OMICS Group
Accelerating Scientific Discovery

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Improved Food Preservation and Shelf Life Stability By Ultrasound Processing Technologies: Case Studies

KEY NOT FORUM

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CONGRESS CO-CHAIR
CELAL BAYAR ÜNİVERSİTESİ

July 21, 10:05-10:30,
Hampton Inn Tropicana, Hampton Events Center A, Las Vegas,

Consumer Demands

- **With less additives**
- **With high nutritional value**
- **High quality**
- **Less thermal damage**
- **Good sensory properties**
- **Safe products**



Thereby, food manufacturing designed for better food safety and quality.

Strategies for Food Processors



- **Premium food products**
- **Long lasting Foods**
- **Convenience foods**
- **Minimally processed foods**
- **Ready-to-cook meals**
- **Ready-to-eat foods**
- **Low-fat foods**
- **Low-carbohydrate foods**
- **Specialities in foods**

(For Health Treatments
For Kids
For Military
For Pregnants
For Sportmans)



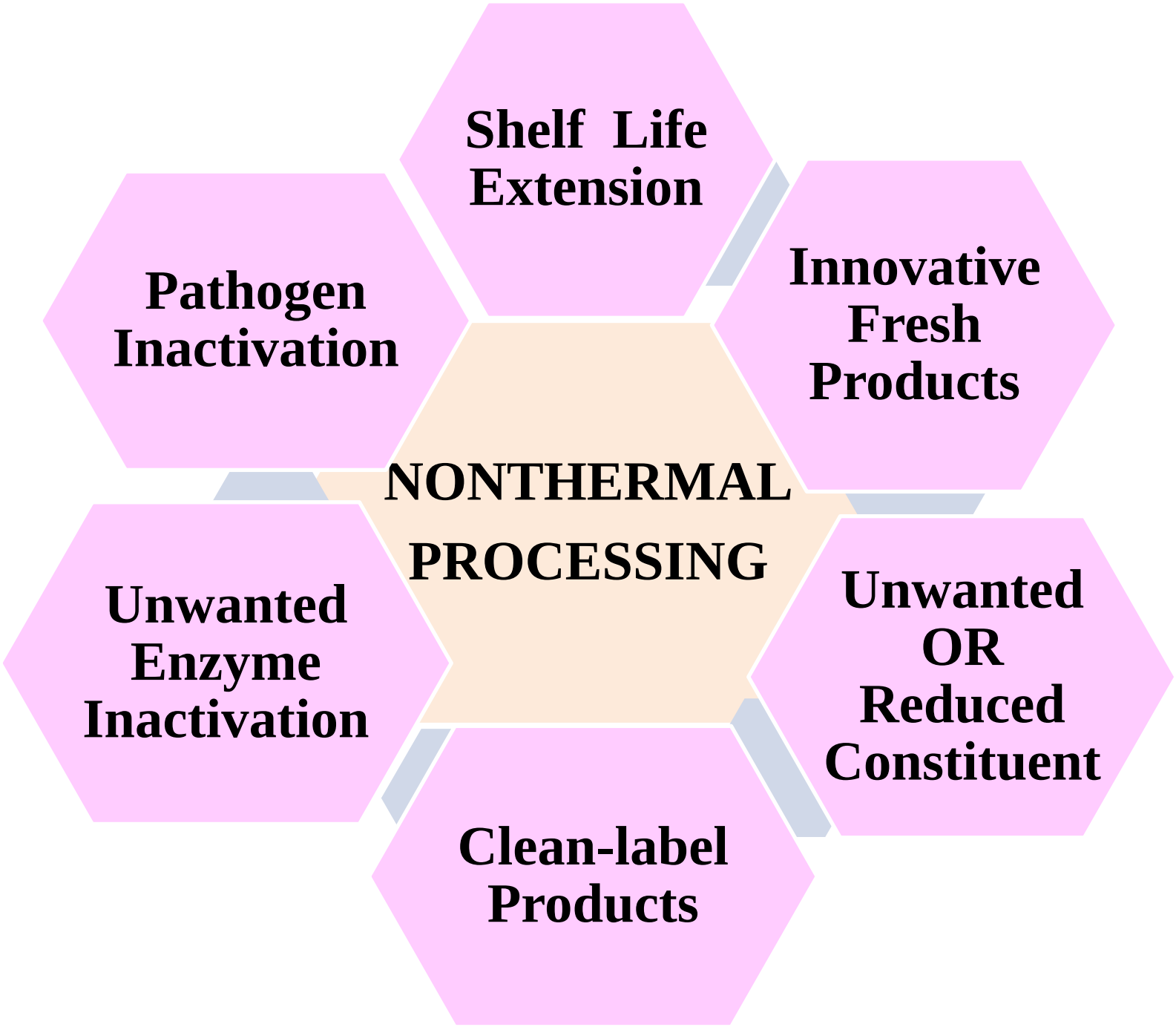
NONTHERMAL

- High Hydrostatic Pressure
- Pulsed electric fields
- Ultrasound
- Ultraviolet
- Irradiation
- Cold Plasma
- DensePhase CarbonDioxide
- Ozone
- Chemicals

THERMAL

- Microwave
- Radiofrequency
- Ohmic Heating
- Induction Heating

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Shelf Life Extension
Innovative Fresh Products
Pathogen Inactivation
NONTHERMAL PROCESSING
Unwanted Enzyme Inactivation
Unwanted OR Reduced Constituent
Clean-label Products

Fundamentals:

Ultrasound Theory ; Definitions

Ultrasound is one of the emerging technologies that were developed to minimize processing, maximize quality and ensure the safety of food products.

Ultrasound is applied to impart positive effects in food processing such as improvement in mass transfer, food preservation, assistance of thermal treatments and manipulation of texture and food analysis

Fundamentals:

Ultrasound Theory

Ultrasound is considered as one such nonthermal processing alternative, which can be used in many food processing operations.

It travels through a medium like any sound wave, resulting in a series of compression and rarefaction.

At sufficiently high power, the rarefaction exceeds the attractive forces between molecules in a liquid phase, which subsequently leads to the formation of cavitation bubbles.

Each bubble affects the localized field experienced by neighboring bubbles, which causes the cavitation bubble to become unstable and collapse, thereby releasing energy formany chemical and mechanical effects. The collapse of each cavitation bubble acts as a hotspot,which generates energy to increase the temperature and pressure up to 4000 K and 1000 atm, respectively.



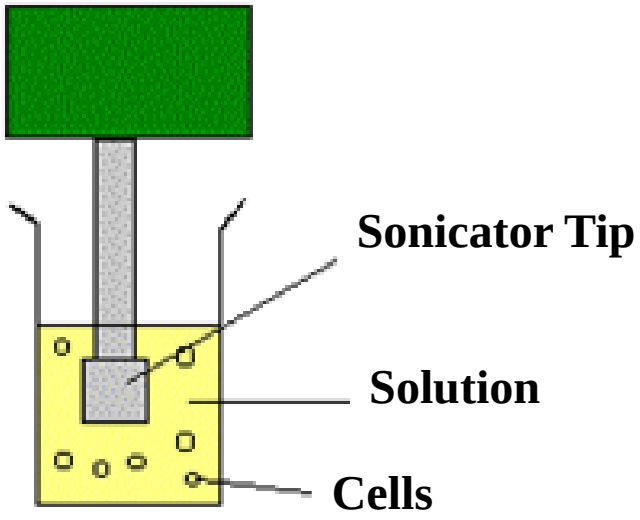
UP200S with S40 at stand

Ultrasound is efficient non-thermal alternative. Ultrasonic cavitation creates shear forces that break cell walls mechanically and improve material transfer.

- **There are a number of mechanisms by which ultrasound can affect mass transfer. The high ultrasonic intensity of the waves can generate the growth and collapse of bubbles inside liquids, a phenomenon known as cavitation.**

- **Ultrasound that can affect the resistance to mass transfer are the heating of materials due to thermoacoustic effects, the microstirring in fluids, mainly at interfaces, and some structural effects such as the so called “sponge effect” when the samples are squeezed and released like an sponge and the creation of microchannels**

Fundatementals: Ultrasound Processing Principle



- **Energy generated from waves o**
  20,000 or more vibrations per econd
  - ***high frequency or diagnostic (2-10 MHz)***
  - ***low frequency or power (20-100 kHz)***
- **Lyses and inactivates cells**
  Intracellular cavitation
- **Variables to control:**
  Temperature
  Amplitude of the ultrasonic wave
  Time of treatment
  Cycles

Sonication Modes

- **Sonication (US)**

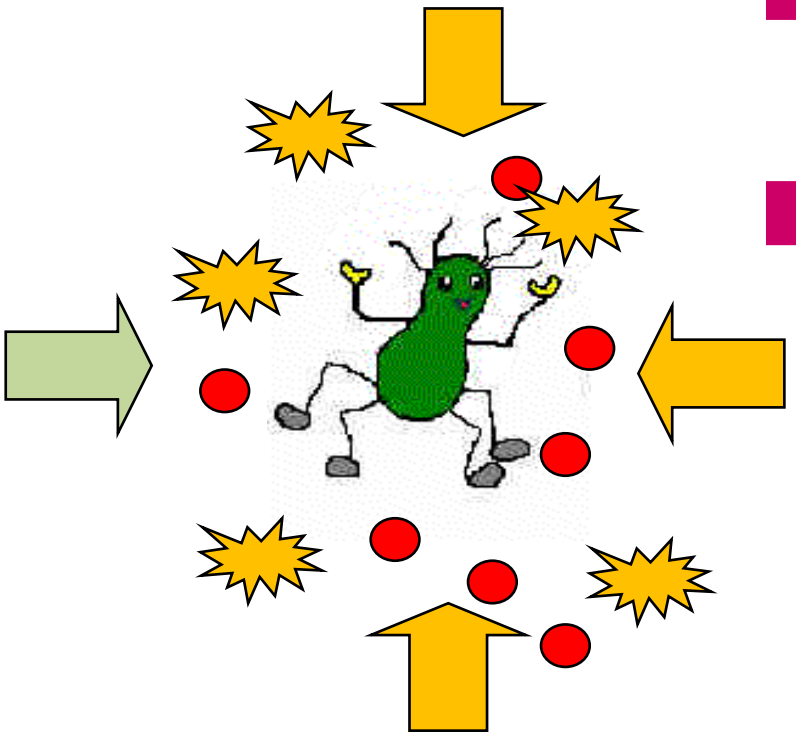
  Ultrasound

- **Thermo-sonication (TS)**

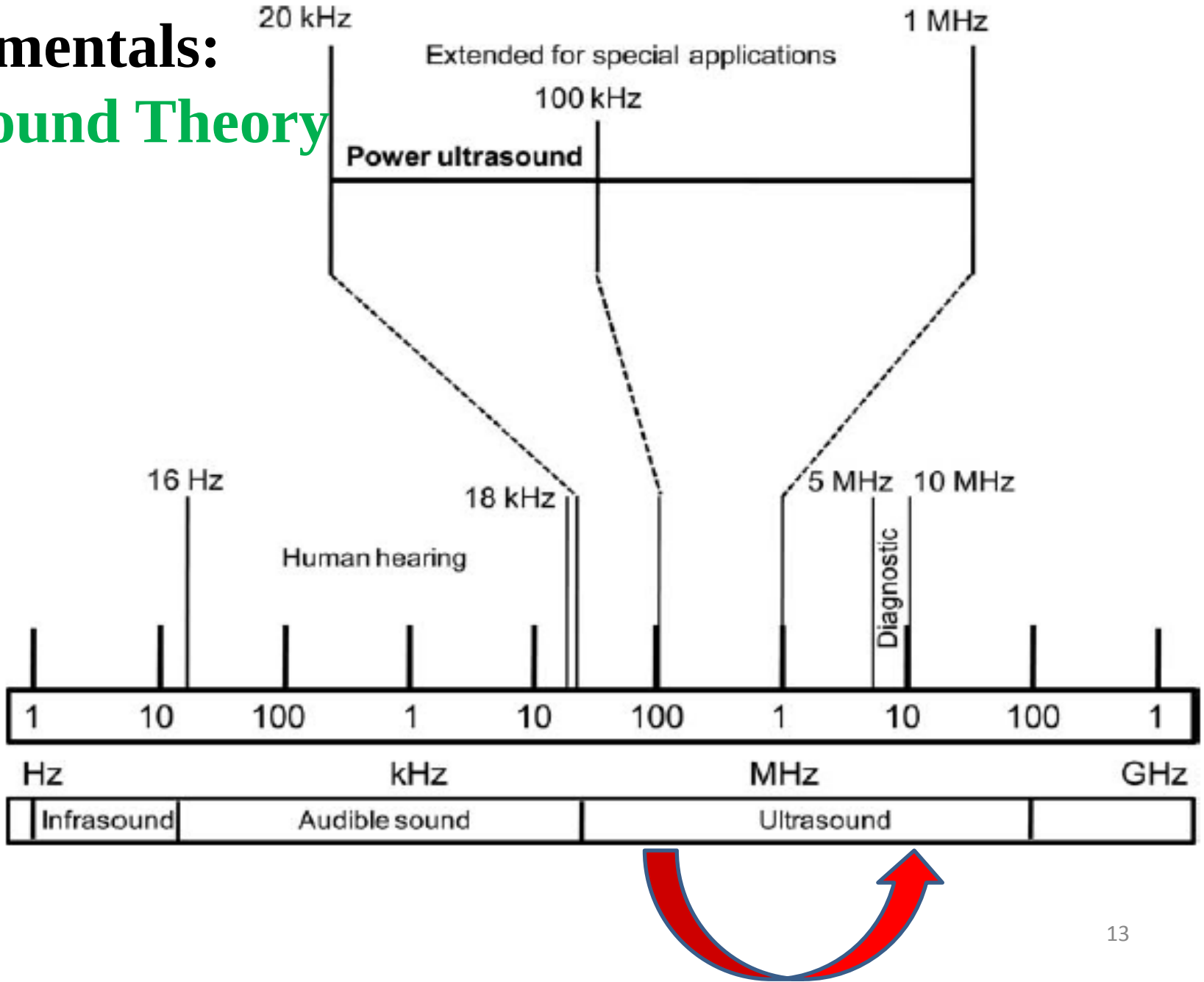
  Ultrasound plus heat

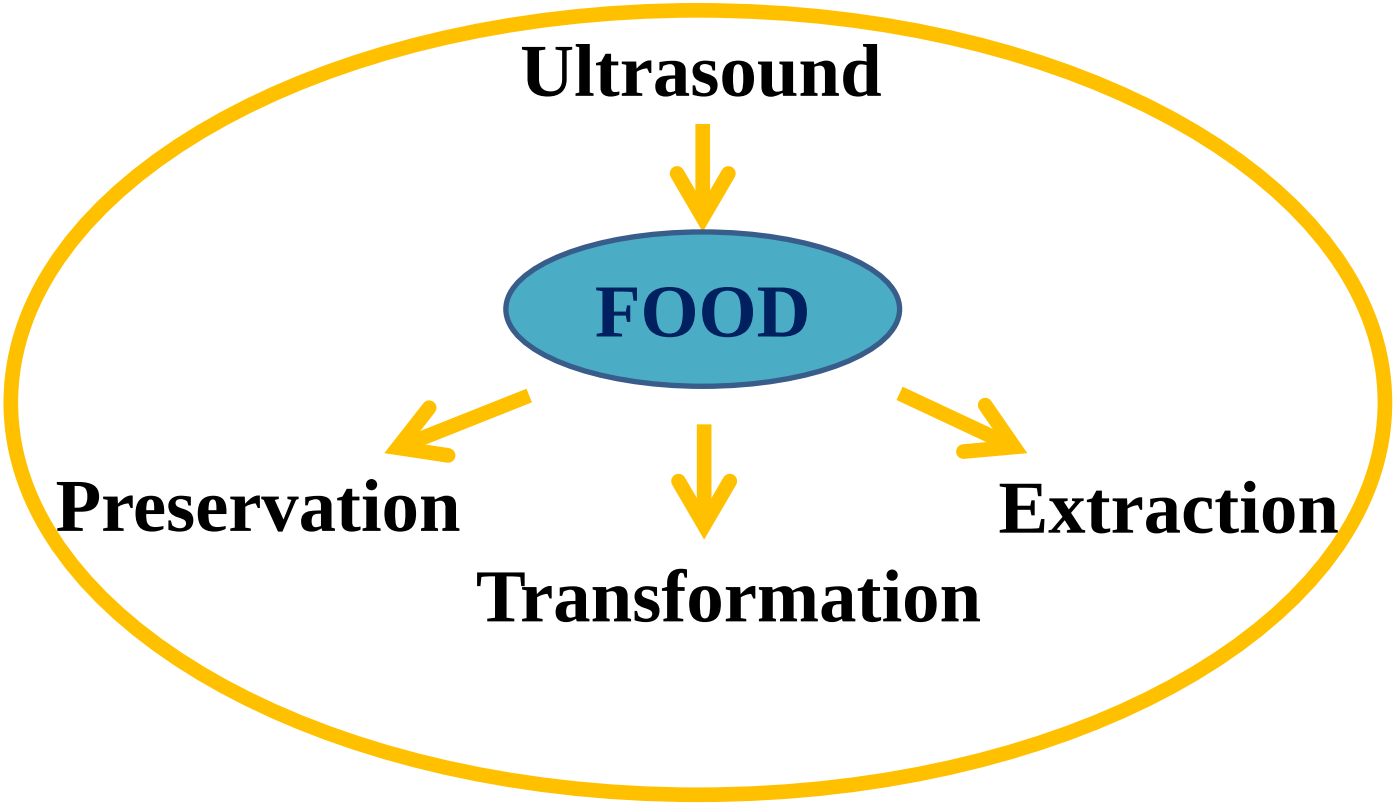
- **Mano-thermo-sonication (MTS)**

  Ultrasound plus heat and pressure



Fundamentals:
Ultrasound Theory





The potential utilizing effects by ultrasound cavitation phenomena are shown in Fig.2.

Cavitation may cause to off-flavors, structural modifications, free radicals, and sometimes metallic taste

Utilizing of Ultrasound in Food Science &Technology

Inactivation of Microorganisms and Enzymes

Enhancing the Efficiency of Unit Operations

- Ultrasound-Assisted Extraction
- Ultrasound Assisted Drying
- Ultrasound Assisted Osmotic Dehydration
- Ultrasound Assisted Filtration
- Ultrasound Assisted Freezing
- Emulsification in Lipid Containing Foods
- Hommogenization in Lipid Containing Foods
- Cutting in Lipid Containing Foods

Modifications

- Color Modifi.
- Antioxidant Modifi.
- Bioactive Modifi.
- Polysacharide Modifi

Most Frequently Utilizing of Ultrasound ;

- **Ultrasonic extraction of phenolic compounds and phenolic pigments (Anthocy., Betacyanin, Betaxanthin) from plant tissues**
- **Ultrasonic extraction of lipids and proteins from plant seeds, such as soybean**
- **Cell membrane permeabilization of fruits**
- **Ultrasonic processing of fruit juices, purees, sauces, dairy**
- **Ultrasonic processing for improving stability of dispersions**
- **Microbial and enzyme inactivation (preservation) is another application of ultrasound in the food processing**

High energy ultrasound can be used in preservation and safety and are applying to food enzymes, in microbial inactivation, in ultrasound assisted extraction whereas low power ultrasound can be used for analysis and quality control of

- **plant food resources including fruit and vegetables, fruit juices, peels, oils and**
- **fat-based products including meat products, oil seeds**
- **cereals products as bread dough, batters and biscuits, food pastes**

Ultrasound- Plant Food Applications

Fruit Juices

Tomato Juices



Ultrasound Condition	Ultrasound Processing Effects
20 kHz, 24.4 to 61.0 μm, 2 to 10 min and pulse durations of 5 s on and 5 s off.	It is reported that power ultrasound is a potential non thermal technique to inactivate microorganisms pertinent to fruit juices. Sonication alone was found an effective process to achieve the desired level of yeast inactivation (YI) in tomato juice, YI was found to follow the Weibull model. *Adekunte et al., (2010).*
20 kHz, amplitude of 65 μm and temp. Between 50 and 75◦C.	In tomato juice, the ultrasonic inactivation kinetics of polygalacturonase (PG) and pectin methylesterase (PME) was performed ***Combined ultrasound and heat (thermosonication) enhanced the inactivation rates of both PME and PG.*** *Terefe et al., (2009).*

Fruit Juices Orange Juices

Ultrasound Condition	Ultrasound Processing Effects
20 kHz, Wave amplitude of 89.25 μm for 8 min	The use of ultrasound extended the shelf-life of orange juice by 4 days. The control juices were rejected by the sensory panel members after 6 days storage at 4◦C (refrigerator) owing to off-flavor, and ultrasonicated juice after 10 days due to off-odor. Also, sonication affected the color and decreased ascorbic acid level.



Ġomez-Ĺopez et al.,(2010)



Ultrasound Condition

20 kHz, 24.4–61.0 μm, 5–30 ˚C, 0–10 min

20 kHz, 2-10 min, pulse durations of 5 s on and 5 s off, amplitude levels 40 to 100%

Ultrasound Processing Effects

Low temperatures and intermediate amplitude (42.7 μm) resulted in lower non-enzymatic browning and ascorbic acid deterioration, and better quality orange juice *Valdramidis et al. (2010)*

In the study of the effect of amplitude level and sonication time on juice quality parameters, there was no significant difference on pH, ◦Brix and titratable acidity. It was found the degradation of color, cloud value and an increase in browning index. *Tiwari et al., (2008 a,b,c)*

20

Ultrasound Condition	Ultrasound Processing Effects
600 W, 20 kHz, 95.2-μm wave amplitude	**Combination of high intensity ultrasound with mild heat treatment (45◦C), and natural antimicrobials (vanillin 1,000 ppm and citral 100 ppm) was reported to be the most effective treatment for the control of *L.monocytogenes* in orange juice** *Ferrante et al., (2007).*
20 kHz, 95 μm-wave amplitude	**Combined treatment involving high-intensity ultrasound and short-wave ultraviolet radiation was more effective in simultaneous rather than in series for the inactivation of *Escherichia coli*, *Saccharomyces cerevisiae*, and a yeast in fruit juice** *Char et al., (2010).*



Fruit Juices

Apple Juices





Ultrasound Processing Effects

With ultrasonic treatments, about 60% and 90% of the *Alicyclobacillus acidoterrestris* cells were inactivated after treating the apple juice with 300-W ultrasound for 30 & 60 min, respectively. The lowest D value at 36.18 min was found when using 600-W. The alterations of sugar level, acidity, haze and juice browning were not affected the juice quality. *Yuan et al., (2009*

23 kHz, 200–700 W, 10–60 min

20 kHz, ultrasound amplitude 0.4 to 37.5 μm

Ultrasound treatment alone can be effective for inactivation of *E. coli* *Patil et al., (2009).*

Fruit Juices

Strawberry Juices

Condition	Ultrasound Processing Effects
20 kHz, amplitude level 40–100%, 2–10 min, pulse durations of 5 s on and 5 s off.	The ultrasound amplitude level and sonication time was performed on strawberry juice quality. It was found that sonication reduced the anthocyanin and ascorbic acid contents by 3.2 and 11%, respectively, at the maximum treatment conditions. *(Tiwari et al., 2008d)*
20 kHz, energy density 0.33–0.81 W/mL, 0–10min, pulse 5 on 5 off	Ultrasound treatment (energy density 0.81 W/mL and treatment time 10 min) resulted in 5% and 15% reductions in anthocyanin and ascorbic acid, respectively during storage 4 and 20◦C for 10 days *The improved stability was higher for ascorbic acid and anthocyanins retention as compared to control sample.* *Tiwari et al., (2009d)*



Fruit Juices

Blackberry Juices

Ultrasound Condition	Ultrasound Processing Effects
20 kHz, 37.5 μm to 61.0 μm, 0–10 min, pulse durations of 5s on 5s off	Significant alterations in color and anthocyanins with insignificant alterations in pH, titratable acidity, and degree brix were obtained in case of blackberry juice



Tiwari et al., (2009e)

Fruit Juices

Red Grape Juices

Ultrasound Condition

20 kHz, 37.5 μm to 61.0 μm, 0–10 min, pulse durations of 5s on 5s off

Ultrasound Processing Effects

Highest degradation of malvanidin-3-O-glucosides (48.2%), cyanidin-3-O-glucosides (97.5%) and delphinidin-3-O-glucosides (80.9%) at 61.0 μm for 10 min were found. It was determined that significant alterations in anthocyanins and color of juice *Tiwari et al., (2010)*



Fruit Juices

Guava Juices

Ultrasound Condition	Ultrasound Processing Effects
35 kHz, 30 min	Ascorbic acid content was found to be significantly higher in samples treated with carbonation and sonication than in the control. juice. Carbonation provided more nuclei for cavitations that permitted the elimination of dissolved oxygen in the juice. Also, further treatment gave rise to a greater cloudiness and PPO activity. *Cheng et al., (2007).*



Fruits &Vegetables



Plant foods including fruits and vegetables are highly attenuating materials owing to the scattering of sound from voids and pores, that complicates the interpretation of ultrasound data and thereby unsuitable for evaluating their tissues

(McClements & Gunasekaran, 1997; Povey, 1998; Sarkar & Wolfe, 1983; Sarkar & Wolfe, 1983)

In Quality control of fresh vegetables and fruits By Ultrasound

Preharvest and postharvest applications are important..



(Mizrach, 2008)

Physiological and physiochemical alterations during
growth and maturation,
harvest period,
storage and shelf-life

&

Ultrasound measurements & other physiochemical measurements,
firmness,
mealiness,
dry weight percentage (DW),
oil contents,
total soluble solids (TSS),
acidity *(Mizrach, 2008)*

Case Studies on Preharvest Fruits by Ultrasound

✓ Color Changes & Ripeness Correlation

The amplitude of the ultrasound wave transmitted through fruit peels increased when the color changed from green to yellow indicating a good correlation between the ripeness and the acoustic attenuation

The maturity and sugar content of plum fruits determined by measuring ultrasound attenuation in the fruit tissue correlated well with the firmness of plums and that of tomato in other study





(Mizrach , 2007,2004; Mizrach , et.al.,1991)

With using the ultrasound attenuation parameter, the detecting of defective potatoes was performed.



(*Cheng & Haugh, 1994*).

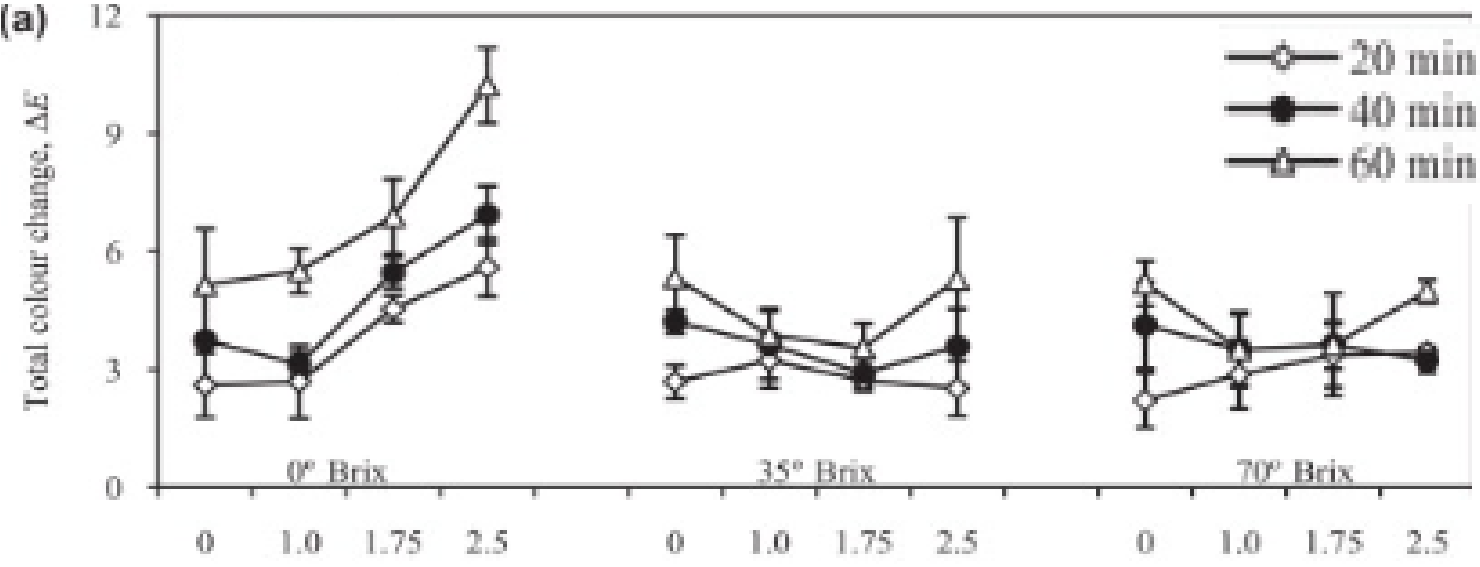
Case Studies on Postharvest Fruits by Ultrasound

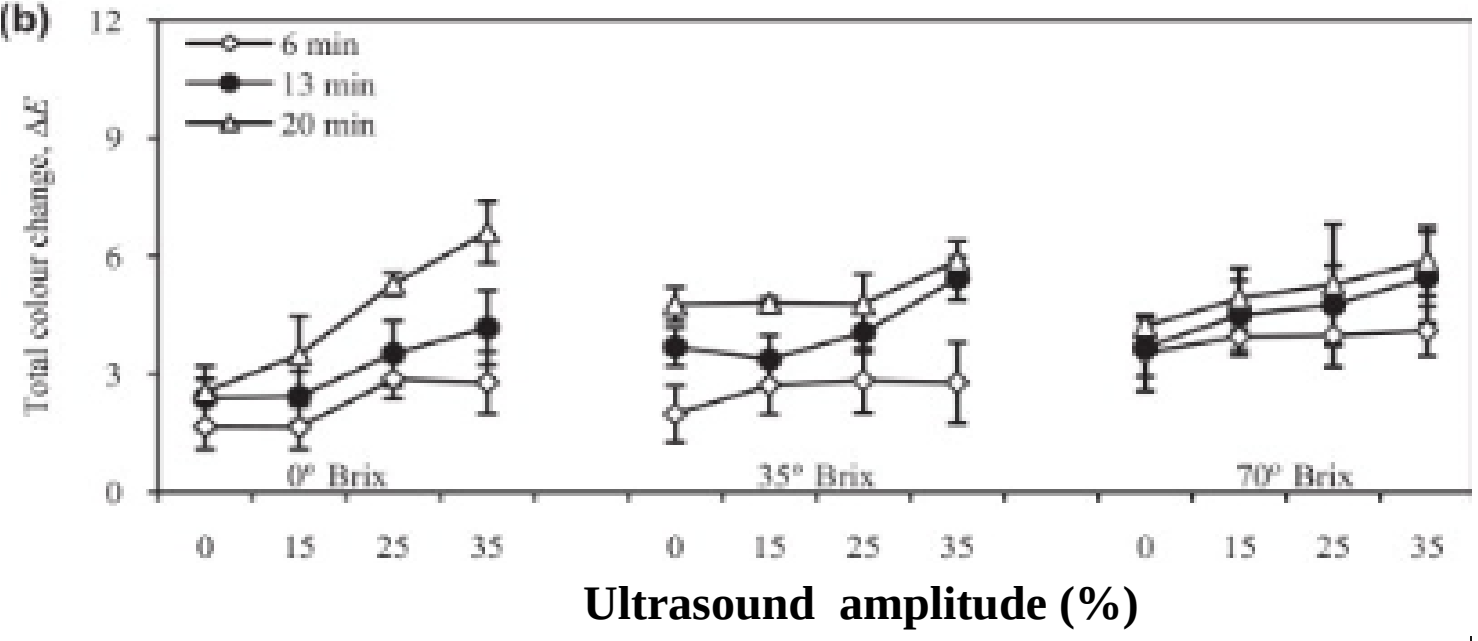
Application of ultrasound to osmotic dehydration of guava slices via indirect sonication using an ultrasonic bath system and direct sonication using an ultrasonic probe system.



Pre-treatments were designed in three osmotic solution concentrations of 0, 35, and 70 °Brix at indirect ultrasonic bath power from 0 to 2.5 kW for immersion times ranging for 20–60 min and direct ultrasonic probe amplitudes from 0 to 35% for immersion times of 6–20 min.

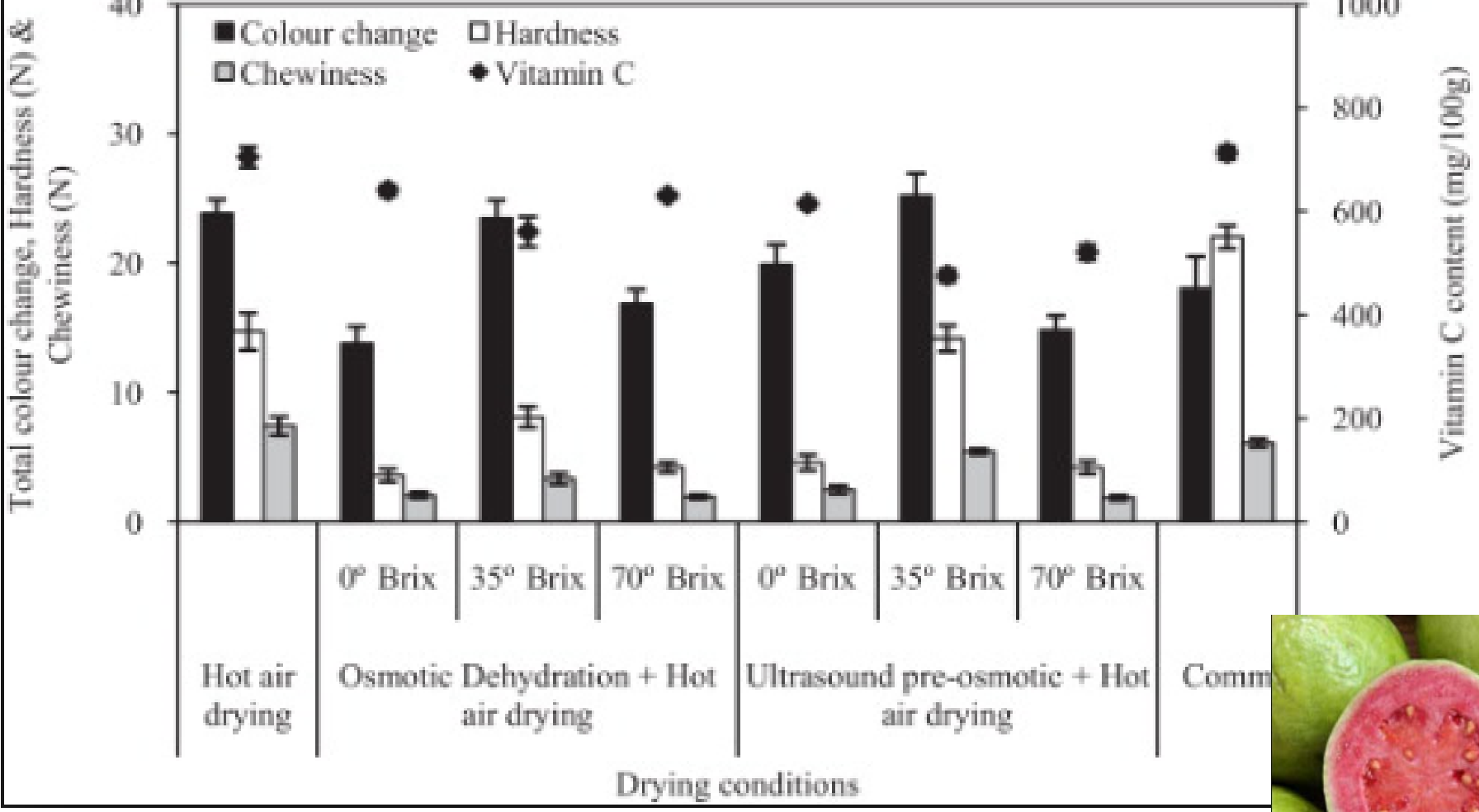



(a)
Total colour change, ΔE
12
9
6
3
0
20 min
40 min
60 min
0° Brix
35° Brix
70° Brix
0
1.0
1.75
2.5
Ultrasound power (kW)


(b)
Total colour change, ΔE
12
9
6
3
0
6 min
13 min
20 min
0° Brix
35° Brix
70° Brix
0
15
25
35
Ultrasound amplitude (%)

Ultrasound input as power and amplitude, osmotic solution concentrations, and immersion time increased the water loss, solid gain, and total colour change of guava slices significantly with $p < 0.0005$.

Applying ultrasound pre-osmotic treatment in 70 °Brix prior to hot-air drying reduced the drying time by 33%, increased the effective diffusivity by 35%, and decreased the total colour change by 38%. A remarkable decrease of hardness to 4.2 N obtained was also comparable to the fresh guava at 4.8 N.

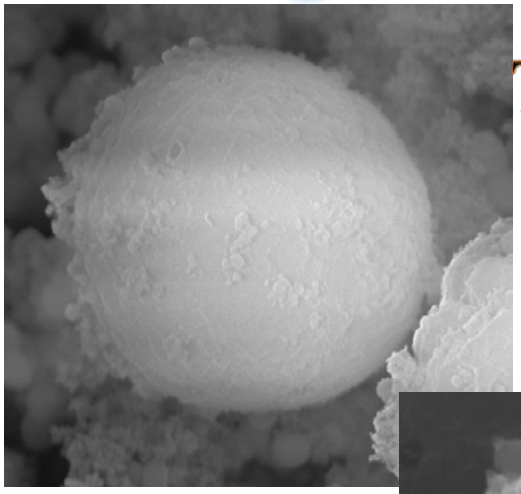




Total colour change, vitamin C content, hardness, and chewiness of dried guava after hot-air drying, osmotic dehydration prior to hot-air drying, and ultrasound pre-osmotic treatment prior to hot-air drying with the commercially dried guava

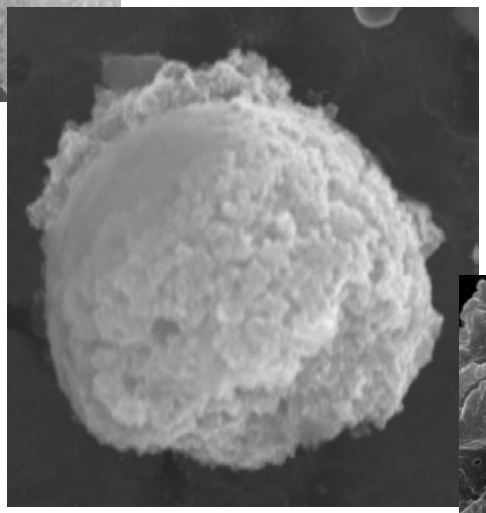
(Kek et.al.,2013)

Disruption of fat globules of milk by thermo-sonication

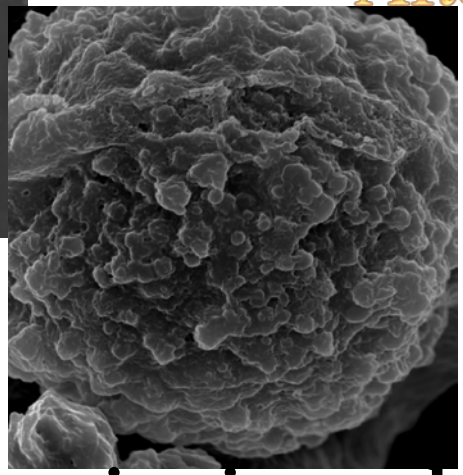


Thermal treatment

Ultrasound
After 10 min



Ultrasound
After 30 min

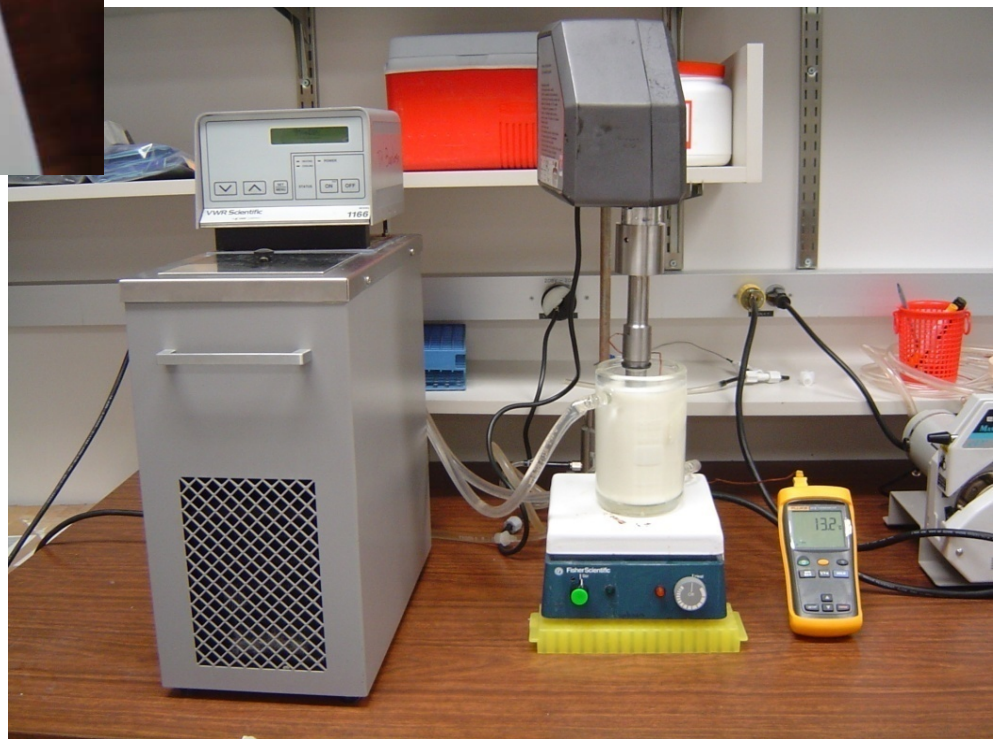


By US, better homogenization, color, appearance and consistency

Ultrasound treatment of milk at WSU



Ultrasonic processor Hielscher® UP400S (400 W, 24 kHz) with a 22 mm probe



Ultrasound –Assisted Extraction



Ultrasound (*Hielscher,USA*)

Ultrasound is probably the most simple and most versatile method for the disruption of cells and for the production of extracts. It is efficient, safe and reliable.

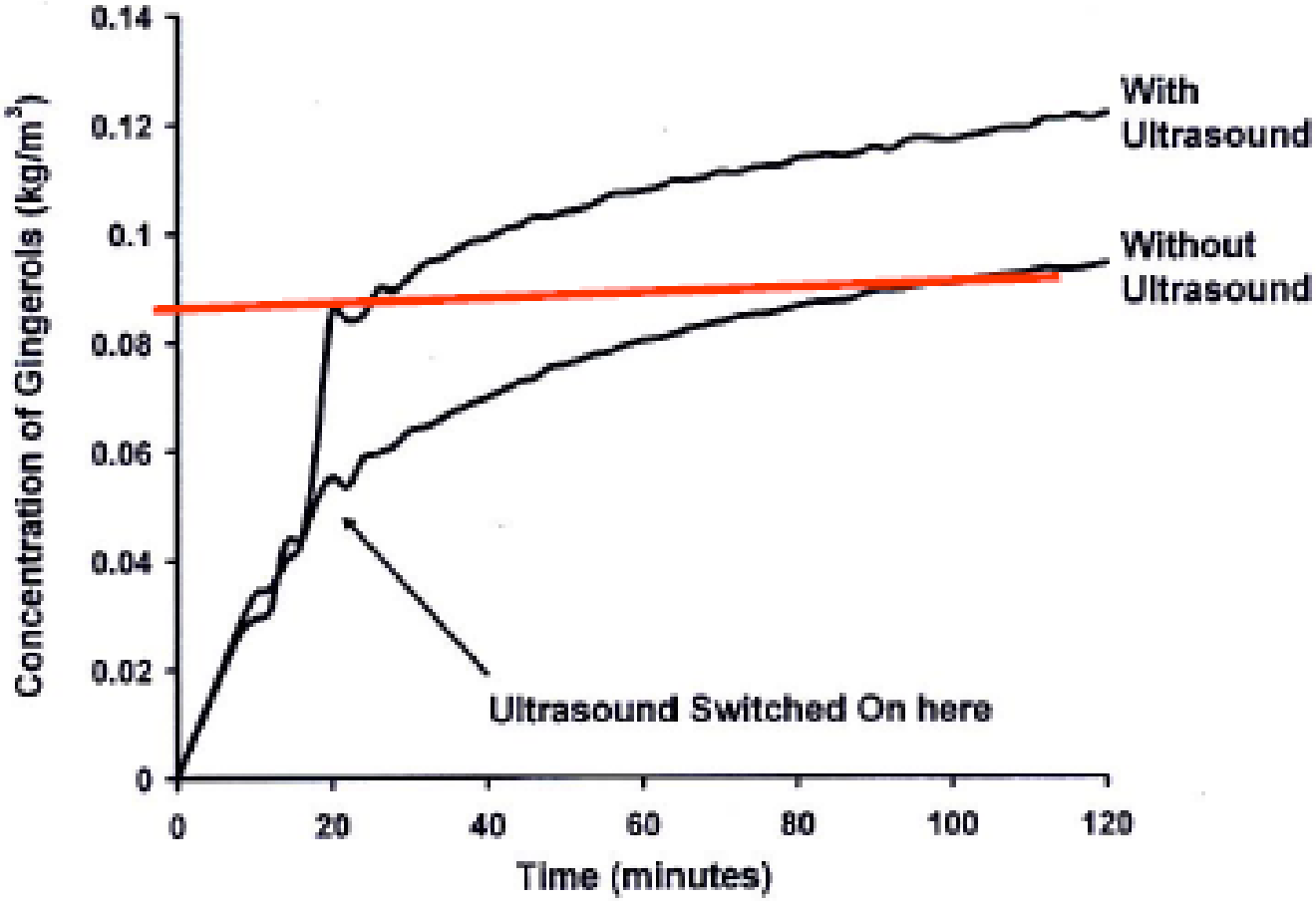
Due to ultrasonic cavitation creates shear forces that breaking cell walls mechanically and improving the material transfer; this effect is being used in the extraction of liquid compounds from solid cells (solid-liquid extraction).

Ultrasound is faster and more complete than maceration or stirring. The particle size reduction by the ultrasonic cavitation increases the surface area in contact between the solid and the liquid phase, significantly.

The mechanical activity of the ultrasound enhances the diffusion of the solvent into the tissue. As ultrasound breaks the cell wall mechanically by the cavitation shear forces, it facilitates the transfer from the cell into the solvent.

Extraction Yield Improvements By Ultrasound

Supercritical extraction (SCF-CO_2)



Source: Balachandran et al. (2006)

Extraction Yield Improvements By Ultrasound

Product	Extract	Solvent	Yield increase (%)
β - carotene	Carrot	Aqueous	8-25
	Carrot	Ethyl-acetate	20-25
Polyphenols	Grape must	Aqueous	16-18
	Grape marc	Aqueous	11-35
	Black tea	Aqueous	6-18
	Apple	Aqueous	6
Gingerol	Ginger	SCF - CO_2	30

*CFNS data

Ultrasound- Oily Food Applications

Target extract : Phenolics of nuts and pastes
Solvent: ethanol-distilled water (30/70, v/v)
Process: Laboratory 24 kHz, 20-75 W s ml^{-1}
Processing conditions: Ambient
Exposing duration: 10 min

Target extract : Lipids of nuts and pastes
Solvent: chlorophorm /methanol (2/1, v/v)
Process: Laboratory 24 kHz, 20-75 W s ml^{-1}
Processing conditions: Ambient
Exposing duration: 10 min

Target: Microbiological quality of nuts & pastes
Solvent: Pepton water (0.1%)
Process: Laboratory 24 kHz, 20-75 W s ml^{-1}
Processing conditions: Ambient
Exposing duration: 10 min

Tokuşoğlu et.al.,2011

The Alterations of Total Lipid Value After Processing

NUTS Total Lipid g/100 g	KONTROL	Ultrasound Treated
Almond	42.3 ± 1.9	38.63 ± 2.1
Pistachio	54.3 ± 0.8	46.12 ± 1.8
Peanut	48.9 ± 1.2	43.66 ± 1.3
Hazelnut	62.6± 2.03	57.25± 2.83

Total lipid content decreased after ultrasound treatment ($p<0.05$)

With ultrasound, the destruction of the cell walls facilitates the pressing and thereby reduces the residual oil or fat in the pressing cake.

Tokuşoğlu et.al.,2011

Total Phenolics of Studied Nuts

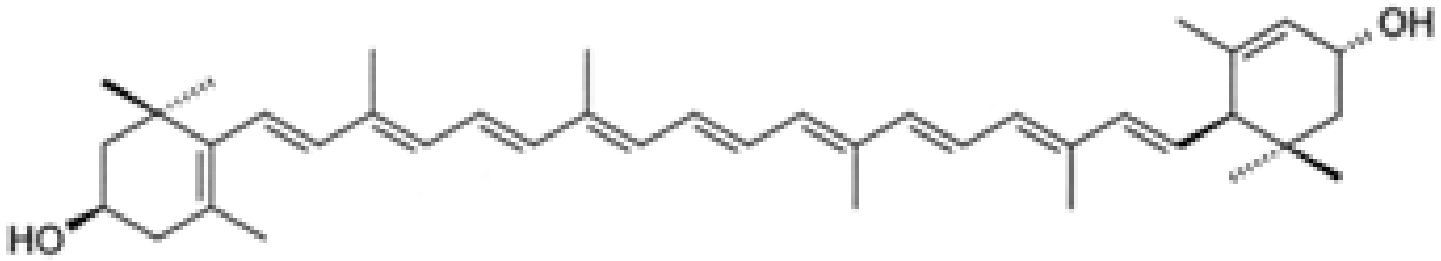
NUTS	CONT . Total Phenolics g/100g D.W	UP Effect g/100g D.W
Almond	176.58 ± 13.83	192.43 ± 6.75
Pistachio	378.72 ± 9.77	397.23 ± 11.04
Peanut	334.51 ± 6.06	361.30 ± 5.46
Hazelnut	278.43 ± 10.1	298.55 ± 7.22

After Ultrasound Processing
(Avg. 12% increasing in total phenolics)

The use of Ultrasound Ass.extraction enhanced mass transfer rates, increases cell permeability, and increased the extraction capacity of phenolic constituents, and higher levels of bioactive compounds are preserved with ultrasound assisted extraction.

Minor Bioactive (Lutein Xanthophylls) of Studied Nuts

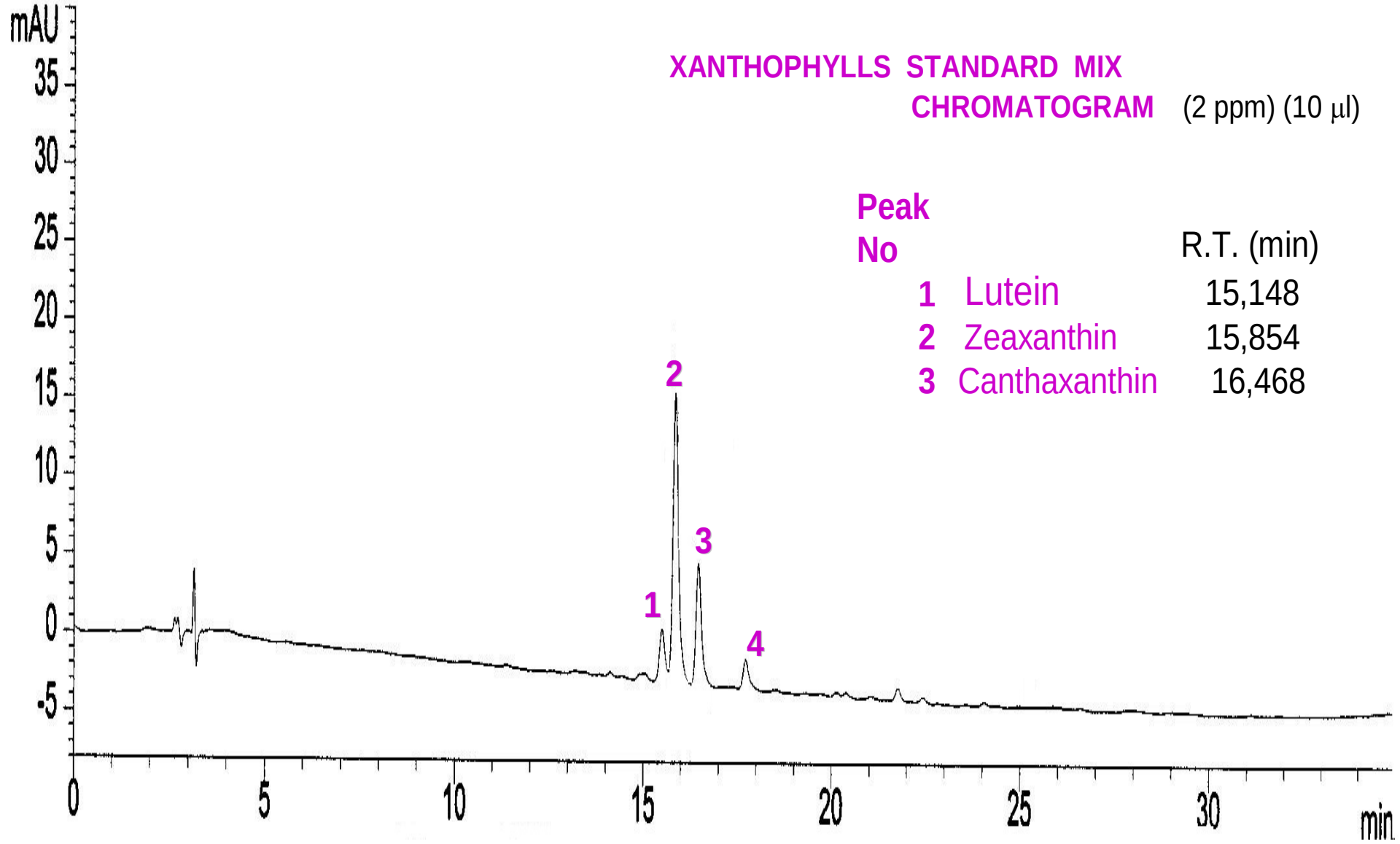
NUTS	Lutein Xanthopyyllsg /100g D.W	UP Effect
Almond	ND	ND
Pistachio	4.12 ± 0.48	7.3 ± 2.02
Peanut	ND	ND
Hazelnut	ND	ND



Lutein Xanthophyll

PISTACHIO LUTEIN

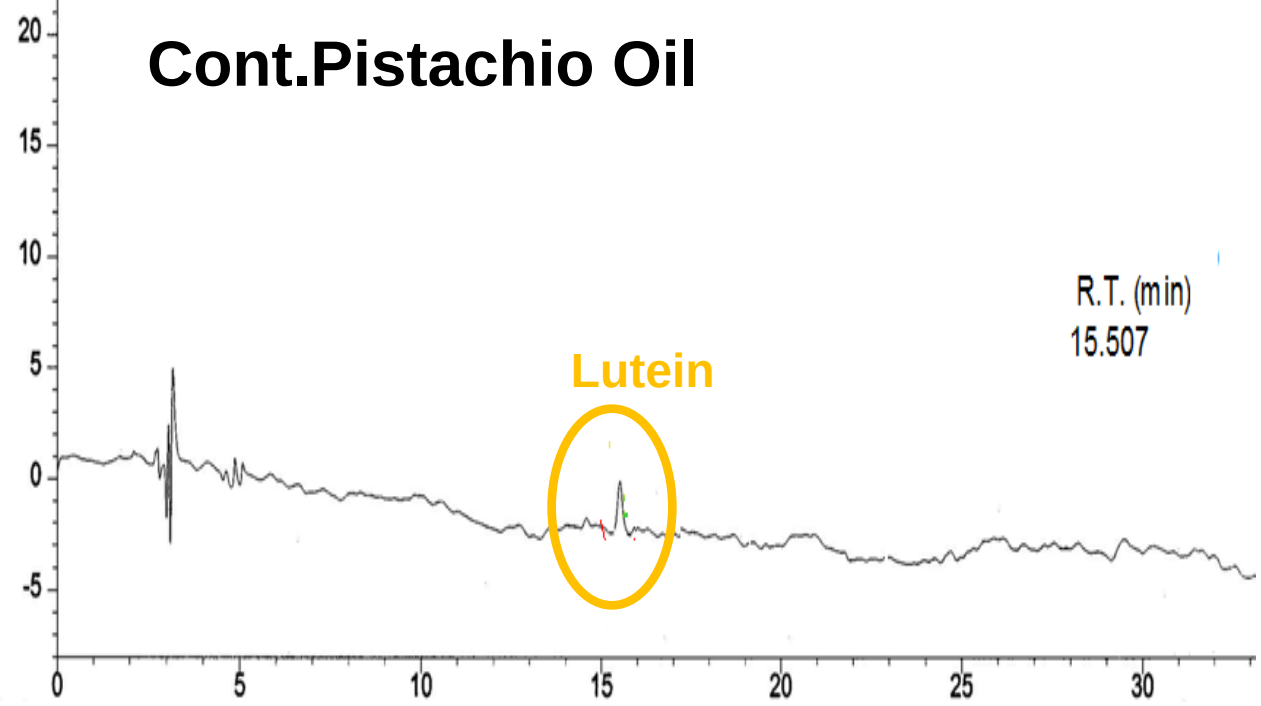
73% Increasing



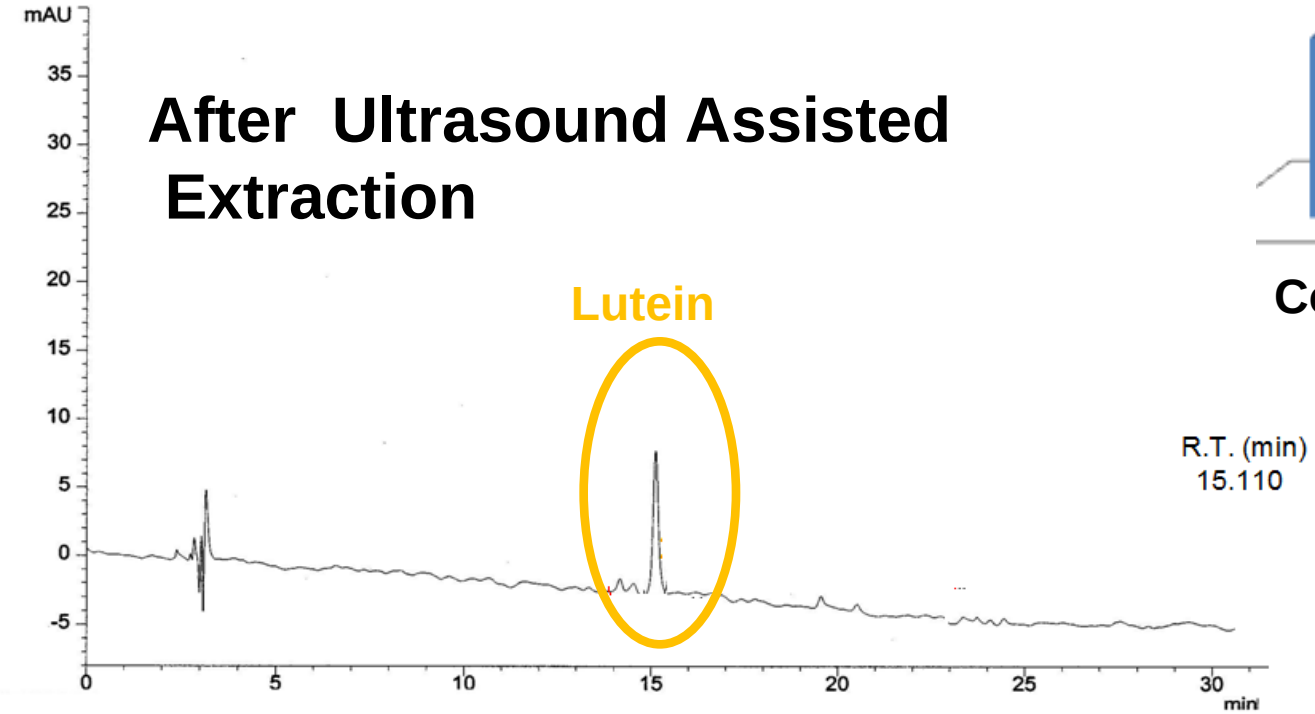
XANTHOPHYLLS STANDARD MIX
CHROMATOGRAM (2 ppm) (10 μl)

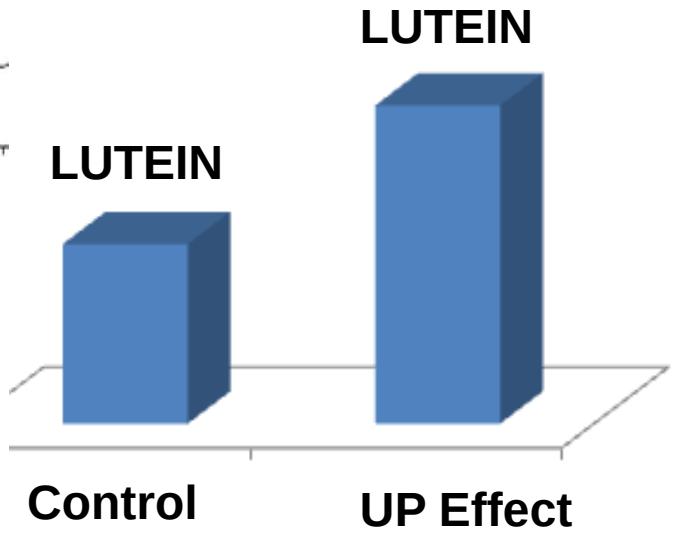
Peak No		R.T. (min)
1	Lutein	15,148
2	Zeaxanthin	15,854
3	Canthaxanthin	16,468

Cont.Pistachio Oil



After Ultrasound Assisted Extraction



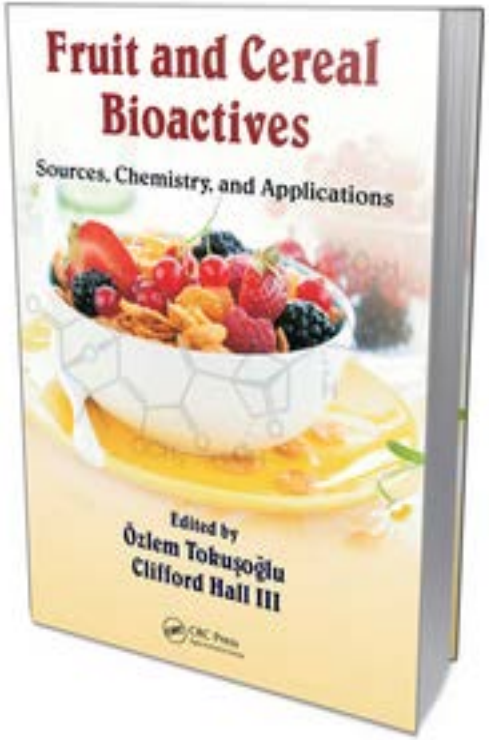


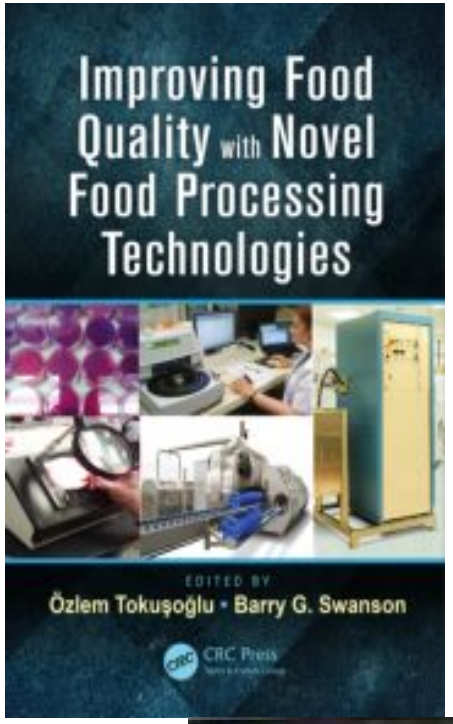
Conclusion

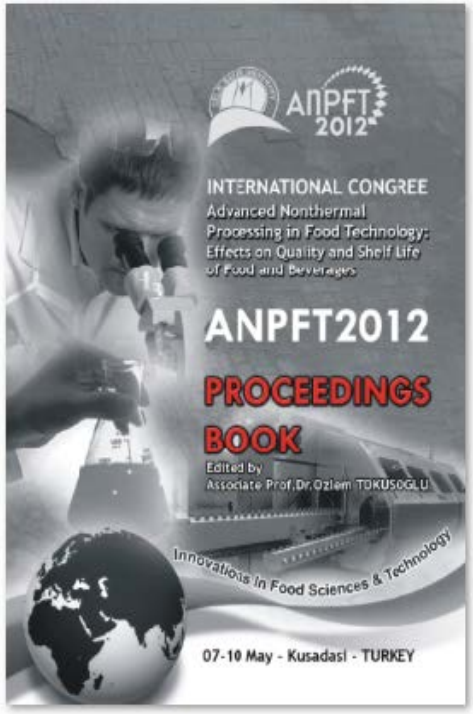
- Potential inactivation of pathogens and unwanted enzymes
- Enhanced yield or extraction rate, maintaning and enhancing bioactive levels
- Enhancement of extraction processes where solvents cannot be used (juice concentrate processing).
- Enhance extraction of heat sensitive constituents
- Potential opportunity for aqueous extraction or use of alternative (GRAS) solvents
- Commercially viable and scaleable.

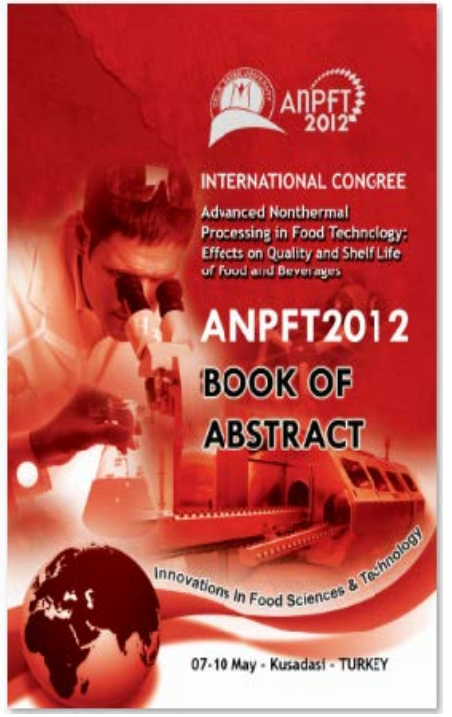


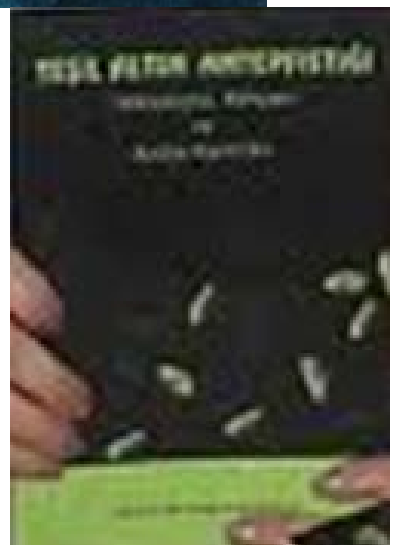


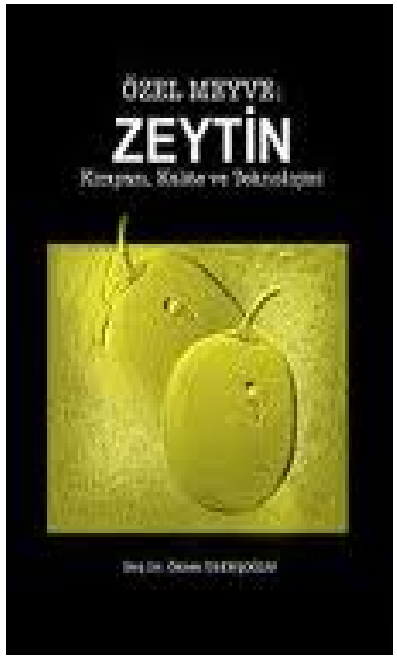








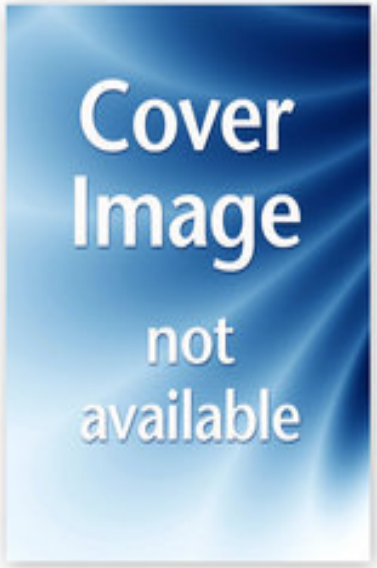






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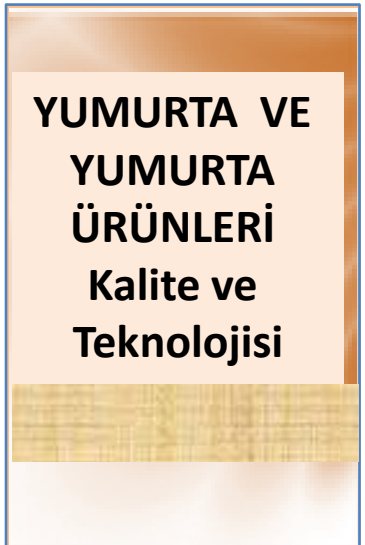
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