MRI
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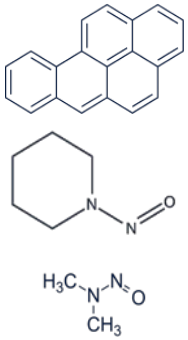

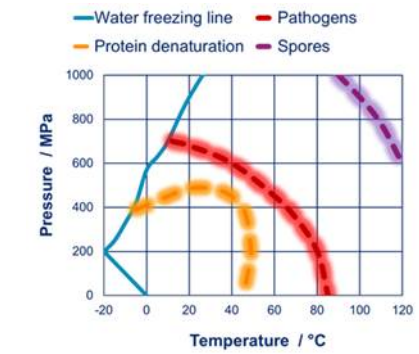

Process-induced undesirable compounds: chances of non-thermal approaches

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Safety and Quality of Meat, Kulmbach

Max Rubner-Institut
Federal Research Institute of Nutrition and Food
Germany

Process-induced undesirable compounds
Chances of non-thermal approaches

Outline

1 Process-induced undesirable compounds

2 Traditional thermal processes

- Compounds with health concerns
- Current regulatory limits
- Strategies for inhibition or reduction of their formation

3 Non-thermal processes

- Emerging technologies
  - High pressure processing

Food Processing

Desirable effects

- Safety issues
  - Food-borne pathogens inactivation
  - Toxins inactivation
  - Spoilage microorganisms and enzymes inactivation
- Nutritional issues
  - Digestibility enhancement (e.g. proteins)
  - Bioavailability enhancement (e.g. carotenoids)
  - Anti-nutrients inactivation
- Sensory issues
  - Palatability, flavour, texture, colour enhancement
- Convenience issues
  - Ready-to-eat, semi-finished products availability
  - Independence from the seasonal availability

Undesirable effects

- Nutritional issues
  - Nutrient losses (e.g. vitamin C)
  - **Generation of compounds with health concerns** *(contaminants, toxicants)*
- Sensory issues
  - **Generation of compounds presenting a negative effect on flavour, colour or texture perception**

Contaminants in meat and meat products

Origin	Substance
Environmental pollutants	arsenic, lead, cadmium
	dioxin, dioxin-like polychlorinated biphenyls
	organochlorine pesticides
	polycyclic aromatic hydrocarbons
Microorganism, plant and animal toxins	aflatoxins, ochratoxins; ptaquiloside; phytanic acid
Veterinary drugs	growth promoting substances, antibiotics
Processing and storage	polycyclic aromatic hydrocarbons
	heterocyclic aromatic amines
	biogenic amines
	N-nitrosamines
	chloropropanols and chloroesthers
	peroxidation products of polyunsaturated fatty acids
Food contact material	bisphenols, phtalates, perfluorinated compounds

Andrée et al. (2010) Meat Sci. 86; Püssa (2013) Meat Sci., 95

Processing and preparation methods		Toxicants
Thermal		
Conventional	boiling, steaming	furan
	smoking	PAH, N-N, 3-MCPD
	roast, grill, fry	PAH, HAA, N-N, 3-MCPD
	char-grill / barbeque	PAH, HAA, N-N, 3-MCPD
Emerging technologies	microwave	3-MCPD ?, (furan)
	ohmic heating	PAH, HAA, metal contamination
Non thermal		
Conventional	curing / salting	N-N
	fermentation	biogenic amines
Emerging technologies	pulsed electric fields	peroxides
	high pressure	bioactive peptides
	irradiation	furan

PAH: Polycyclic Aromatic Hydrocarbons **HAA**: Heterocyclic Aromatic Amines

3-MCPD: 3-Monochlorpropane-1,2-diol (chloropropanols/esthers) **N-N**: N-Nitrosamines

Process-induced undesirable compounds
Chances of non-thermal approaches

Origin	Substance
Environmental pollutants	arsenic, lead, cadmium dioxin, dioxin-like polychlorinated biphenyls organochlorine pesticides polycyclic aromatic hydrocarbons (PAH)
Microorganism toxins	aflatoxins, ochratoxins
Plant toxins	ptaquiloside
Animal toxins	phytanic acid
Veterinary drugs	growth promoting substances, antibiotics
Processing and storage	PAH HAA biogenic amines N-nitrosamines (N-N) 3-MCPD
Food contact material	bisphenols, phtalates, perfluorinated compounds

1 Process-induced undesirable compounds

- Health concerns: contaminants or toxicants
- Negative effect on flavour, colour or texture perception

2 **Traditional thermal processes**

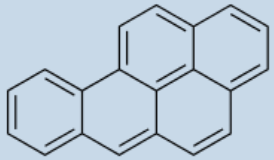
Polycyclic Aromatic Hydrocarbons (PAH)

Current regulatory limits

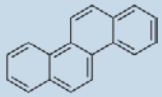
Strategies for inhibition or reduction of their formation

Polycyclic aromatic hydrocarbons

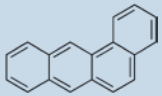
- Incomplete combustion or pyrolysis of organic matter
  - natural sources: forest fire, volcanic eruption
  - man-made: industrial processes, burning tobacco, wood, commercial and home food preparation, e.g. smoking, drying, roasting, char-grilling, frying….
- Persistent Toxic Substances
  - highly toxic organic or carbon-based compounds
  - persistent in the environment
  - increasingly accumulate as they move up the food chain



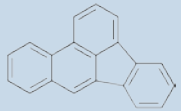
Benzo[a]pyrene
BaP
carcinogenic



Chrysene



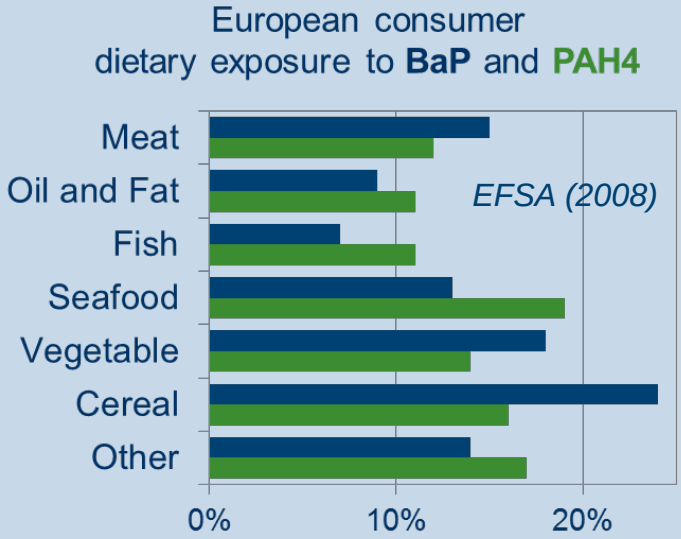
Benz[a]anthracene



Benzo[b]fluoranthen

➔ PAH in food: environmental (air, water, soil) and/or process-induced contaminants
meat: smoked, barbecued, grilled, roasted

Polycyclic aromatic hydrocarbons



	N	BaP [µg kg^{-1}]	PAH4 [µg kg^{-1}]
Meat	777	0.3	1.4
Barbequed	39	**1.9**	**5.3**
Grilled	53	0.6	2.3
Smoked	562	0.2	1.3
Other	123	0.05	0.4

EU regulatory limits for smoked meat & meat products — 2.0 µg kg^{-1} [5.0] — 12.0 µg kg^{-1} [30.0]

*Commission Regulation (EU) No 1881/2006 and 835/2011**

Formation conditions and reduction strategies

- **Incomplete combustion of wood or coal**
  Smoking, char-grilling, barbecue
  Processing parameters
  - temperature
  - oxygen concentration
  - type of wood
  - smoker type

➔ optimise smoking process
liquid smoke flavouring

- **Pyrolisis of dripped fat**
  Roasting and grilling
  Processing parameters
  - temperature
  - fat content /distribution in the meat product matrix

  ➔ formulation

Process-induced undesirable compounds
Chances of non-thermal approaches

1 Process-induced undesirable compounds
- Health concerns: contaminants or toxicants
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2 Traditional thermal processing and preparation processes
- High temperature, e.g. pan frying or grilling over an open flame, and smoking induce the formation of toxicants
- Formation ↓ ⟷ ↓ T, t
  Grilling, frying: marinades with antioxidants
  Smoking: optimise process, liquid smoke

3 **Non-thermal processes**

Emerging technologies

High pressure processing

Pressure-temperature-induced matrix modifications

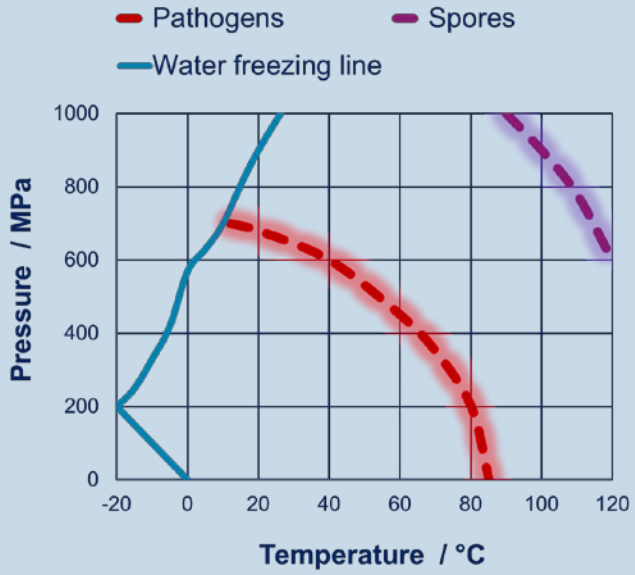
Process-induced undesirable compounds

Non-Thermal Emerging Technologies

▪ Ultrasonication	- enhance mass transport brining, curing	*Cárcel et al. (2007)* *McDonnel et al. (2014)* *Siró et al. (2009)*
	- improve water holding capacity	*Stadnik et al. (2008)*
▪ Pulsed electric fields	- enhance mass transport drying, marinating, brining, curing	*Puértolas et al. (2012)* *Töpfel & Heinz (2008)*
	- reduction microbial load of blood	*Kiessling & Töpfe (2012)*
▪ Cold plasma	- decontamination of surfaces sliced ready-to-eat meat product	*Rød et al. (2012)*
▪ High pressure		
dynamic (shock wave)	- tenderisation	*Bolumar et al (2013)*
static	- pasteurisation, sterilisation	

High hydrostatic pressure processing (HHP)

Pressure	100 - 800 MPa
Temperature	< 0 °C - >100 °C
Time	milliseconds - 20 minutes
Operation	batch, semi-continuous application of pulses



Applications

- Pasteurisation
- Controlled denaturation of proteins, gelation, phase change of lipids
  ➔ innovative product design

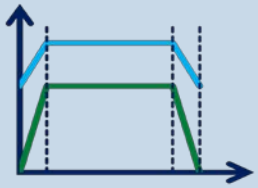
Advantages

- low T inactivation
- very short t
- processing in final packaging possible

Pasteurisation	
Pathogenic target microorganisms	
E. coli, Salmonella, Listeria	
Process parameters	
Pressure, MPa	**400 - 600**
T_0 Material, °C	< 0 - 40
Temperature, °C	< 50

Pressurisation effect: Quasi-adiabatic heating

Temperature increase



	ΔT / ΔP °C/100 MPa
Water	3
Meat	3
Oil	7 - 9
Beef fat	6

Temperature profile

- Pressure container
  - geometry, material, insulation
  - rate of pressure build-up
  - rate of heat transfer
- Material
  - composition
  - initial temperature

350 L, Uhde High Pressure Technologies GmbH, Thyssen Krupp, Germany

Patazca et al. (2007) J.Fd. Eng.; Knoezer et al. (2010) J. Fd. Eng.

Reactions with negative reaction volumes or activation volumes

- **Hydrophobic interactions**
- **Ionic interactions**

} protein structure, denaturation

- **Ionisation of water, acids phenols, amines**

} pH shift

- **Hydrogen bonds formation**

} protein structure

- Covalent bonds formation
  2+4 (Diels-Alder) and polar 2+2 cycloadditions
- Menschutkin reactions
  quaternisation of nitrogen, formation of sulphonium- or phosphonium salts
- Solvolysis of ethers, esters, acetals and ketals

Pressure-temperature-induced modifications

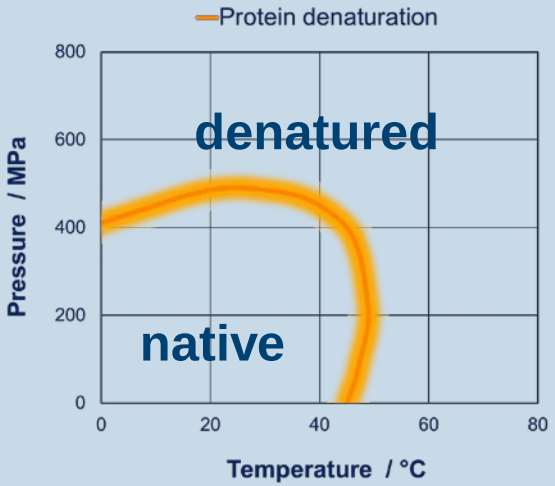
Proteins and Enzymes

Native proteins stabilisation:

- covalent bonds
- hydrogen bridges
- **electrostatic interactions**
- **hydrophobic interactions**

⟷ No effect on primary structure

⟷ Pressure affects mainly tertiary and quaternary structure



➡ Functional properties: water holding capacity, gelation

Sensory properties: appearance, colour, texture

P / MPa	
< 150	dissociation of oligomeric proteins
150 - 300	>>> actin and myosin are destabilised
≥ 200	>>> beginning denaturation of globular portion of myoglobin
≥ 300	increased denaturation, aggregation, gelation
≥ 400	>>> globular portion of myoglobin denatured, iron released, met-myoglobin responsible for greyish-brown
> 700	secondary structure affected; irreversible denaturation

Pressure-temperature-induced modifications

Lipids

Membrane phospholipids phase transition liquid-crystalline to gel

P > 300 MPa ↑ Lipid oxidation ↑ pressure
↑ storage time

➡ Rancidity, off-flavour

Proposed mechanisms for lipid oxidation

- Radical formation catalysed by metal ions ($Fe^{+2/+3}$) ➔ Fenton like reaction
- Membrane disruption ➔ no compartmentalisation ➔enzyme catalysis
- Protein-derived free radicals generated during pressurisation

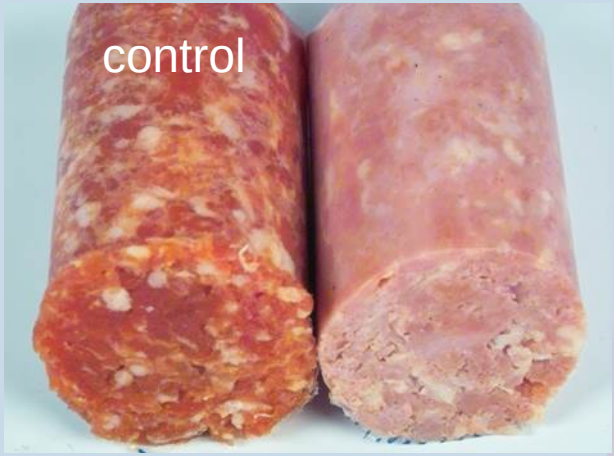
Bolumar et al. (2012) Fd Chem, 134; Bolumar et al. (2014) Fd Chem, 150; Medina.-Meza et al (2014) Inn Fd Sci & Emerg Tech

Pressure-temperature-induced modifications

Texture and colour

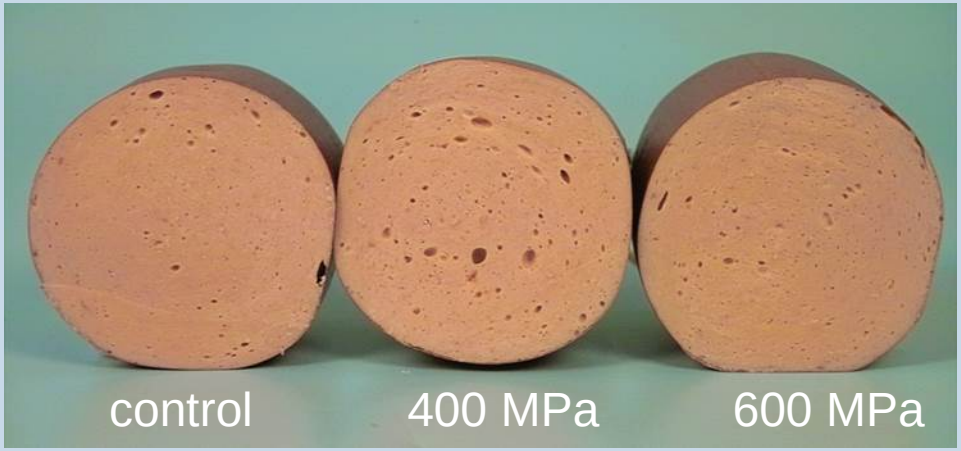
- Spreadable fermented raw sausages

Before fermentation
400 MPa, 20 ºC



After fermentation

- Cooked sausages Bologna-type



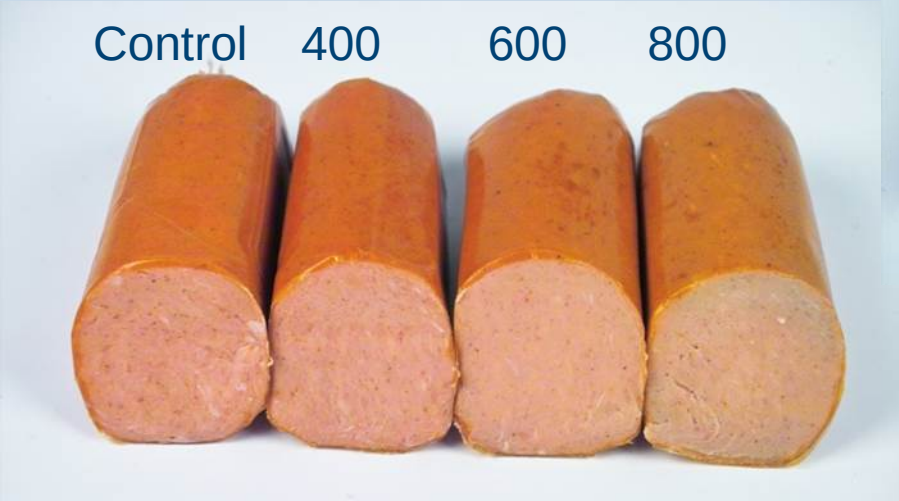
Safety and Quality of Meat

Lautenschlaeger (2005)

Pressure-temperature-induced modifications

Texture

- **Tea sausage**



24 days after manufacture
18 days after HPT

Control 600 800

Safety and Quality of Meat

Lautenschlaeger (unpublished)

Health concerns: open questions

MRI

+ **Reduction of biogenic amine formation**
  - HHP a strategy to reduce the formation of BA?

Latore-Mortalla et al. (2007)
Ruiz-Capillas et al. (2012)

+ **Reduction of salt content**
  - Saltiness perception is enhanced

Sikes et al. (2009)
Trintchev et al. (2013)

+ **Elimination of prion infectivity**
  - Pressure affects a highly infectious subpopulation of scrapie prions

Cardone et al. (2006)
Heindl et al. (2008)

+ **Inactivation of virus**
  - Human norovirus surrogates, hepatitis A are pressure sensitive

Grove et al. (2006)
Kovač et al. (2010)

- **Generation of bioactive peptides**
  - Potential metabolic regulators and peptides with hormone like activities

Butz et al. (1997, 2002)
Fernandez-García et al.(2003)

? **Allergenicity**
  - Some protein groups lose their immune reactivity, others remain unchanged
  - New protein aggregates with weak immune reactivity may be formed

Simonin et al.(2012)
Huang et al. (2014)

Regulatory Status

USA

- **HHP** approved as an intervention method for *Listeria* contaminated pre-packed ready-to-eat meat products (USDA)
- **Pressure-Assisted Thermal Sterilization** (PATS) processes accepted for application in the production of low acid foods (LAF) (FDA, February 2009)

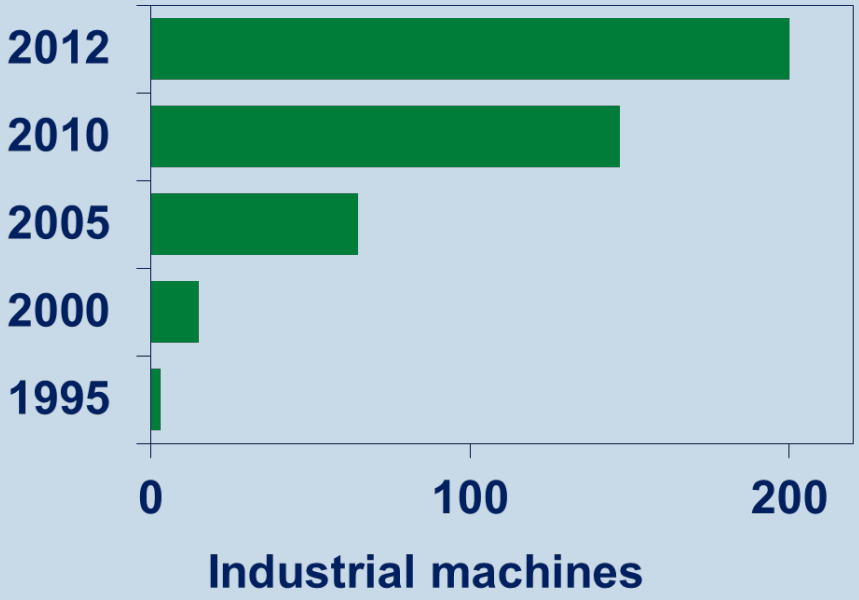
EU

- **HHP** classified as a **novel technology**
- HHP processed foods could be considered as the novel foods if **significant changes in the composition of the material** result from the process
  - ➔ fall under the Novel Foods Regulation (EC 258/97)
    microbial safety, toxicological data, allergenic potential, …….
- HHP approved only for fruit-based preparations (800 MPa for 6 minutes at 20 ^{o}C)

Since 2001 National authorities decide on the legal status of HHP processed food

>>>> A variety of HHP foods are produced and commercialised in the EU without specific approval

Commercial applications

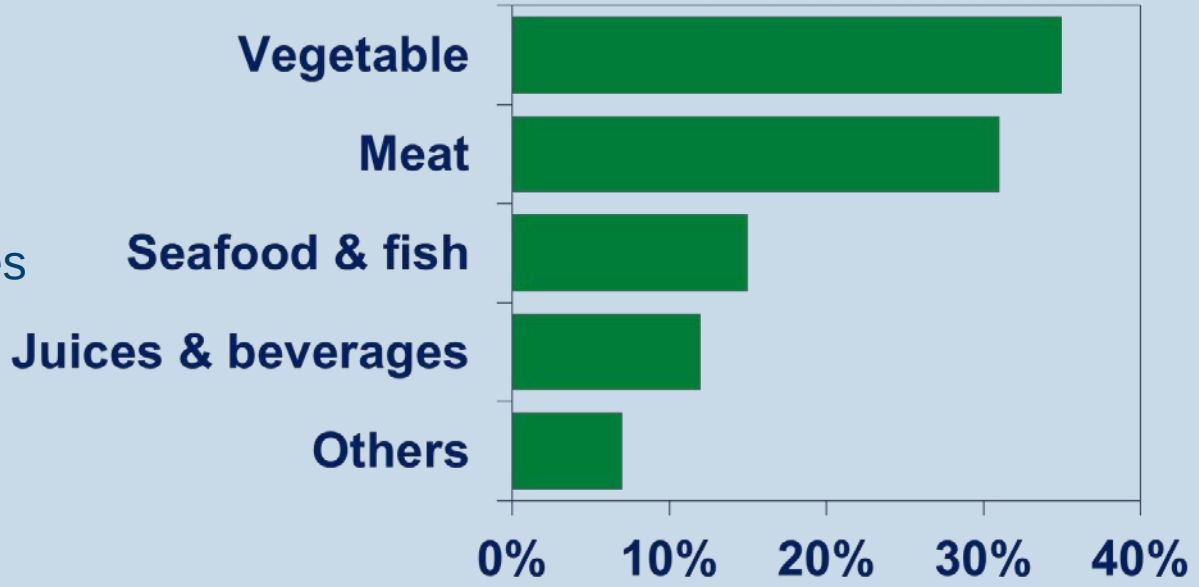


- Evolution of HHP industrial machines

2012 200 HHP facilities worldwide
25% in Europe

200 kg h^{-1} - 2 tons h^{-1}

- Distribution of HHP machines in relation to the food sector
Meat 31 %



Tonello (2012) Hyperbaric

HHP – Commercial meat products		
1998	Sliced cooked ham and tapas	Spain
2001	Sliced cooked products and prosciutto - Poultry products	USA
2002	Pre-cooked chicken and beef stripes	USA
	Sliced cooked chicken, ham & turkey products and Serrano	Spain
2003	Prosciutto, salami, pancetta	Italy
2004	Cured and smoked sliced and diced ham	Germany
	Nitrite-free bacon, sausages and sliced meat	Japan
2005	Ready-to-eat meat based products	USA
	Cured meat products and Serrano	Spain
2006	Cured and cooked meat products	Canada
	Whole roasted chicken - Sliced cooked turkey and chicken	USA
	Ready-to-eat meat meals	Canada
2007	Chicken sausages	USA
2008	Sliced cooked pork and beef products - Pet food	USA
	Sausages and bacon	Canada
2009	Germany style cooked meat products	Canada
	Sliced ready-to-eat meats	USA
2010	Prosciutto and cured meats	Canada
	Sliced and diced products and sausages	Australia
2011	Sliced cooked pork products and sausages	Switzerland
	Prosciutto and cured meats - Sliced ready-to-eat meats	USA
	Ready to eat pork products	Rumania
	Serrano and cured meats	Spain

Tonello (2012) Hyperbaric; Buckow & Bull (2012) CSIRO

Process-induced undesirable compounds
Chances of non-thermal approaches

MRI

Process-induced undesirable compounds

- Health concerns: contaminants or toxicants
- Negative effect on flavour, colour or texture perception

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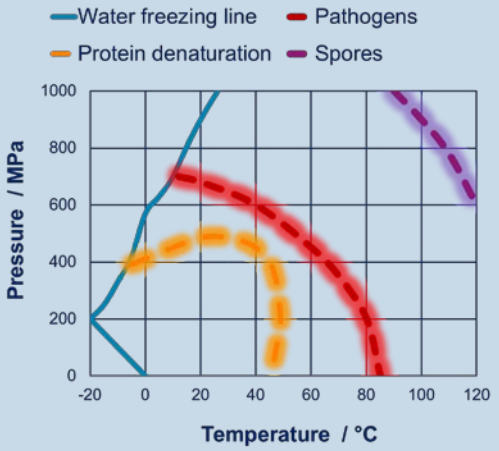
  Grilling, frying: marinades with antioxidants

  Smoking: optimise process, liquid smoke

Non-thermal emerging technologies

- More investigation towards the generation of process-induced undesirable compounds is necessary
- HHP processing is an established technology for the pasteurisation of meat products



Process-induced undesirable compounds chances of non-thermal approaches

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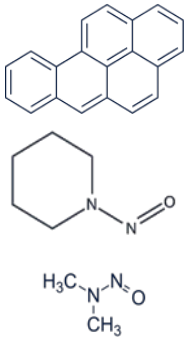

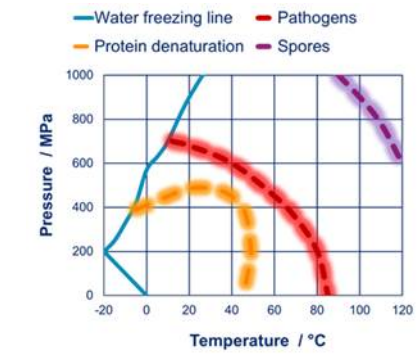

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Thank you!

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4th International Summer School
Raw fermented sausages & Dry-cured meat products
September 16–19, 2014
International Competence Centre on Meat Quality
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