Valorization of peach peels with an optimized drying process based on ultrasounds pretreatment with ethanol

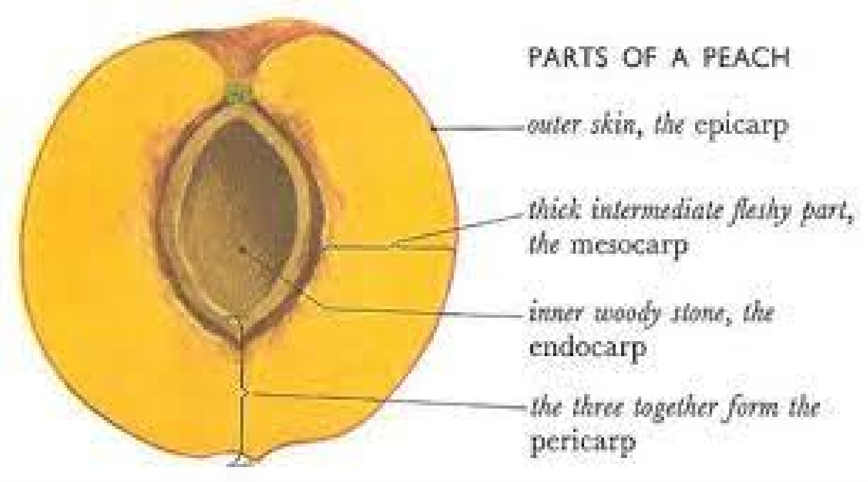
D. Fotiou, K. Argyropoulos, P. Kolompourda, N. Solomakou, A.M. Goula

Department of Food Science and Technology, School of Agriculture, Forestry and Natural Environment, Aristotle University, 541 24 Thessaloniki, Greece

Corfu 2022

Peach (*Prunus persica* L. *Batsch*)

- ❖ Family: *Rosaceae*
- ❖ Genus*: Prunus*
- ❖ Morphology: Round shape with yellow to orange color palette and characteristic fuzz
- ❖ Stone Fruit: Freestone or Clingstone



(Bianchi et al., 2017; Kant et al., 2018)

⚠ Climacteric Fruit: rapid ethylene production following the onset of the ripening stage

➢ Accelerates the biochemical changes of the fruit
➢ Heavily affects the aroma, texture and color
➢ Induces changes to sugar and acid content affecting taste quality

(Minas et al., 2018)

Peach Fruit Chemical Composition

Nutrient	**Per 100 g** Fresh Fruit
Energy	42 kcal
Water content	88.87 g
Proteins	0.91 g
Fats	0.27 g
Carbohydrates	10.1 g
Sugars	8.39 g
Fibers	1.35 g

Vitamins	**Per 100 g** Fresh Fruit
Vitamin C	6.6 mg
Vitamin E (tocopherols)	0.73 mg
Vitamin K	0.0026 mg
Thiamin (B1)	0.02 mg
Riboflavin (B2)	0.03 mg
Niacin (B3)	0.81 mg
Pantothenic acid (B5)	0.15 mg
Pyridoxine (B6)	0.03 mg
Folate (B10)	0.004 mg

(Alvarez-Parrilla et al., 2013)

Phenolics	**Per g** Fresh Fruit
Total Content	0.7 mg
Procyanidin B1	14.7 µg
Protocatechuic acid	10.2 µg
Neochlorogenic acid	25 µg
Catechin	42.3 µg
Epicatechin	9.2 µg
Chlorogenic acid	29.3 µg

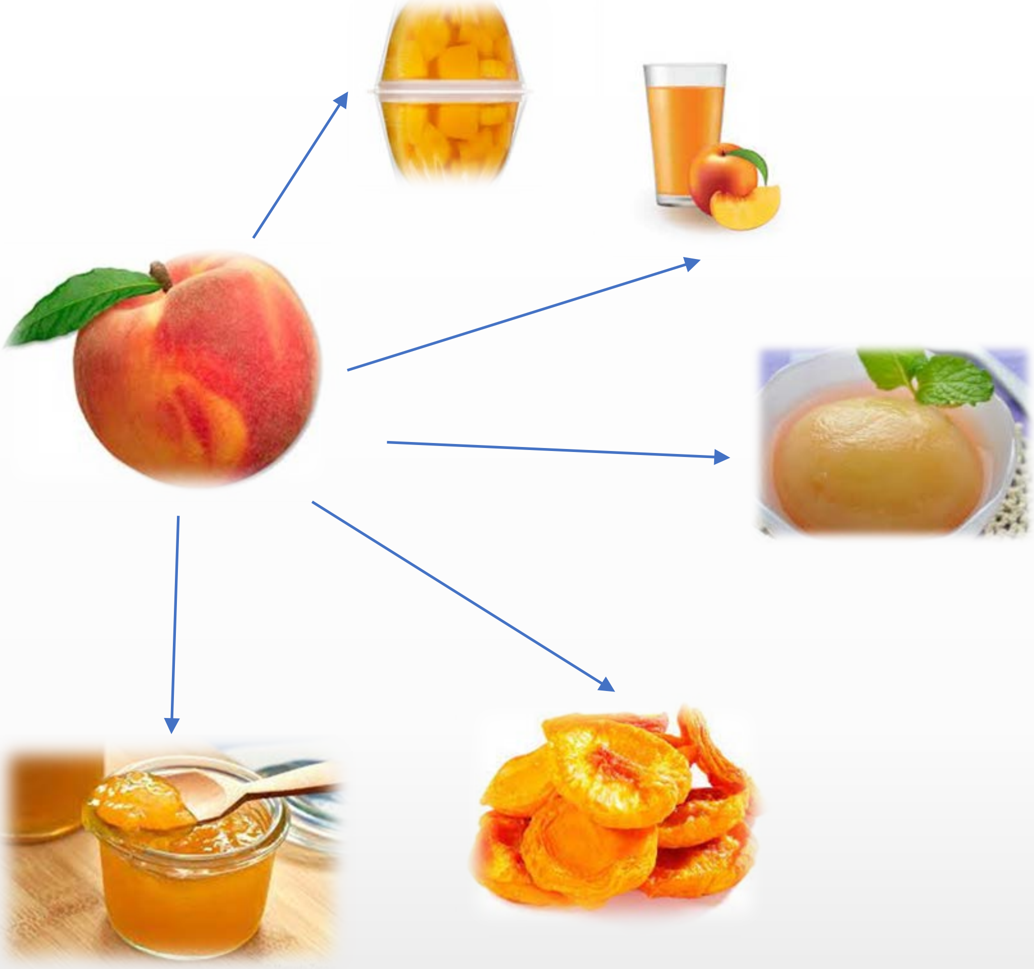
(Oliveira et al., 2012)

Biological properties

- ✓ Antioxidant
- ✓ Anticancer
- ✓ Antidiabetic
- ✓ Antimicrobial
- ✓ Anti-Inflammatory

(Kant et al., 2018)

Peach Proccessing



Stone or Pit

Peels

Peach peel (epicarp) is believed to have high amounts of phenolic and carotenoid compounds as to protect the flesh (mesocarp) from environmental stresses and microbial threats

(Chang et al., 2000 ; Gasparotto et al., 2014)

Both peach peel and kernel are valuable by-products

- ✓ Peach **kernels** contain **high cellulose and lignin** content along with **phytochemical compounds**
- ✓ Ideal targets to be used in **food, pharmaceuticals and cosmetics** ***(Nowicka & Wojdyło, 2019)***
- ✓ **Biofuel** and **activated carbon source** ***(Kaynak et al., 2005; Dardick et al., 2010)***
- ✓ **Bio-hydrogen** production ***(Argun & Dao, 2017)***
- ✓ **Peach seed oil** or **essential oil** production is also a promising aspect (***Wu et al., 2011)***

- ❑ **Peach peel** is an under-utilised crude material of high nutritional value
- ❑ **High phenolic** and **carotenoid** content enables its use as food additive or in pharmaceuticals
- ❑ Valorisation prospects are compounds isolation or **drying procedures and implementation to food and supplements**

(Hong et al., 2021; Şahin & Bilgin, 2021).

Peach Waste Management

Peach peel Composition

Property	Fresh Unpeeled Fruit	Peeled Fruit
Dry weight (%)	**15-16.37**	**14.07-15.63**
Phosphorus, *P* (ppm)	2340-4352	2055-4070
Pottasium, *K* (ppm)	9700-12650	9475-12275
Calcium, *Ca* (ppm)	350-790	335-470
Magnesium, *Mg* (ppm)	357-597	300-495
Zinc, *Zn* (ppm)	14.37-28.88	10.39-23.24

Phytochemical compounds

Compound	Fresh Unpeeled Fruit	Peeled Fruit
Total polyphenols (g gallic acid/g)	**15-16.37**	**14.07-15.63**
Flavonoids (g rutin/g)	2340-4352	2055-4070
Flavonoids (g rutin/g)	9700-12650	9475-12275
Anthocyanins (g cyanidin/g)	**350-790**	**335-470**
Flavonols (g rutin/g)	357-597	300-495
Carotenoids (g b-caroten/g)	**14.37-28.88**	**10.39-23.24**

(Michailidis et al., 2021)

Dehydration

Process aiming to reduce the moisture content of the product:

- Microbial stability
- Inhibition to moisture-related deteriorative reactions
- Bulk and weight reduction

Increase in self life expectancy

Lower storage and transportation costs

Methods:

- Solar
- ***Hot air***
- Spray drying
- Freeze drying
- Osmotic dehydration
- Puffing
- Microwave

Observed Stages

Equilibrium period → Constant rate period → Falling rate period

(Deng et al., 2019)

Convective Hot Air Drying

Advantages	Disadvantages

Advantages

- Simple method
- Easier to setup and use compared to novel emerging techniques
- **Can significantly boost efficiency using pretreatments**

Disadvantages

- Low energy efficiency
- Long drying times
- High inlet air temperature
- Organoleptic quality loss
- Bioactive nutrient degradation
- Case hardening
- **In falling rate period, efficiency of mass and heat transfer is really low**

(İlter et al., 2018; Calín-Sánchez et al., 2020)

Drying Pretreatments

Physicochemical processes prior to dehydration in order to enhance heat and mass transfer

- **Solution immersion**
  - Acid liquor
  - Alkali liquor
  - Hyperosmotic liquor
  - **Ethanol**
- **Thermal process**
  - Hot Bath
  - Steam
  - Ohmic heat
  - Microwave
- **Non-thermal process**
  - **Ultrasonication**
  - Freezing
  - Vacuum
  - High hydrostatic pressure
- **Gas injection**
  - Sulfur Dioxide
  - Carbon Dioxide
  - Ozone

Reduced drying time

Higher energy efficiency

Nutrient and quality retention

Combination of methods seems promising for even greater results

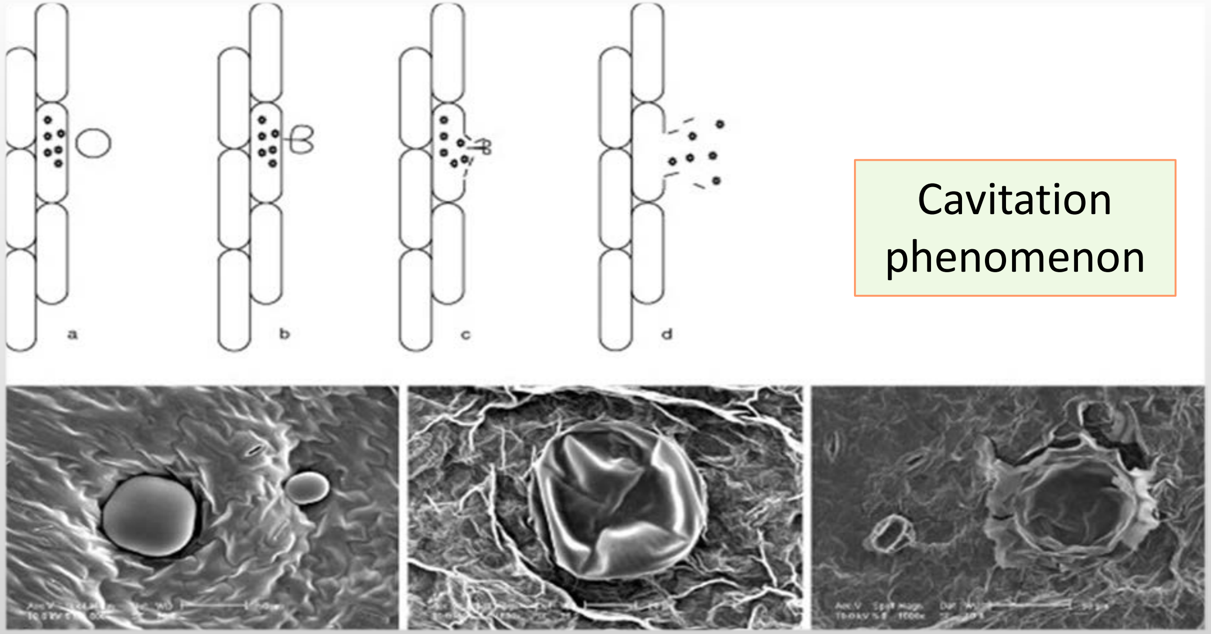
(Yu et al., 2017; Deng et al., 2019; Wang et al., 2019; Amanor-Atiemoh et al., 2020)

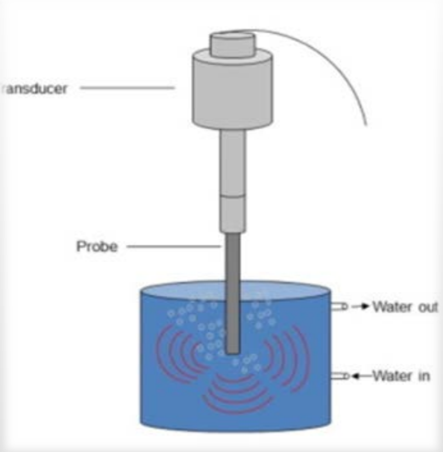
Ultrasonic Waves

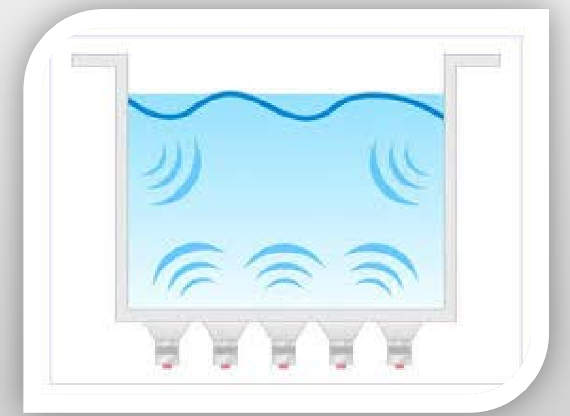
- Mechanical waves with frequency of 20 kHz-10M Hz
- Necessity of a medium to operate properly
- Direct sonication through a probe
- Indirect sonication through a liquid bath

Ultrasounds induce the mechanical compression and expansion of the food material, which resembles a sponge that is squeezed and released repeatedly **(sponge effect).**
Pressure shifts in the liquid contributes to the formation of bubbles that expand, contract, and finally explode violently causing rapid and transient changes in pressure and temperature, intensely affecting surrounding tissues (**cavitation effect**).

(Cravotto & Cintas, 2006 ; Fijalkowska et al., 2015)





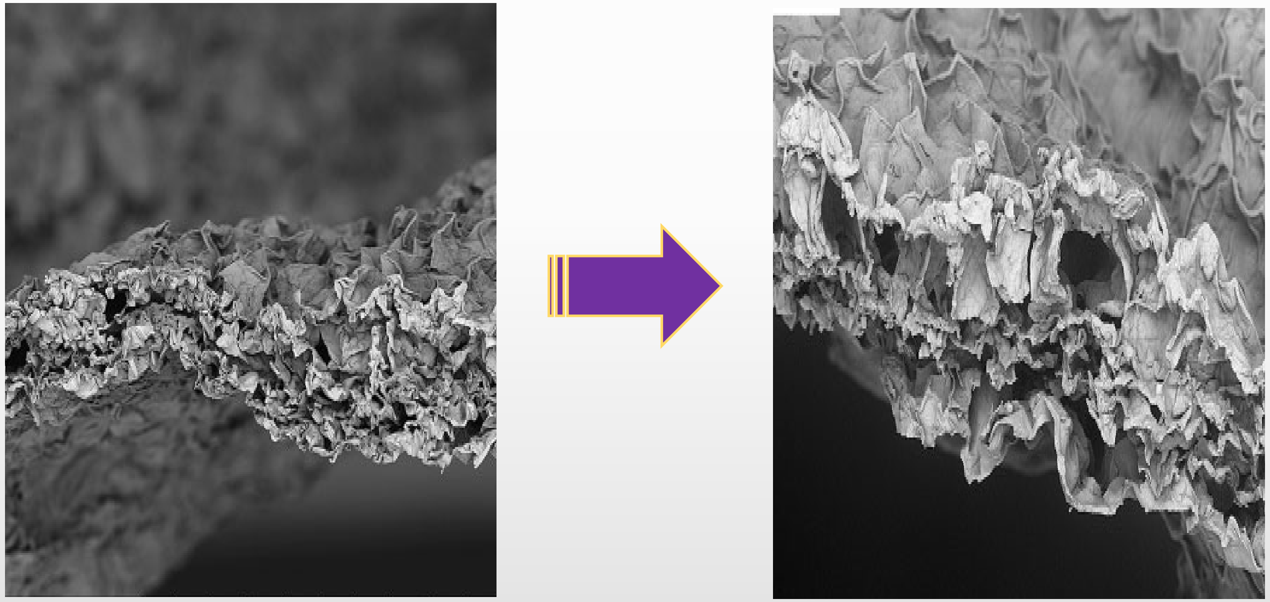


(Chemat et al., 2011)

Ultrasound Pretreatment

Ultrasound pretreatment effectiveness stems from the combined activity of collapsing bubbles, cavitation effect, and the concurrent pressure shifts that are induced to the food matrix, sponge effect.

- ✓ Alterations in surface tension and viscosity
- ✓ Cell wall disruption and microscopic channel formation, changing the **food matrix to assume a more porous structure**
- ✓ Increased water diffusivity
- ✓ Less nutrient deterioration results in higher food quality



Porous structure formation in basil tissue

(Sledz et al., 2015)

(Carcel et al., 2011; Siucińska & Konopacka, 2014; Mothibe et al., 2011; Fijalkowska et al., 2015; da Silva et al., 2016; Zhang et al., 2017)

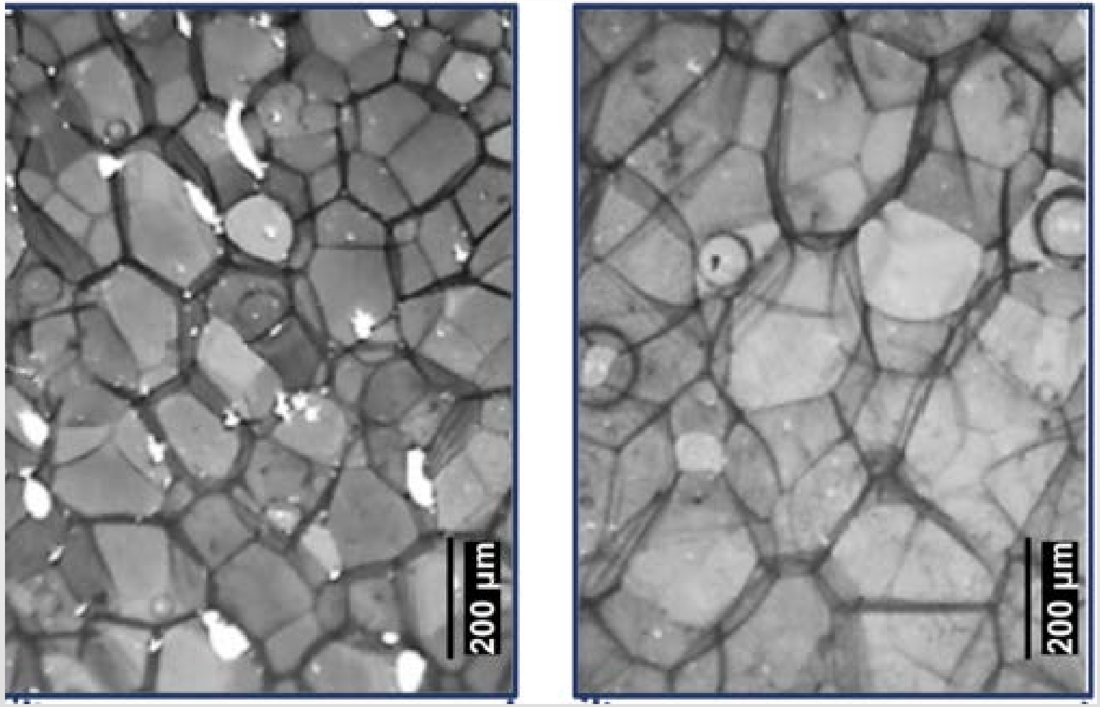
Ultrasound Pretreatment

Product	Conditions	Results	Citation
Button mushrooms Brussels sprouts Cauliflower	Both direct and indirect sonication 40 kHz / 20 kHz 0.5 W/cm^2 / 39-43 W/cm^2 3 and 10 min accordingly Distilled water sonication	Higher drying rates and enhanced rehydration rate after. Both methods affected differently the product and were considered equal in effectiveness.	*Jambrak et al., 2007*
Apple Slices	Ultrasonic distilled water bath 21 / 35 kHz 3 / 4 W/cm^2 30 min	Reduction in drying time and enhancement of rehydration properties. Varied color difference results.	*Fijalkowska et al., 2015*
Apple cubes	Ultrasonic distilled water bath 35 kHz 10 / 20 / 30 min	Drying time reduction by 31-40%, increased shrinkage by 9-11%, porosity increase by 9-14%. Intense tissue rapture.	*Nowacka et al., 2012*
Malay apple slices (*S. malaccense* L.)	Ultrasonic distilled water or 25 ^{o}Brix sucrose solution 25 kHz 1.785 W/m^2 10 / 20 / 30 / 45 / 60 min	Ultrasound pretreatment in water seemed to reduce total solid concentration. Both solutions reduced the required drying time. Water diffusion increased by up to 28%.	*Oliveira et al., 2011*
Berries (Rubus glaucus Benth)	Direct sonication 24 kHz 85 W/cm^3 10 / 20 / 30 / min Distilled water solution	Antioxidant compounds were prevalent in the water solution after pretreatment. Increased water diffusion rates even at lower temperatures, resulting in higher energy efficiency.	*Romero & Yepez, 2015*
Parsley leaves	Ultrasonic distilled water bath 21 kHz 12 W/g 20 min	Drying time reduction by 29.8% and energy expenditure by 33.6%. Stable color results.	*Sledz et al., 2016*

Ethanol Pretreatment

Ethanol acts directly to the food matrix because of its ability to dissolve components of the cell walls, effectively altering the microstructure of product. Vapor pressure changes induce intracellular air loss and because of a surface tension gradient with the water the Marangoni effect occurs.

- **Marangoni effect:** mass transfer along an interface between two fluids due to a gradient of the surface tension, along with the concentration gradient of the two liquids
- ✓ **Water** is observed to effectively **transport from the inner to the outer layers of the food matrix**, meaning increased water diffusivity.
- ✓ **Cells** are observed to be more **compact and thin-walled**
- ✓ **Permeability is increased** and pores are formed
- ✓ **Bioactive compound stability and color retention have shown mixed results**



Ethanol pretreatment of potato slices (before and after)

(Rojas & Augusto, 2018)

(Rojas & Augusto, 2018; Llavata et al., 2020; Zhou et al., 2020)

Ethanol Pretreatment

Product	Conditions	Results	Citation
Potato Slices	100% ethanol solution 3 min immersion 125 mL	Loss of intracellular air and thinner cell walls. Reduction in drying time and elasticity of product.	*Rojas & Augusto, 2018b*
Melon Slices	50% / 100% ethanol solution 10 min immersion	Reduction in drying times, but quality parametres were negatively impacted. Lower concentration of ethanol solution showed higher total phenolics, ascorbic acid and carotenoid content retention.	*Cunha et al., 2020*
Potato Slices	100% ethanol solution 15 min immersion 60 mL per slice	Reduction of drying time by 10%. Rehydration properties showed negatively results when ethanol was present.	*Rojas et al., 2019*
Scallion	75% ethanol/water solution 3-5 min immersion 100 g raw fresh product	Enhanced cell wall permeability and reduction of browning due to enzymatic activity. Retention of ascorbic acid levels, taste and antibacterial ability.	*Wang et al., 2019*
Pumpkin cylinders	100% ethanol solution 1 hour immersion	Reduction of drying time by 49.5% while increasing rehydration rate afterwards.	*Rojas & Augusto, 2018a*
Scallion Stems	75% ethanol/water solution 5 / 10 / 20 / 30 min 100 g fresh product	Increased rehydration properties along with color, aroma and microbial stability. Reduction of drying time.	*Zhou et al., 2020*

Aim of Study

- **Valorization of peach peels**, a major by-product of the peach industry, through drying procedure with the added effects of ultrasound waves and immersion in ethanol solution.

- **Study of main parameters** and their effect on drying rates and total phenolic content of the product.
  - **Ultrasound Amplitude**
  - **Duration of Sonication**

- **Statistical analysis** of each parameter, as to determine its **importance** and possible interactions between them.

- Granulation of the dried product in order to be added as a **bioactive supplement** in foods.

Peach Species : Katerina
Location: Crya Vrysi Pellas
Time of foraging and storage: July, 2021

Foraging → Screening → Cleaning and rinsing → Peeling with knife → Separation of peels in packages → Preservation at -20º C

Drying Process

Defrosting

Pretreatment 25ºC

Ultrasounds

75% Ethanol/Water Solution

Hot air Drying 70ºC

Weight measurements

Convective Air Dryer (*Memmert, model U40 791 450, Western Germany)* Power: 2000 W

Kinetic Modelling of Drying

Mechanistic model

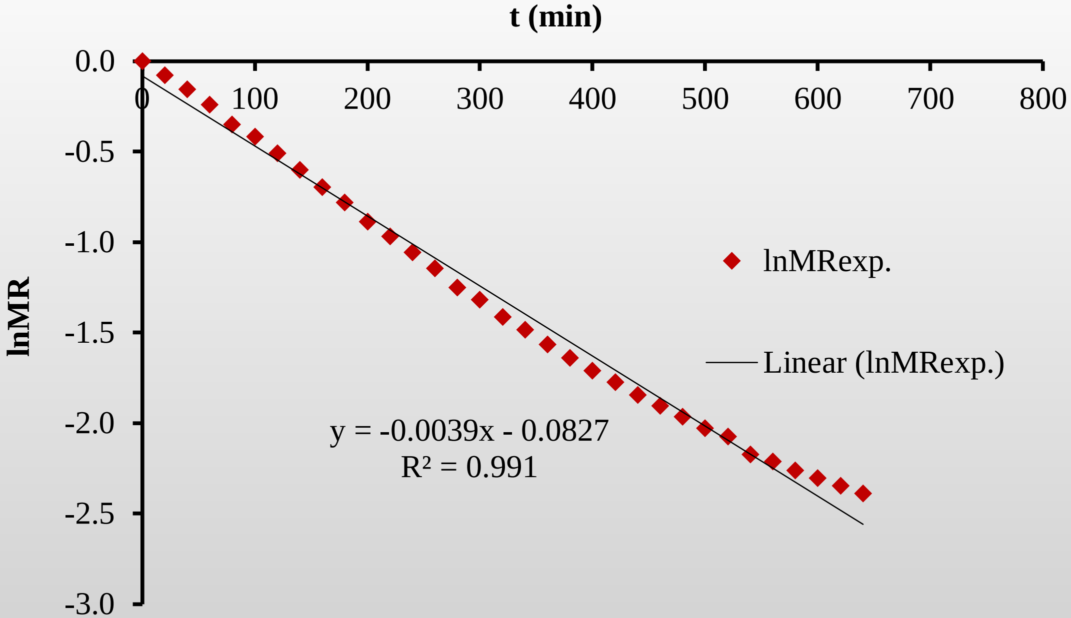
Diffusion approach

$$MR = \frac{X - X_e}{X_0 - X_e} = \frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n+1)^2}\exp\left[-\frac{(2n+1)^2\pi^2 Dt}{4L^2}\right]$$

MR : moisture ratio
X_0 : initial moisture content
X : moisture content at time t
X_e : equilibrium moisture content
L : slab thickness

$$\ln MR = \ln\frac{8}{\pi^2} - \frac{\pi^2 Dt}{4L^2}$$

Simplification for long drying periods



Ultrasounds

Hot air Drying 70^{o} C → Granulation → Extraction → Folin-Ciocalteu

Extraction Conditions:

- Ultrasound Amplitude 40%
- Water Solution
- Time: 15 min
- Temperature $35^{o}C$
- 7 s Sonication – 6 s Pause

Total Phenolic Content

Pretreatments

Direct Ultrasound Device: 130 W, 20 kHz VCX-130 Sonics and Materials (Danbury, CT, USA) with Ti–Al–V probe (13 mm)

75% Ethanol/Water Solution

Parameter	Levels		
Immersion Time (min)	10	20	30

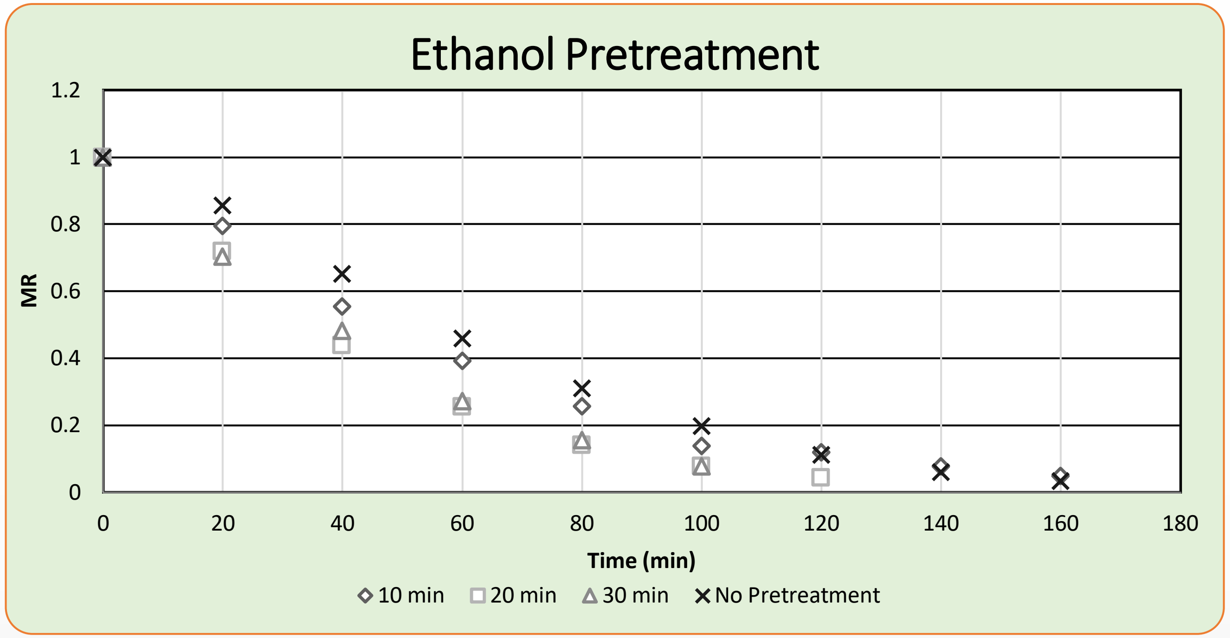
Ultrasounds + Ethanol Solution

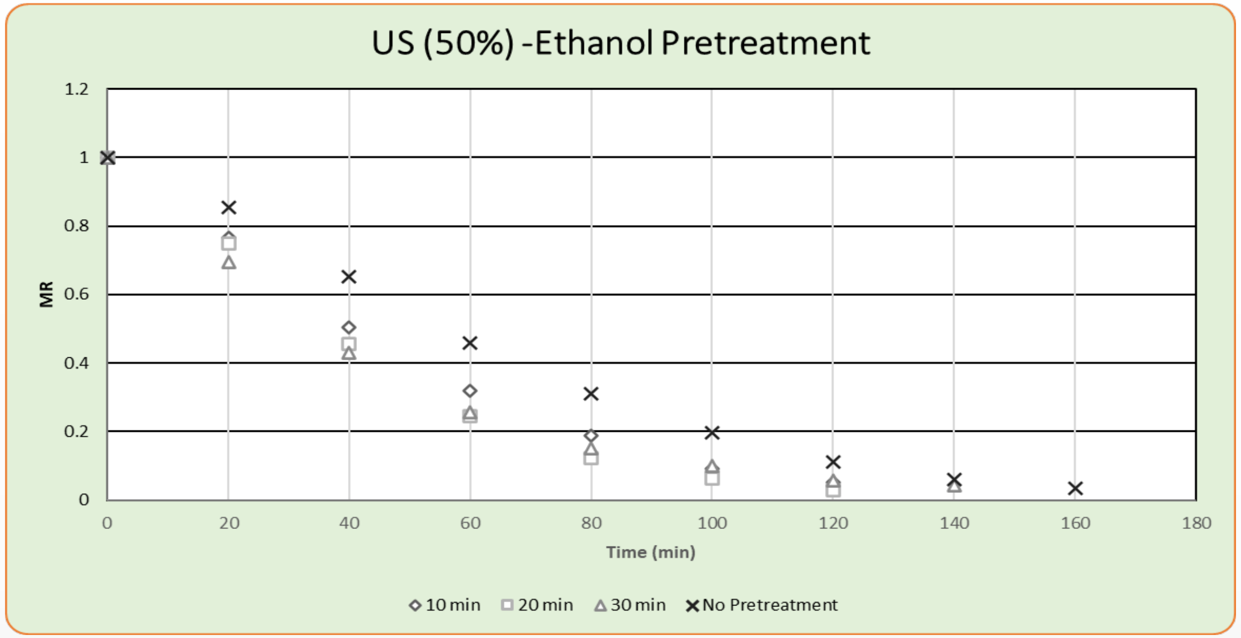
Parameter	Levels		
Amplitude (A, %)	50	60	70
Sonication Time (min)	10	20	30
8 s Sonication – 2 s Pause			

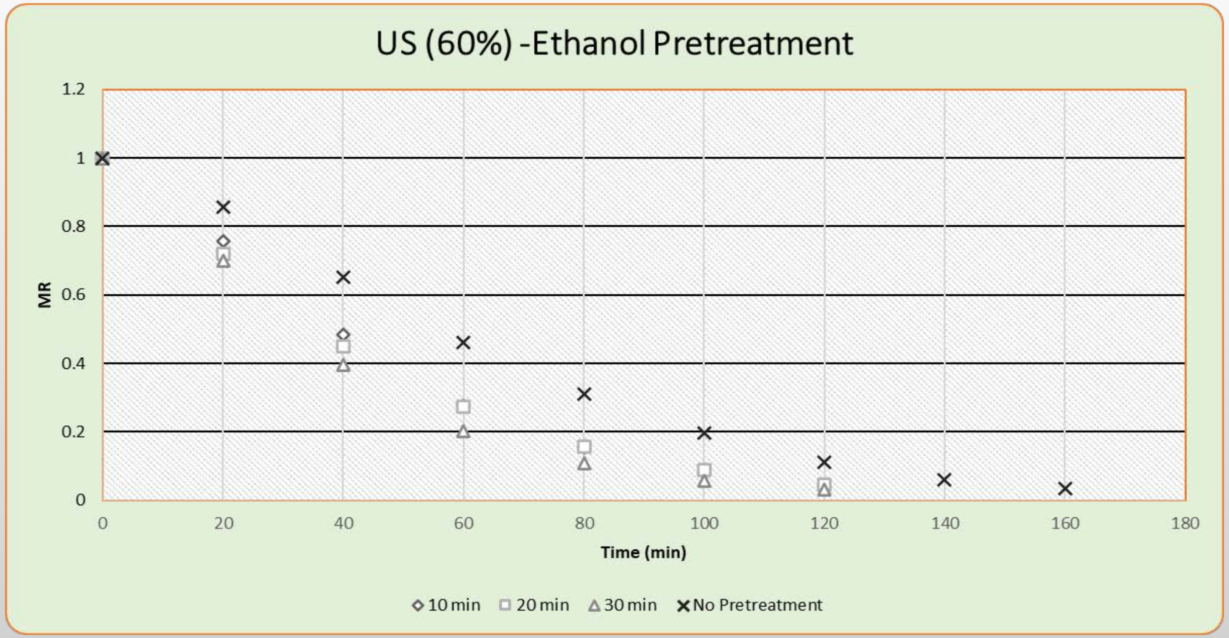
All experiments were carried out in triplicate!!

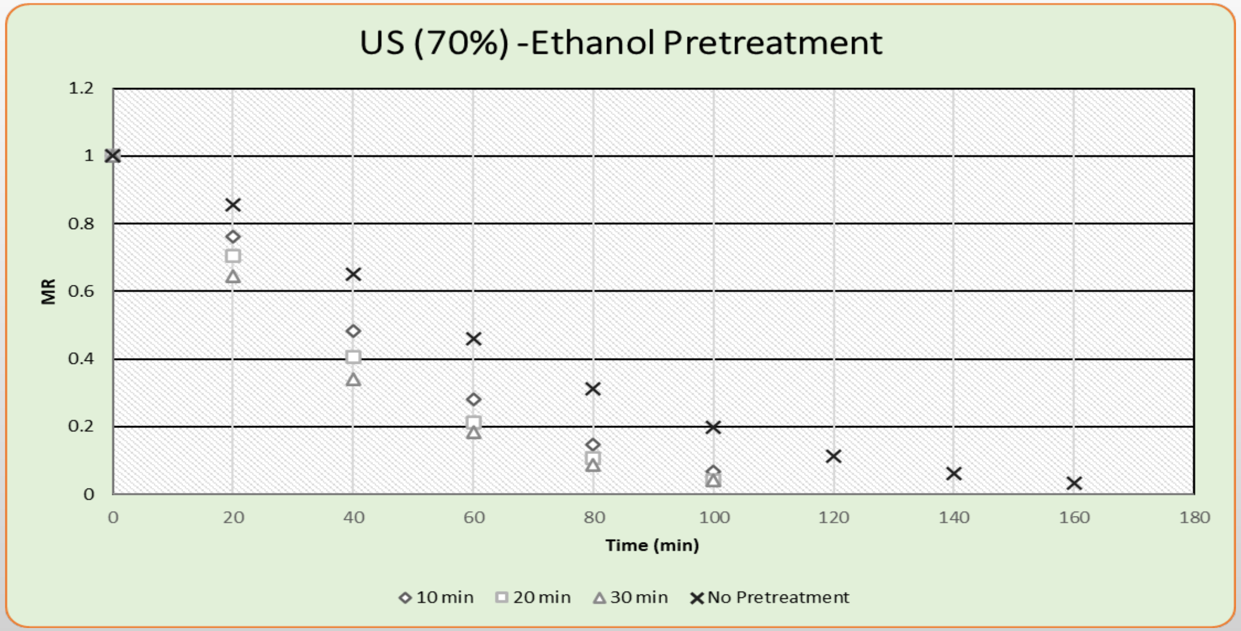
Results

Change of moisture ratio with time

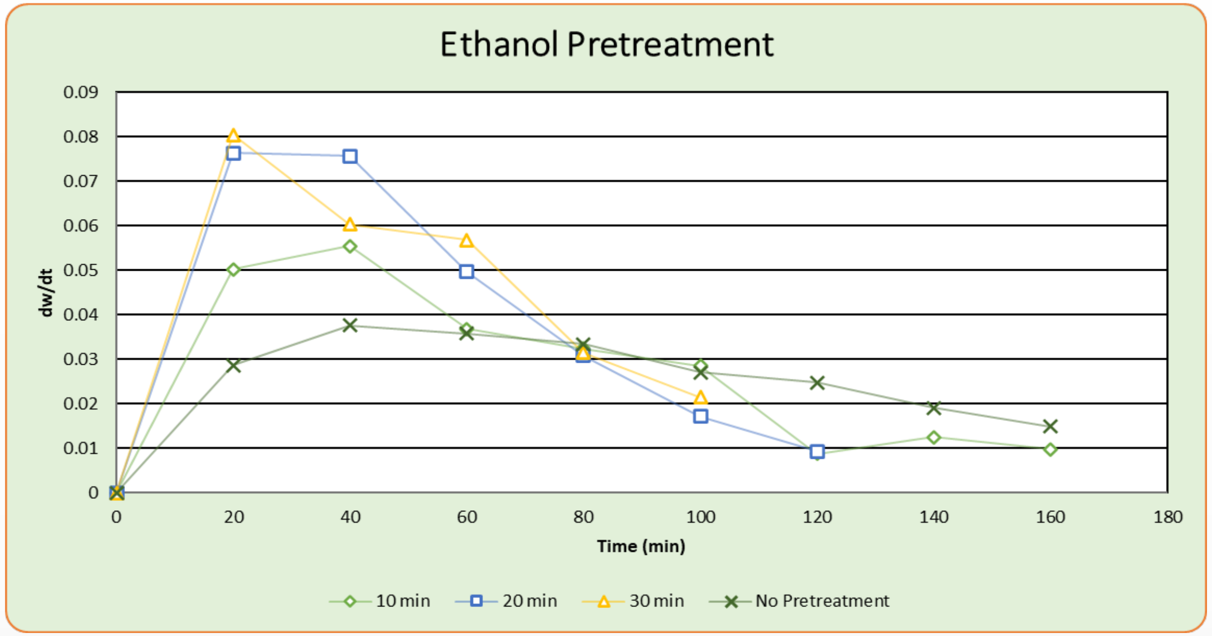


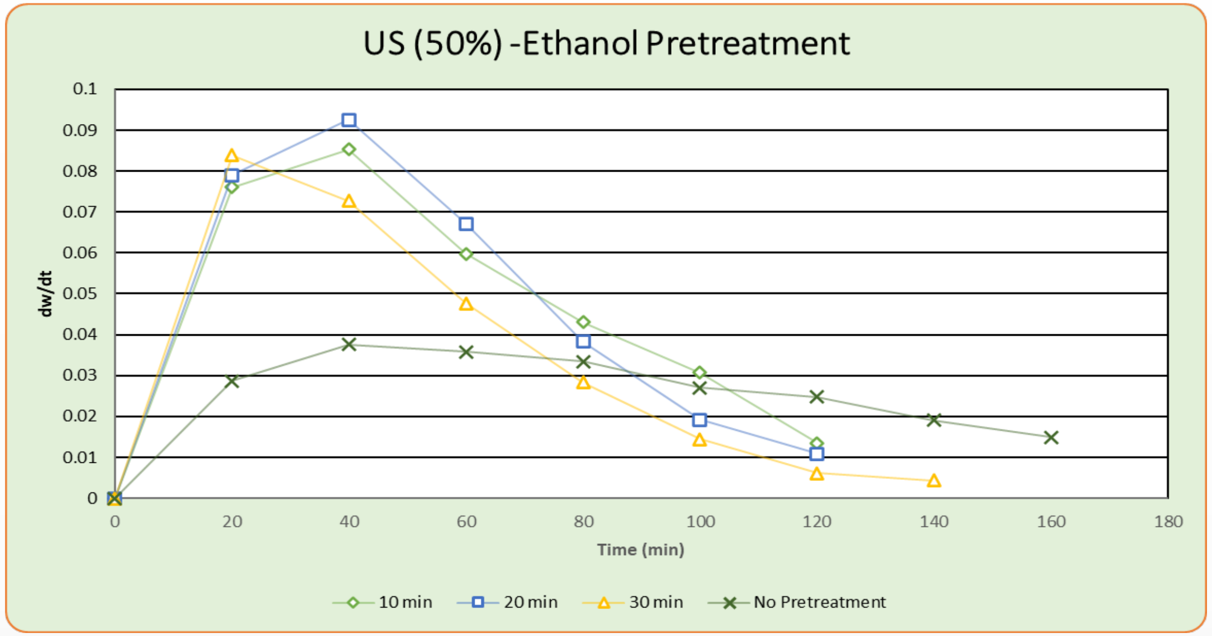


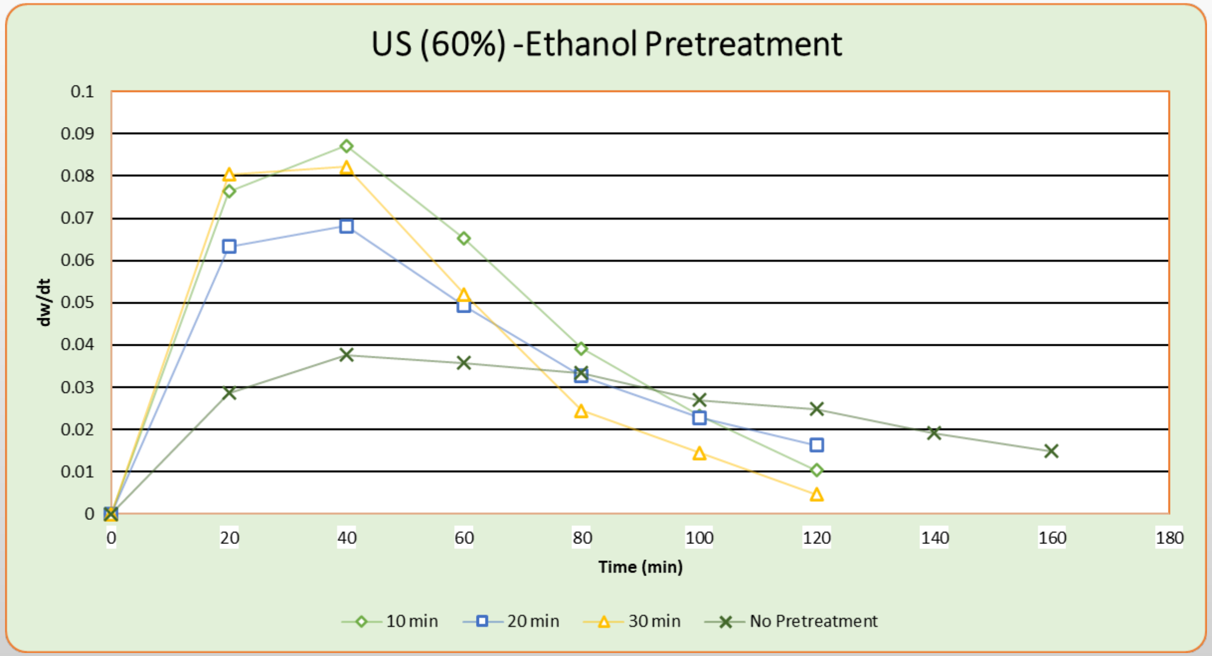


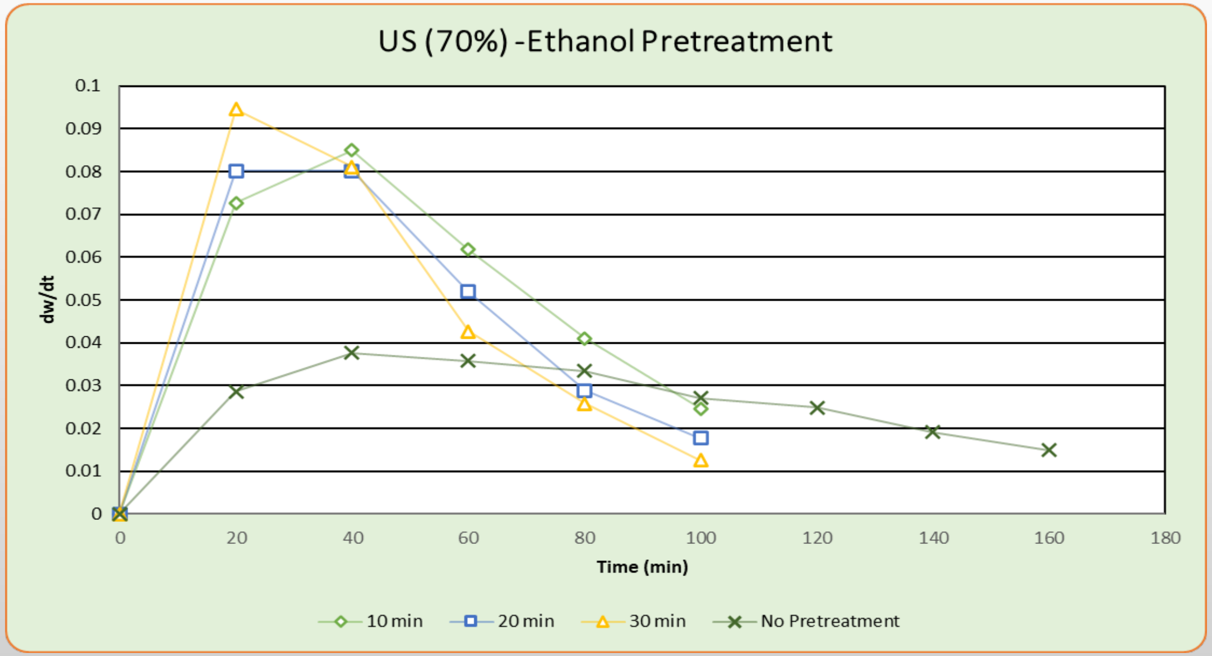


Change of drying rate with time



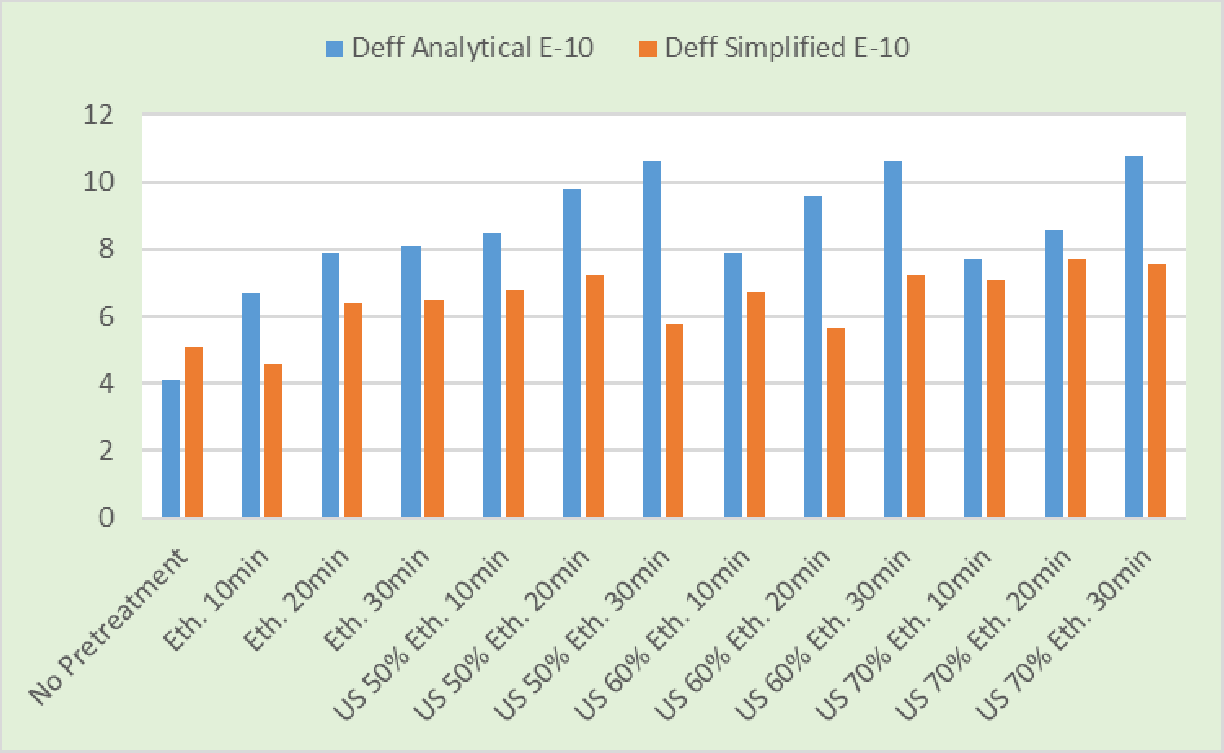






Diffusivity Coefficient

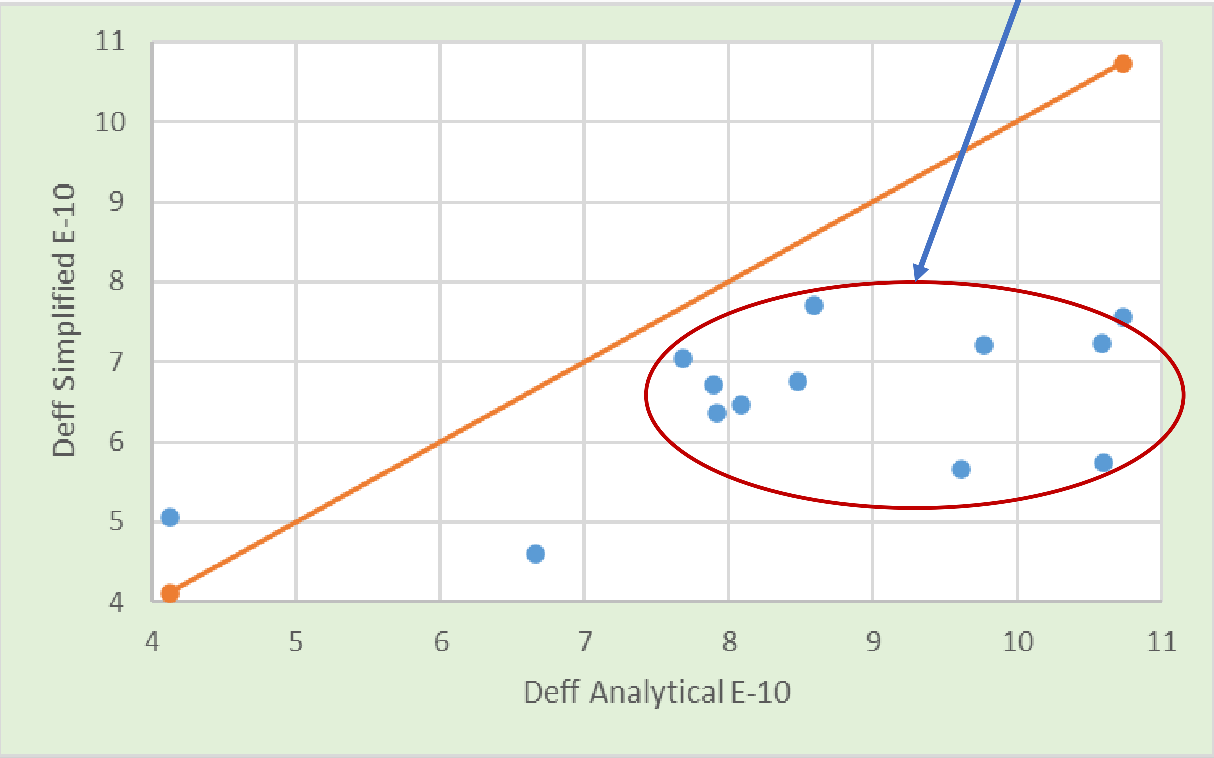
D_{eff} ($\times 10^{-10}$, m^2/s)
4.11 – 10.73



$$MR = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left(-\frac{(2n+1)^2\pi^2 D_{eff}t}{4L^2}\right)$$

(Crank, 1975)

❖ **The simplified form of the equation underestimates the diffusivity coefficient!!**



Regression Analysis of Diffusivity coefficient

Analysis of Variance

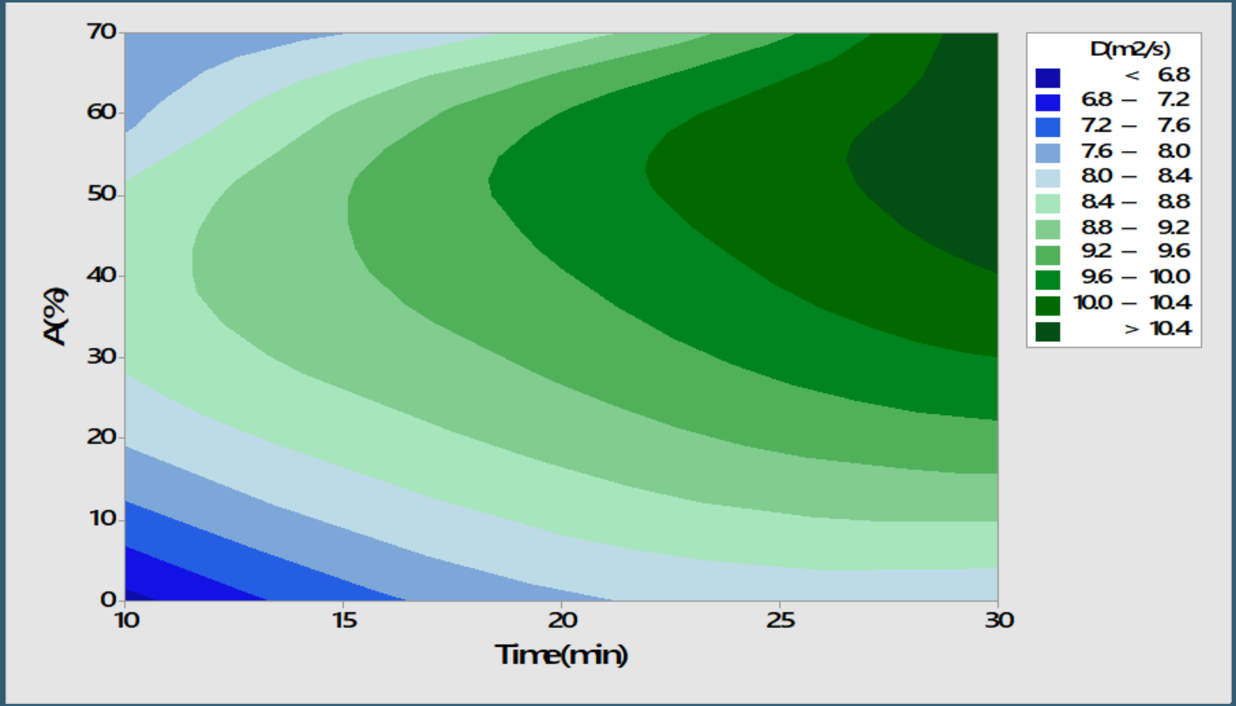
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	19.1387	3.82774	37.95	0.000
Linear	2	11.0854	5.54271	54.95	0.000
A(%)	1	3.2986	3.29863	32.70	0.001
Time(min)	1	7.7868	7.78679	77.19	0.000
Square	2	2.0688	1.03442	10.25	0.012
A(%)*A(%)	1	2.0219	2.02189	20.04	0.004
Time(min)*Time(min)	1	0.0469	0.04694	0.47	0.521
2-Way Interaction	1	0.6864	0.68637	6.80	0.040
A(%)*Time(min)	1	0.6864	0.68637	6.80	0.040
Error	6	0.6053	0.10088		
Total	11	19.7440			

Model Summary

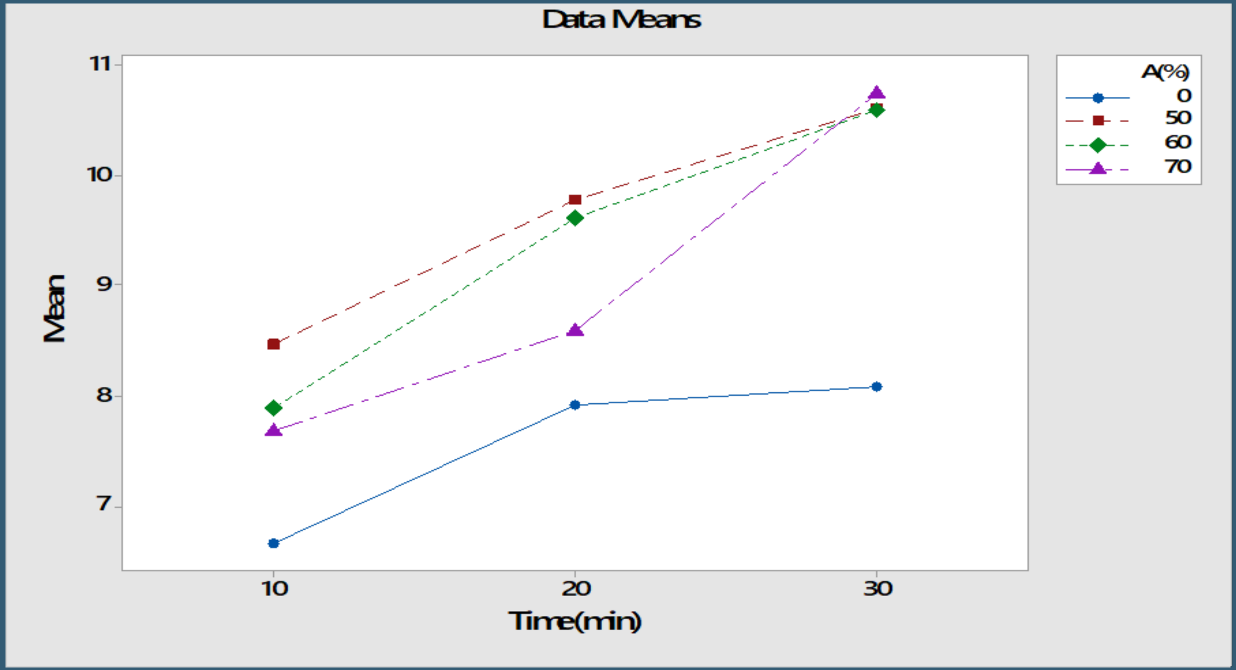
S	R-sq	R-sq(adj)	R-sq(pred)
0.317608	96.93%	94.38%	79.89%

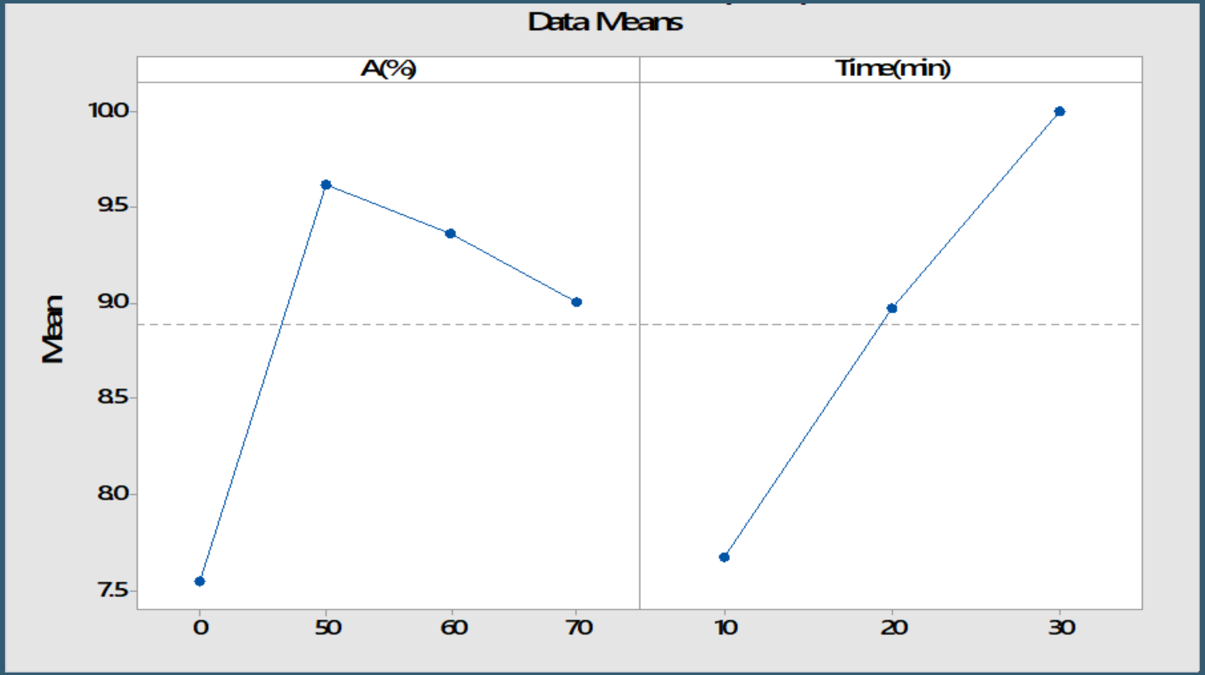
- Both Ultrasound amplitude and pretreatment duration are important factors
- There seems to be minor interaction between them

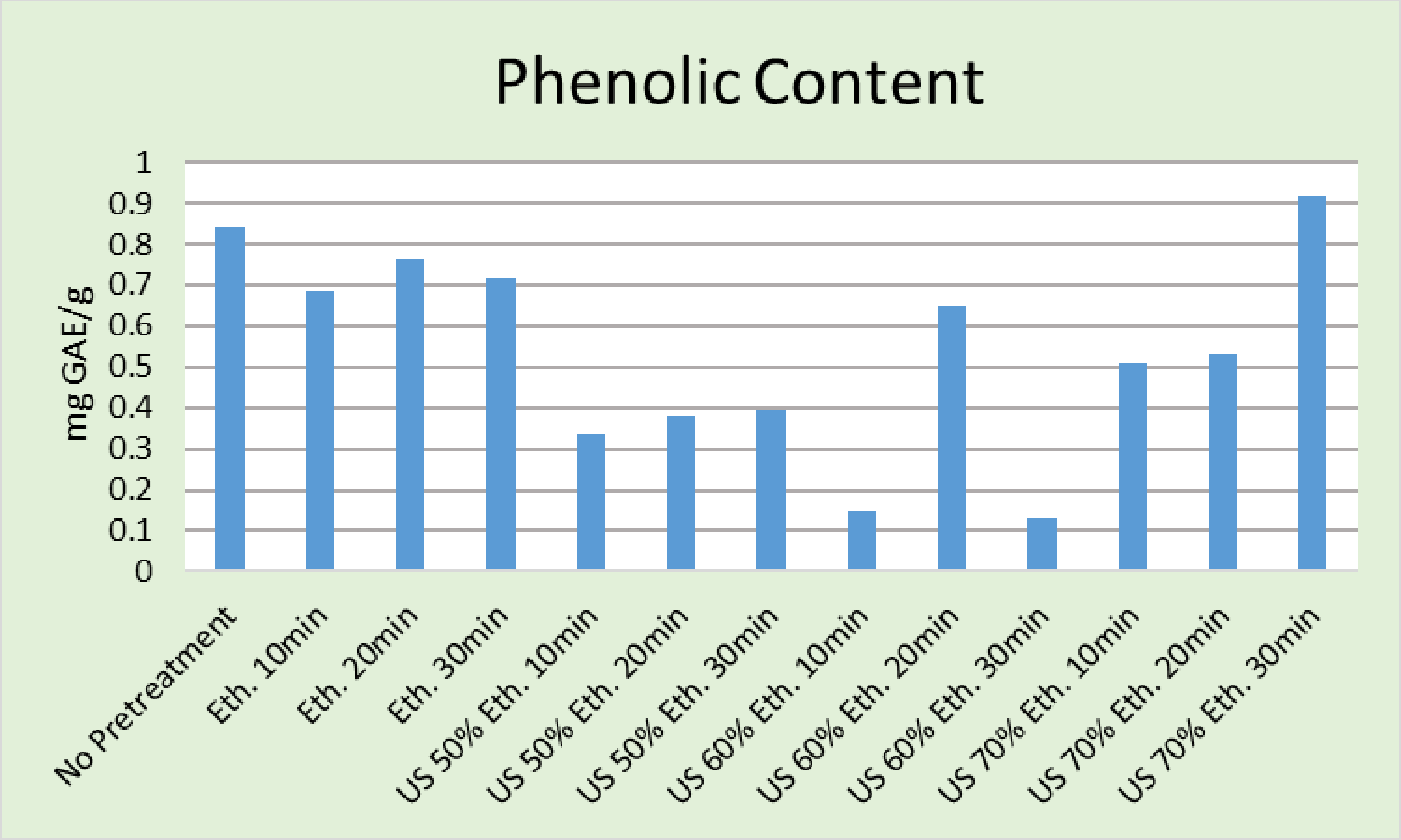
- **The model can sufficiently describe the experimental data** as R^2 is high, 96.93%



- Highest diffusivity coefficients are observed at the highest levels of pretreatment duration
- Interaction is minimal
- Time considerably influences D_{eff}, and the same can be implied about the introduction of the ultrasounds to the procedure.

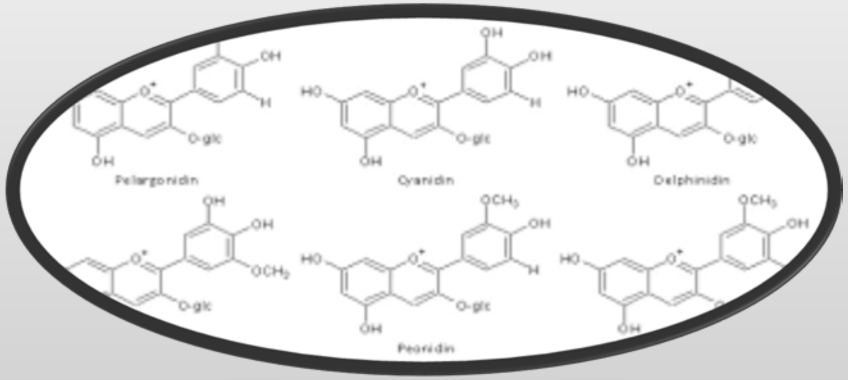






- ❑ **Pretreatment is observed to negatively influence TPC**
- ❑ **However Peach peel seems to have a respectable amount of phenolic compounds, even after a drying process!!**

Phenolic Content
0.131 – 0.916 mg GAE/g



Regression Analysis of Total Phenolic Content

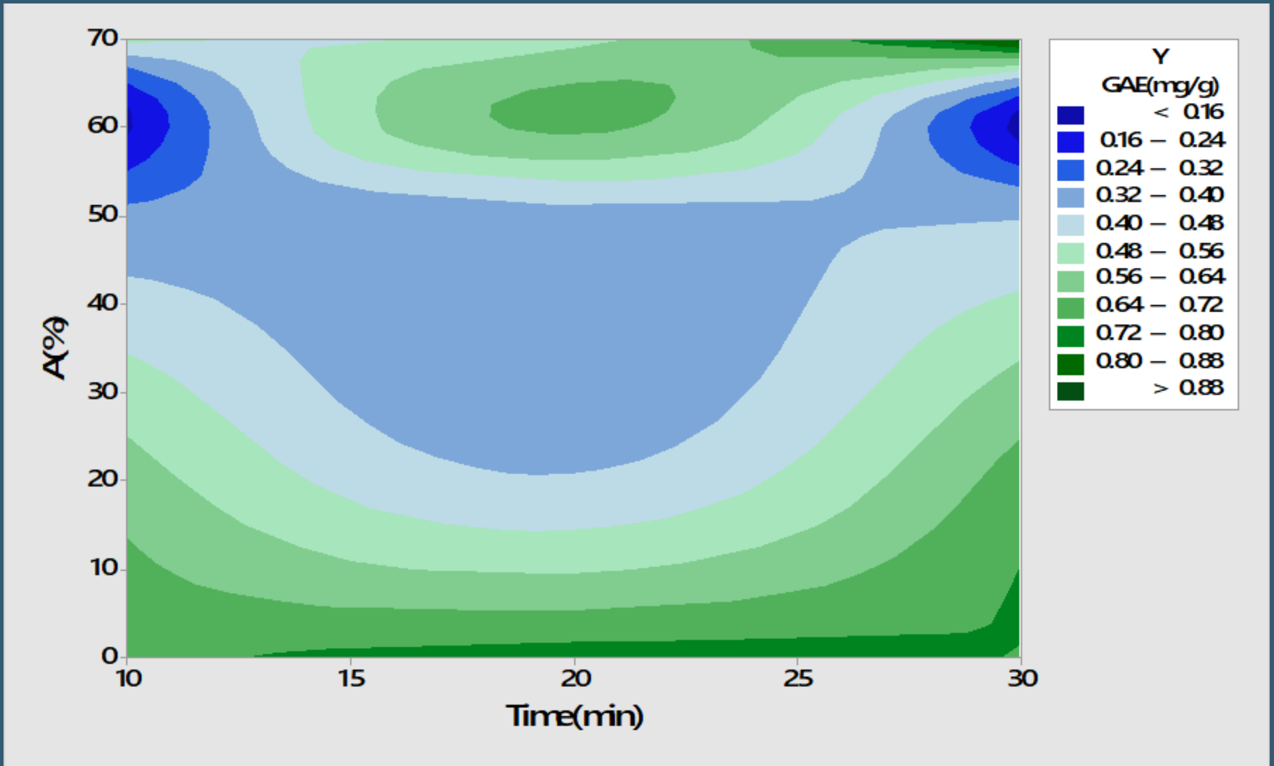
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	0.38776	0.07755	1.72	0.263
Linear	2	0.03755	0.01878	0.42	0.677
A(%)	1	0.02368	0.02368	0.53	0.496
Time(min)	1	0.01387	0.01387	0.31	0.599
Square	2	0.24750	0.12375	2.75	0.142
A(%)*A(%)	1	0.21928	0.21928	4.87	0.070
Time(min)*Time(min)	1	0.02822	0.02822	0.63	0.459
2-Way Interaction	1	0.01395	0.01395	0.31	0.598
A(%)*Time(min)	1	0.01395	0.01395	0.31	0.598
Error	6	0.27042	0.04507		
Total	11	0.65818			

Model Summary

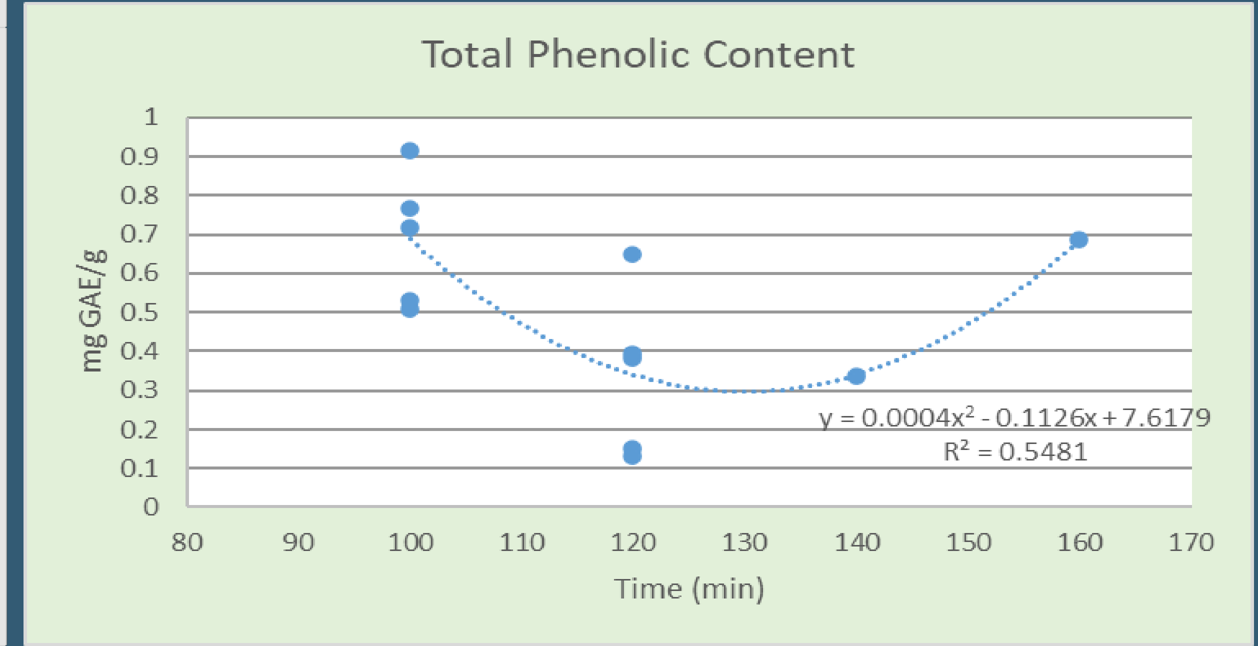
S	R-sq	R-sq(adj)	R-sq(pred)
0.212296	58.91%	24.68%	0.00%

- Factors are not statistically significant and there is no interaction between them



- Ultrasounds have an adverse effect on phenolic content
- Time mildly affects TPC

Pearson's correlation of phenolics to required drying time has a value of p = 0.384



Conclusions

- **Peach peel valorization** is a promising prospect to enrich other products with biochemical compounds of nutritional value, via a drying procedure and granulation
- Pretreatments have shown an interesting **decrease on the required drying time** of the peel
- The **diffusion coefficient** increased in every case of pretreatment and the highest values were observed at the maximum level of pretreatment duration
- Both ultrasound amplitude and pretreatment time period are **statistically significant for the diffusion coefficient**
- It is not yet understood how pretreatments affected the ability of **phenolic compounds** to be extracted, the results were mixed efficiency-wise and the data could not be statistically described
- **Immersion in ethanol solution** as a pretreatment is a novel technique that showed exemplary results and further investigation is encouraged, especially with solutions of various concentrations

Thank you for your time!!