



UCD Institute of Food & Health

## **Green Cooking – The potential for moderate electric field (MEF) processing for milder heat processing of meats**

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# Structure of presentation

1. Mention a new project in this area (MEFPROC)
2. General introduction to MEF heating
3. Prior knowledge of MEF heating of meat wprt impact of
  - Product/Environmental parameters on heating
  - MEF heating on meat product quality
4. MEFPROC
  - a. How could MEF be applied in meat processing?
  - b. How will MEFPROC contribute to this?



# 1. A new project in the area (MEFPROC)

**Title: *Improving Sustainability in Food Processing using Moderate Electric Fields (MEF) for Process Intensification and Smart Processing (MEFPROC)***

## What is the technical focus?

- **Technologies:** Moderate Electric Fields (MEF)(± assisted/combined by/with Ultrasound)
- **Applications:** Food applications (Heat & Mass Transfer – Preservation & Mass Transfer)
- **Foods:** A wide range (not just meat!)

## What is the ultimate aim?

- Facilitate **technology transfer/innovation** in the food industry & improve process control

## Why these technologies?

Improve process intensification, sustainability, product quality and/or extraction/impregnation

## Who is involved?

Research Performing Organisations + Equipment Manufactures + Food Manufacturers  
 (Strong Track Records) (Capability) (Technology Interest)



Sheffield  
Hallam  
University



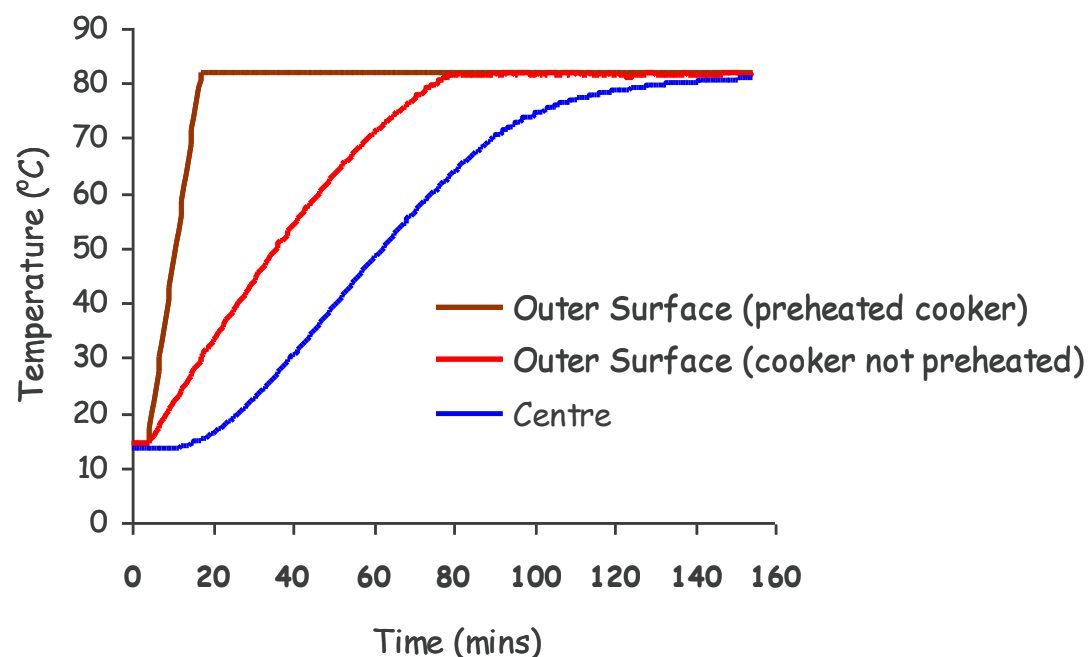
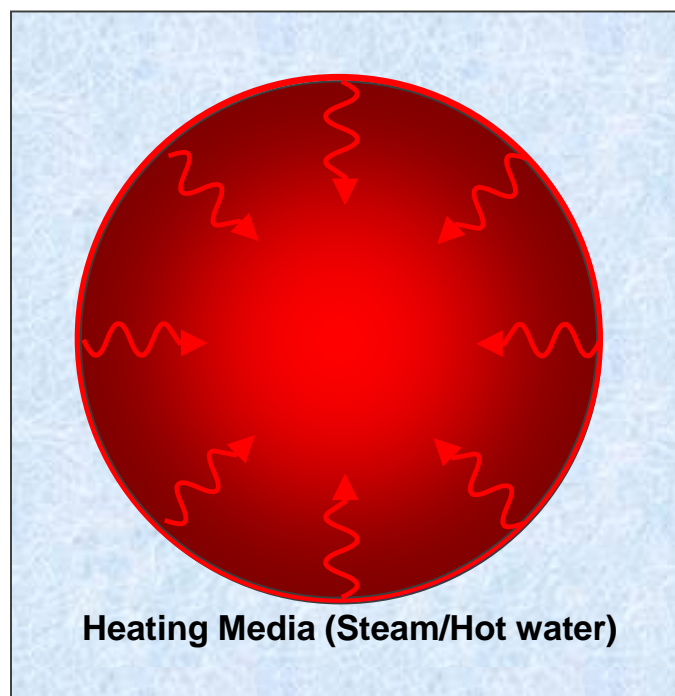
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## 2. General introduction to MEF heating

### Conventional heating of meat

Heat transfer  $\approx$  conduction (slow)

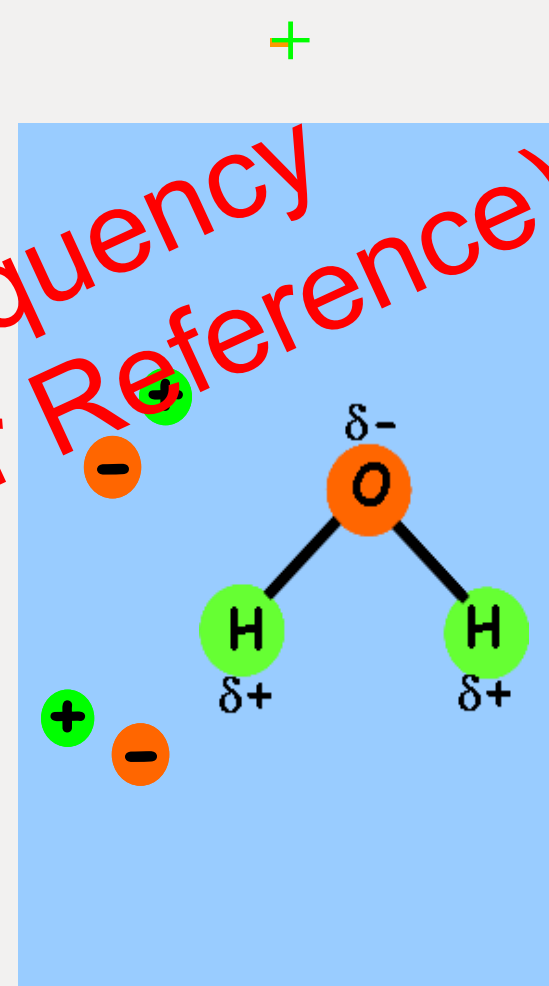
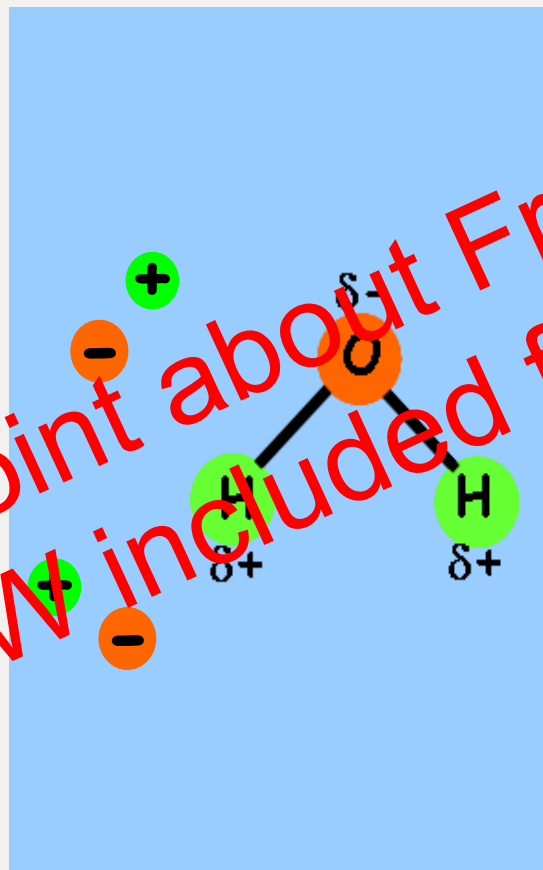
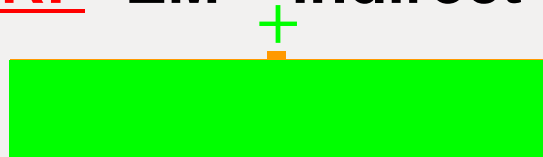
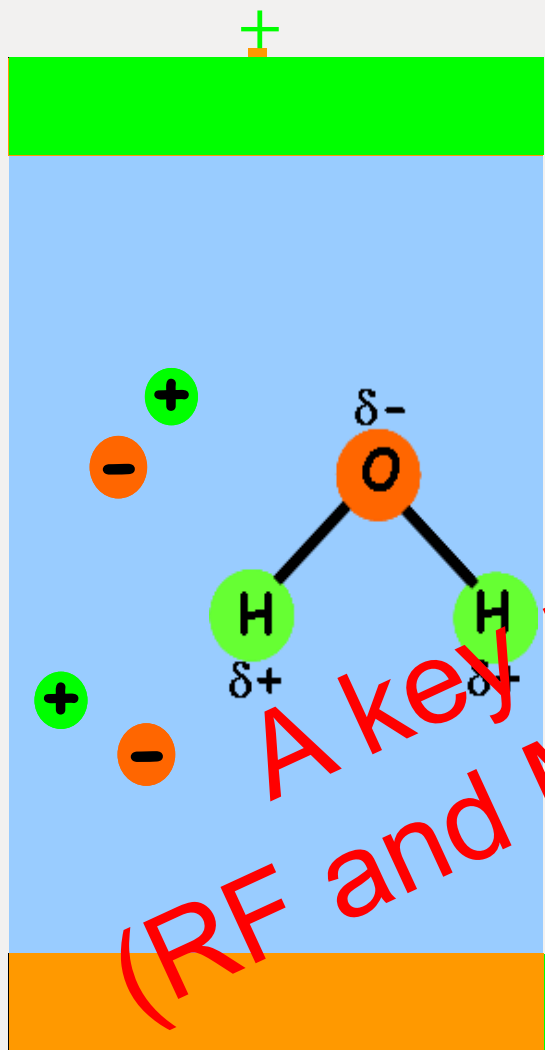
#### Conventional temperature profile



MEF/OH -AC – direct

RF -EM –indirect

MW -EM – indirect



Freq ( $f$ ): 50-25,000 Hz  
(Lowest)

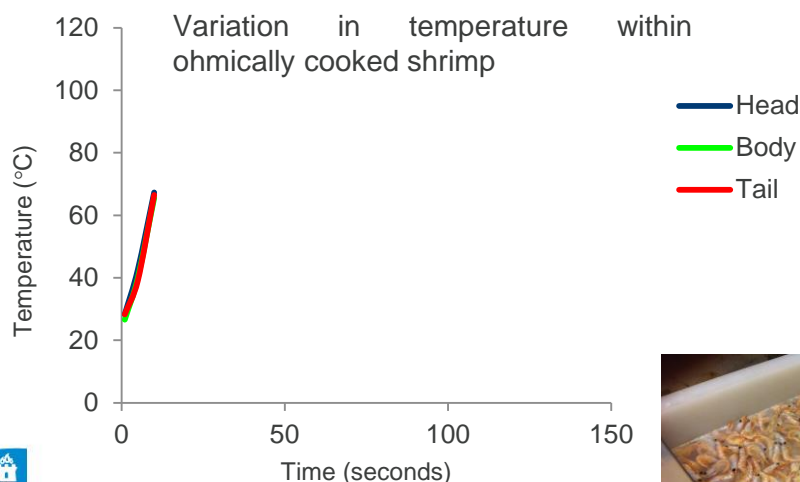
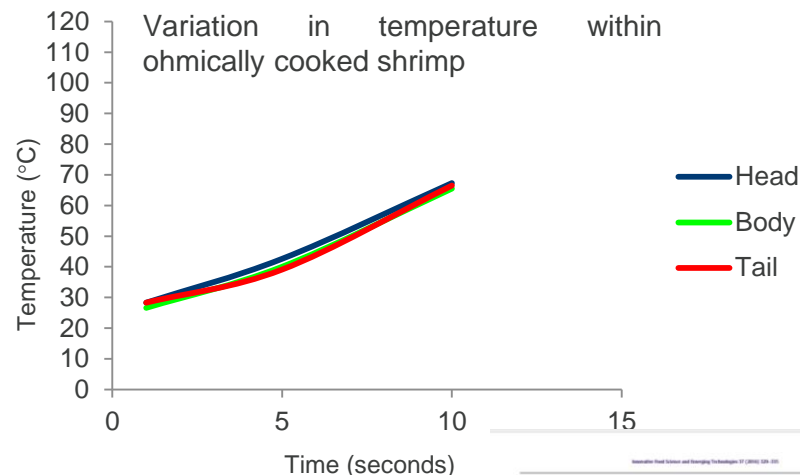
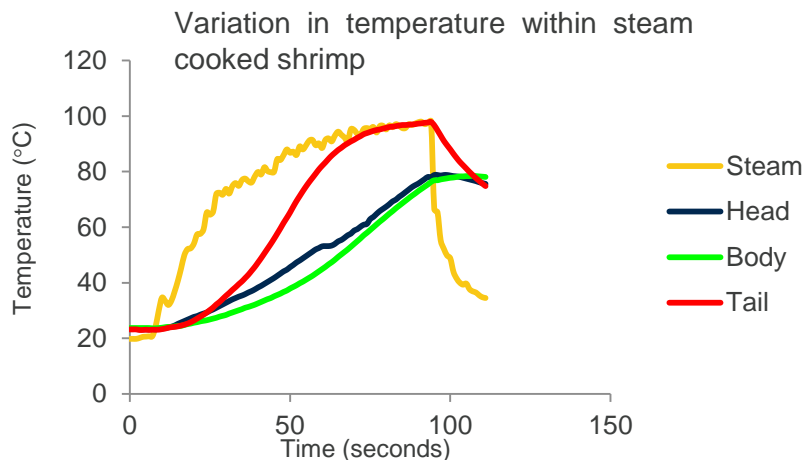
$f$ : 13.6-40.7 MHz  
(Intermediate)

$f$ : 896-2450 MHz  
(Highest)

A key point about Frequency  
(RF and MW included for Reference)

# 2. MEF (volumetric) benefits (shrimp) - Example

## Large Shrimps (steam vs MEF)



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The potential of ohmic heating as an alternative to steam for heat processing shrimps

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<sup>b</sup> Department of Food Science, University of Idaho, Pullman, WA, USA

ARTICLE INFO

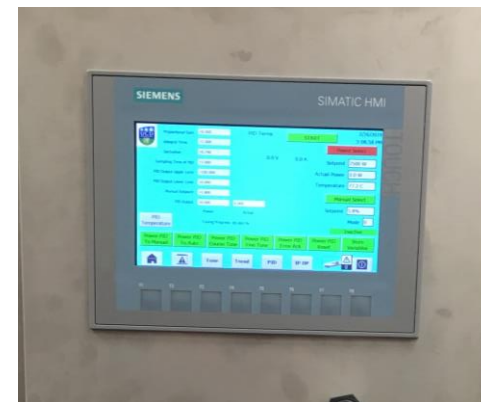
ABSTRACT

The potential application of ohmic heating as an alternative to the conventional steam cooking for shrimps is evaluated in this study. Defrosted segmented shrimps (Drosopoda borealis) were cooked either in a steamer or ohmic bath up to 120 °C cooking temperature. The head, body and tail of steam heated shrimps exhibited an internal temperature distribution that was more uniform and stable. The ohmic heating process resulted in an internal temperature distribution with an overall cooking time of 10 s and 10 s for the steam-cooked head and large shrimps, respectively, with only 80 °C water content for 100 s regardless of shrimp size and measured anatomical location. The differences were found for cook time and texture (MEF and texture methods) between cooking methods. Ohmic heating was superior to steam for the effect of 10 s on other differences (L<sup>2</sup>), with greater differences observed in large vs. small shrimps, although overall ohmically cooked shrimps showed less colour differences compared to steam cooked counterparts. Finally, a cooking or steaming process is considered suitable for shrimps. However, the low cost of heat penetration in the thermal center of shrimps leads to heterogeneous heat transfer resulting in overcooking which may reduce MEF. Ohmic heating technology offers a potential alternative over conventional heat treatments as heat is generated substantially inside the food. This form of heat generation results in more uniform temperature distribution which leads to shorter processing times and potentially higher quality while still maintaining the colour and nutritional value of food. This paper therefore explores the potential of ohmic heating technology as an alternative to conventional steam processing for the cooking of shrimps.

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## 2. MEF systems at UCD?



6 x systems, largest 18 kW (18,000W) – Theoretically it can heat  
 1 × 200 g white pudding 5-73°C ( $\Delta T$  68 °C) in 3 seconds or  
 10 × 200 g white pudding 5-73°C ( $\Delta T$  68°C) in 30 seconds or  
 25 × 200 g white pudding 5-73°C ( $\Delta T$  68°C) in 75 seconds  
MEF preheating (!!!) followed by conventional holding



e-Cooker®



## 2. Where does “Green heating” and “process intensification” come in?

Basic energy balance

Energy Required: Fixed by quantity (m), c &  $\Delta T$

$$P\psi = \frac{mc(\Delta T)}{t}$$

**Conversion Efficiency: Much higher in MEF vs. Conventional**  
(e.g. MEF  $\leq 95\%$  vs. conventional 50%)

**Power input vs. time**  
(shorter t > P)

**with volumetric nature of heating + Correct System design**  
**→ Continuous cooking of meat is possible**



# 3. Prior knowledge

## Critical parameters - Product - Electrical conductivity $\sigma$ ( $S m^{-1}$ )

Distribution is critical: Emulsions easier than injected/tumbled

Ionic Ingredients (e.g. Salt):  $\uparrow$   
 Salt  $\rightarrow \uparrow \sigma \uparrow$  heat rate

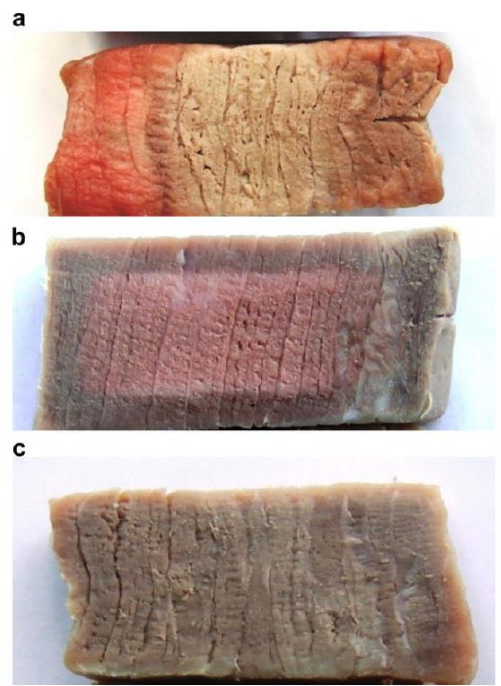
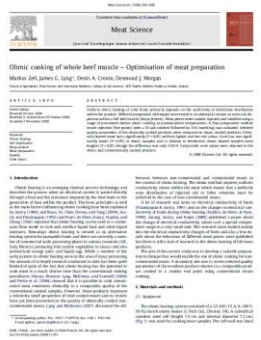
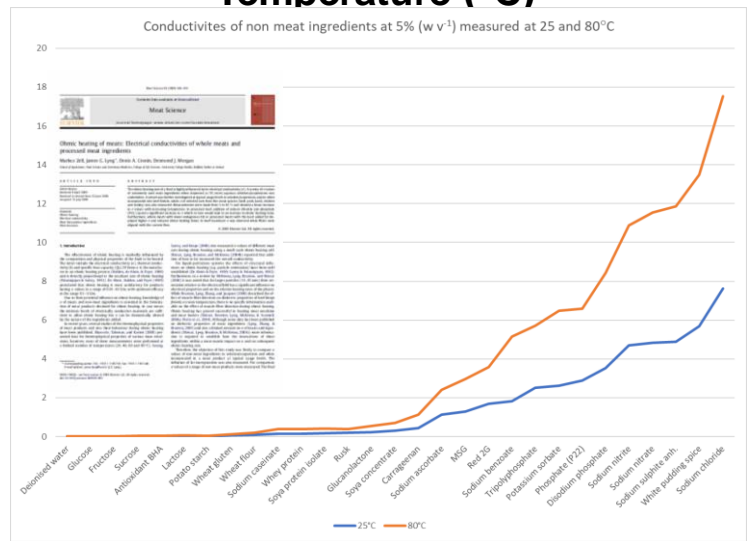
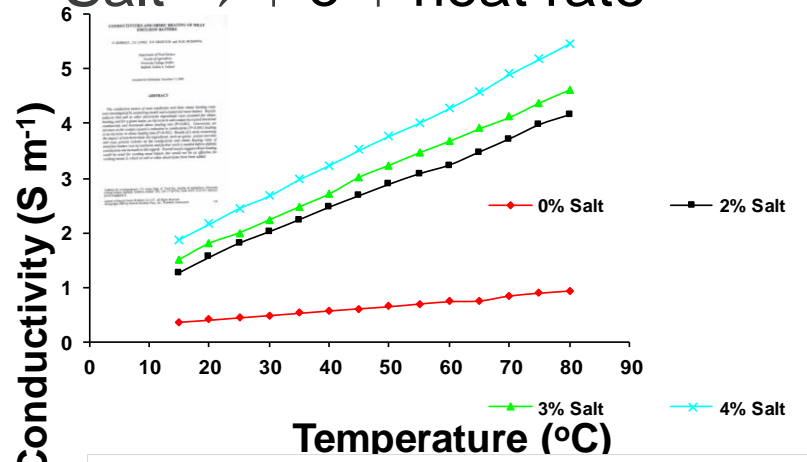
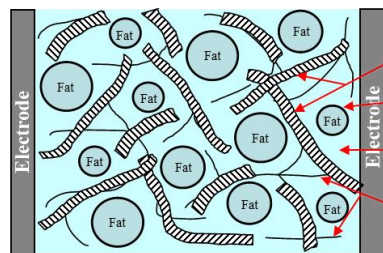
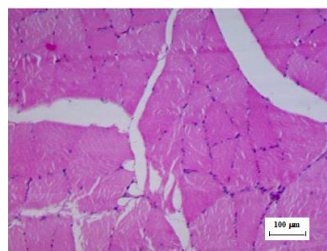
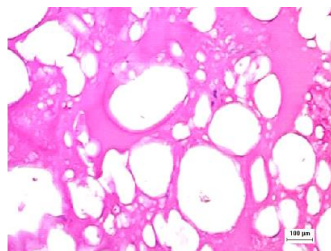


Fig. 3. A selection of beef meat cross-sections prepared by (a) centre injection (3% saline) (b) soaking (5% saline for 48 h) and (c) multi-injection (3% saline, 16 h in bag tumbling) followed by ohmic cooking.

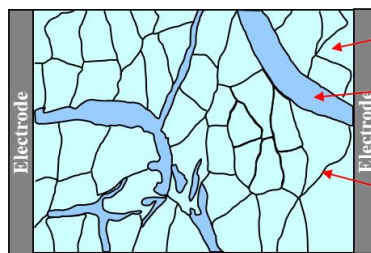


# 3. Prior knowledge

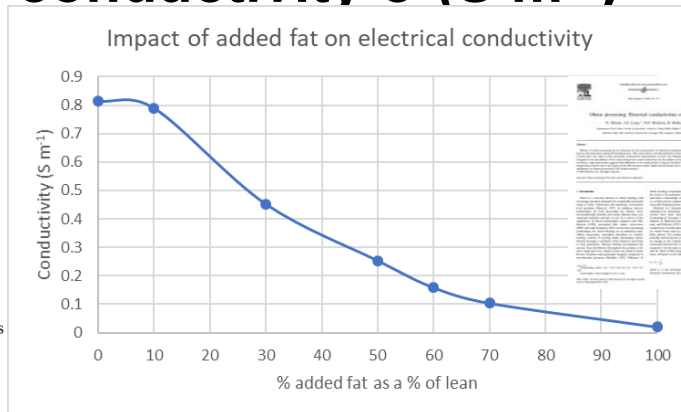
## Critical parameters - Product - Electrical conductivity $\sigma$ ( $S m^{-1}$ )



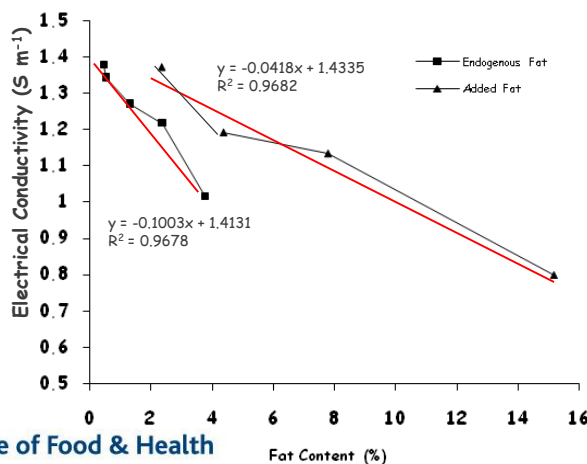
Muscle Fibre Segments  
Soluble protein coating on fat droplet  
Aqueous medium  
Connective tissue fibres



Intact muscle Fibres  
Intramuscular fat  
Intact connective tissue network



**Fat Content:**  $\uparrow$  Fat (partic - Salt)  $\rightarrow \downarrow \sigma \downarrow$  heat rate



**Endogenous vs. added fat**

$\uparrow$  added fat % less impact on  $\sigma$  vs.  $\uparrow$  endogenous fat%

**Easier for current to negotiate emulsified fat?**

18 Ohmic Pasteurization of Meat and Meat Products  
J. G. Lyng and S. M. Wellstone  
School of Agriculture, Food Science and Veterinary Medicine, Dublin Institute of Technology

18.1 Introduction

Ohmic heating is a term used to describe direct electrical resistance heating of food products. It is a technology which was awarded the U.S. Institute of Food Technologists industrial achievement award for 1996 and is a type on which water content and particle size (Strommen, 1998; Sjöberg, 1992; Taylor, 1994; Eick, 1995; Larkin and Schmidt, 1996; Bostick, 1996; Zolner and Swearingen, 1996; Bostick et al., 2003; Sauer, 2003) have been various applications, which have been proposed for ohmic heating include:

- modification of single and multistep processes (Dierck, 2002; Zhou, Yuan et al., 2003; Elmi-Gadban et al., 2003; Barlow et al., 2004; Chen Shi et al., 1999; Zolner, 1997; Sauer, 1993; Paros, 1990; Sauer and Palumbo, 1992; Ludwig, 1991);
- pasteurization (Lindstrom and Shewen, 2005a,b; Taylor et al., 2002);
- protein recovery from certain wash water (Bostick et al., 1997; Huang et al., 1994);
- enhancing extraction yield (Oroszka and Ejlert, 2002; Popowicz et al., 2002; Han Lakshmi et al., 2004; Wu, Chi and Sauer, 2002);
- blanching (Ullar et al., 2006; Sauer and Sauer, 2004; Minski, 1996);
- pre-treatment for enhanced drying rates (Schlegel and Sauer, 2005; Tawana and Linn, 2001; Linn and Sauer, 1999);
- process intensification (Carter et al., 2004);
- blanching (Bakhti et al., 1998, 2002; Ched-Guo et al., 1998);
- cooking (Ullar et al., 1990); and
- starch gelatinization (Wu, Chi et al., 1997).

Identification of suitable average products in the area on which much work has been done and relevant papers focus on the influence of electrical conductivity (Haldor et al., 1990; de Abreu and Frey, 1992) and particle shape (de Abreu et al., 1998) on heating rates.

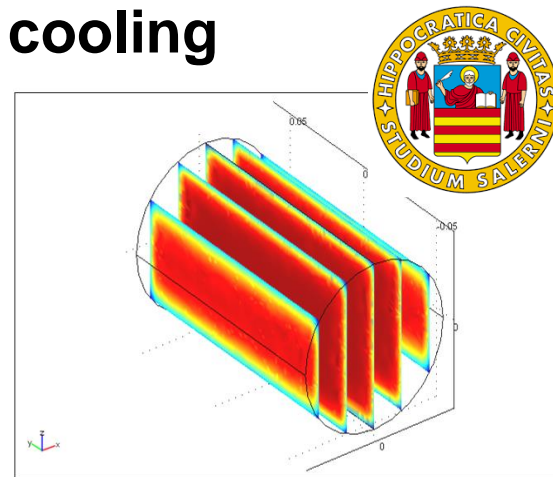
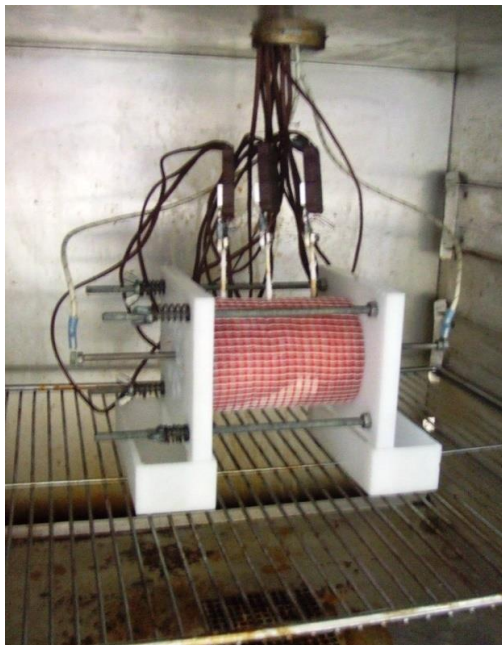
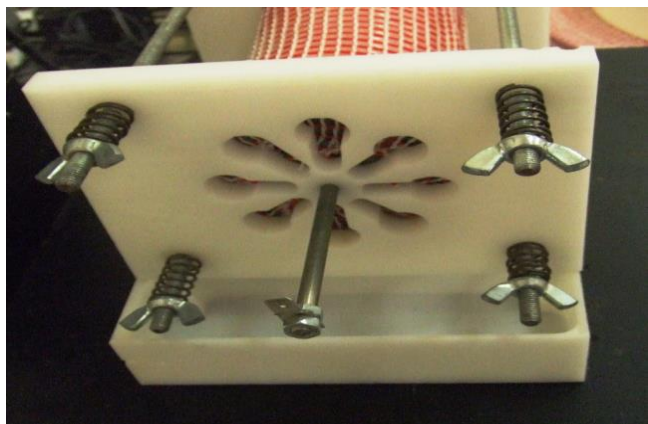


### 3. Prior knowledge

## Critical parameters – Environmental impact on heating uniformity

Electrode: Thinner & ext. heated

Cell: External heating vs. surface cooling



Journal of Food Engineering

Analysis of heat transfer during ohmic processing of a solid food  
 M. Del Valle, G. Lopez, D.J. Morgan, D.A. Cooke

Journal of Food Engineering

Minimizing heat losses during batch ohmic heating of solid food  
 M. Del Valle, G. Lopez, D.J. Morgan, D.A. Cooke

Journal of Food Engineering

Development of rapid response thermocouple probes for use in a batch ohmic heating system  
 M. Del Valle, G. Lopez, D.J. Morgan, D.A. Cooke

Journal of Food Engineering

Development of a rapid response thermocouple probe for use in a batch ohmic heating system  
 M. Del Valle, G. Lopez, D.J. Morgan, D.A. Cooke

### 3. Prior knowledge

## Critical parameters – Product Packaging

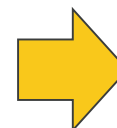


**Direct electrode contact  
(seal product after)**

**Shuttle mission  
(packaging with  
conductive regions) –  
Astronaut OH dinners**



**Sealed Casing  
+  
Plastic Clips**



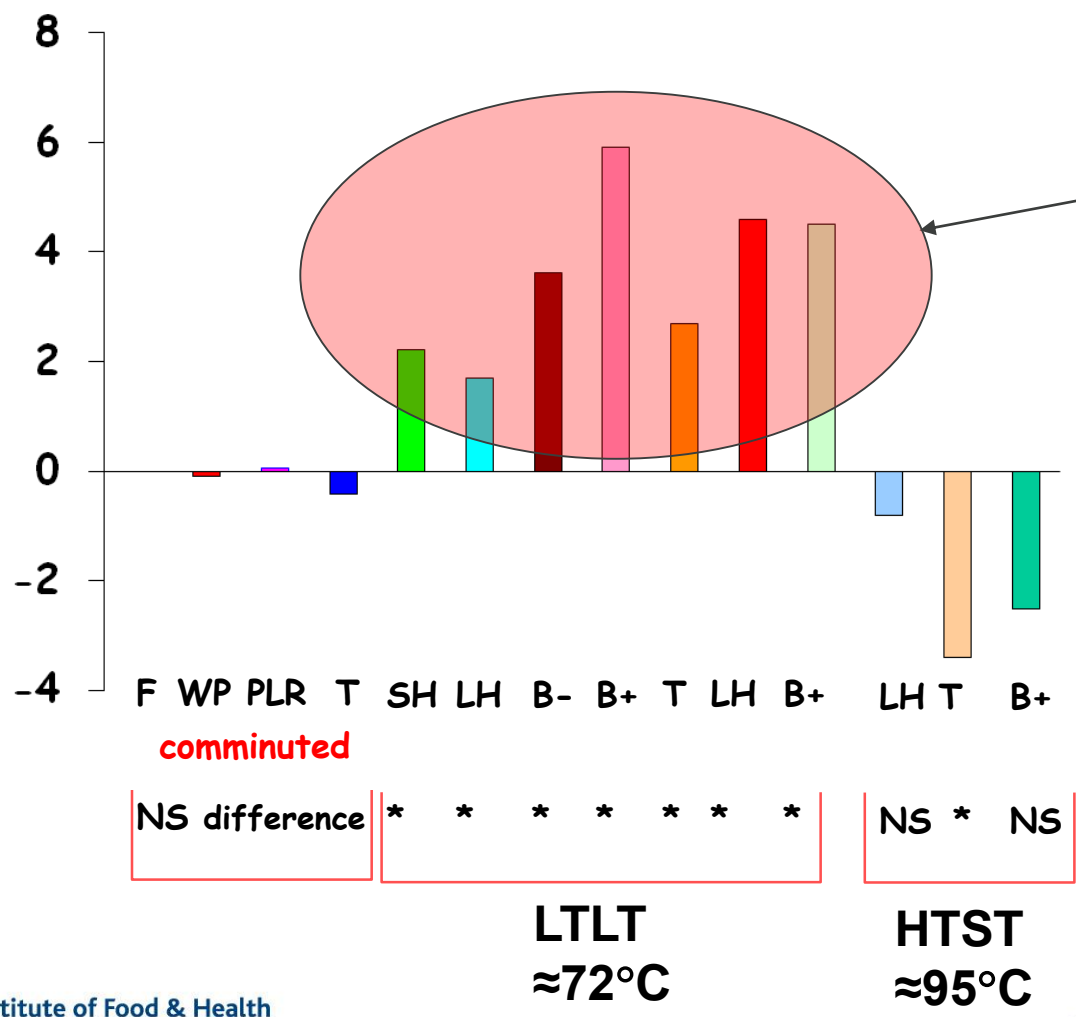
**Sealed Casing  
+  
Metal Clips**

# 3. Prior knowledge

## Impact on product: Post Cooking Yield

Positive Balance ↑

Volumetric % - Steam %



Vol > MC  
< PR + F  
(dilution)

Suggest less heat induced protein (myosin/collagen) denat.



# 3. Prior knowledge

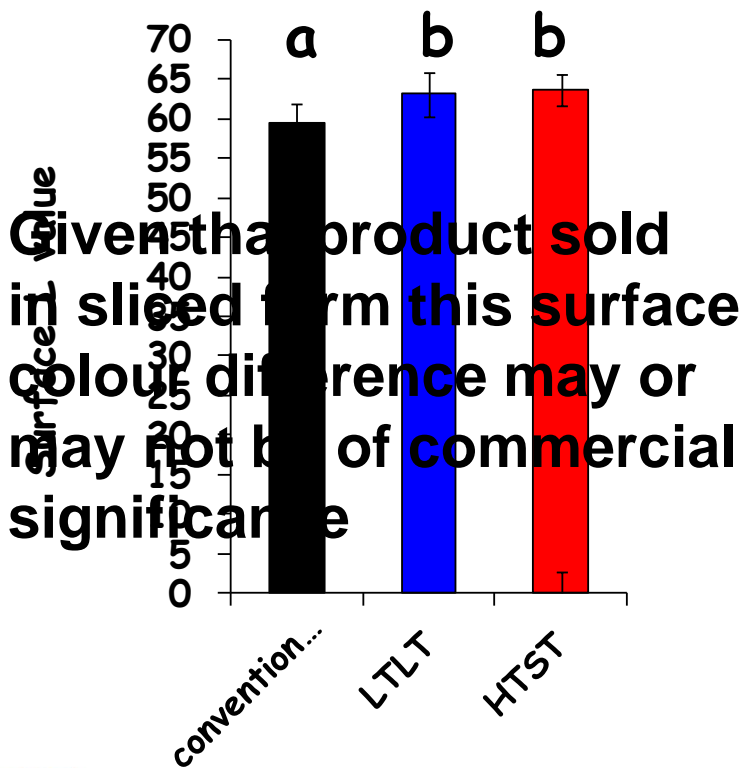
## Impact on product: Surface Colour

Instrumental colour (L, a, b, hue angle and chroma)

Centre ≈ no differences or very small

Surface a, b, hue angle and chroma ≈ as above

But: L (Lightness) → **Lighter surface in MEF processed non- comminuted**



Given that product sold in sliced form this surface colour difference may or may not be of commercial significance



Conventionally cooked beef *Semitendinosus* (105 min)



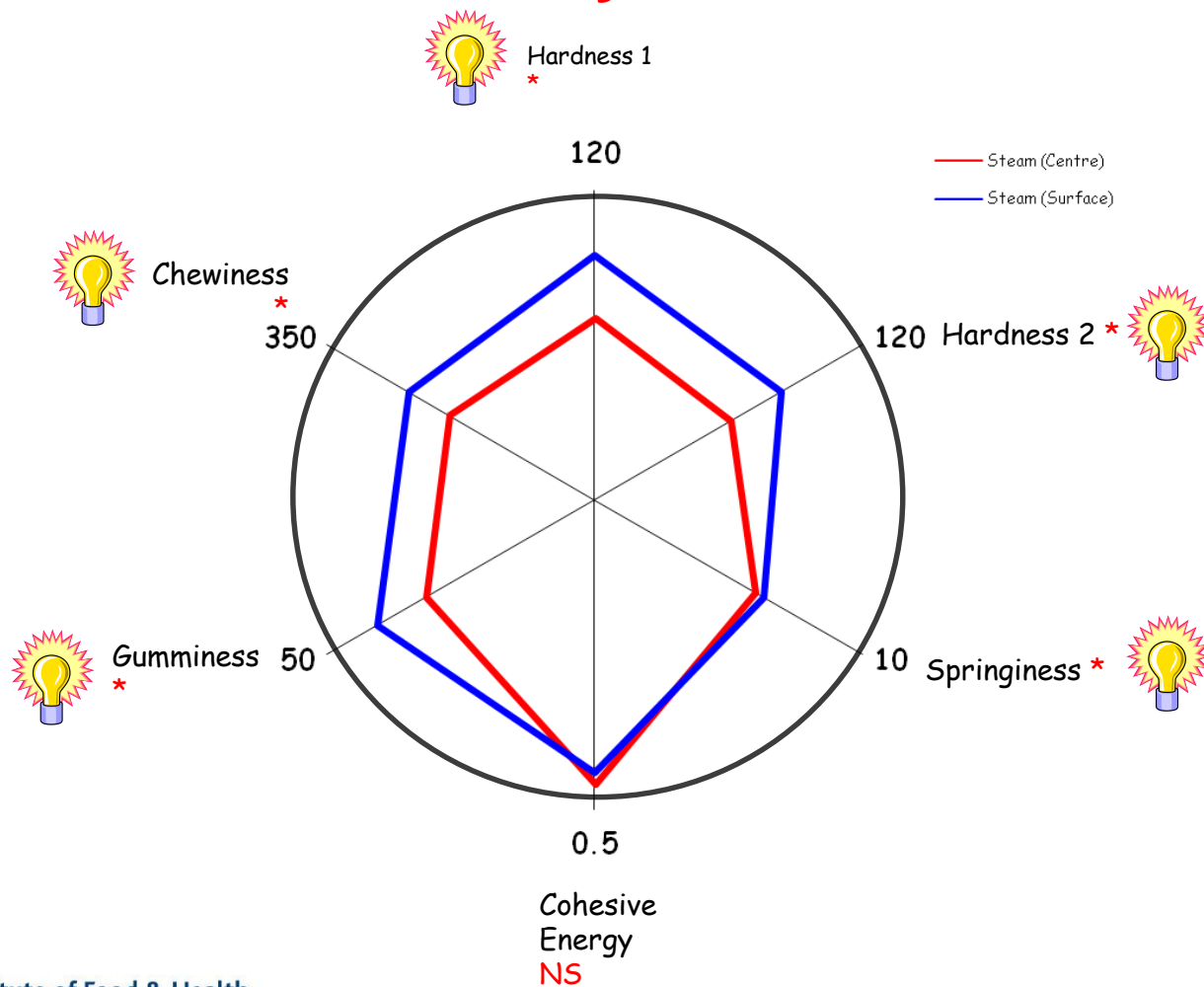
MEF HTST cooked beef *Semitendinosus* (7 min)



# 3. Prior knowledge

## Impact on product: Texture (surface vs centre)

### TPA - (Conventional Turkey – Variation across diameter)



Food Chemistry

Chronic cooking of whole turkey meat – Effect of rapid ohmic heating on selected product parameters

Markus Zill, James C. Eging\*, Denis A. Craigm, Desmond J. Morgan

ARTICLE INFO

1. Introduction

2. Materials and methods

2.1. Meat handling

2.2. Ohmic heating

2.3. Cooking

2.4. Sensory evaluation

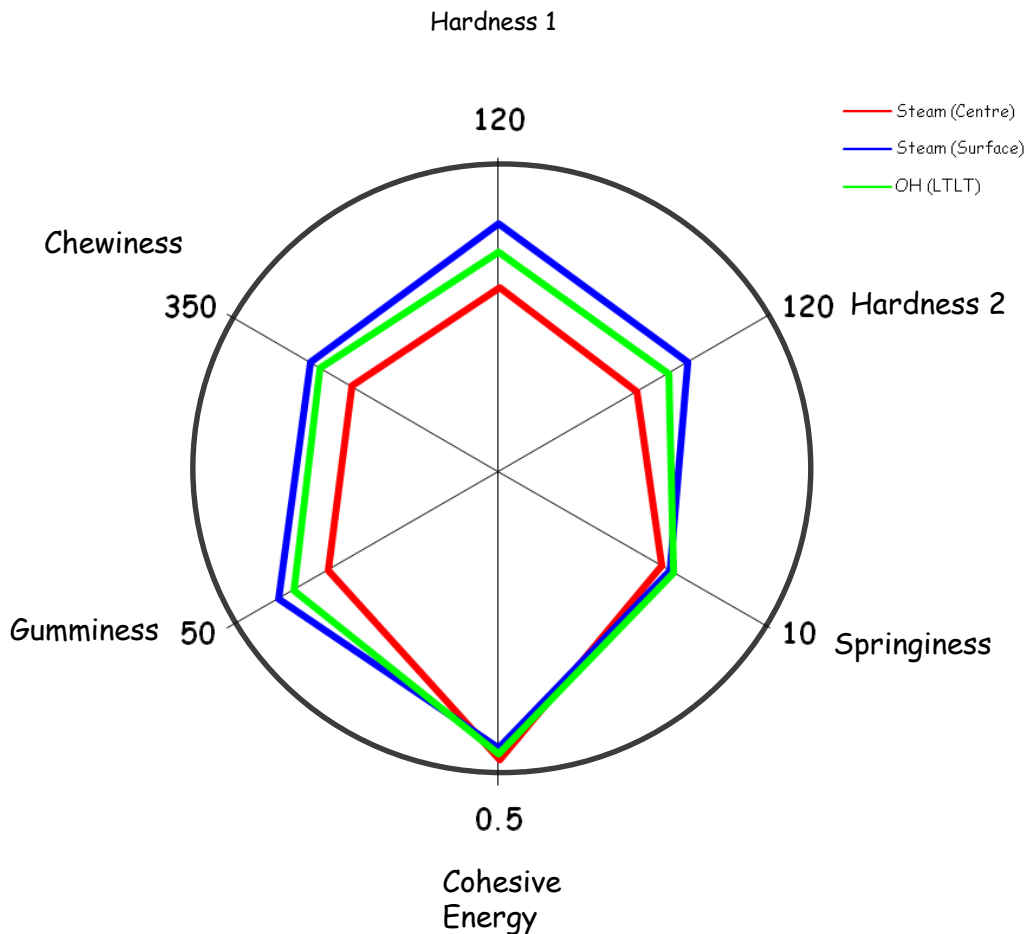
2.5. Statistical analysis



# 3. Prior knowledge

## Impact on product: Texture (surface vs centre)

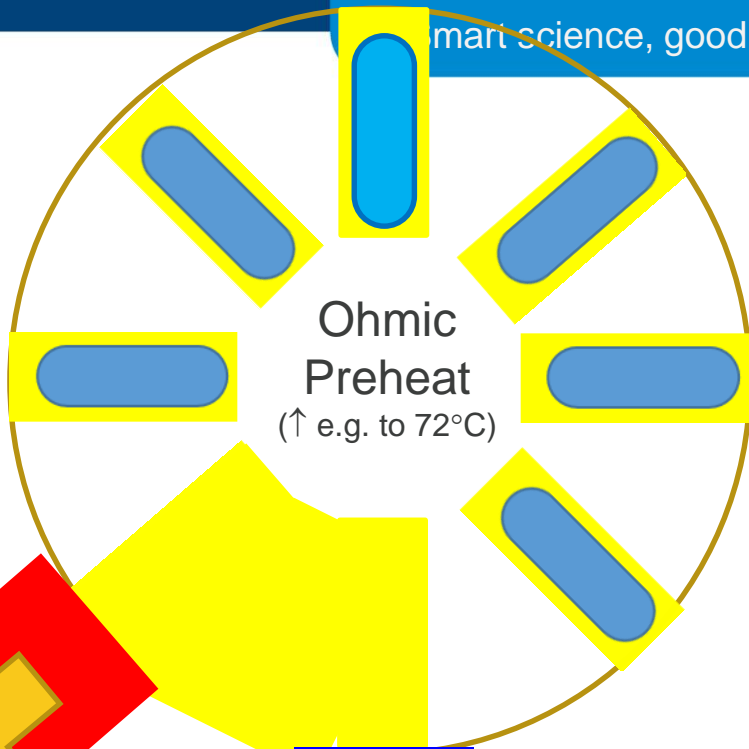
### TPA - (MEF Turkey – Variation across diameter)





# 4. How could MEF be applied?

Holding Time – Sufficient → Pasteurisation and Cooking



Loading



Decision on process conditions



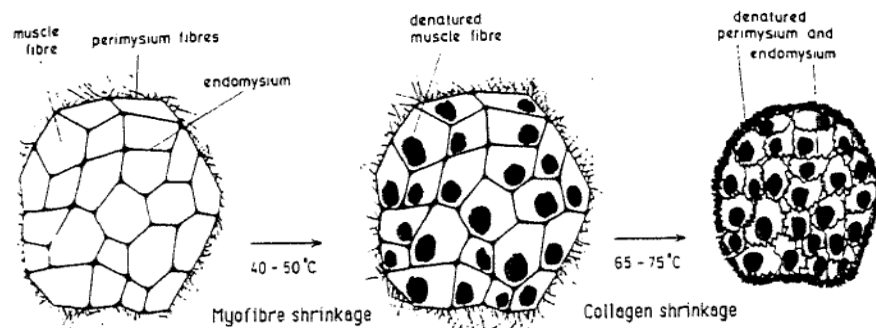
# 4. What will MEFPROC do that's new?

## Smart Cooking of meat

a. Tailoring cooking – Predicting requirements for variable cuts – decision?



b. Optimising Power delivery during MEF Preheating - feedback loop to optimise delivery to optimise structure and maximise yield?



Sims and Bailey (1991)

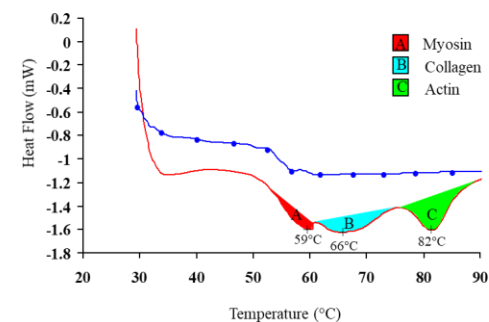


Fig. 3. Differential scanning calorimetry thermogram of uncooked — and cooked — beef muscle

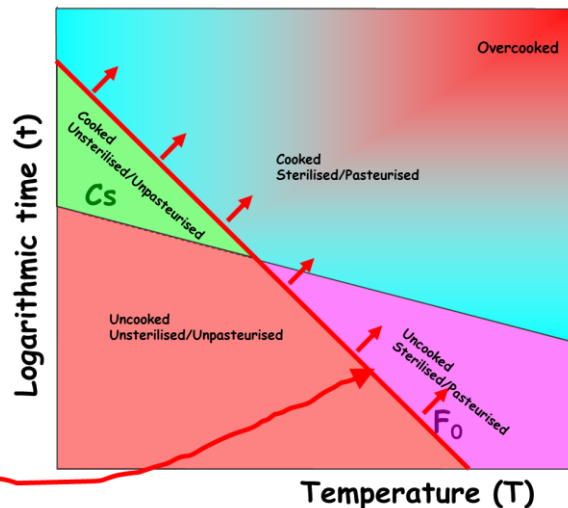
# 4. What will MEFPROC do that's new?

## c. Optimising conventional holding time to optimise structure/yield

Pasteurisation (micro) is rapidly achieved but when is optimal structure (chemical) achieved? (i.e. how long/short should your holding time be)

Source: Adapted from Holdsworth (1984)

[Note: With most beverages aim is generally to end up uncooked (i.e. "fresh like") not overcooked]



Whatever the heat process, it must be sufficient to render the product microbiologically safe

### Minimum $C_s$ ( $C_{s-min}$ )?

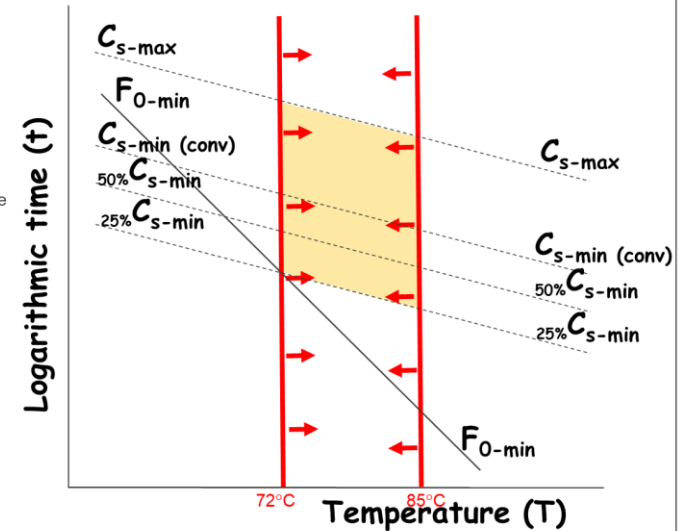
Can we go lower than  $C_{s-min}$  (conv)?

Finding the "edge of this envelope" and particularly the minimum  $C_s$  ( $C_{s-min}$ ) will form the basis of Kims MSc!

Lower the  $C_s$  the shorter the cooking time, higher the throughput, lower the energy cost (Yield could be better)!

Will always be microbiologically fine as will be above target  $F_0$

However, don't want chemically undercooked





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# Thank you for your attention!

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Bia agus Mara**





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Smart science, good food

# Comments?

