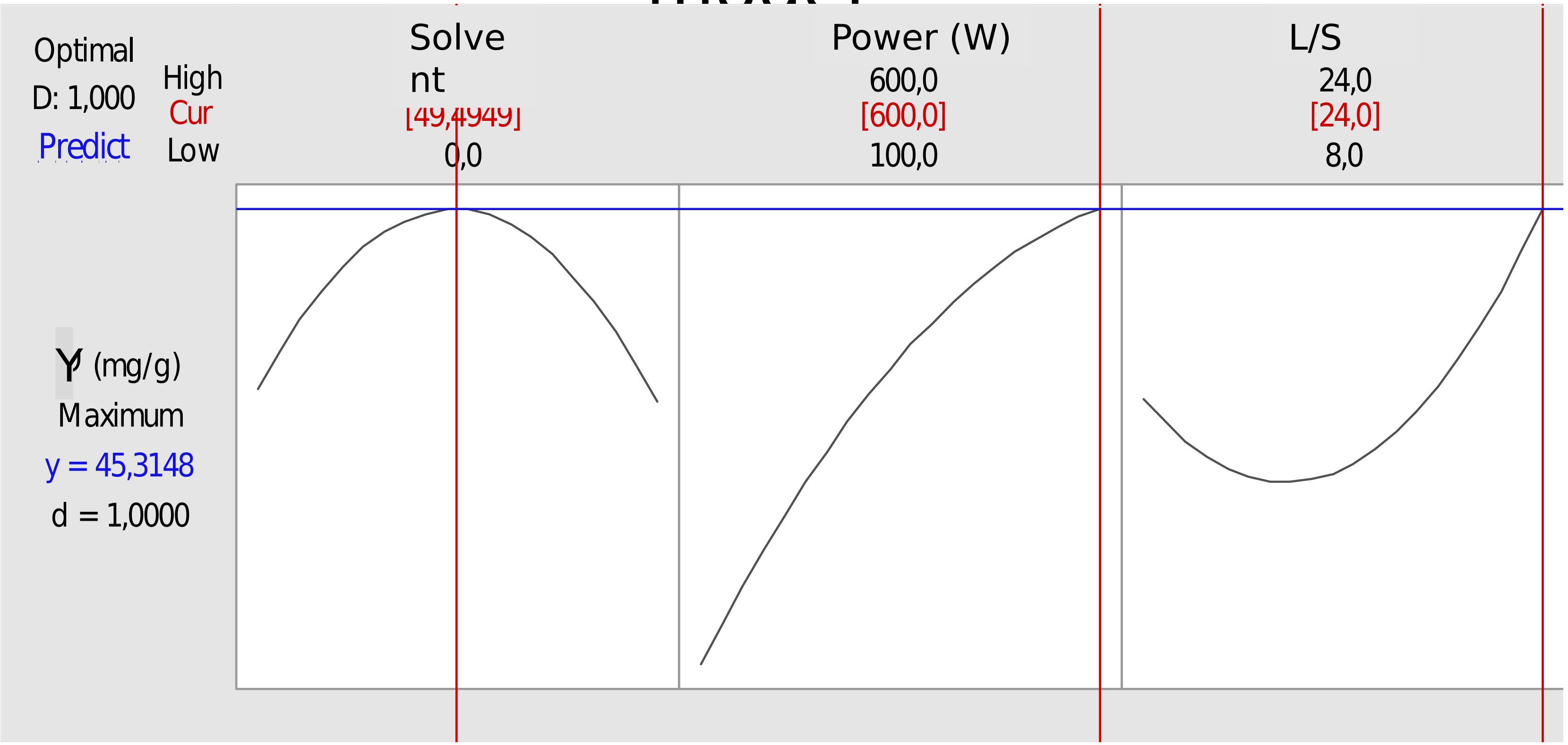
# Microwave-assisted Extraction Yield-Effects of various parameters



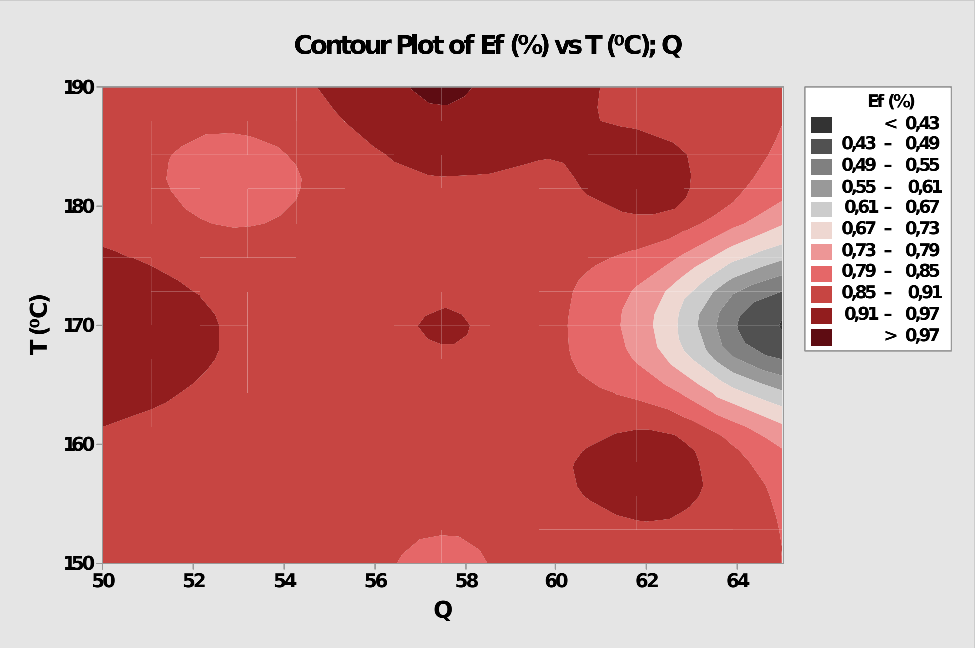
# Extraction Yield-Optimization-Empirical model

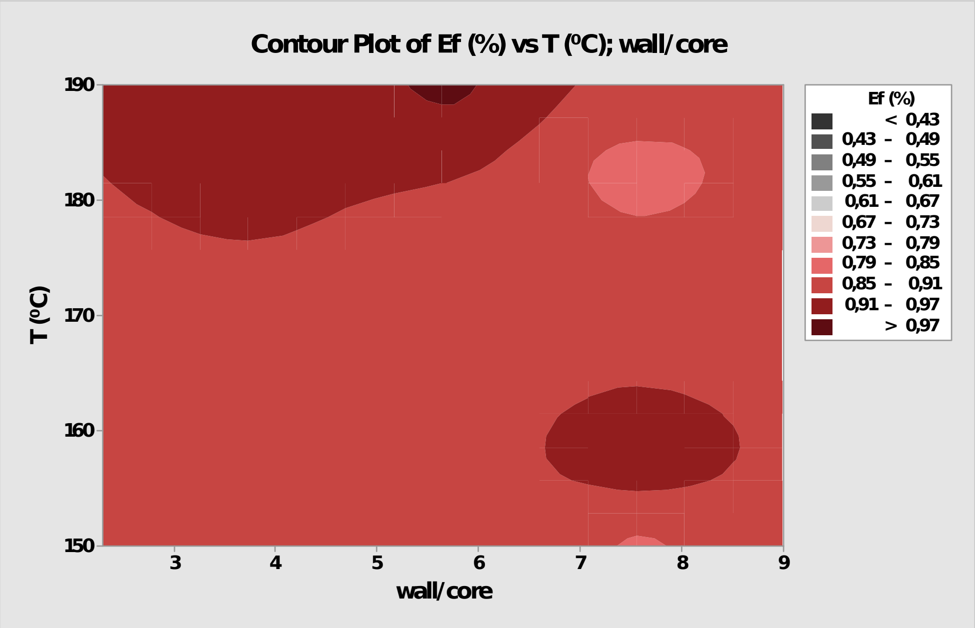


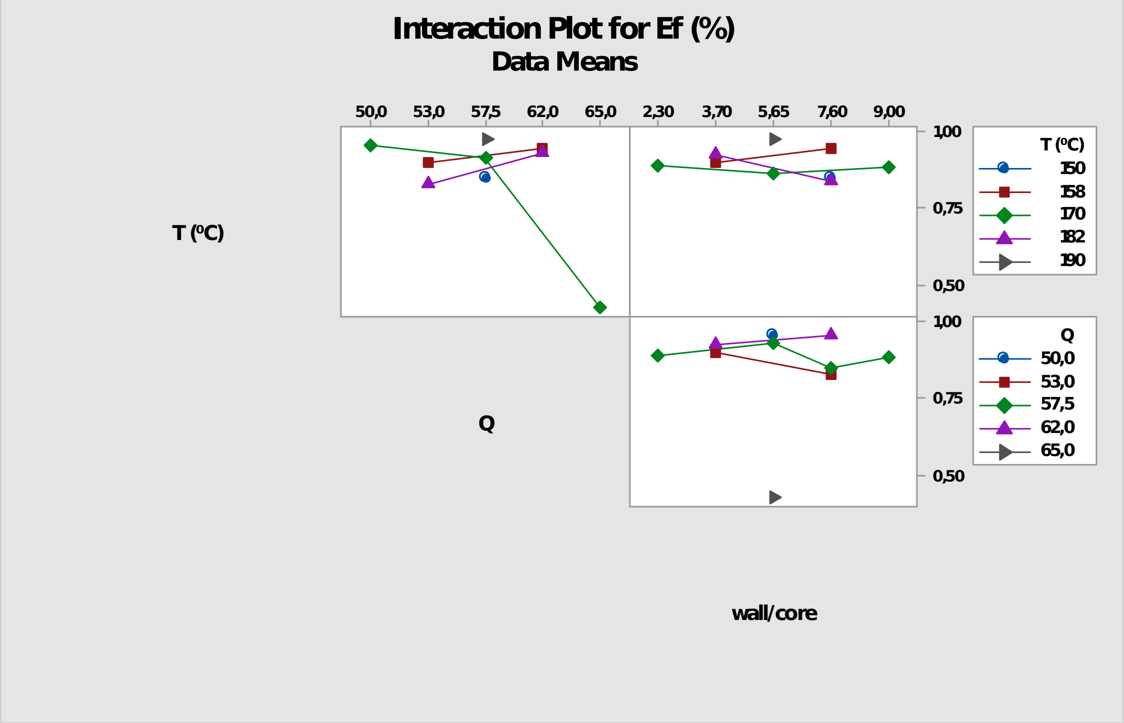

***Empirical model of extraction yield:***

$$Y\ (\%) = 28.03-3.09*S+4.46*P+0.01*L/S-3.73*S^2-1.64*P^2+3.17*(L/S)^2$$
$$+1.83*S*P-0.11*S*(L/S)+1.90*P*(L/S)$$

# Encapsulation efficiency-Effects of various parameters



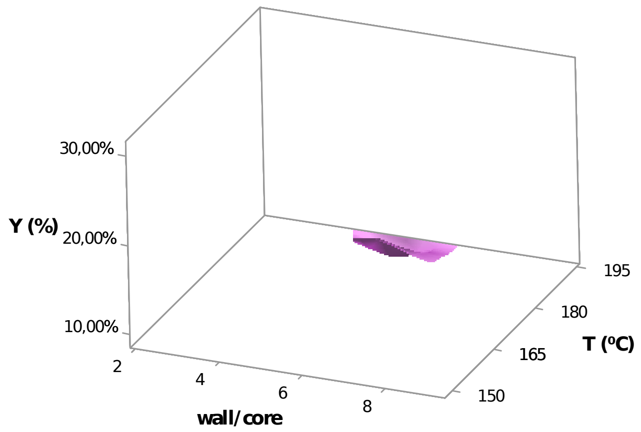




- **Microencapsulation efficiency (E)**

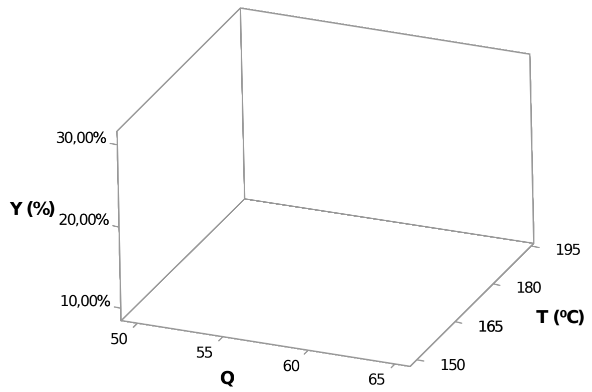
$$E_f = (1 - \frac{\text{Phenolics on microcapsule surface}}{\text{Total phenolics of microcapsule}}) * 100$$

# Encapsulation Yield-Effects of various parameters

**Surface Plot of Y (%) vs T (ºC); wall/core**




**Surface Plot of Y (%) vs T (ºC); Q**




Coded Coefficients

| Term | Effect | Coef | SE Coef | T-Value | P-Value | VIF |
|---|---|---|---|---|---|---|
| Constant | | 0,2174 | 0,0138 | 15,71 | 0,000 | |
| T (□C) | 0,0134 | 0,0067 | 0,0160 | 0,42 | 0,686 | 1,09 |
| Q | 0,0179 | 0,0089 | 0,0154 | 0,58 | 0,574 | 1,00 |
| wall/core | 0,0213 | 0,0107 | 0,0155 | 0,69 | 0,506 | 1,04 |
| T (□C)*T (□C) | 0,1774 | 0,0887 | 0,0264 | 3,36 | 0,007 | 1,11 |
| Q*Q | -0,0420 | -0,0210 | 0,0254 | -0,83 | 0,428 | 1,03 |
| wall/core*wall/core | -0,1041 | -0,0520 | 0,0261 | -1,99 | 0,074 | 1,04 |
| T (□C)*Q | -0,0389 | -0,0195 | 0,0334 | -0,58 | 0,573 | 1,00 |
| T (□C)*wall/core | 0,1079 | 0,0540 | 0,0322 | 1,68 | 0,125 | 1,17 |
| Q*wall/core | 0,0487 | 0,0243 | 0,0344 | 0,71 | 0,495 | 1,00 |

❖ **Microencapsulation yield (Y)**

$$Y = \frac{\text{Mass of micocapsules (g)}}{\text{Total mass of initial substances (g)}} * 100$$

# Conclusions

- Microwave assisted extraction is more effective than ultra sound-assisted extraction and in shorter time
- Interactions between factors are not statistically significant
- In microwave-assisted extraction no factor effects statistically significant
- In ultrasound-assisted extraction solvent and amplitude effect statistically significant
- Solvent ratio has a very significant effect on extraction

Thank you for your attention!