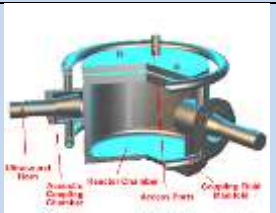
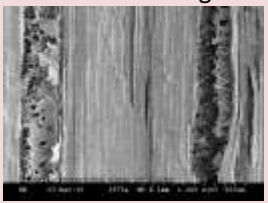
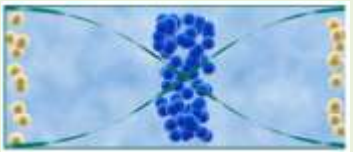
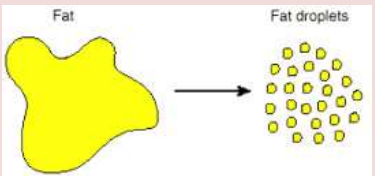
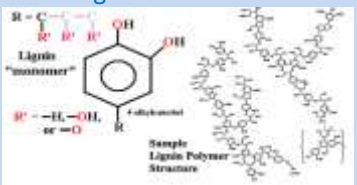
Industrial demonstration of megasonic technology to maximise EVOO recovery and quality

Pablo Juliano

3RD INTERNATIONAL VALE SYMPOSIUM ON
OLIVE OIL & HEALTH
III SIMPOSIUM INTERNACIONAL DE VALE SOBRE ACEITE DE OLIVA Y SALUD
IV CONGRESO INTERNACIONAL SOBRE ACEITE DE OLIVA, OLIVAR Y SALUD
9-12 Diciembre 2021

CSIRO

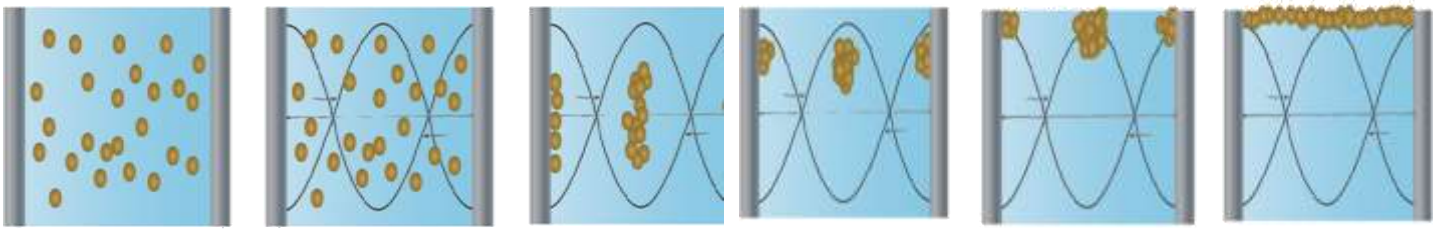
Ultrasound in Processing

Low Frequency (20-100 kHz)	Medium Frequency (100-400 kHz)	High Frequency (Megasonics) (400 - 3000 KHz)
		
Surface Damage 	Chemical Reactions $C_{10}H_{22} \rightarrow 2R^{\cdot}$ $R^{\cdot} \rightarrow R^{\cdot} + C_2H_4$ $R^{\cdot} \rightarrow RCH{-}CH_2$ $R^{\cdot} + C_{10}H_{22} \rightarrow RH + R{-}CH^{\cdot}{-}R$ $H^{\cdot} + C_{10}H_{22} \rightarrow H_2 + R{-}CH^{\cdot}{-}R$ $R{-}CH^{\cdot}{-}R \rightarrow RCH{-}CH_2 + R^{\cdot}$	Standing Wave Separation 
Emuslification 	Lignin Breakdown 	Oil Separation (De-emulsification) 

Megasonic separation technology

Treatment of oil bearing materials with high frequency ultrasound waves provides

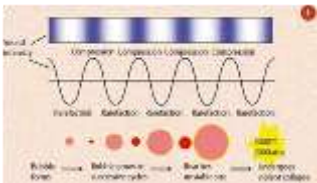
- Increased oil recovery in oil extraction processes
- Faster oil separation



Megasonic waves for oil separation

-acoustic trapping of particles in standing waves

-demulsification through droplet-droplet collisions or microjets from bubbles or microstreaming



Megasonic de-emulsification of milk fat

Proof of concept in recombined milk

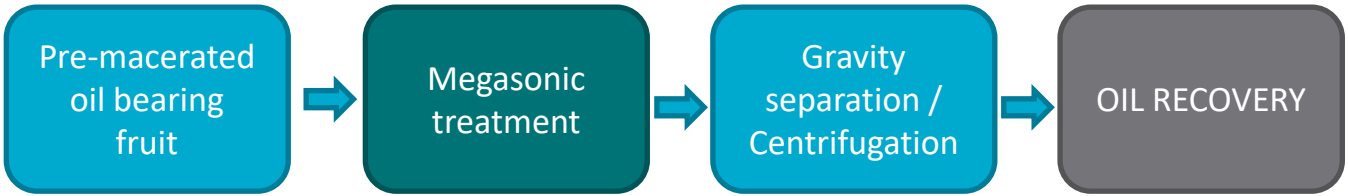
US on

US off

- Reconstituted solution
  - 4% milk fat coarse emulsion (added with oil-red-O dye 0.05%), particle size 6-7 microns
  - 3.5% MSNF reconstituted skim milk
- US treatment: 400 kHz, 90% amplitude

1 + 2 MHz dual frequency, 150 W/L,
15 minutes treatment

Megasonic process – principle for aqueous extraction



Technology Readiness Level

Technology Readiness Levels (TRL)

TRL9 **Operations**

TRL8 **Active Commissioning**

TRL7 **Inactive Commissioning**

TRL6 **Large Scale**

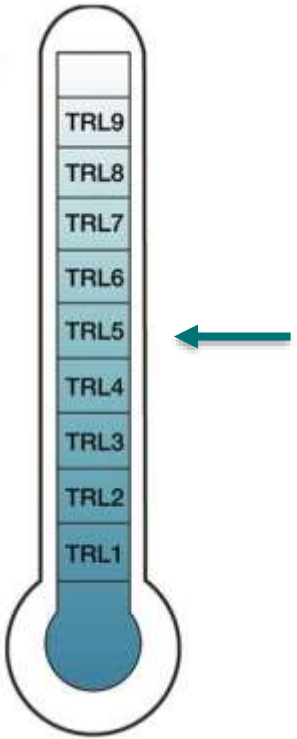
TRL5 **Pilot Scale**

TRL4 **Bench Scale Research**

TRL3 **Proof of Concept**

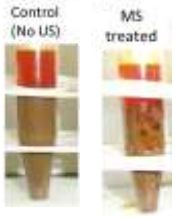
TRL2 **Invention and Research**

TRL1 **Basic principles**



Megasonics for assisted oil extraction

- High frequency standing waves improve oil recovery



Laboratory scale

Palm, coconut, olive, canola, and avocado oils

Batch (100 L) scale

Palm, olive oils

Continuous 3-5 T/h scale

Palm, olive oils

Industrial 45 T/h scale

Palm oil

Control Ultrasound

2015

Start R&D lab scale megasonics olive oil separation

2016

350 kg batches

Salute Oliva

Boundary Bend

Australia

2017

350 kg/h

Andria, Italy

Technology Evaluation Agreement Univ Foggia

2018

SIEF GRANT

Demo 3 t/h

Australia

2021

Publications and opportunities for further prototyping and scaling up

Processors and equipment manufacturers interviews

Eureka Award nomination

The olive oil megasonic development team

Pablo Juliano, Peter Mansour, Piotr Swiergon, Kai Knoerzer, Phil Muller, Rod Smith, Mary Ann Augustin, Fabian Baincyck, Ian Supriyatna, Xinqing Xu, Fouad Gaber

Leandro Ravetti, Pablo Canamasas, Claudia Guillaume, many others

Sponsor

Alessandro Leone, Roberto Romaniello, Antonia Tamborrino, others

Maurizio Servilli
Stefania Urbani

Antonia Grompone, Miguel Amarillo, Adriana Gambaro, Nicolas Perez, Florencia Blasina, Ana Claudia Ellis, Bruno Irigaray Jimena Lazaro

Supporters
Salute Oliva
RVS Industries
Tarle Brothers
University of Mannheim
University of Wageningen

https://sief.org.au/csiro-gift/what-has-been-funded/what-has-been-funded-experimental-development-program/megasonics/megasonics-for-olive-oil-recovery/

Small plant demo for olive oil extraction

-Olive oil separation – pilot reactor (2016) – Salute Oliva

300 kg olive fruits

Crushing
7-11 min

Malaxation
T = 35ºC
t= 70 minutes

+30% water

+/-
MS-treatment

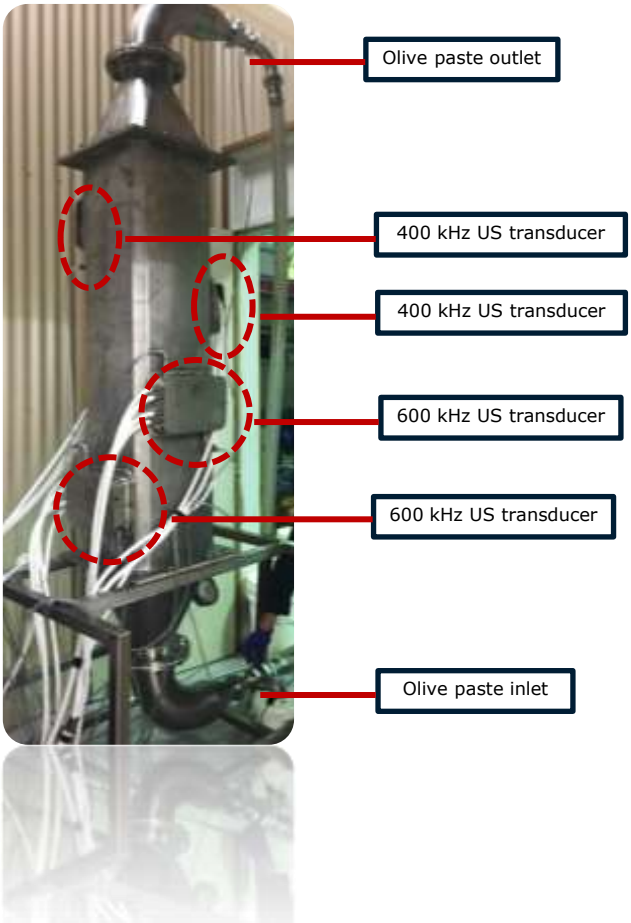
Centrifugation

Vegetable water

Olive pomace

Olive oil

Additional 1.2% oil recovery



Italy trials (2016)

Additional 2.1% oil recovery
18 kJ/kg

350 kg/h

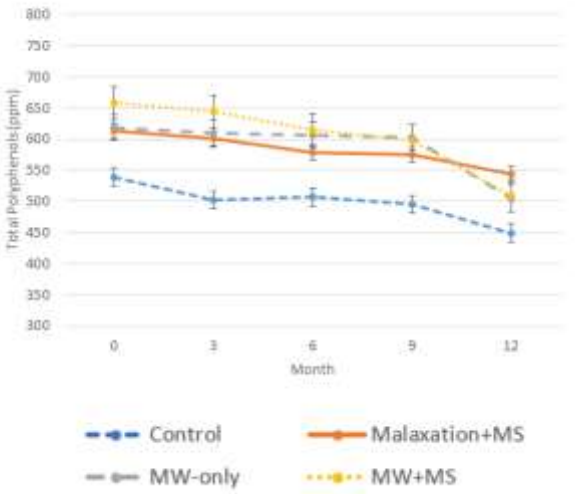
Olive maturity index 1.5

Mori-Tem mill

Leone et al. 2018, Innovative Food Science & Emerging Technologies

Small plant demo for olive oil extraction
Quality, sensory and shelf trials
(Shelf life study and sensory - Uruguay, 2017-2019)

Treatment	Extractability (g oil/100 g olive paste)
Control	84.7 c
Malaxation+MS	86.7 a,b
MW-only	85.2 b,c
MW+MS	86.9 a
p-value	0.0348



- No sensory defects found by trained panel in 12 months
- Enhanced phenolics and preserved tocopherols
- Decreased waxes

Leone et al. 2018, Lipid Science and Technology; Amarillo et al., LWT 2021

Industrial (350 kg/h) demonstration olive oil extraction Oil quality (phenolics composition) (Italy, 2016)

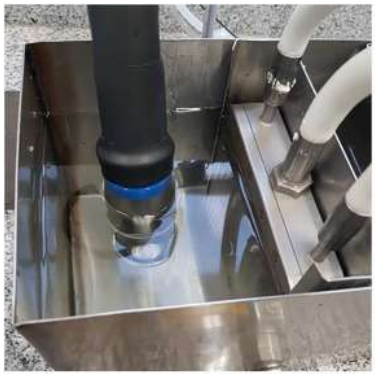
Parameter	Control (No MS treatment)	With MS treatment
3,4-DHPEA	3.8 ± 0.9^{a}	2.5±0.3^{b}
p-HPEA	5.7 ± 0.8^{a}	4.6±0.4^{b}
Vanillic acid	0.8 ± 0.1^{a}	0.7±0.1^{ab}
3,4-DHPEA-EDA	702.2 ± 103.5^{a}	823.5 ± 71.7^{a}
p-HPEA-EDA	134.6 ± 17.9^{b}	166.9 ± 7.0^{a}
(+)-1-acetoxypinoresinol	47.0 ± 4.9^{ao}	47.1±0.8^{a}
(+)-pinoresinol	21.4 ± 1.1^{c}	24.8±0.8^{bc}
3,4-DHPEA-EA	281.2 ± 22.2^{b}	356.6 ± 33.3^{a}
Ligstroside aglycone	25.5 ± 7.3^{a}	27.8±6.1^{a}
Total phenolics	**1222.2 ± 110.0^{b}**	**1454.5 ± 86.3^{ab}**

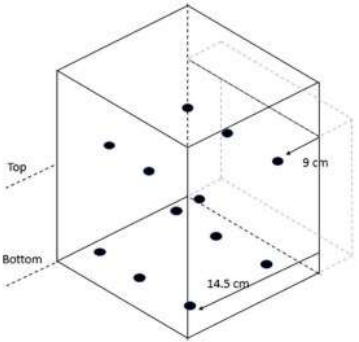
(n=4), $p<0.05$ (Tukey's test)

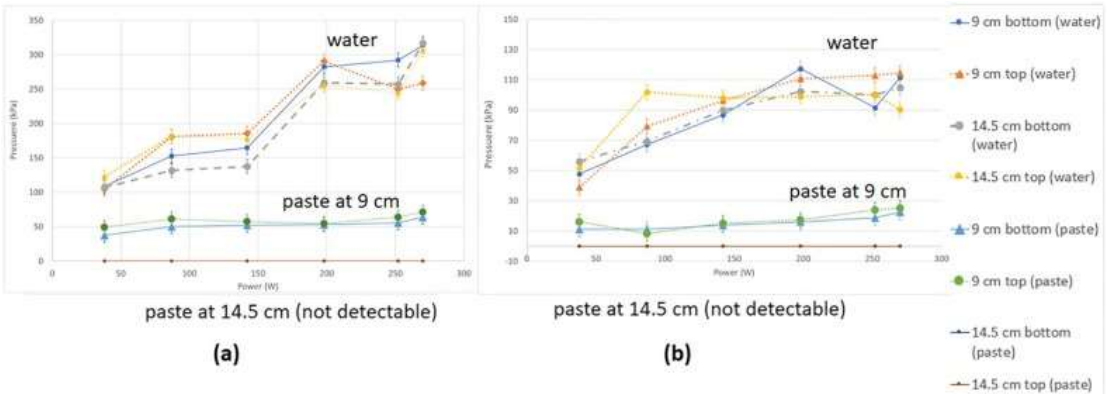
Quality unchanged with an increased total phenolics
Other parameters, free acidity, PV, induction time, DAG and volatiles were also unchanged.

Leone et al. 2018, Lipid Science and Technology

Sound attenuation trials in 1 L megasonic reactor





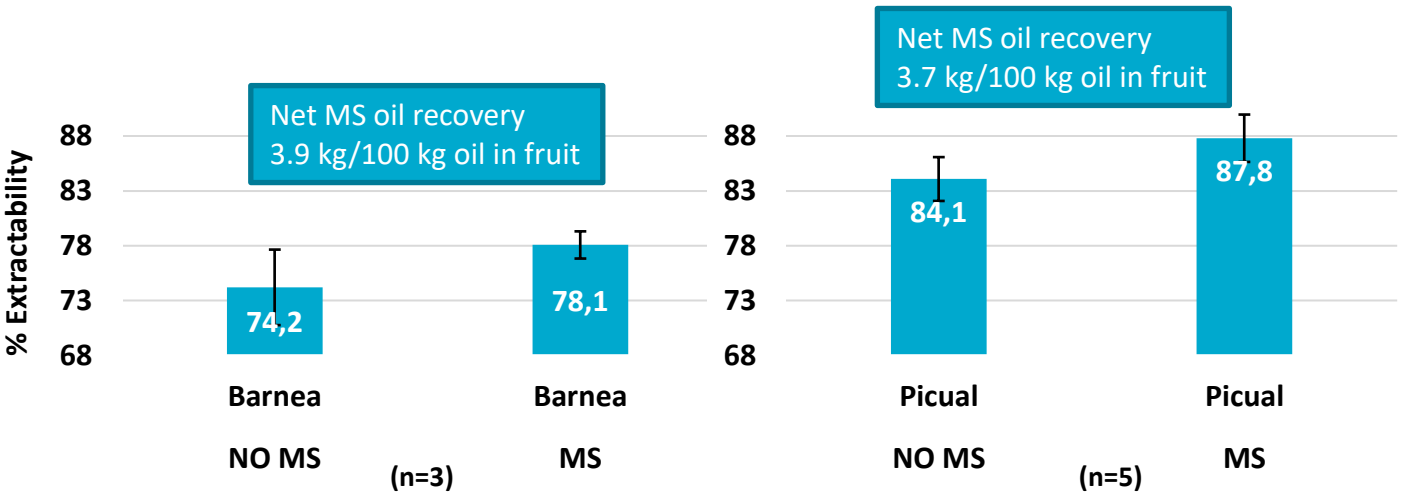


Amarillo et al. 2019, Ultrasonics Sonochemistry

Industrial (2.8 tonne/h) demonstration olive oil extraction Australia (2018)

4 x 375 L reactors (parallel / series configuration)

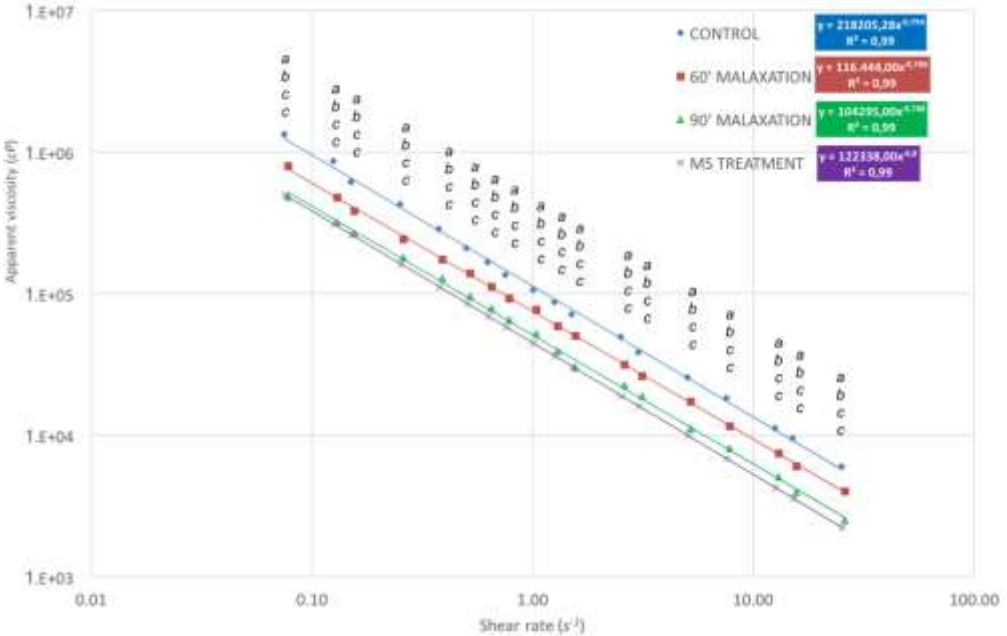
Industrial demonstration olive oil extraction (Australia, 2018)



- 60 min malaxation time
- 2.8 tonnes/h
- Maturity index 2.0-2.6
- Ultrasound energy 10 kJ/kg

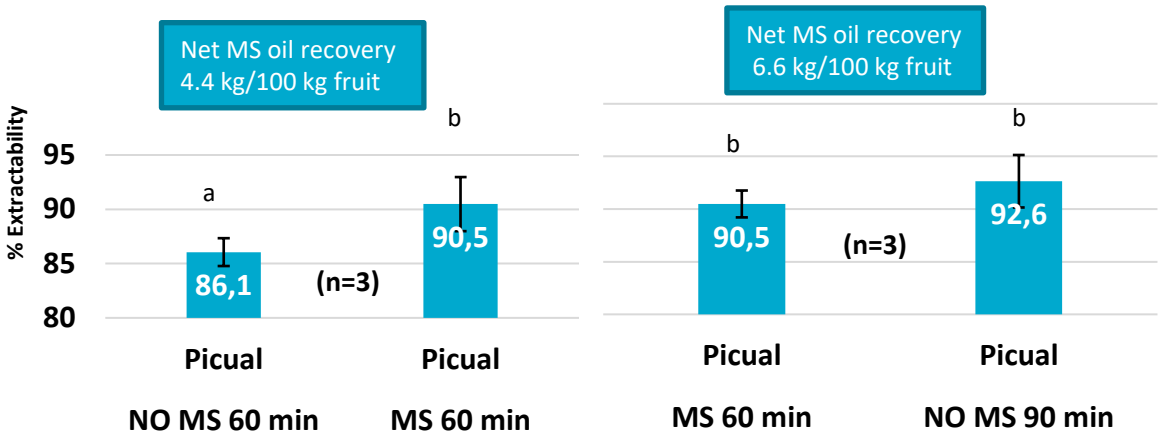
Opportunity:
Additional oil recovery of $270-300k per year
Plant 1000 L oil/year

Effect of MS on paste viscosity reduction



Increase in malaxation time reduces apparent viscosity of the paste
A megasonic treatment further reduces viscosity

Industrial demonstration olive oil extraction
Malaxation time reduction
(Australia, 2018)



- Additional oil recovery demonstration
- 60 min (MS ON/OFF) & 90 min malaxation time (MS OFF)
- 2.8 tonnes/h
- Maturity index 4.1-5.0

Megasonics application in EVOO recovery

- Enhanced oil recovery
  - Reduced paste viscosity
- Malaxation time reduction
- Increased phenolics (specific to trial)
- Preserved tocopherols
- Decreased waxes (specific to trial)

- Microwave combination opportunity to by-pass batch malaxation process

Juliano et al. 2017, Ultrasonics Sonochemistry

Leone et al. 2018, Innovative Food Science & Emerging Technologies

Thank you

Agriculture and Food
Pablo Juliano
Group Leader, Food Processing and Supply Chains

+61 3 9731 3276
Pablo.juliano@csiro.au

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