

# LOS PULSOS ELÉCTRICOS DE ALTO VOLTAJE COMO HERRAMIENTA PARA IMPLEMENTAR LA ECONOMÍA CIRCULAR EN LA INDUSTRIA ALIMENTARIA Y BIOTECNOLÓGICA



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# FOOD PROCESSING

- **Food processing**, involves a variety of operations conducted in the food industry by which raw foodstuffs are made suitable for consumption, cooking, or storage. ...

## Unit Operations

- Material Handling
- Cleaning
- Separating
- Size reduction
- Fluid Flow
- Mixing
- Heat transfer
- Concentration
- Drying
- Forming
- Packaging
- Controlling



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## Problems

- Sensory and nutritional properties affected



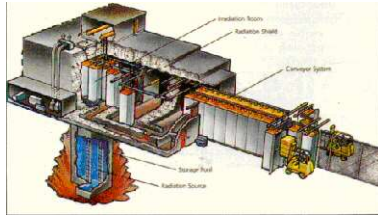
- Energy consumption



- Waste generation



# Nonthermal Processing Technologies



Improving Food Quality



- ❑ Irradiation (IR)
- ❑ Ultra-violet light (UV)
- ❑ High Hydrostatic Pressure (HHP)
- ❑ Ultrasound (US)
- ❑ **Pulsed Electric Fields**



New Products



Energetic Cost Reduction



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# Definition of PEF

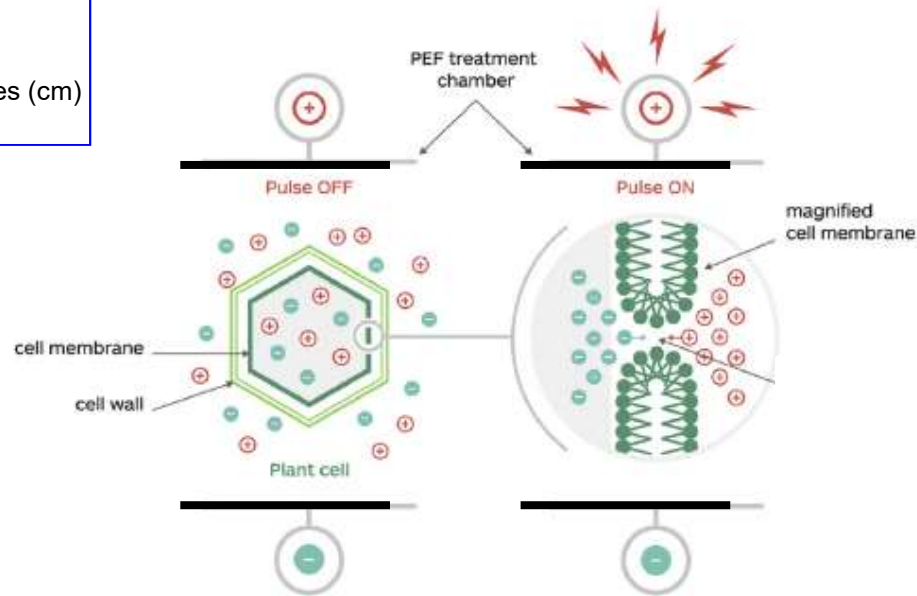
- Application of pulses of high voltage (kV) and short duration ( $\mu$ s) to a biological material placed between two electrodes

- Electrical Field Strength:

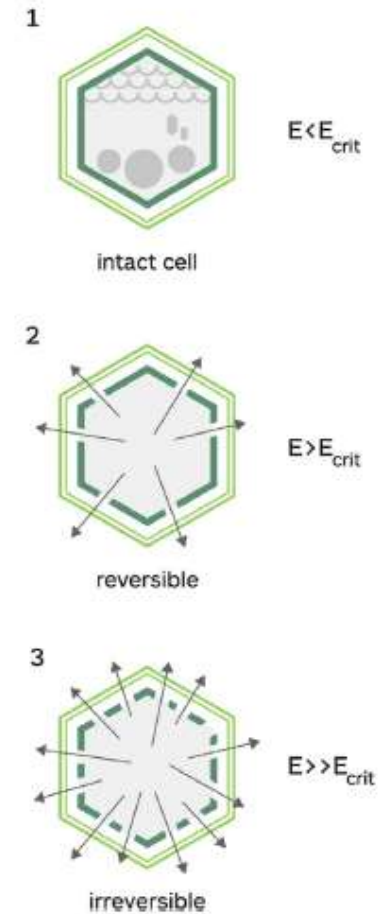
$$E = V/d$$

V= voltage (kV)

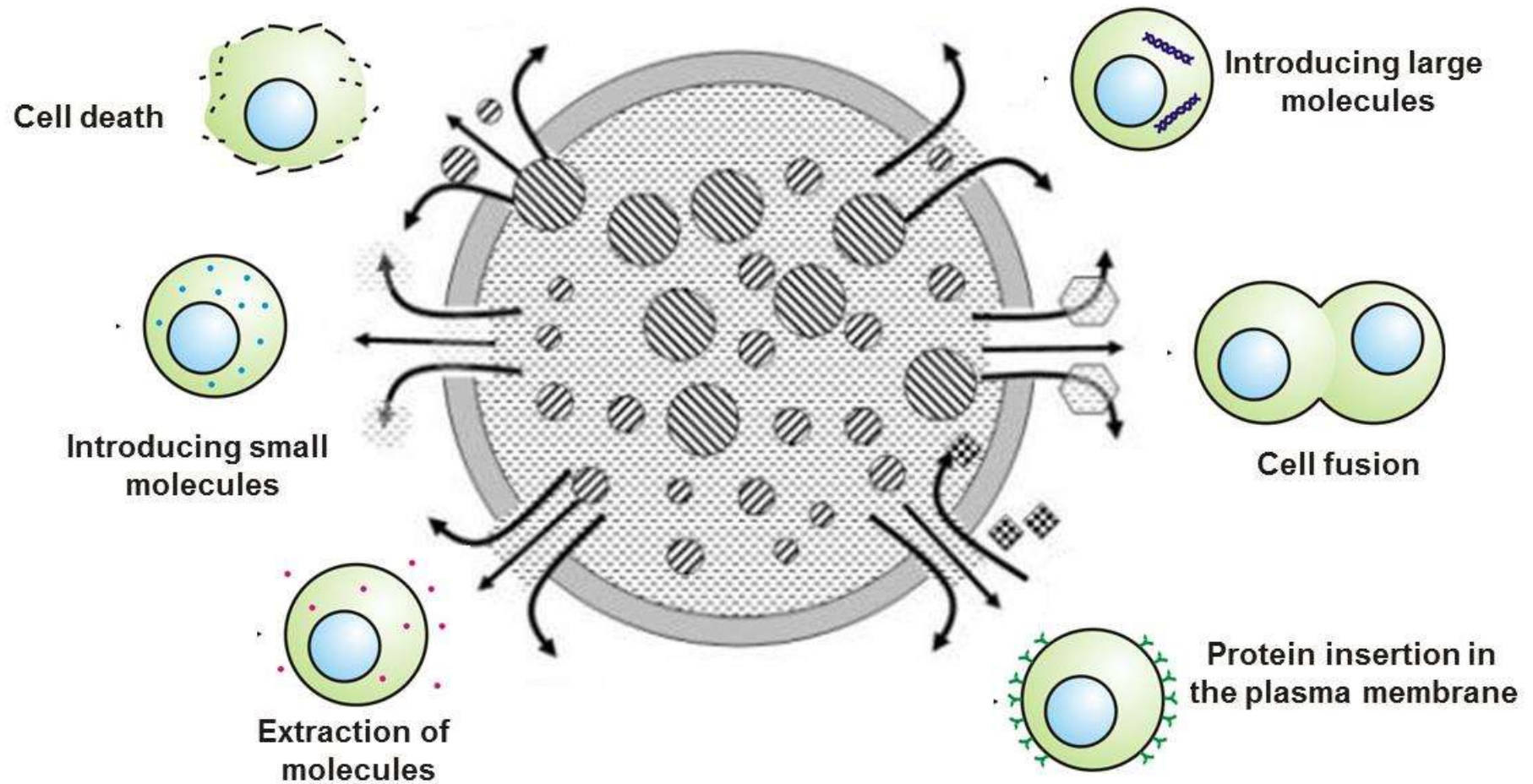
d= distance between electrodes (cm)



## Electroporation

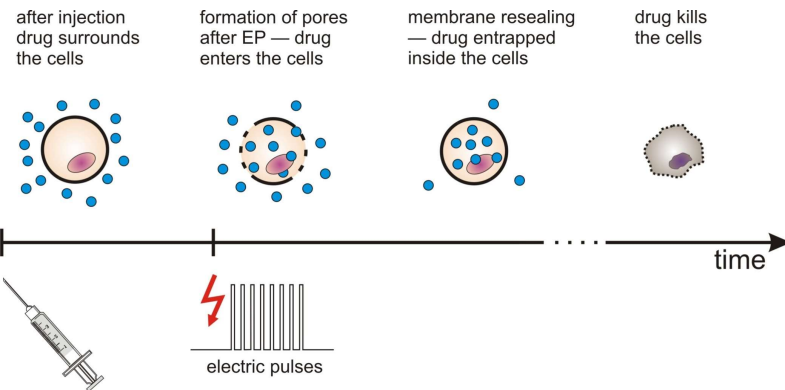


# Electroporation

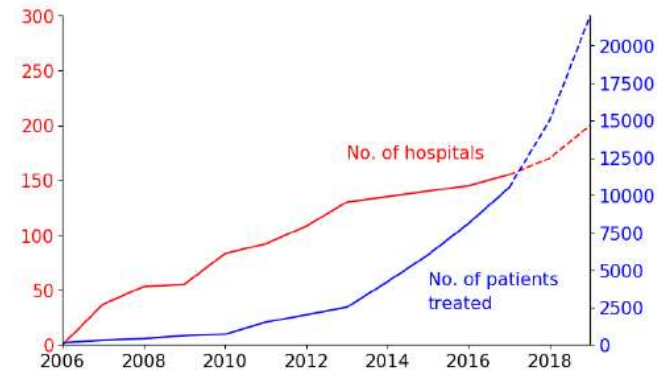




# Electroporation



## Clinical use of electrochemotherapy in EU



Reimbursed in:  
Switzerland, Austria, Germany, Denmark, Spain, UK, Italy, Portugal, Slovenia.  
France, Poland – in progress for reimbursement.



Source: IGEA S.p.A., Italy

Julie Gehl.

*Ugeskrift for Laeger* 167(34): 3156-9, 2005.

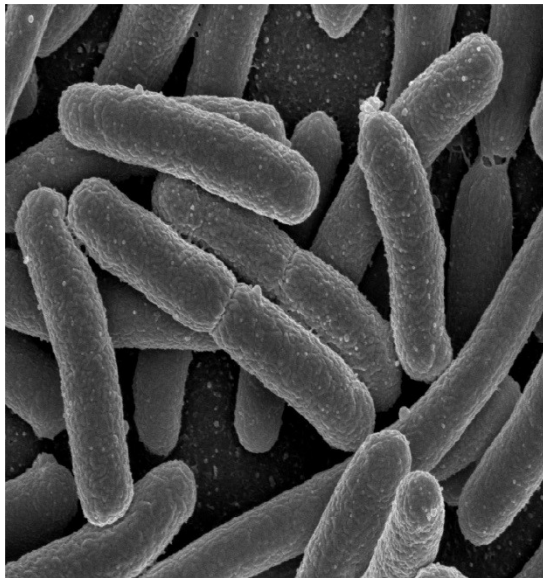
Jarm, Cemazar, Miklavcic, Sersa.  
*Expert Rev. Anticancer Ther.* 10: 729–746, 2010



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# Applications of PEF in the Food Industry

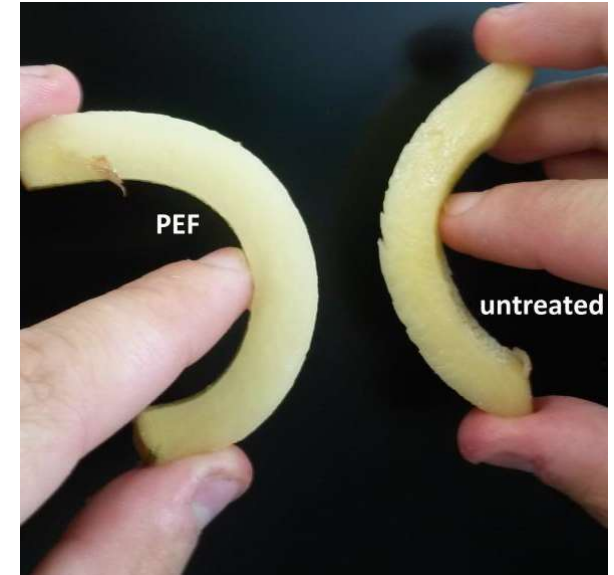
Microbial inactivation



Improving Mass Transfer

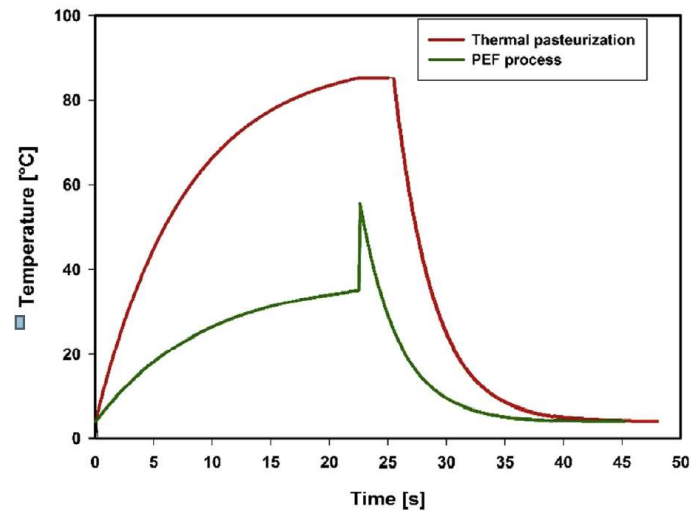


Food Structure Modification





# Microbial inactivation by PEF



These smoothies are slightly pasteurized. Pasteurization is a simple treatment that is known of milk, a perishable product as well. When Fruity King pasteurizes her products it is a mild pasteurisation, which won't affect the taste. The shelf life will be extended and therefore it becomes easier for kids to take it to school and drink it during the day.

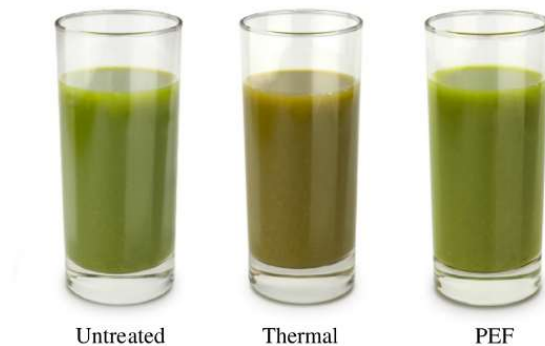


Figure 2.4 Color difference of untreated, thermally treated, and PEF-treated green smoothie (Elea, 2018). PEF, Pulsed electric field.

## Producers



(Netherlands)



(Netherlands)



(Germany)



(UK)



(Italy)

## Supermarkets



(UK)



Albert Heijn

(Netherlands)



(Germany)



(Germany)

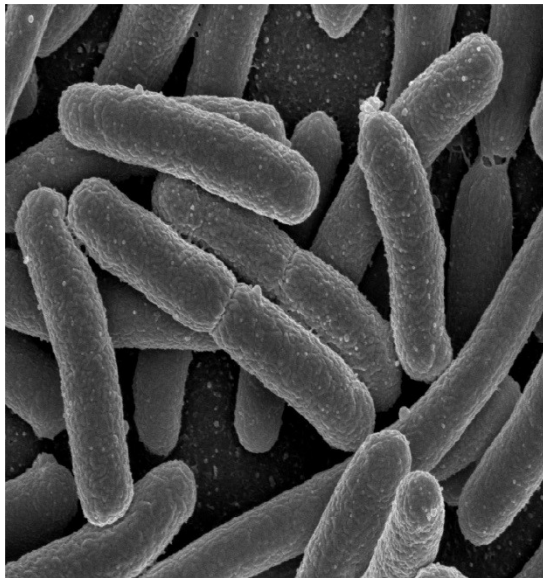


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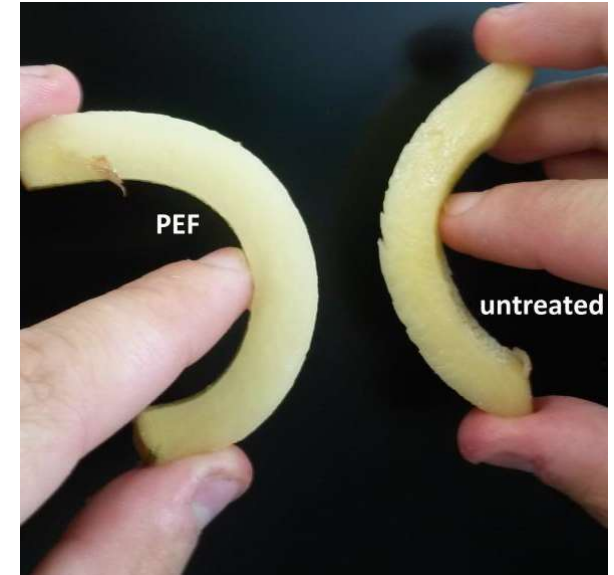
Microbial inactivation



Improving Mass Transfer

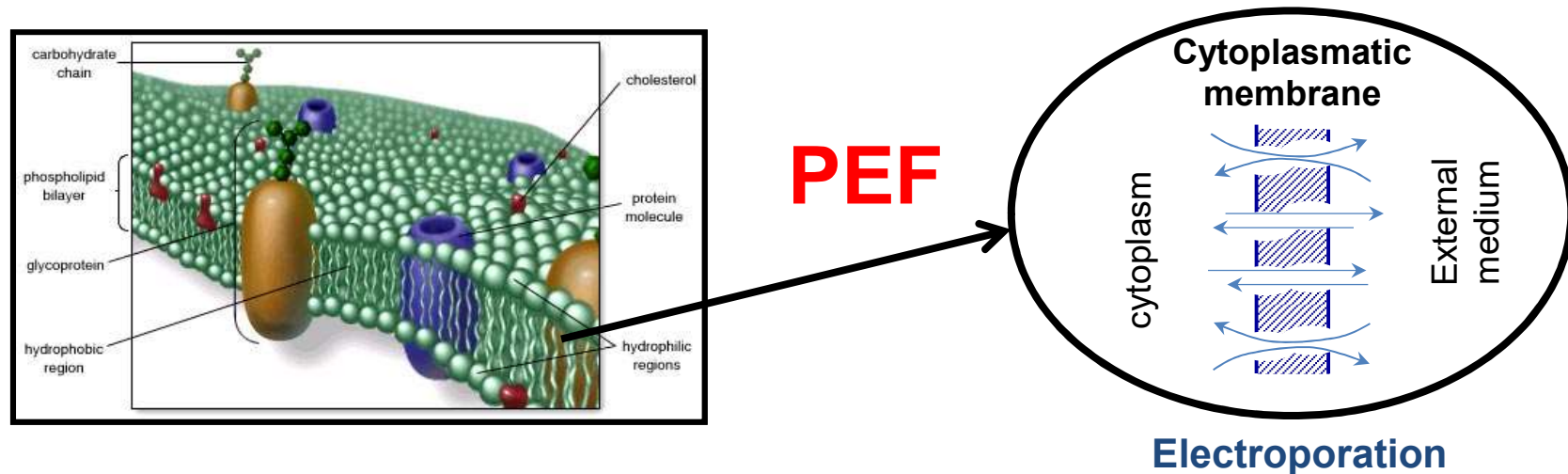


Food Structure Modification



# Pulsed electric fields: mass transfer

- Migration of a substance between two phases under the influence of a concentration gradient in order to reach chemical equilibrium



## Extraction of intracellular compounds

- Juices from fruits (Apple juice, Carrot juice)
- Sugar from beets
- Pigments from plants (Anthocyanins, betains)
- Phenolic components (Winemaking)

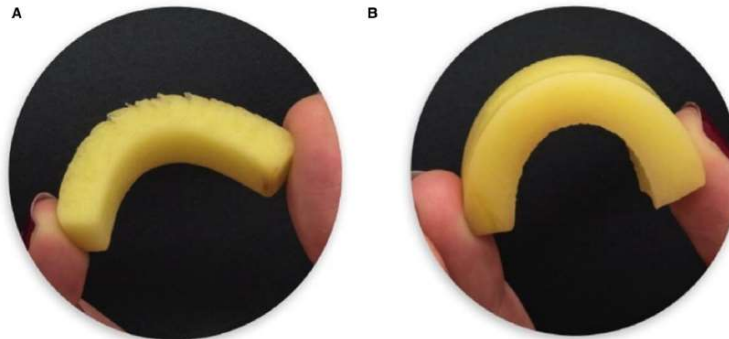
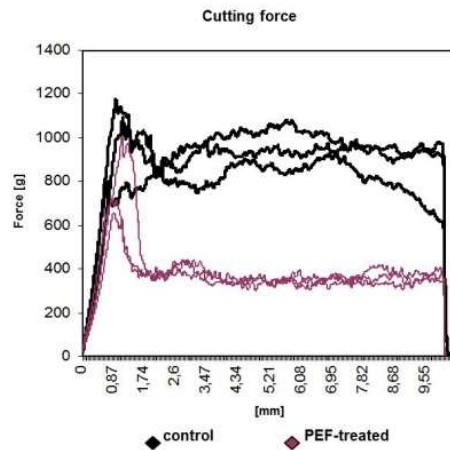
## Removing water

- Drying

## Introduction of a substance into the food matrix

- Osmotic dehydration (apple, pepper)
- Salting (Serrano type ham)
- Brining (cooked ham)

# Other applications of PEF



**Figure 3** Typical rough and scaly surface appearance of untreated potato sticks (a) and smooth surface of PEF pretreated sticks. (Elea GmbH, 2019).



# Benefits of PEF for Circular economy

- Reduction energetic consumption
- Reduction the use of organic solvents in extraction process
- Use of by-products





# Reduction energetic consumption

Drying



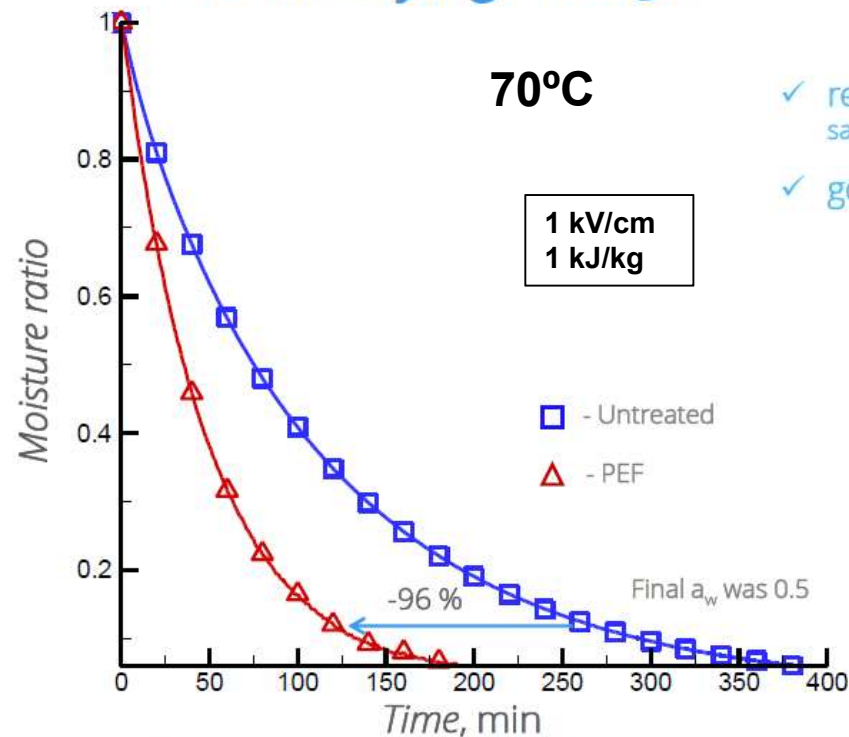
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# Reduction energetic consumption

## Drying



### Hot air drying - mango



PEF resulted in

- ✓ reduction of drying time by 50% (to the same water content MR=0.06)
- ✓ good colour retention

Untreated



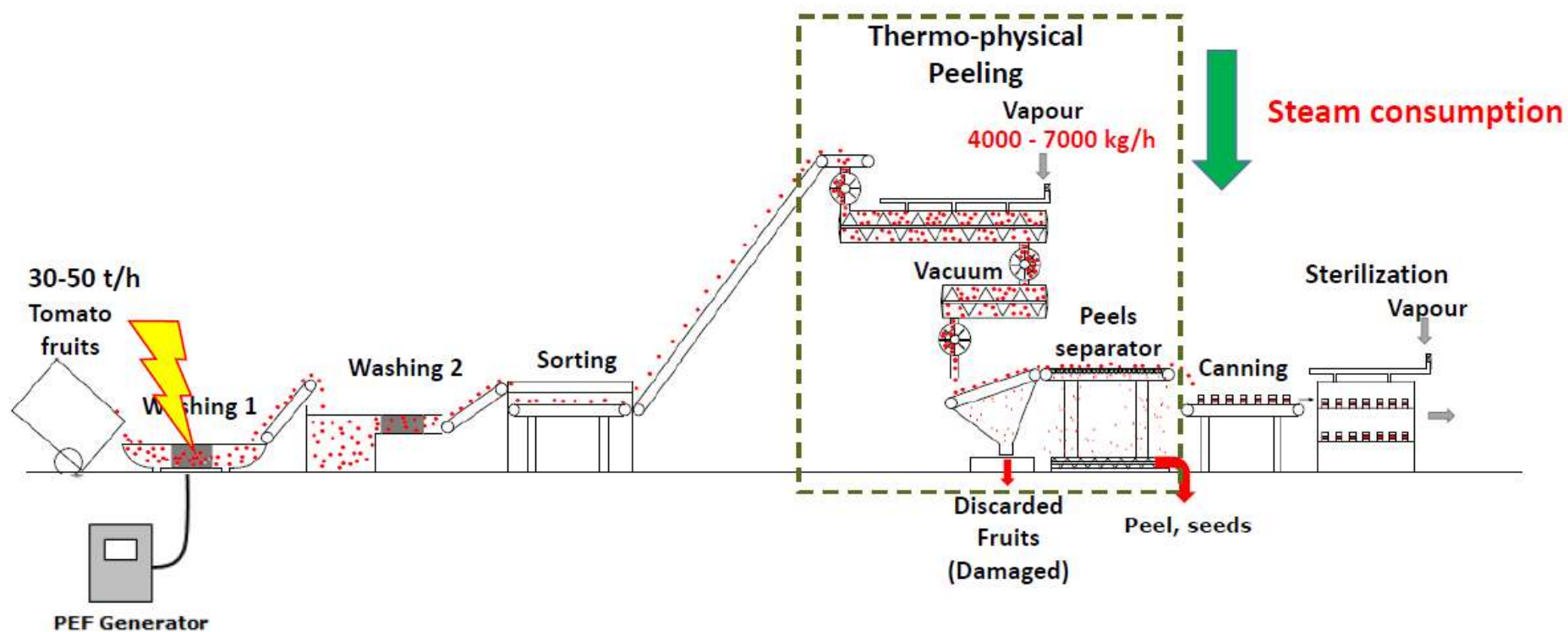
PEF



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# Reduction energetic consumption

## Improving Tomato Peeling by PEF





# Reduction energetic consumption

## Improving Tomato Peeling by PEF

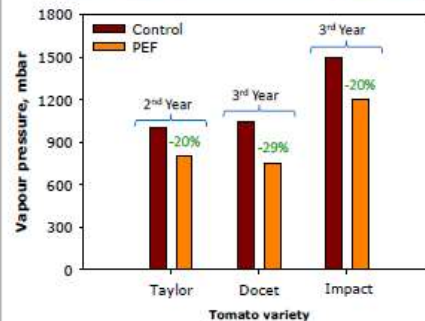


PEF pre-treatment can improve the efficiency of industrial processing of tomato fruits



### Improving peelability

- ✓ Reduction of peel resistance and adhesiveness
- ✓ Promoting cracking formation
- ✓ Reduction of peeling index
- ✓ Improving peeling performance

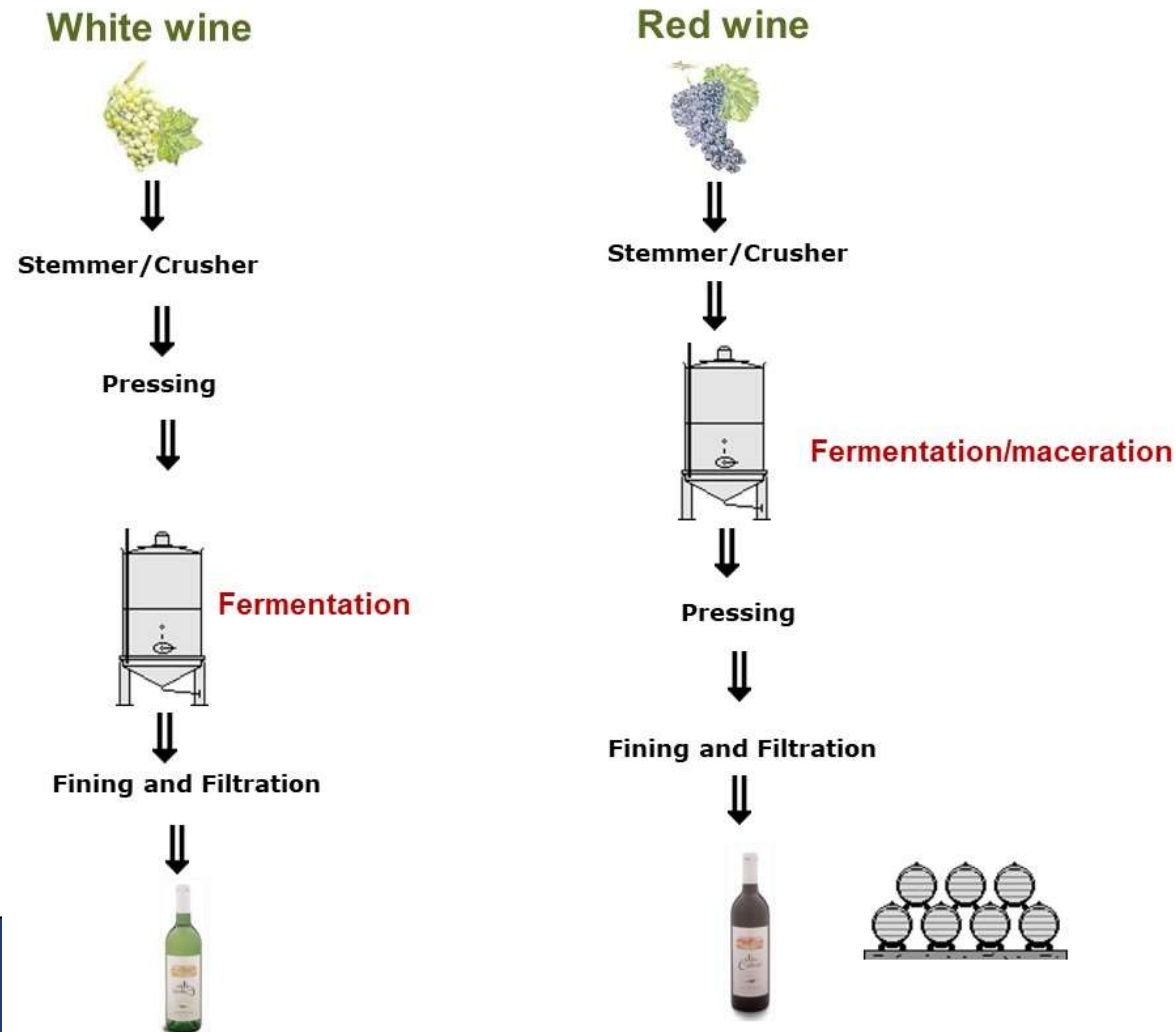


### Lowering energy costs of the process

- ✓ Steam saving (20-30%) during the thermophysical peeling phase

# Reduction energetic consumption

Improving red winemaking





# Reduction energetic consumption

## Improving red winemaking



### ➤ Sensory properties

Color  
Astringency  
Bitterness



### ➤ Capability for aging



### ➤ Health promoting properties



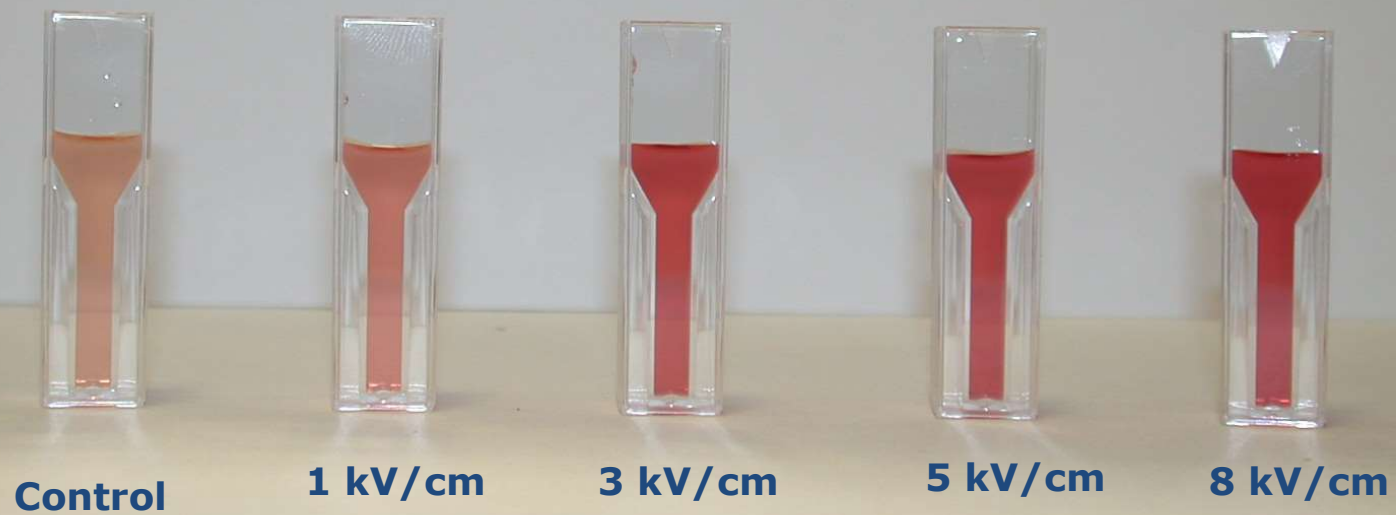
## Problems derived of long maceration:

- Reduction of the production capacity of the wineries
- Cost in manpower and energy for periodically pumping the wine over the mass of skins
- Difficult to control fermentation temperature



# Grenache grapes

1 hour of maceration



# Reduction energetic consumption

## Improving red winemaking



	Total production (tons)	Duration maceration (days)	Energy consumption (kWh/t)	Total Energy consumption kWh	Energy cost €/kWh	Total cost €	Saving costs €
Control	13000	10	23.23	302043	0.09	27184	0
PEF	13000	8	21.86	284173	0.09	25576	1608
PEF	13000	7	19.54	253969	0.09	22857	4237
PEF	13000	6	17.21	223764	0.09	20139	7045
PEF	13000	5	14.89	193560	0.09	17420	9763

**Table 3.-** Comparison of the annual total **energy consumption** and its cost in the maceration/fermentation step to process 13.000 tons of untreated grapes (10 days of maceration) or of grapes treated by PEF (maceration ranging from 8-5 days).



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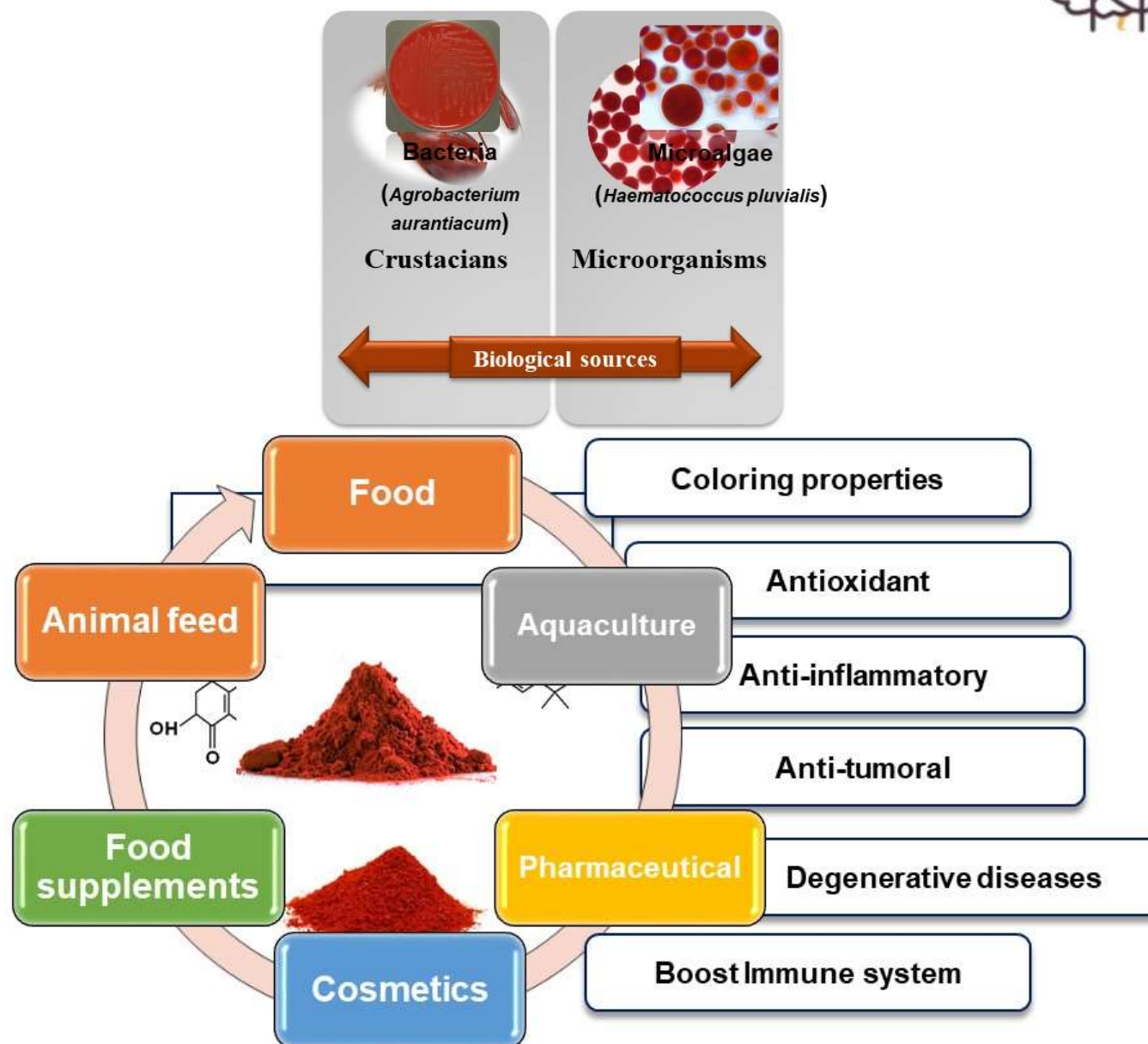
# Benefits of PEF for Circular economy

- Reduction energetic consumption
- Reduction the use of organic solvents in extraction process
- Use of by-products





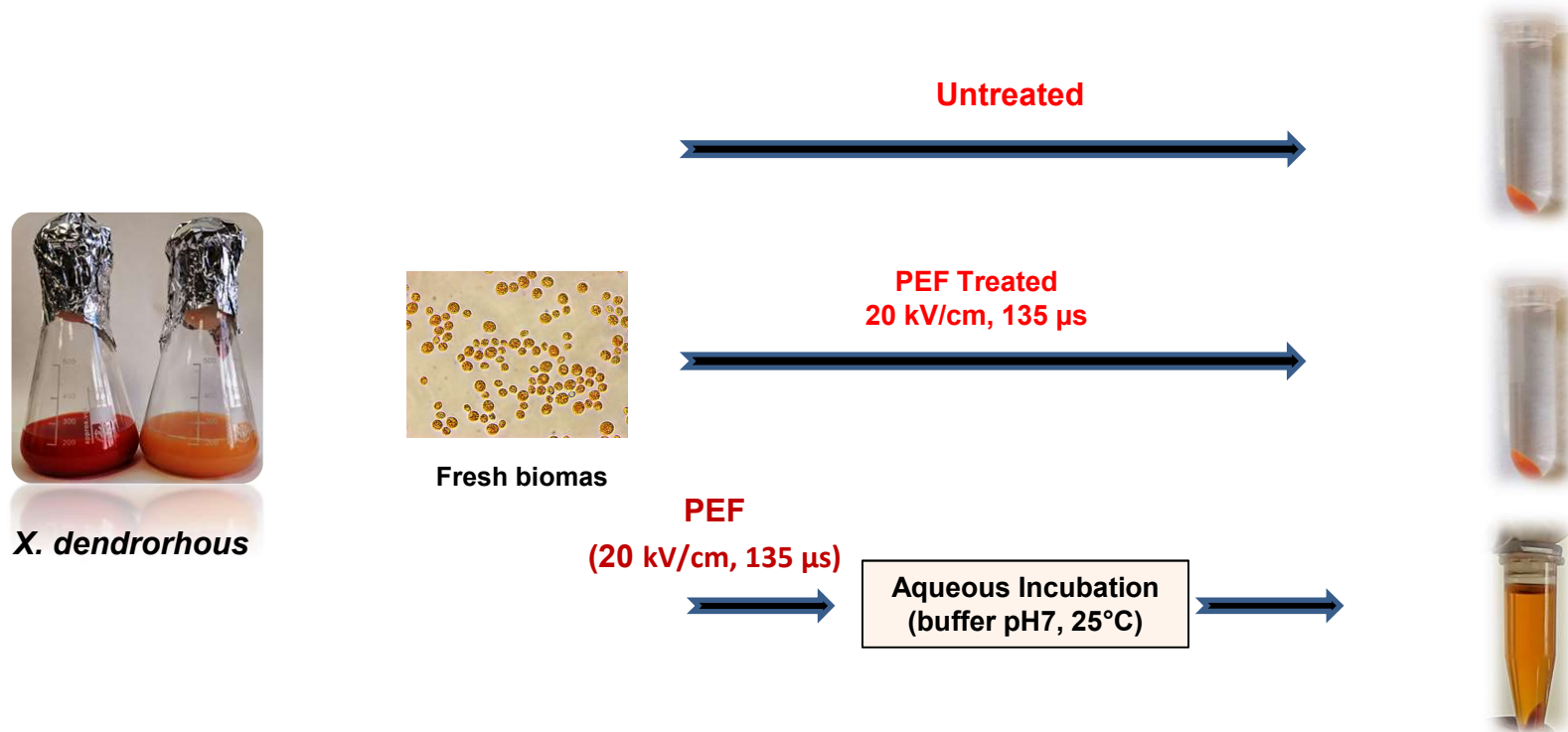
# Reduction the use of organic solvents





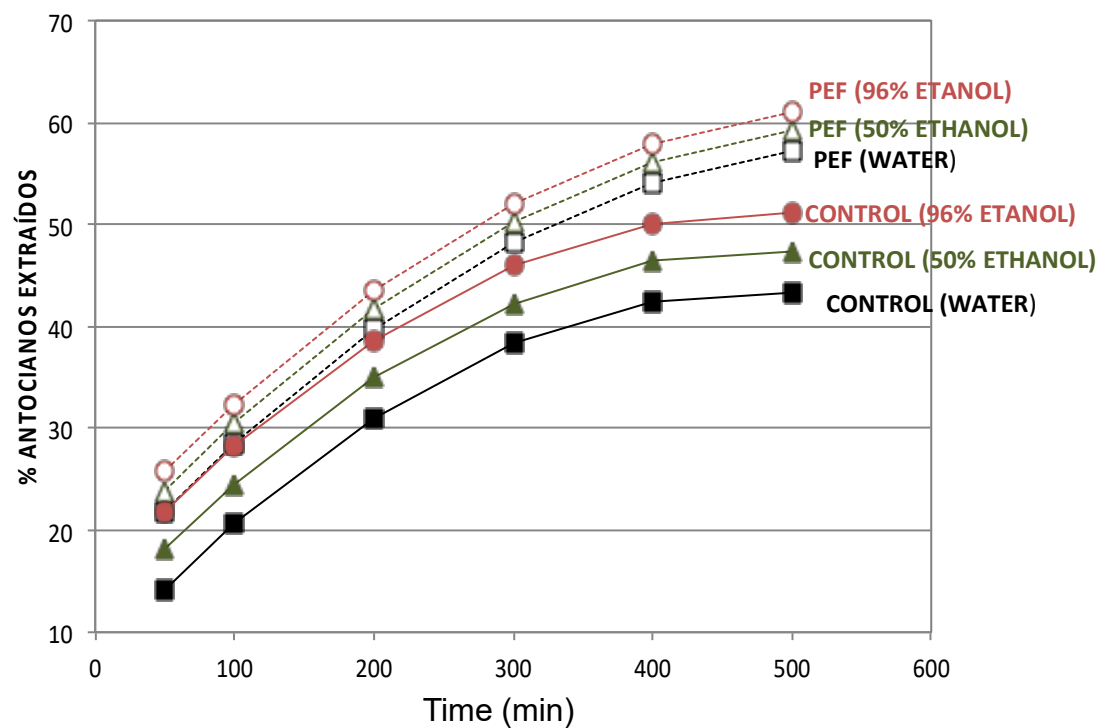
# Reduction the use of organic solvents

Extracción of carotenoids assisted by PEF



# Reduction the use of organic solvents

Extracción of Antocianos (E-162) de patata morada



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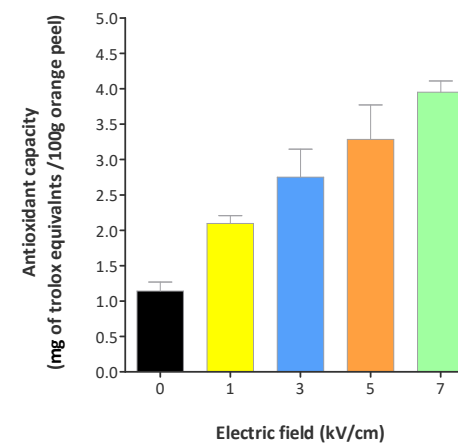
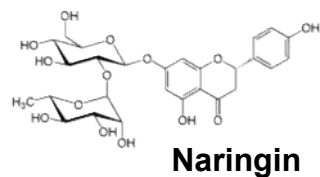
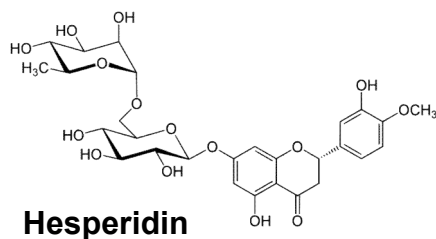
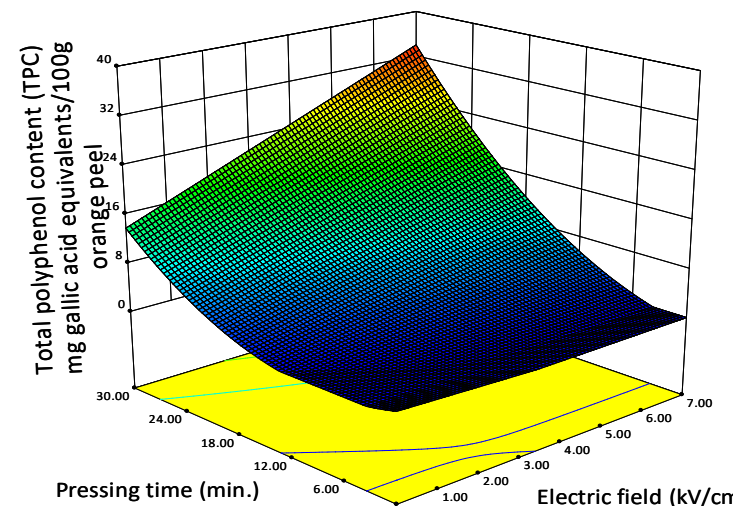
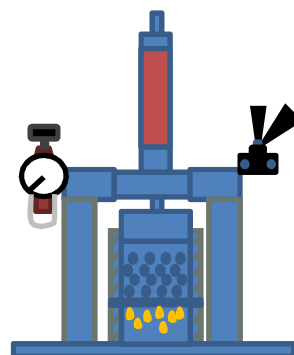


# Use of by-products



# Use of by-products

## PEF assisted polyphenol extraction from orange peels



Electric field (kV/cm)



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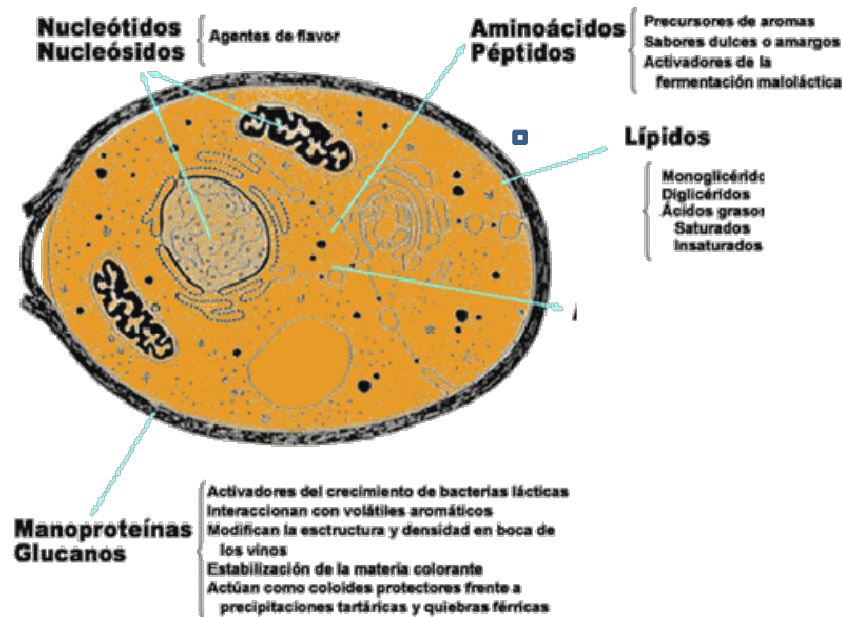


# Use of by-products



PID2020-113620RB-I00, IMPLEMENTACION DE LA TECNOLOGIA DE LOS PULSOS ELECTRICOS DE ALTO VOLTAJE PARA LA REVALORIZACION DE LEVADURAS DEL SECTOR CERVEZERO Y ENOLOGICO

The total amount of yeast biomass produced in the fermentation step of brewing and winemaking is around 1.7-2.3 kg/m<sup>3</sup> of final product



## Yeast extract:

- Natural flavoring ingredient
- Fermentation activator
- Nitrogen source for microbial growth

## Mannoproteins:

- Emulsifying and stabilizing properties
- Pre-biotic properties
- Winemaking:
  - Improve color stability
  - Reduce the astringency
  - Reduce haze formation,
  - Prevent the precipitation of tartaric salt,
  - Contribute to the mouthfeel

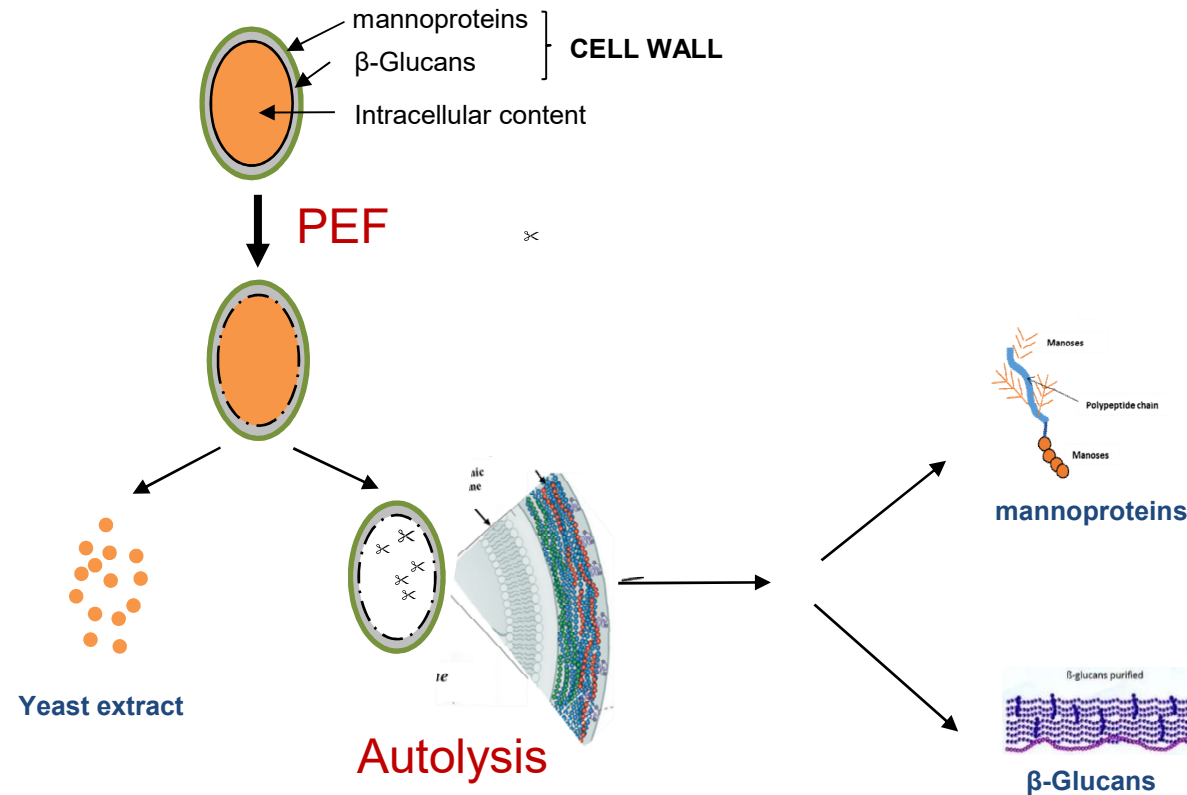
## β-glucans:

- Natural dietary fiber
- Pre-biotic properties
- Thickener,
- Fat replacer

# Use of by-products



PID2020-113620RB-I00, IMPLEMENTACION DE LA TECNOLOGIA DE LOS PULSOS ELECTRICOS DE ALTO VOLTAJE PARA LA REVALORIZACION DE LEVADURAS DEL SECTOR CERVEZERO Y ENOLOGICO



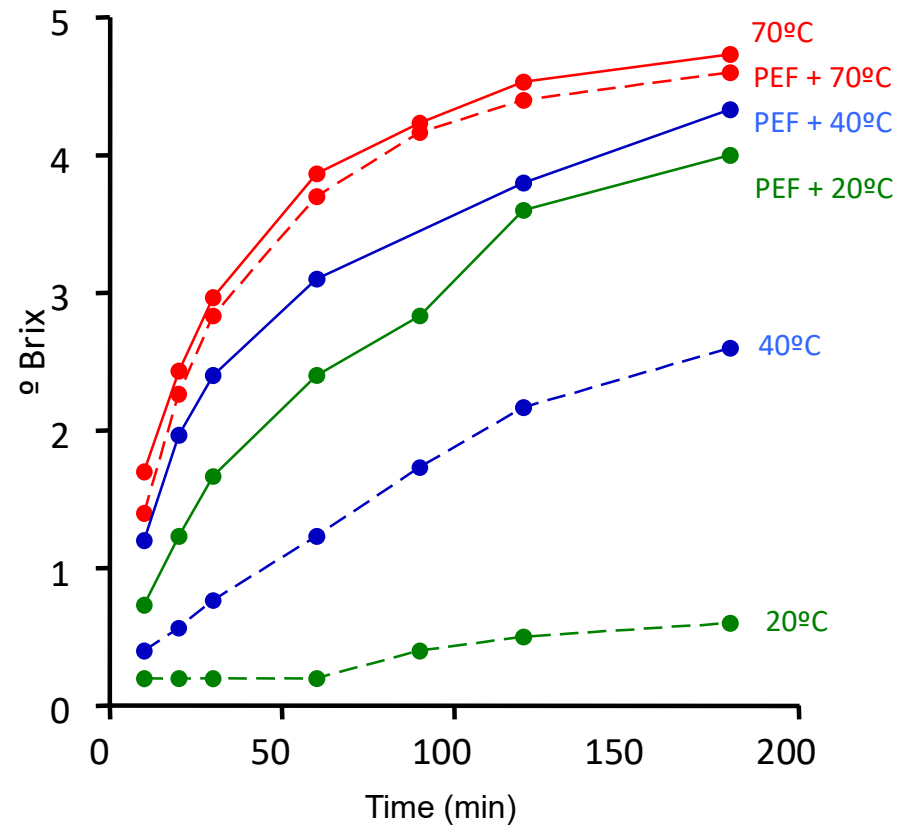
# Conclusions

- Circular economy requires the development of technologies with a lower environmental impact than traditional technologies, which reduce energy costs and produce value-added products from by-products generated in industry.
- PEF technology:
  - Low energy consumption (1-100 kJ/kg)
  - Can be easily introduced in the food or biotechnology industry
  - Modular and portable equipment with different production capacity can be developed as needed
  - Can be used for many different applications
  - Equipment can operate on clean and renewable energy sources



# Reduction energetic consumption

Extracción of Azúcar de remolacha azucarera:



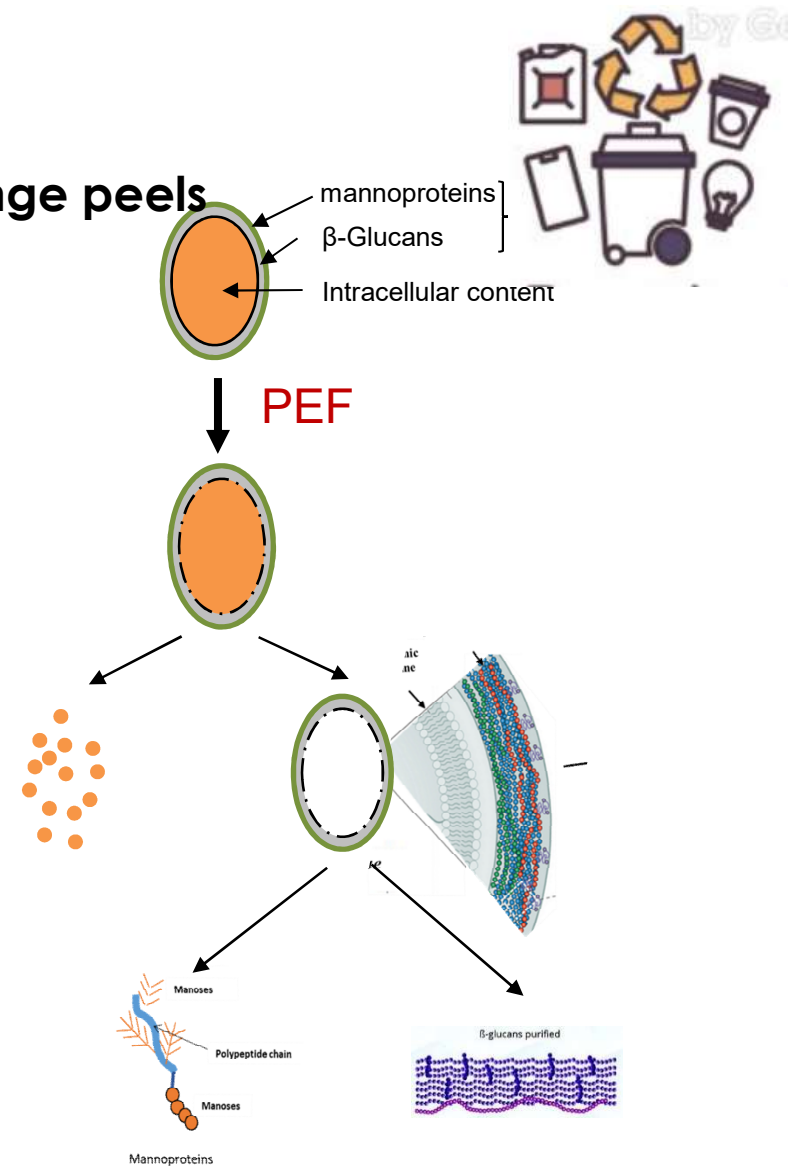
7 kV/cm  
20 pulsos



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# Use of by-products

## PEF assisted polyphenol extraction from orange peels







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