New Theoretical and Practical Aspects about Frying Process

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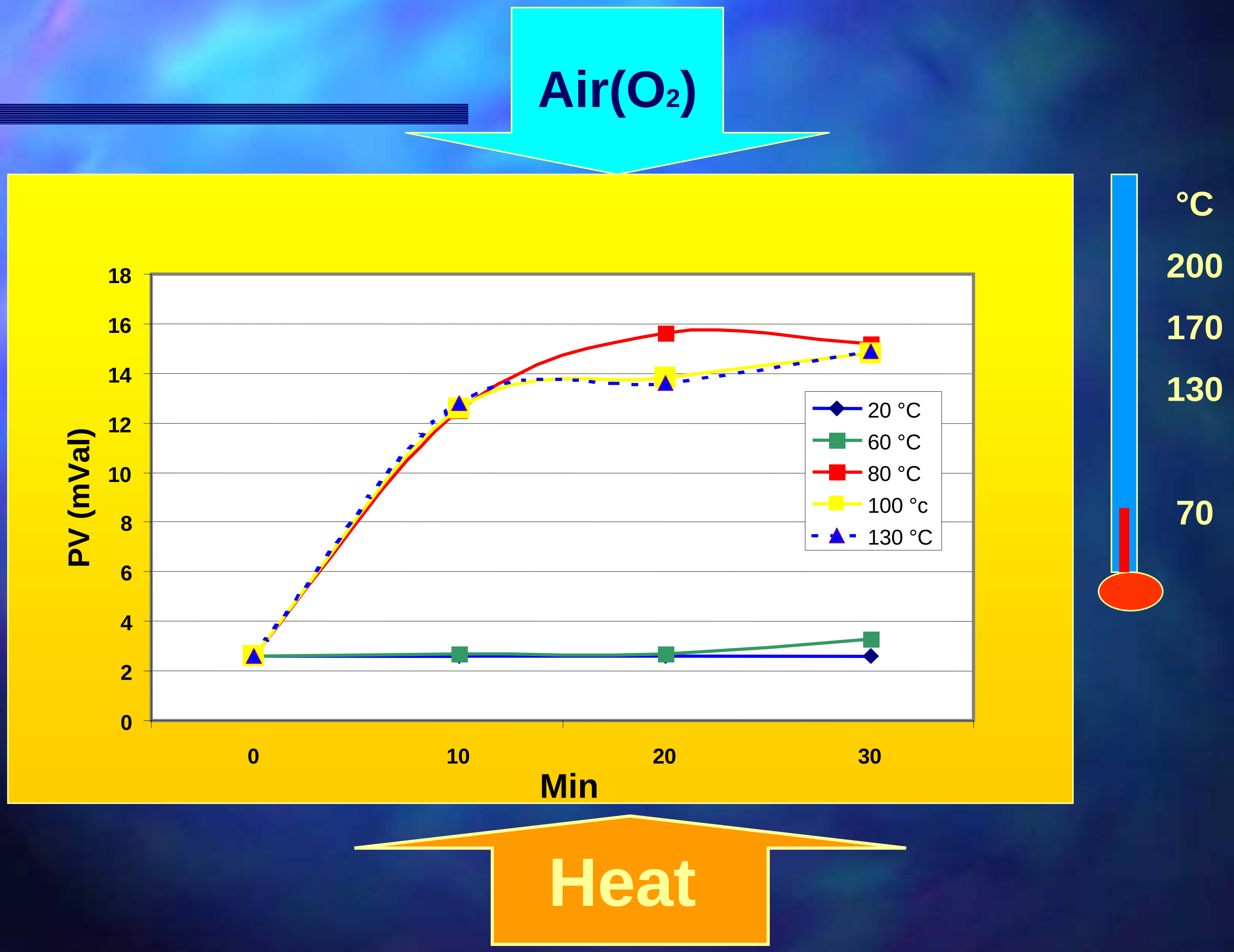
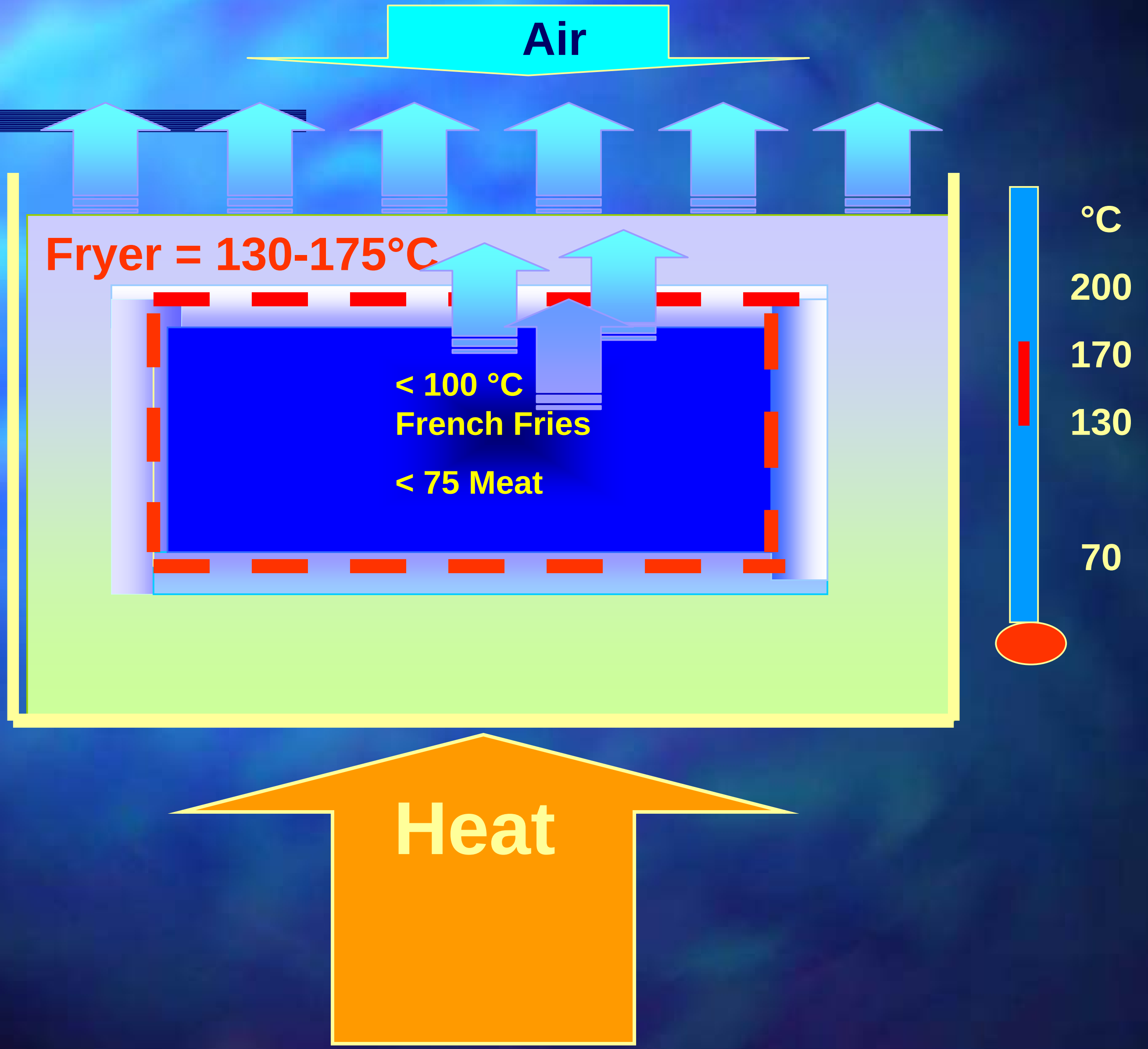
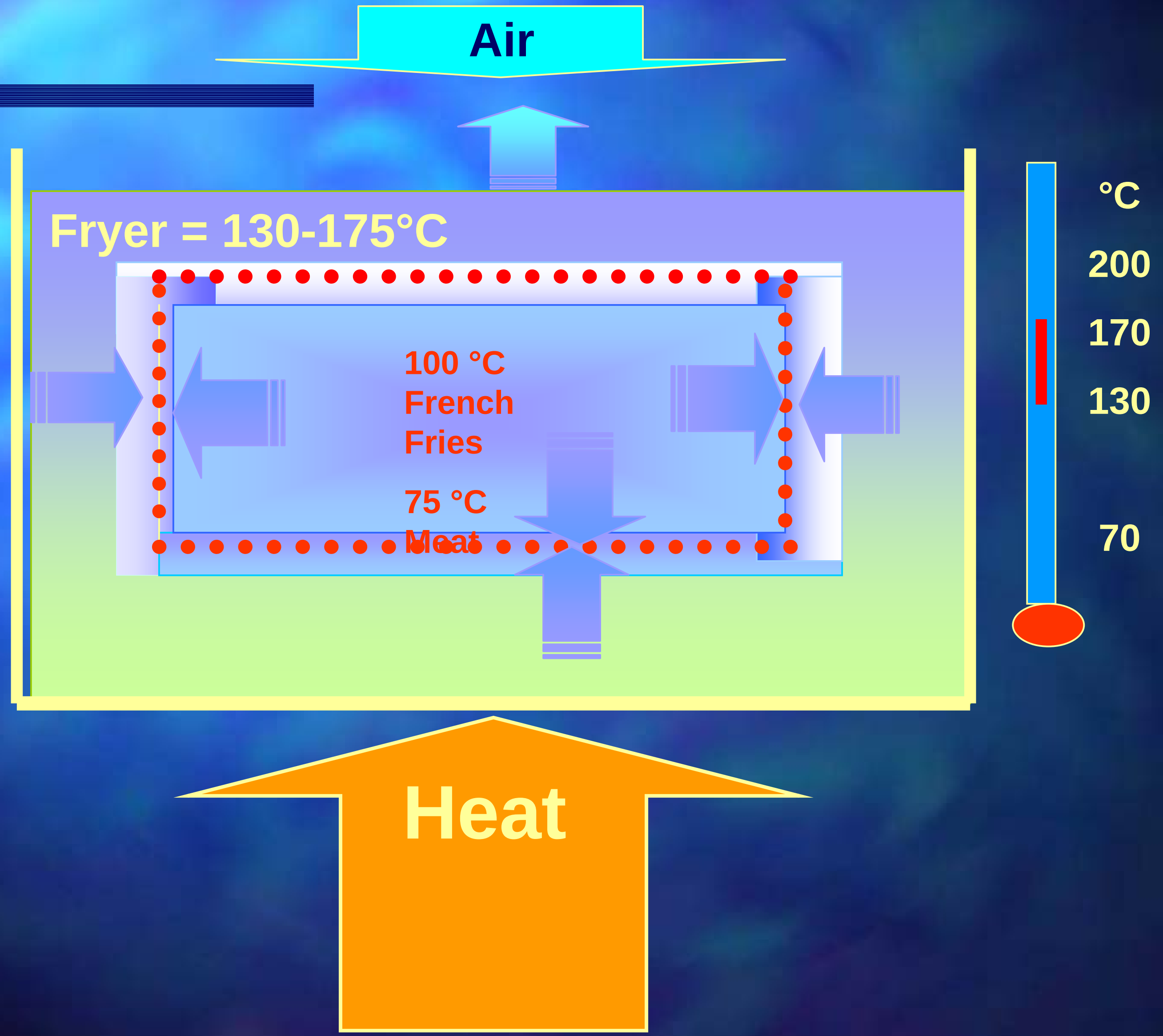
Increase of PV During Preheating 20-130 °C



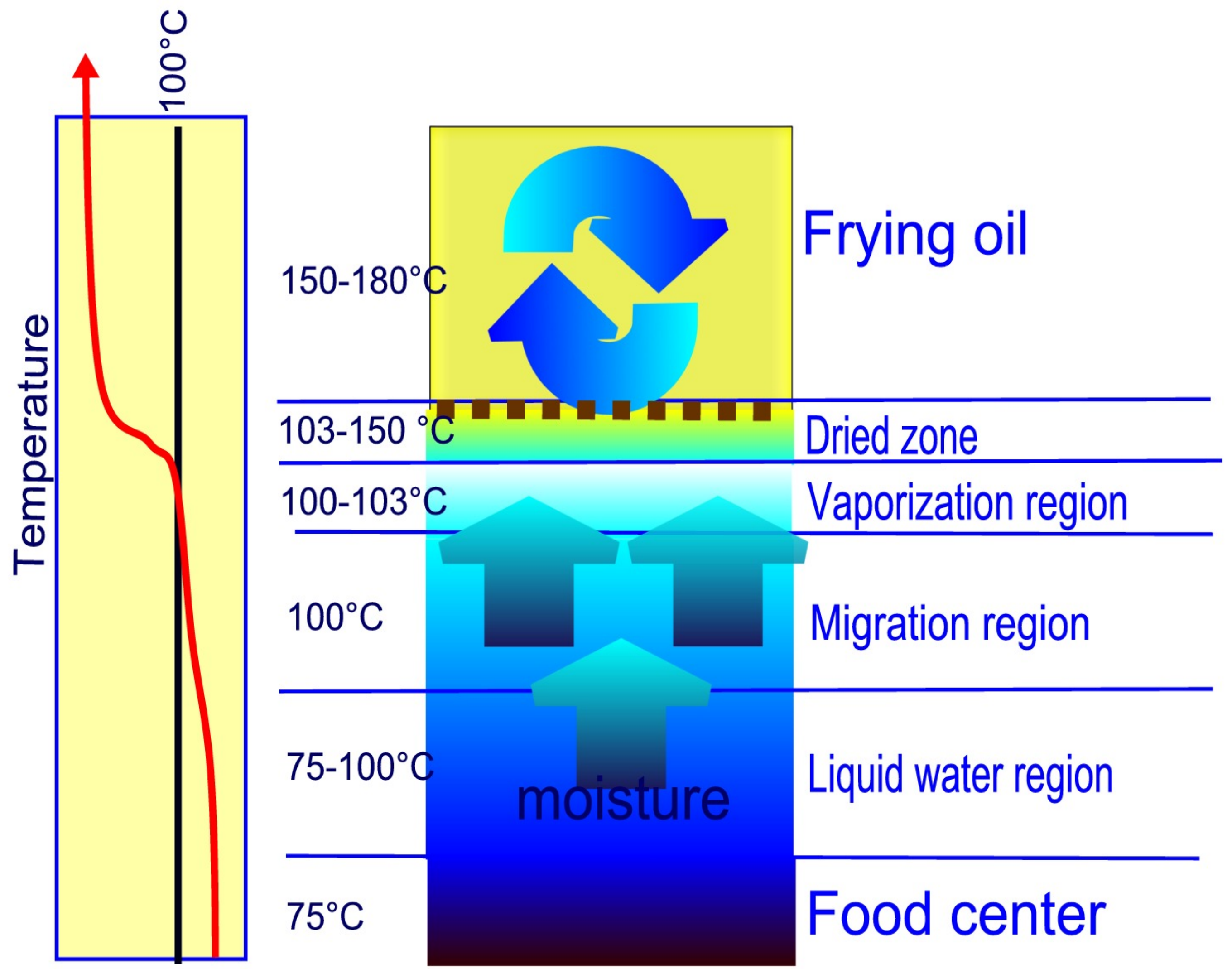
Frying Process



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 ~ 100^0C

The Crust

- Responsible for Crispiness
- Plays Key Role in Oil Uptake

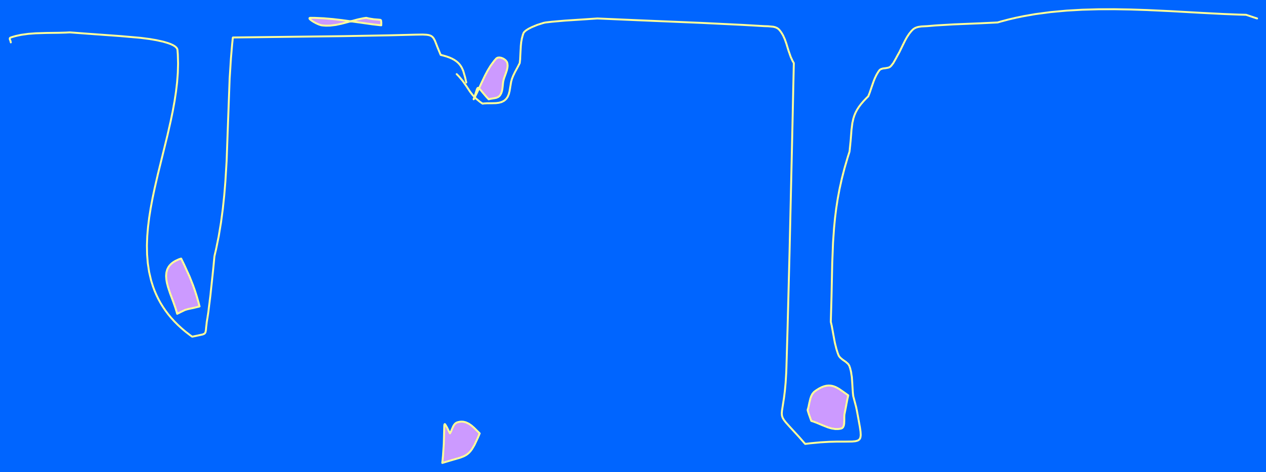
Where Does the Oil Go?

- Oil uptake and water removal are <u>Not</u> 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 Penetrated Surface Oil Structured oil



Autoxidation

Start:

L-H	*Heat (max. 130°C)* *UV* *Metal ions (Cu,Fe)* *Peroxides*	L* Radical
Not: L-H	O2	L* + OOH* (+64 kcal/mol)

Propagation:

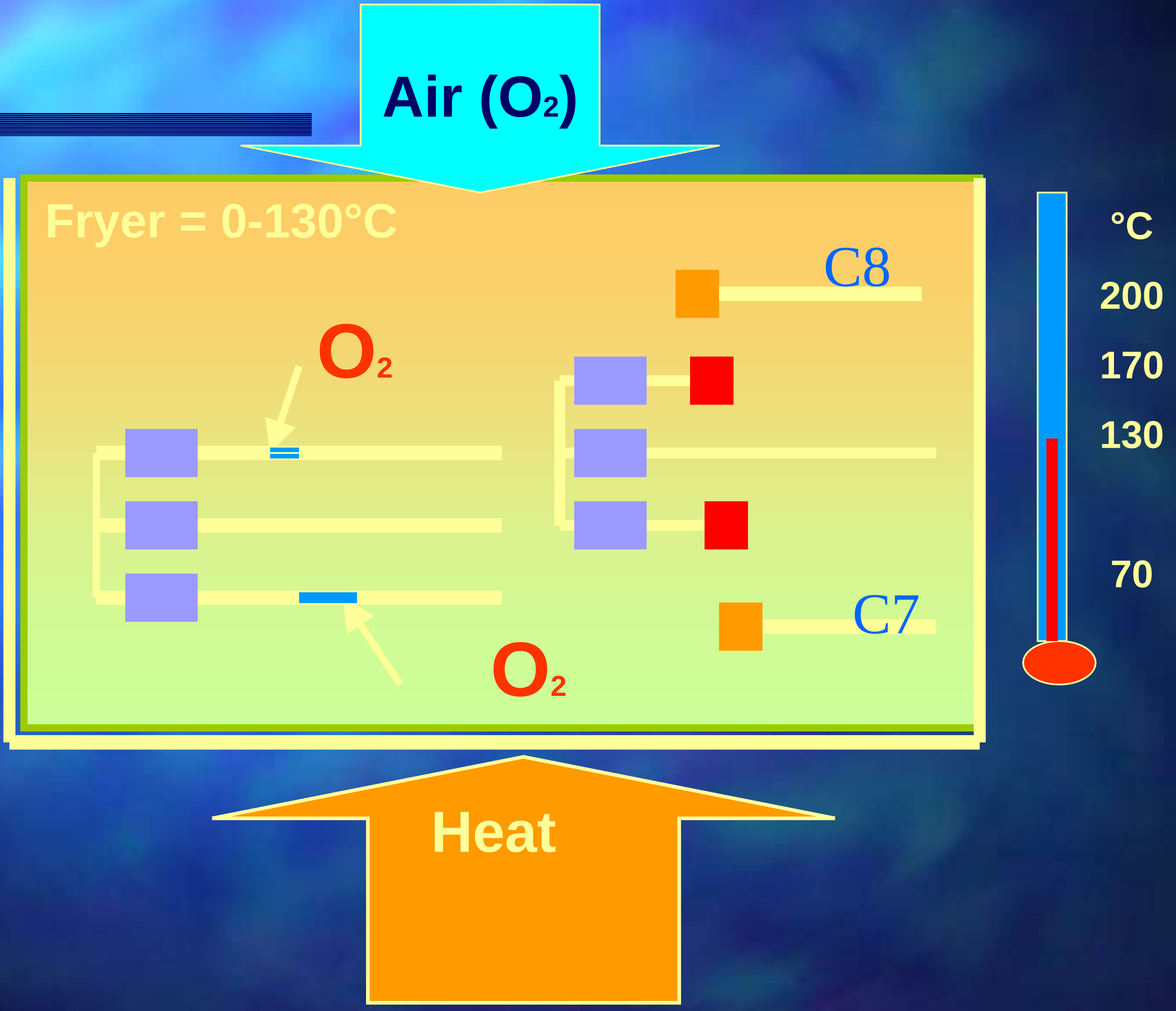
L* + O2 → LOO*

LOO* + LH → LOOH + L*

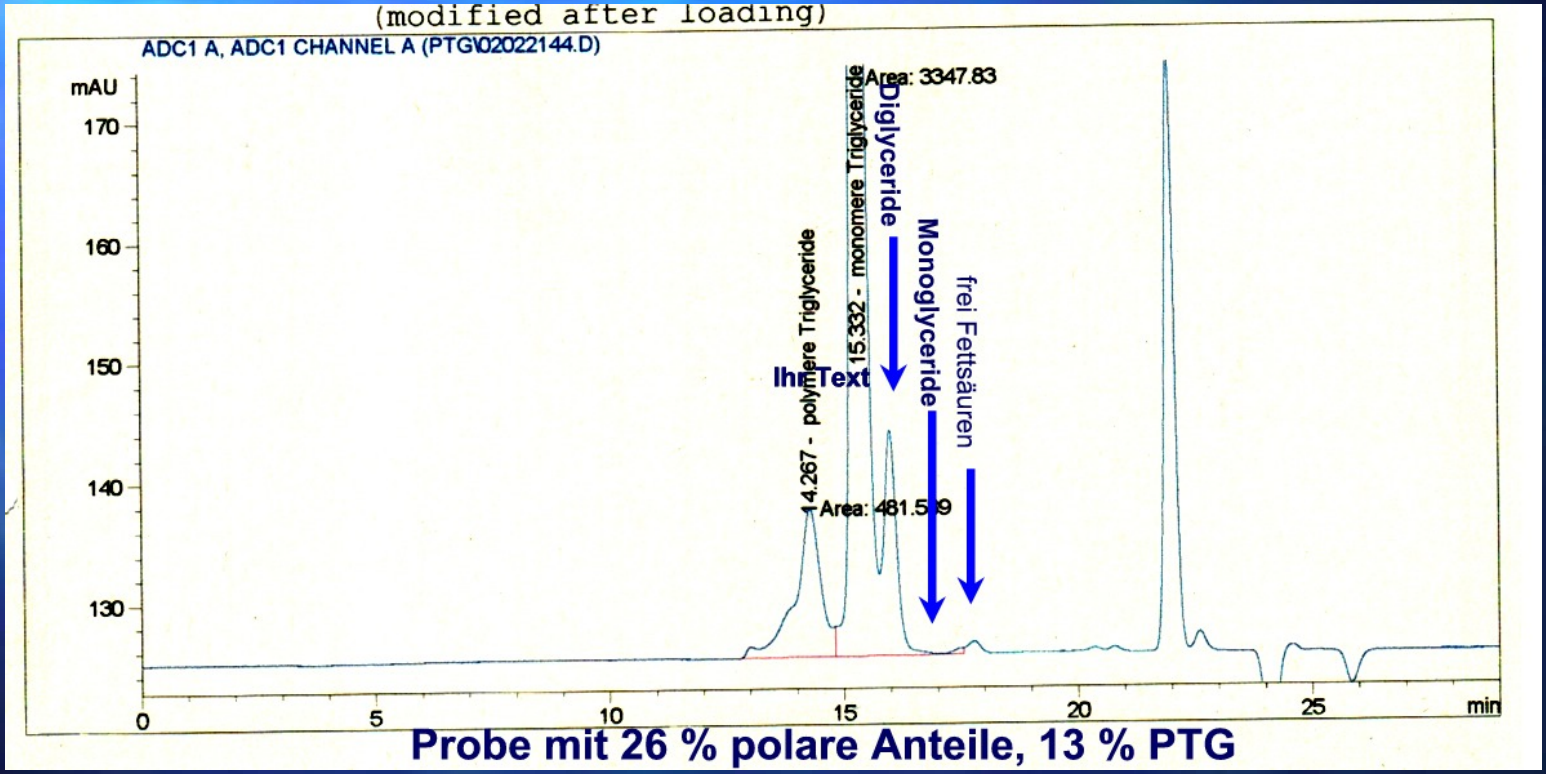
Termination:

LOO* + Terminator → Oxidation product

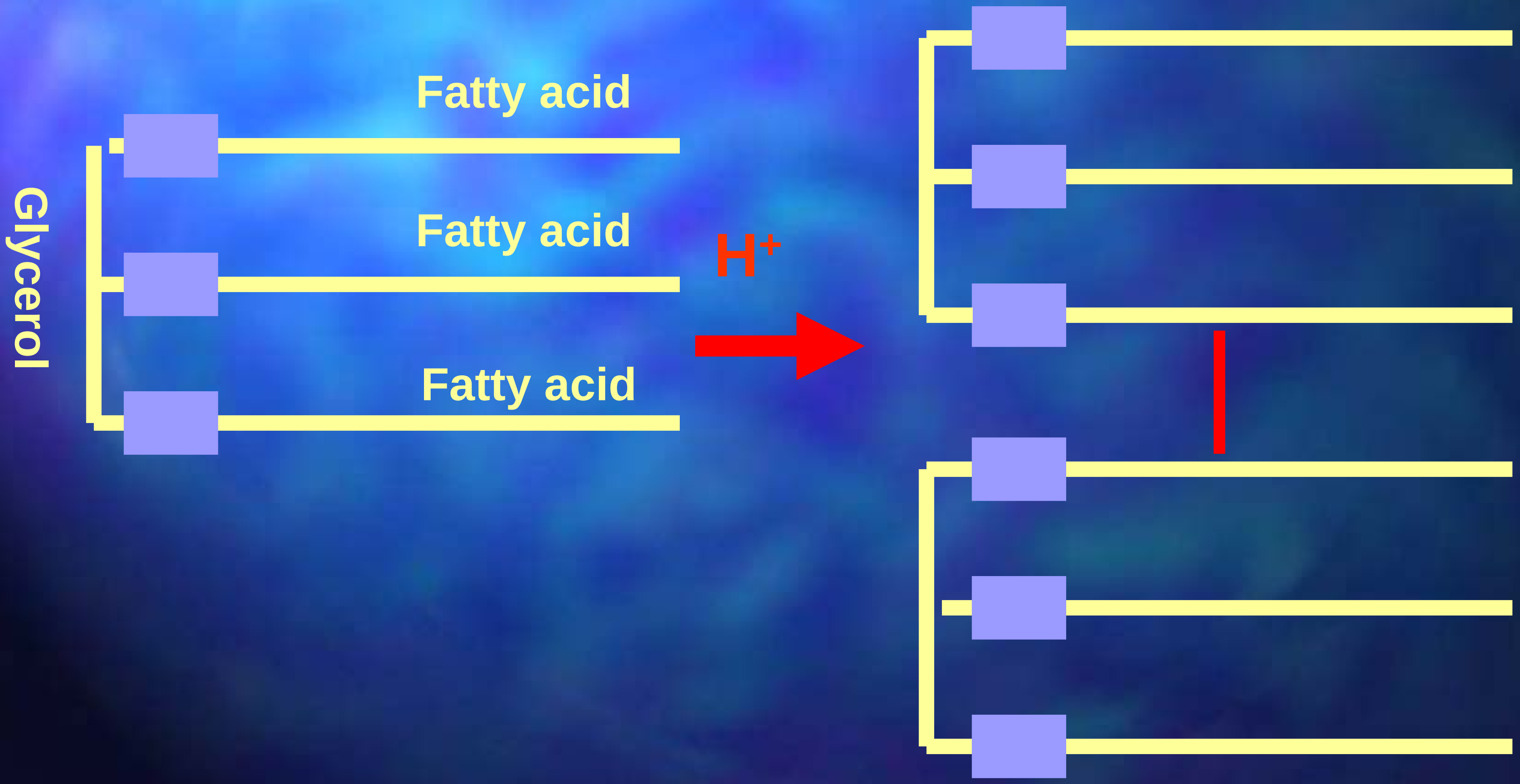
Autoxidation/Oxidation during Frying Process (<130 °C)



GPC of Acylglycerides in Used Frying Fats



Polymerisation during Deep Frying (>130 °C)



m e r e

Start: Forming of Conjugated Fatty Acids by Protonisation

R_1- CH = CH-CH = CH- R_2 (Product 1)

↕ $+H^+$

R_1 – C^+H- CH $_2$ – CH = CH - R_2 ⟷ R_1 – CH $_2$ - CH = CH - C^+H - R_2 (Product 2)

↕

R_1 - CH_2 - C^+H- CH = CH - R_2

Product 1 + Product 2 → Dimer → Cyclic compound

Start: Forming of Conjugated Fatty Acids by Autoxidation

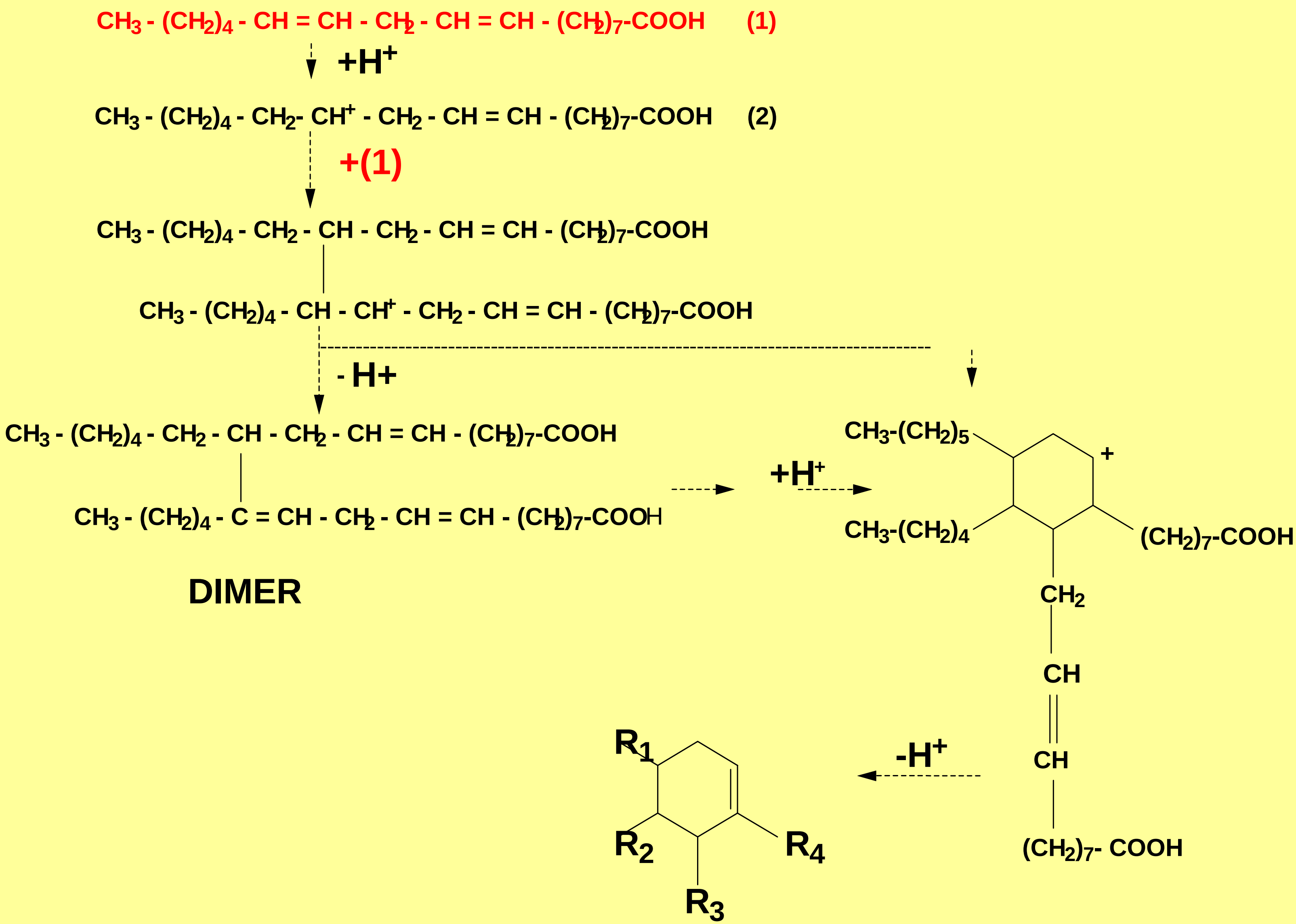
R_1- CH = CH-CH = CH- R_2

↕ - H*

R_1 – C*H- CH $_2$ – CH = CH - R_2 ⟷ R_1 – CH $_2$ - CH = CH – C*H - R_2

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

Acid Catalysed Dimerisation of Triyglcerols



Deterioration at frying temperature by hydrolytic reactions ?

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

Practical Arguments against Radical Route

- Presence of water in frying fats
- Dilution with fresh oil prolonges 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^{TM})

  Oxidograph^{TM}

  Sylvester Test

- **Generation of Oxidation Products**

  Schaal Oven Test

  Swift Test

  (Active Oxygen Method (AOM))

  Rancimat (Conductivity)

  Oxidative Stability Index (OSI)

Limitations of Known Oxidative Stability 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

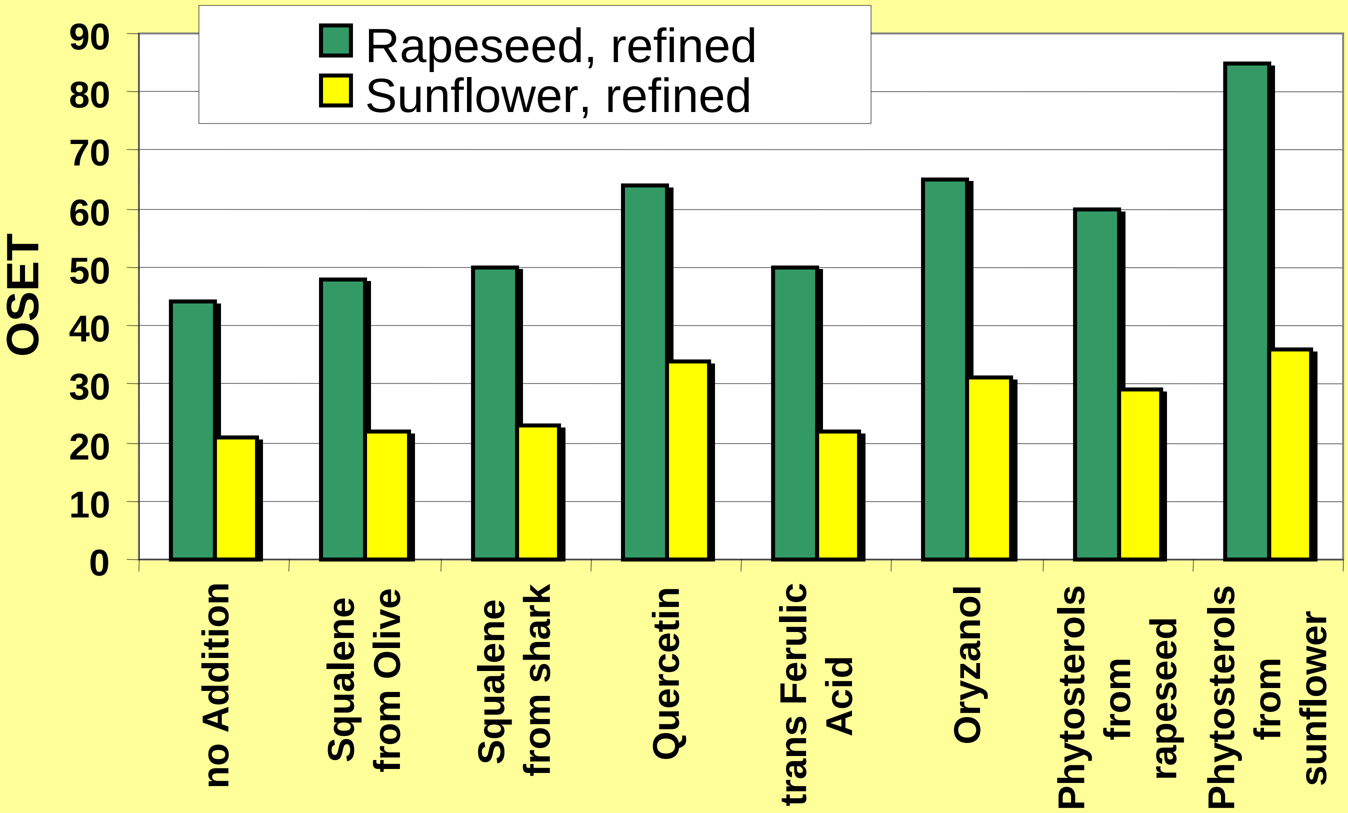
2 h heating in an aluminium box at 170 °C

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

OSET= 100/ PTG (%)

Effectiveness of Natural Antioxidants on Stability of Refined vegetable Oils

(50 mg/20 g)



Heat Stability Effects of Sterols

(OSET-Values)

Sterolfraction (Sample no)	OSET (Rapeseed)	OSET (Sunflower)	Chole-sterol	Brassica-sterol	Campe-sterol	Stigma-sterol	beta-Sitosterol	D5-Avena-sterol	D7-Stigma-sterol	D7-Avena-sterol
St1	83,3	37,0	0,1	3,3	17,9	5,4	55	1,8	9,3	2,3
St2	62,5	33,3	0,2	10,5	36,6	0,8	46,6	1,9	0,2	0,07
St3	62,5	32,3	0,03	0	7,7	1,4	80,1	0,6	0,7	0,3
St4	55,6	31,3	0,5	2,3	27,3	18,1	46,8	0,9	0,4	0,1
St5	55,6	30,3	0,4	2,1	25,3	19,6	46,8	1,3	0,4	0,2
St6	52,6	29,4	0,6	2,2	26,4	17,8	47,6	1,4	0,4	0,2
St7	52,6	28,6	0,4	2,4	27,3	19,4	46,4	0,1	0,3	0,2
St8	50,0	28,6	0,4	1,8	26,8	20,7	45,5	1,1	0,4	0,2
St9	47,6	28,6	0,5	1,5	26,5	20,7	44,9	1,3	0,4	0,2
no Addition	47,6	27,8								

Conclusions

- **There are two mechanisms dominating the fat degradation at frying conditions**
- **A radical mechanism predominates at lower temperature (<130 °C)**
- **The polymerisation, catalysed by acids, happens above 130 °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.**