

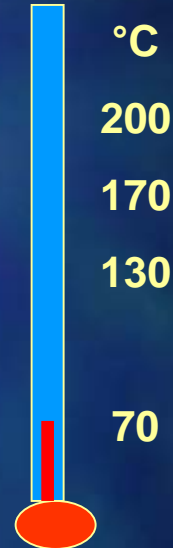
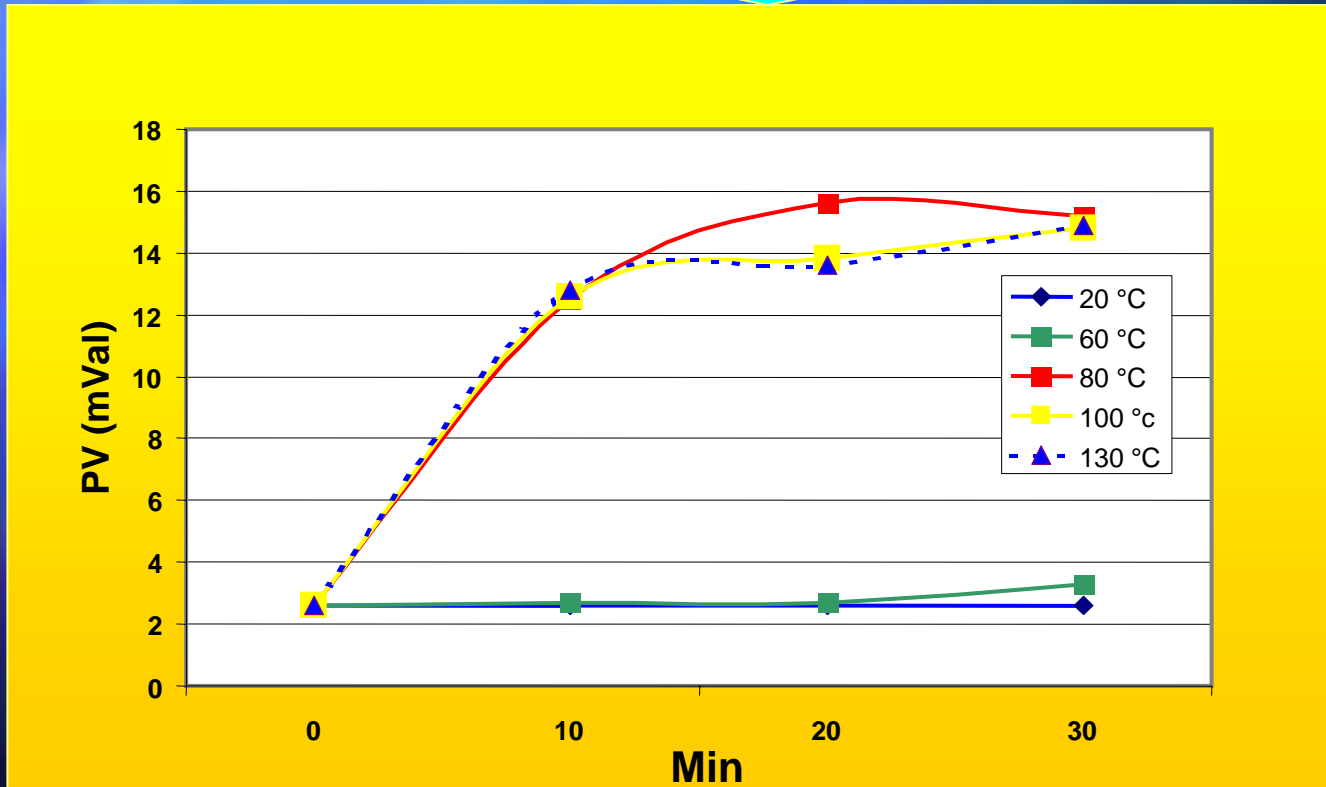
New Theoretical and Practical Aspects about Frying Process

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Christian Gertz

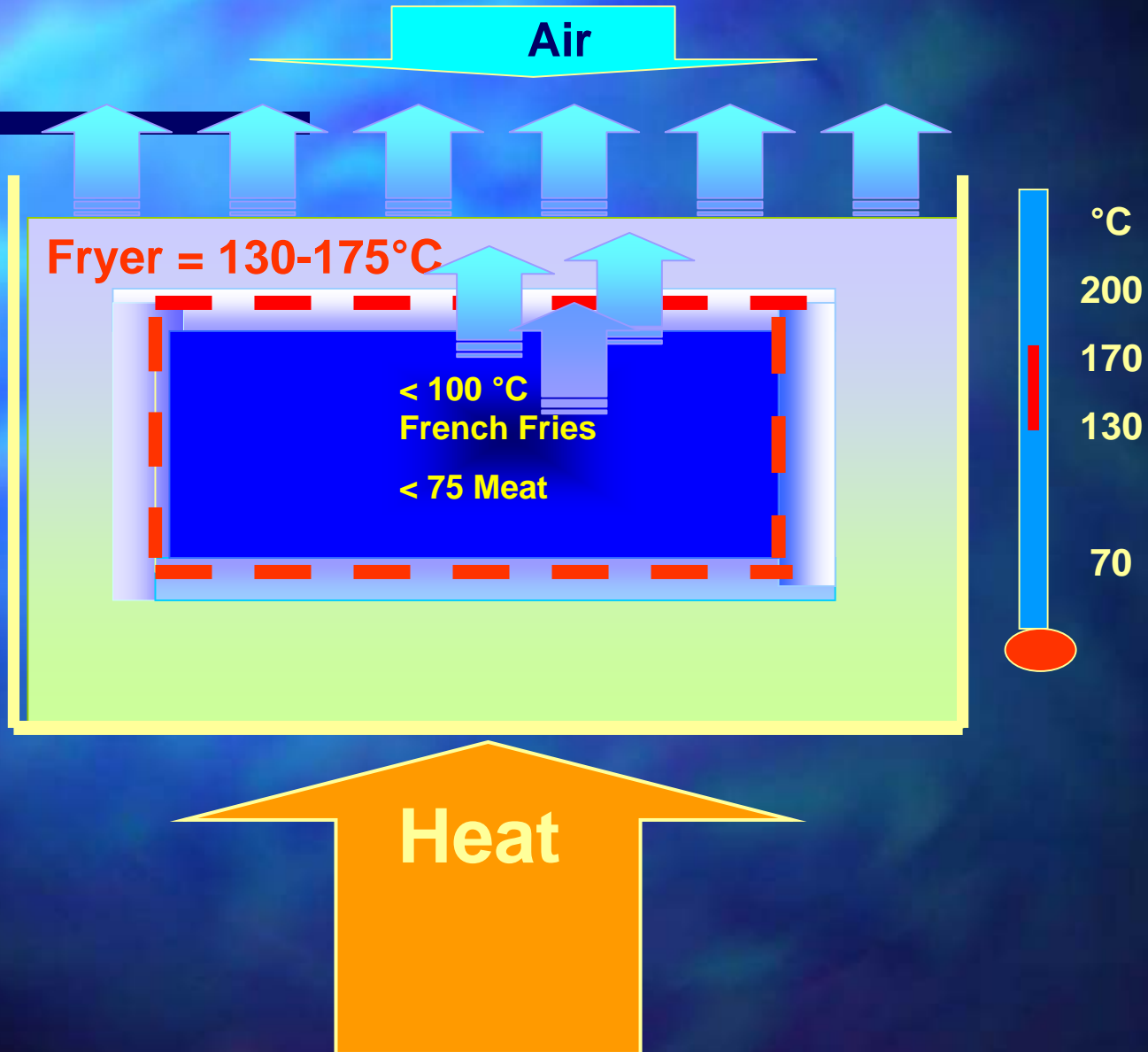
Increase of PV During Preheating 20-130 °C

Air(O₂)

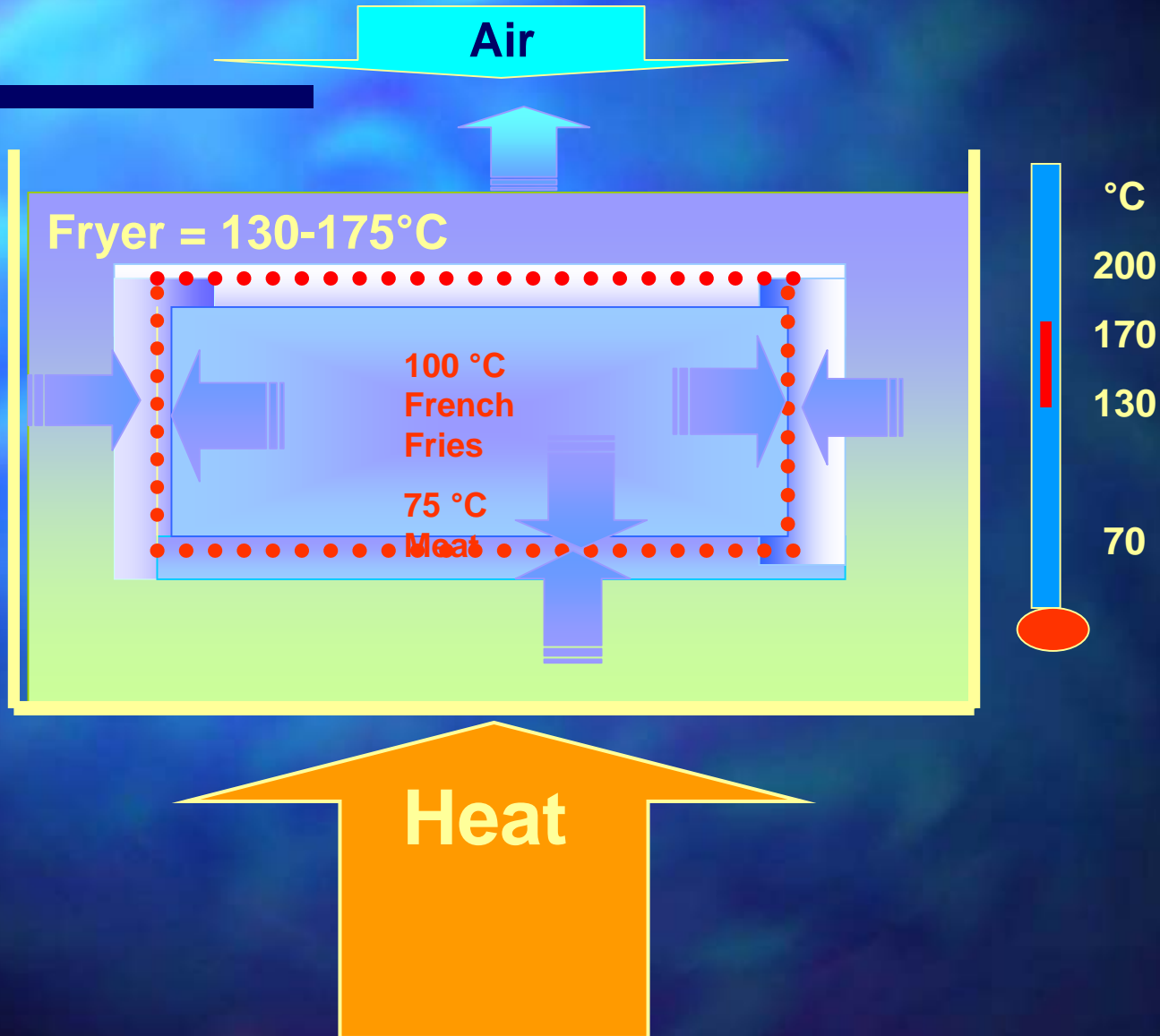


Heat

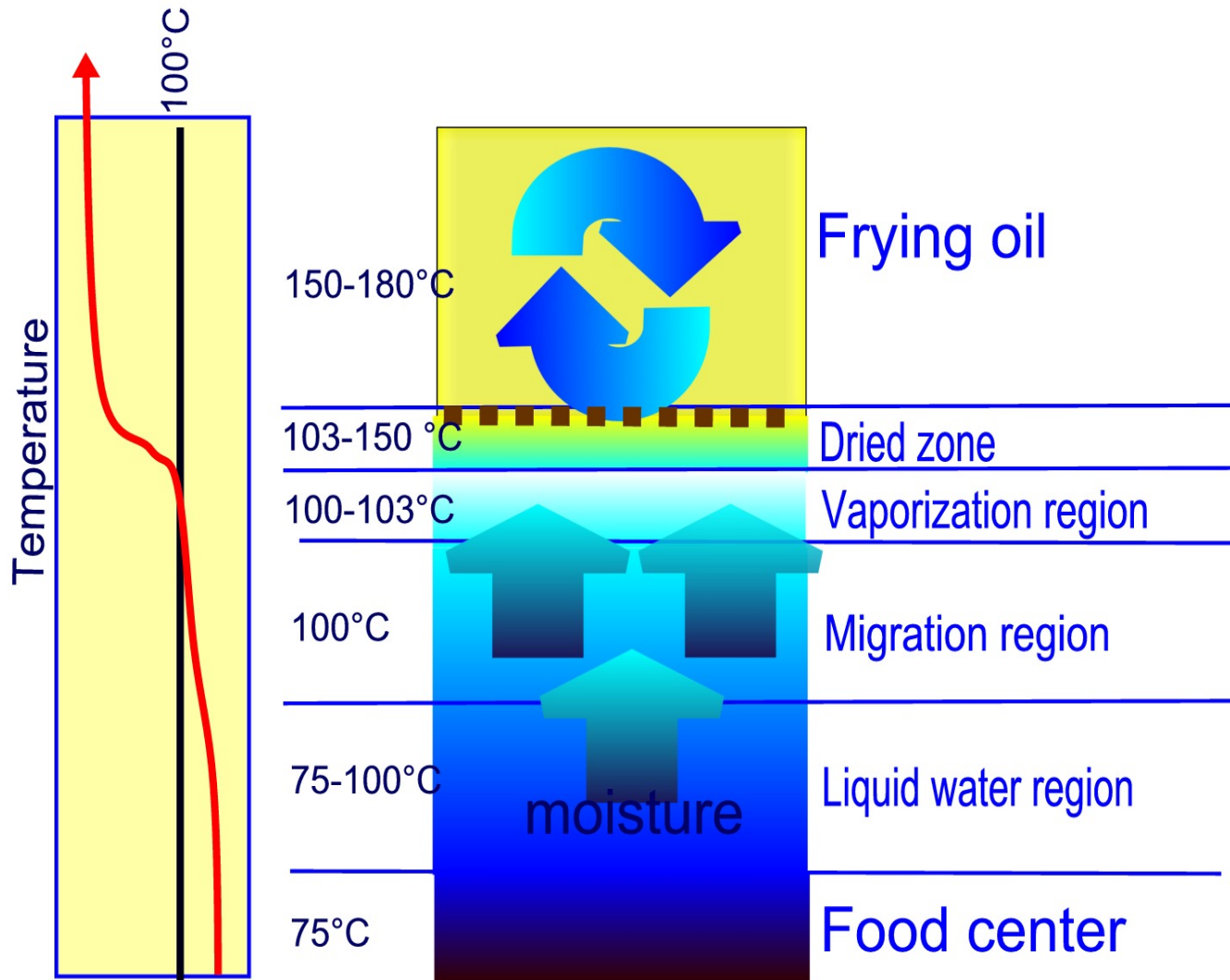
Frying Process



Frying Process: Optimum



Scheme of heat and mass transfer during frying



What Happens during Frying of French Fries?

- Chip heats up from outer layer
- Inside water starts boiling
- Thin crust begins to form
- No oil penetration due to vapour barrier
- Inside heats up and cooks $\sim 100^{\circ}\text{C}$

The Crust

- Responsible for Crispiness
- Plays Key Role in Oil Uptake

Where Does the Oil Go?

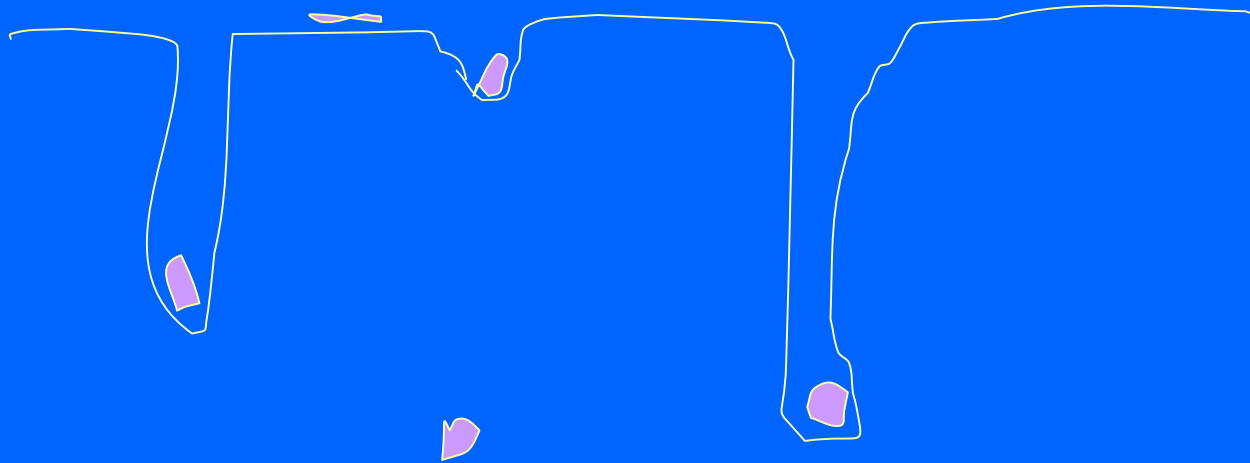
- Oil uptake and water removal are Not synchronous phenomena
- A small amount of oil penetrates during frying and
Most of the oil is picked up at the end of process

Source: Pyle et al. 2003

Diagram showing three locations of oil in French fries

Surface Oil
Oil Structured oil

Penetrated Surface



Autoxidation

Start:

L-H *Heat (max. 130°C)* **L*** Radical
UV
Metal ions (Cu,Fe)
Peroxides

Not: L-H **O₂** **L* + OOH* (+64 kcal/mol)**

Propagation:

L* + **O₂** \longrightarrow **LOO***

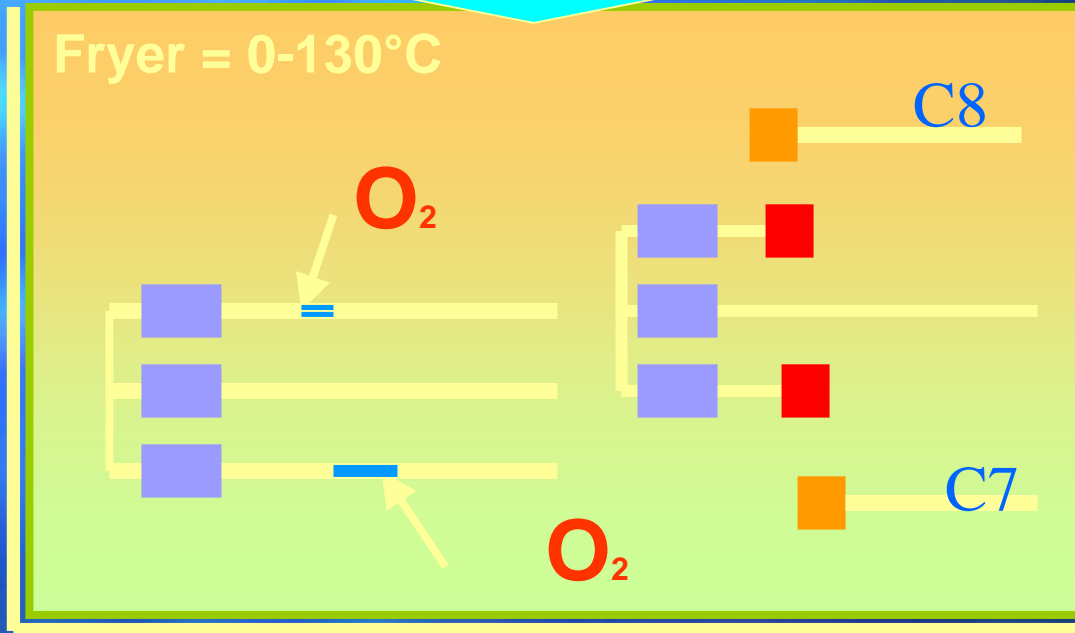
LOO* + **LH** \longrightarrow **LOOH + L***

Termination:

LOO* + Terminator \longrightarrow **Oxidation product**

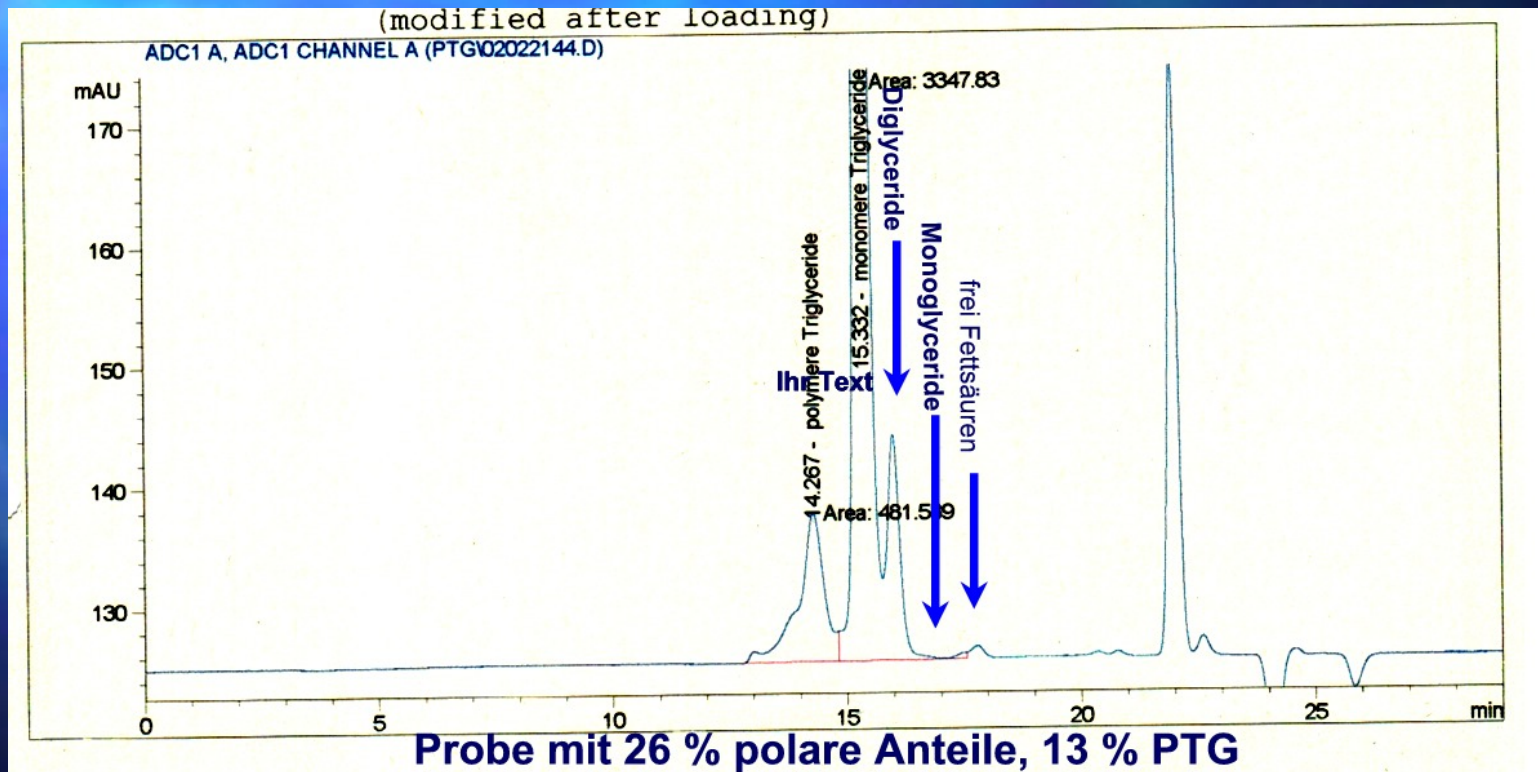
Autoxidation/Oxidation during Frying Process (<math>< 130\text{ }^\circ\text{C}</math>)

Air (O_2)

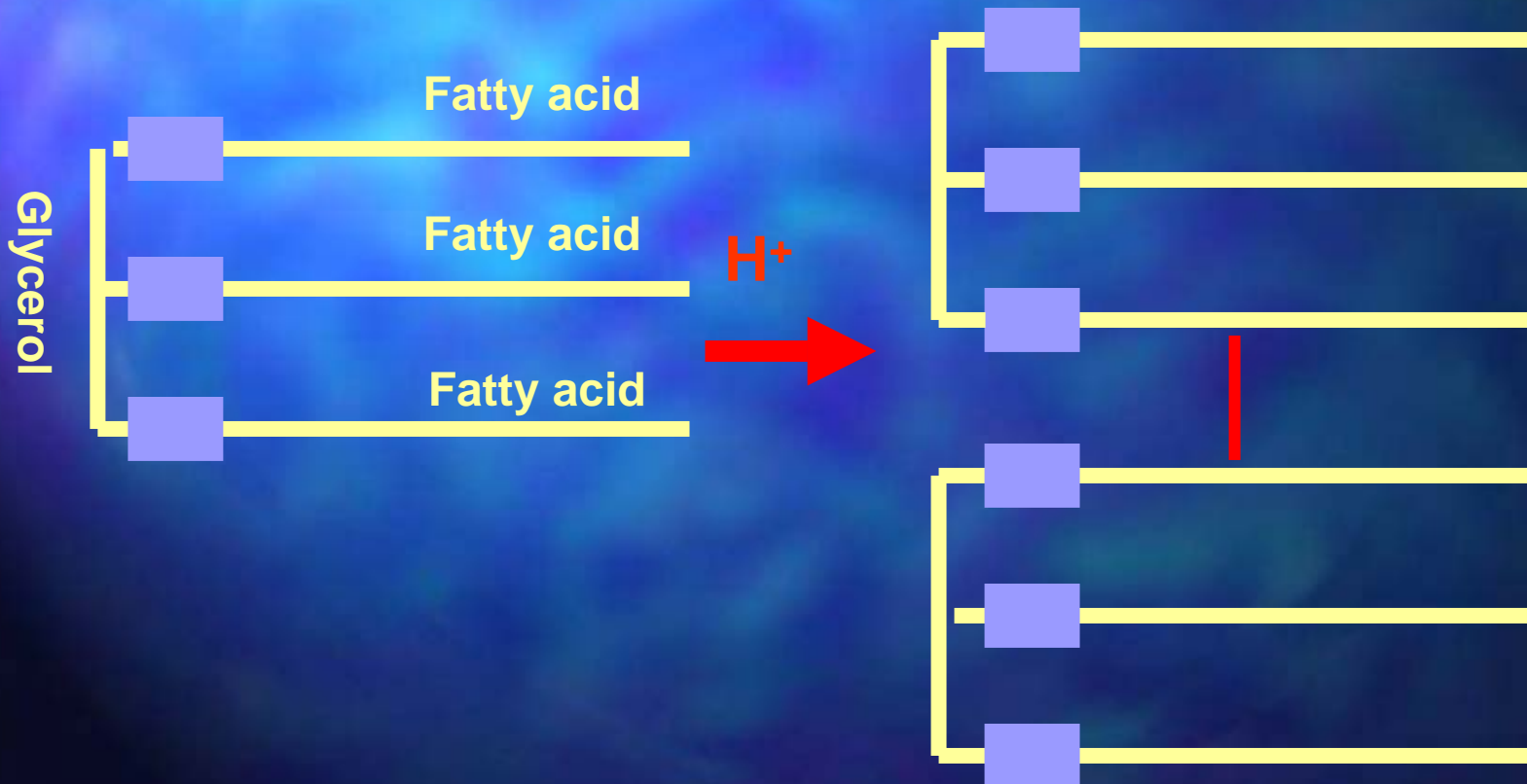


Heat

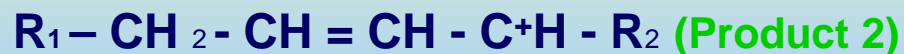
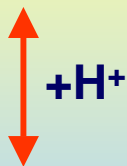
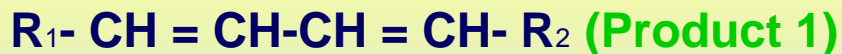
GPC of Acylglycerides in Used Frying Fats



Polymerisation during Deep Frying (>130 °C)



Start: Forming of Conjugated Fatty Acids by Protonisation

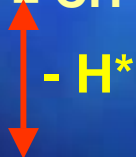


Product 1 + Product 2



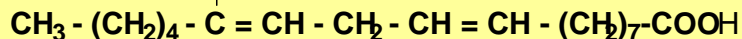
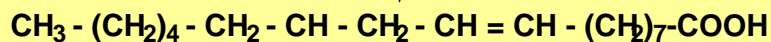
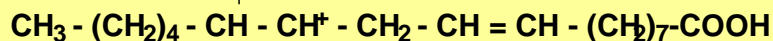
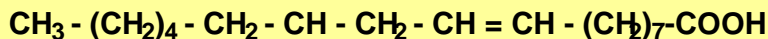
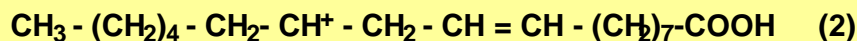
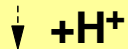
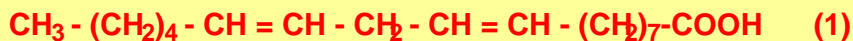
Dimer \rightarrow Cyclic compound

Start: Forming of Conjugated Fatty Acids by Autoxidation

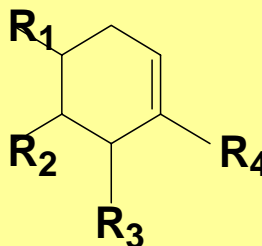
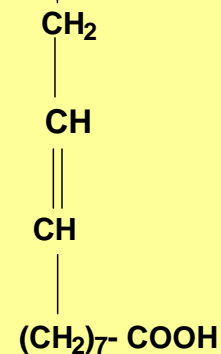
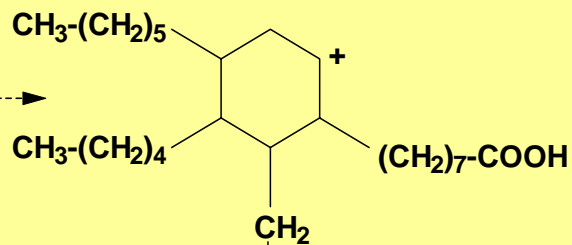


Products: Aldehydes, Ketones, Acids (C8,C7), Hydrocarbons

Acid Catalysed Dimerisation of Triyglcerols



DIMER



Deterioration at frying temperature by hydrolytic reactions ?

- FFA content does not correlate with degradation
- Mono- and Diglyceride contents do not change significantly
- Predominant Formation of Short Chain Fatty Acids

Practical Arguments against Radical Route

- Presence of water in frying fats
- Dilution with fresh oil prolongs heating time of frying fats
- Different oxidative stability effects of some natural antioxidants and AP at ambient temperature and frying temperature

Oxidative Stability Tests

- Based on Oxygen Consumption

 - Oxygen Bomb
(Oxipress™)

 - Oxidograph™

 - Sylvester Test

- Generation of Oxidation Products

 - Schaal Oven Test

 - Swift Test

 - (Active Oxygen Method
(AOM))

 - Rancimat (Conductivity)

 - Oxidative Stability Index
(OSI)

Tests

- Test temperature

- The interference of food and natural food ingredients
- Volatile compounds (short chained fatty acids, BHT)
- Influence of protective measurements
- Time consuming
- Results depend on the instrument (not comparable)

Analytical Procedure of OSET-Test

20 g sample (oil) into a 100ml-glass vessel (40 mm diameter)

1.0 g silica gel (conditioned with 10 % water)

2 h at ambient temperature

1 min treatment in a ultrasonic bath

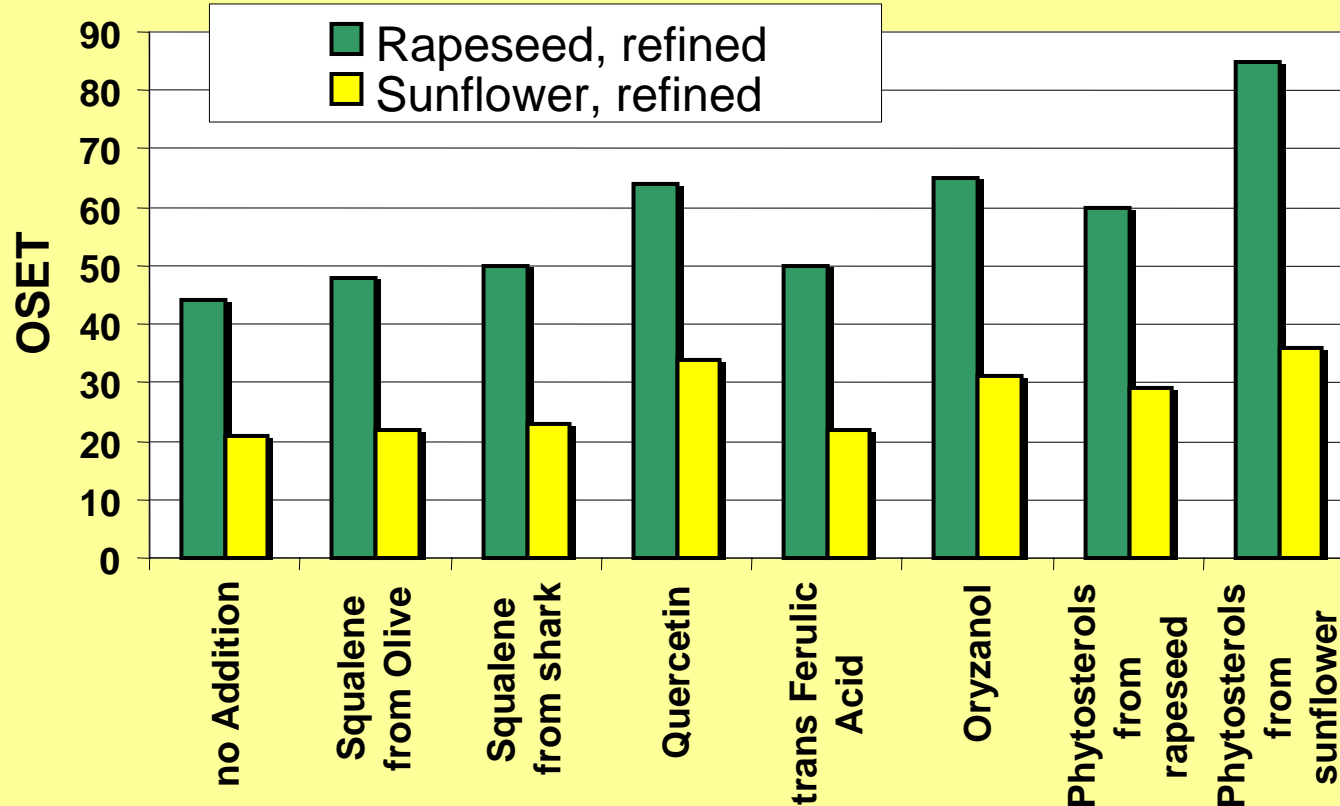
2 h heating in an aluminium box at 170 °C

50 mg in 1 ml THF; **SEC (HPLC)** of dimers

$$\text{OSET} = 100 / \text{PTG} (\%)$$

Effectiveness of Natural Antioxidants on Stability of Refined vegetable Oils

(50 mg/20 g)



Conclusions

- There are two mechanisms dominating the fat degradation at frying conditions
- A radical mechanism predominates at lower temperature ($<130\text{ }^{\circ}\text{C}$)
- The polymerisation, catalysed by acids, happens above $130\text{ }^{\circ}\text{C}$
- Hydrolytic reactions are less important or do not take place.
- The theory of two different mechanism of fat degradation explains the difference in effectiveness of some antioxidants
- The effectiveness of additives or heat stability of oil should be measured by OSET and Rancimat.