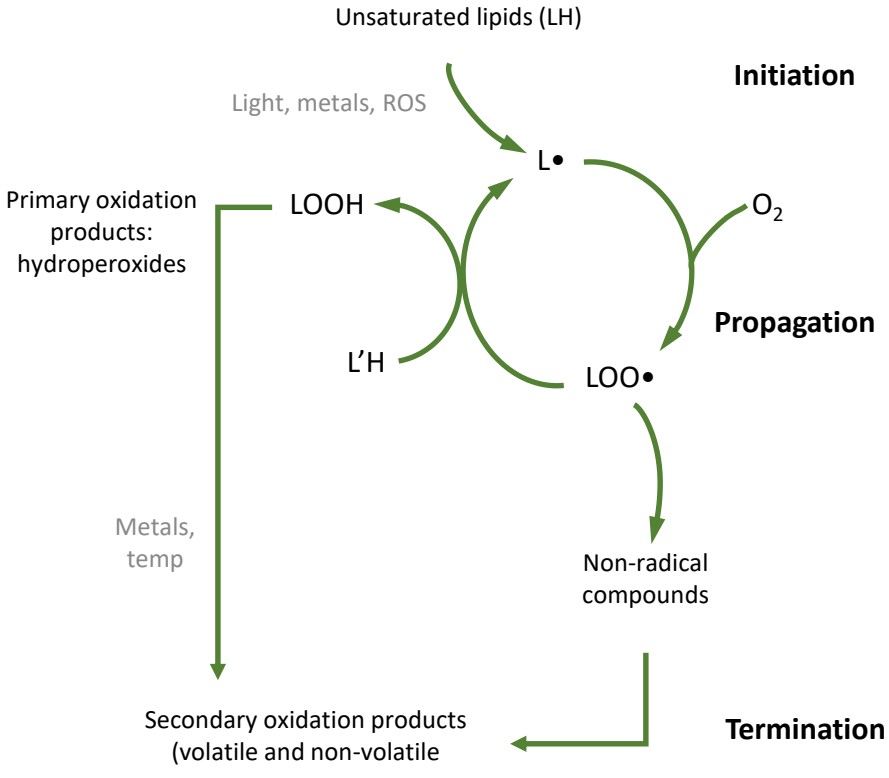
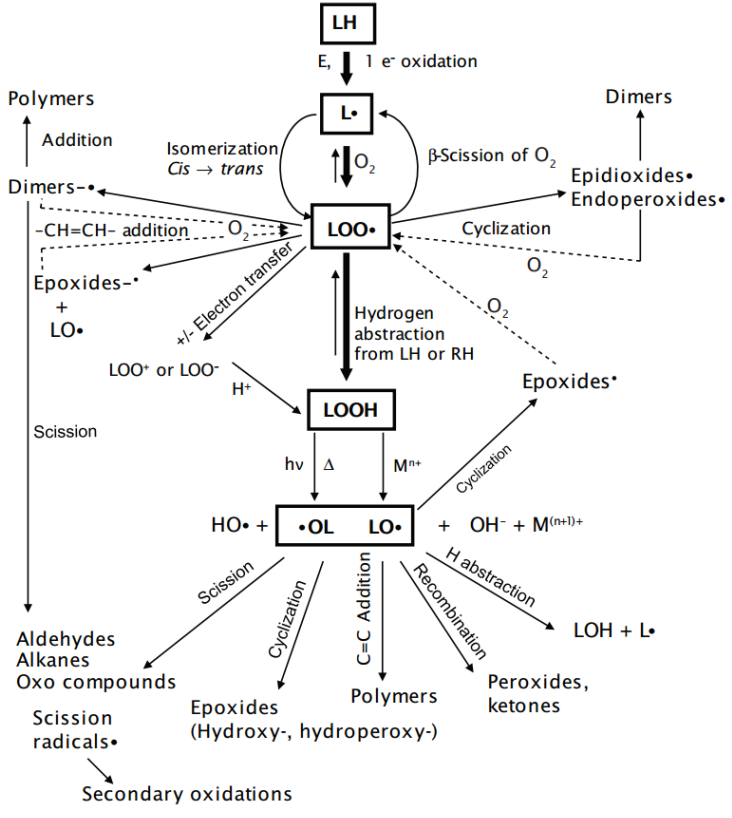
TruGro® AOX

A Technical Approach to Oxidation and Natural Antoxidant Solutions

SCIENCE OF OXIDATION

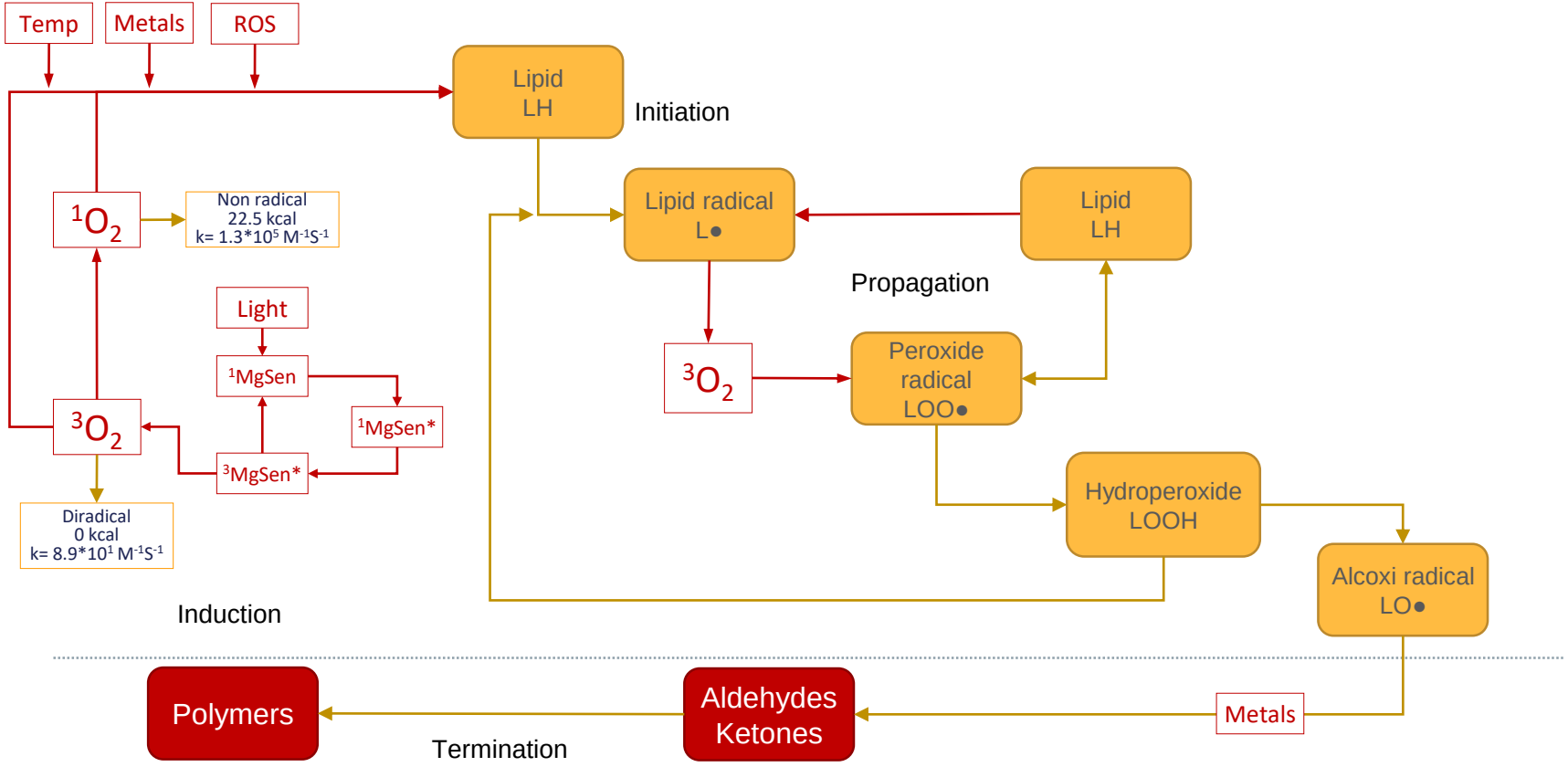
AUTOOXIDATION PROCESS OF FATS AND OILS





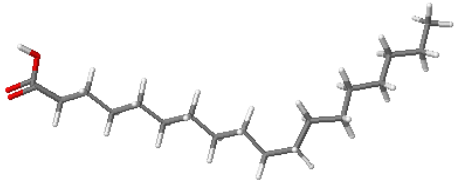
Nawar, 1996; Schaich, 2005; Logan, 2013

AUTOOXIDATION PROCESS OF FATS AND OILS

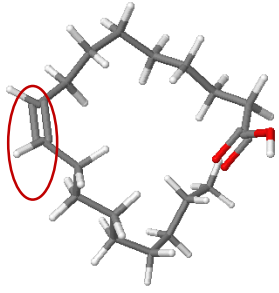


Adapted from Min, 2002; Kim, 2008

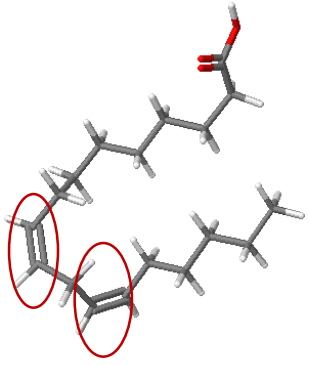
STRUCTURE OF FATTY ACIDS AND OXIDATIVE STABILITY



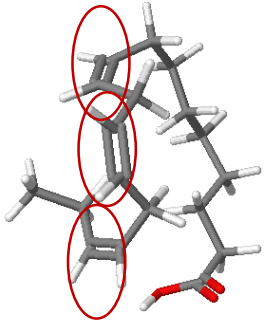
Stearic 18:0



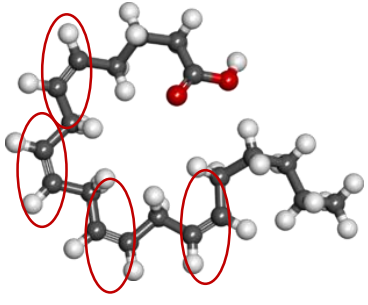
Oleic 18:1



Linoleic 18:2



Linolenic 18:3

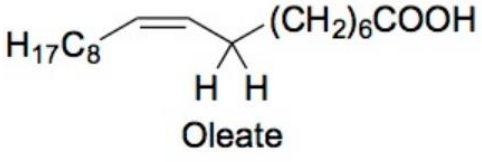


Arachidonic 20:4

Fatty Acid	Relative Rate of Oxidation	
	Fatty Acid	Ester
18:1	1	1
18:2	28	41
18:3	77	98
20:4		195

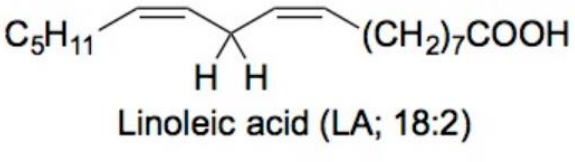
Shaich, 2005; Scott, 1963

NUMBER OF DOUBLE BONDS AND SPEED OF AUTOXIDATION:



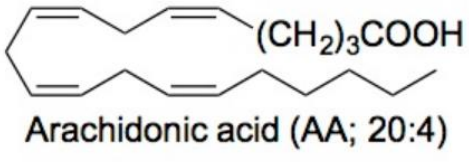
Oleate

***k*=0.8 $M^{-1}s^{-1}$**



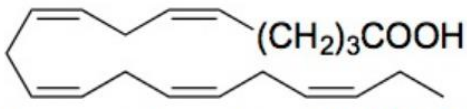
Linoleic acid (LA; 18:2)

***k*=62 $M^{-1}s^{-1}$**



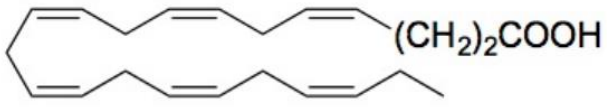
Arachidonic acid (AA; 20:4)

***k*=197 $M^{-1}s^{-1}$**



Eicosapentaenoic acid (EPA; 20:5)

***k*=249 $M^{-1}s^{-1}$**



Docosahexaenoic acid (DHA; 22:6)

***k*=334 $M^{-1}s^{-1}$**

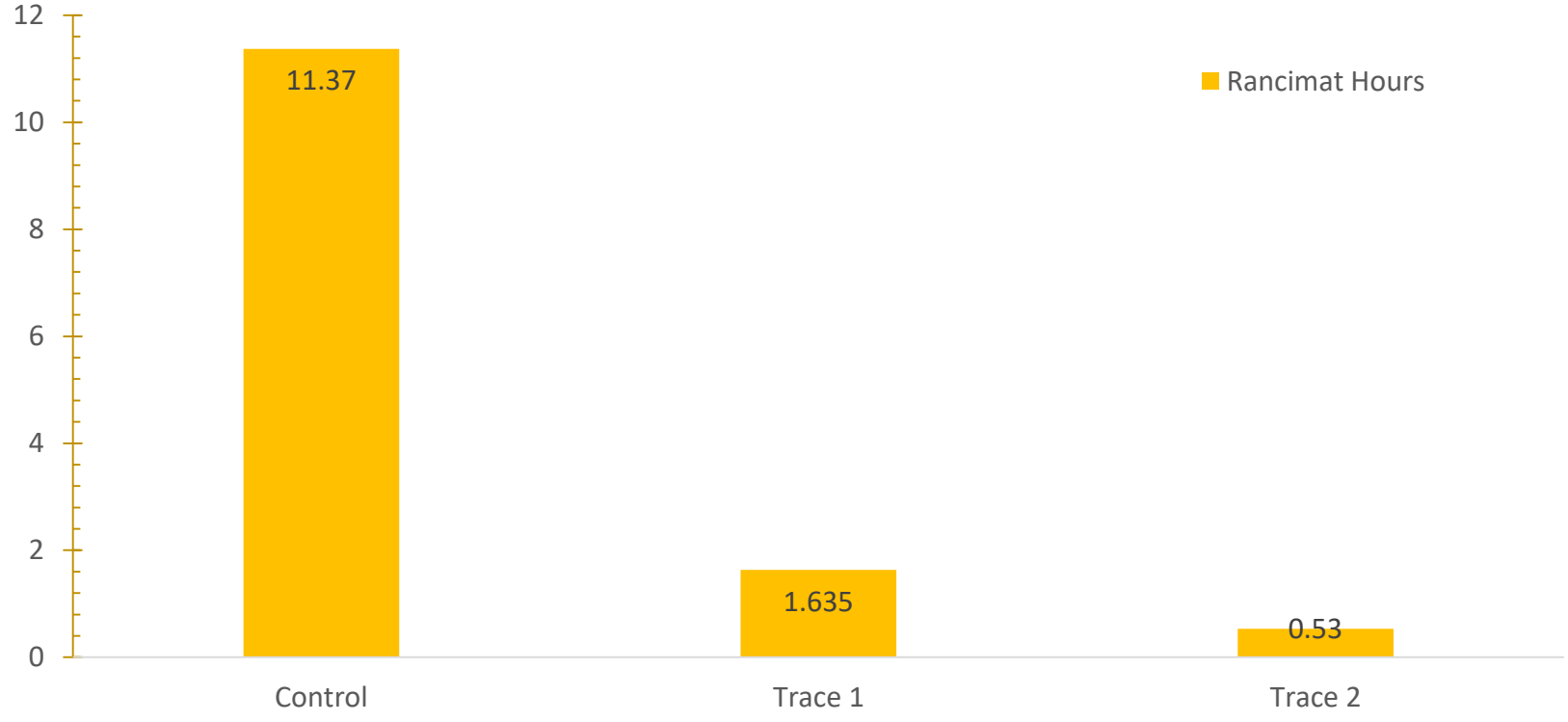
k: hydrogen atom transfer rate constants. After Xu, 2019

FATTY ACIDS PROFILE AND OXIDATIVE POTENTIAL

	Saturated	Mono-unsaturated	Poli-unsaturated	MUFA+PUFA	U/S	Tocopherols Polyphenols	Oxidation Risk
Coconut	86.0	5.9	1.7	7.56	0.09	0.29	*
Bovine tallow	49.8	41.8	4.0	45.8	0.92	2.7	*
Ovine tallow	47.3	40.6	7.8	48.4	1.02	2.8	*
Cotton	25.9	17.8	51.9	69.7	2.69	35.3	*
Palm	49.3	37.0	9.3	46.3	0.94	15.9*	*
Lard	39.2	45.1	11.2	56.3	1.44	0.6	**
Olive	13.5	73.9	10.0	83.9	6.21	15.6*	**
Sunflower HO	9.0	57.3	28.9	86.2	9.58	41.1	**
Soya	14.4	23.3	57.9	81.2	5.64	9.2	***
Corn	12.9	27.5	54.6	82.1	6.36	14.3	***
Chicken fat	29.8	44.7	20.9	65.6	2.2	2.7	***
Canola	7.6	62.1	25.6	87.7	11.52	48.4	***
Menhaden	30.4	26.7	34.2	60.9	2.0		****
Pilchard	29.9	33.8	31.8	65.6	2.19		****
Yellow grease	29.9	49.5	19.4	68.9	2.3	0.6	****
Herring	21.3	56.5	15.6	72.1	3.38		****

Palm: tocotrienols. Olive: polyphenols

LIPID STABILITY WITH TRACE MINERALS



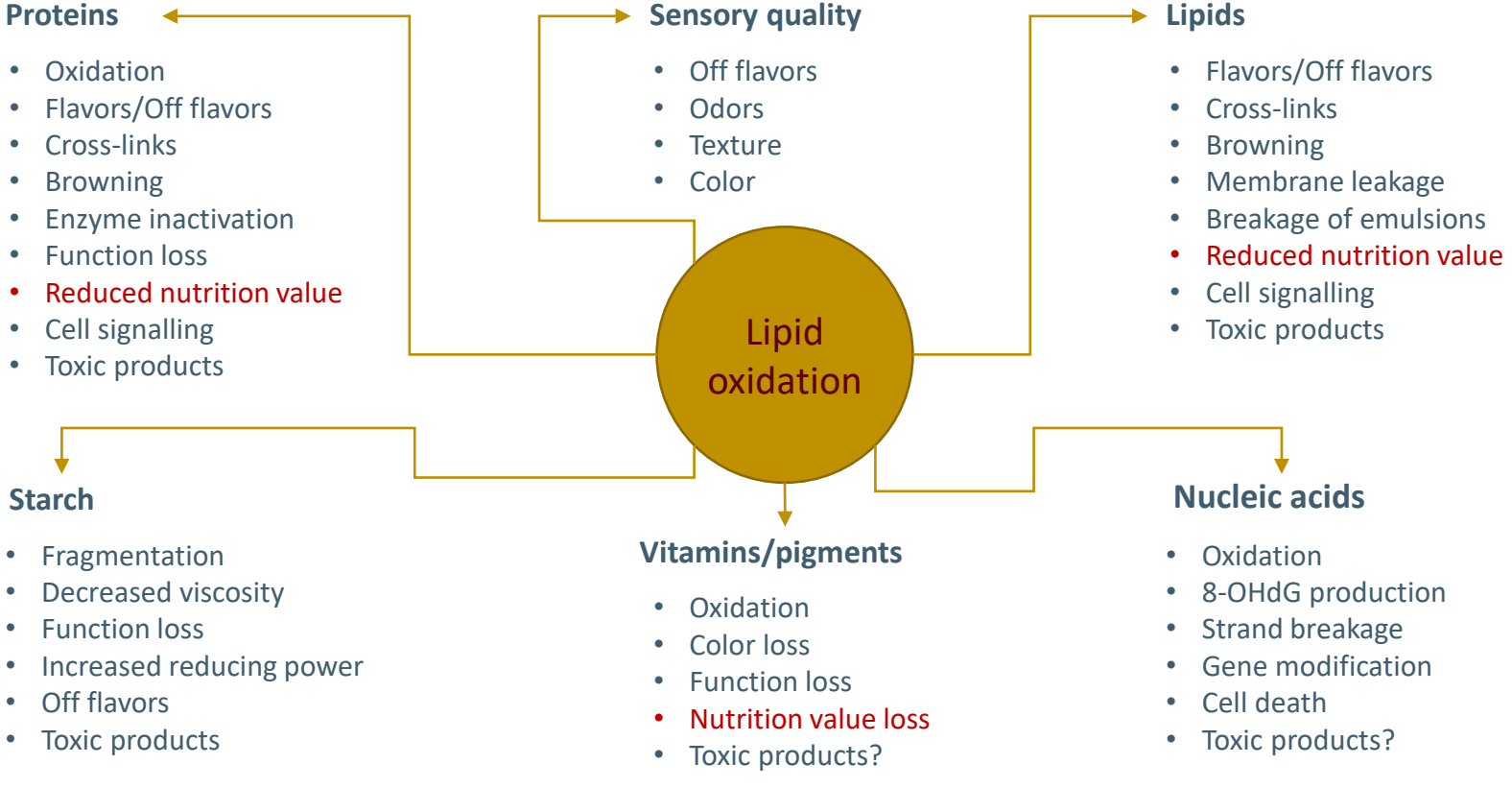
Trace 1: 1.8 ppm Fe + 1.5 ppm Cu. Trace 2: 20 ppm Fe + 16 ppm Cu. Layn, 2019

SOME VOLATILES FROM THE DEGRADATION OF FATTY ACIDS

		Threshold Value (ppm)		
Compound[3]	**Off-Flavor**	**In Oil**		**In Water**
		Odor	**Taste**	**Odor**
Aldehydes				
Pentanal	Sharp, bitter almond	0.24	0.15	0.012
Hexanal	Green—fruity, bitter almond	0.32	0.08	0.008
Octanal	Fatty, soapy—fruity	0.32	0.04	0.0007
Nonanal	Tallowy, soapy—fruity	13.5	0.2	0.001
Decanal	Orange peels	6.7	0.7	0.0001
Nonenal (3c)	Green cucumber	0.25	0.03	
Nonenal (2t)	Tallowy, starch—glue	3.5	0.04	0.0008
Nonadienal (2t,4t)	Fatty, oily	2.5	0.46	
Nonadienal (2t,6c)	Cucumbers	0.01	0.0015	
Nonadienal (2t,6t)	Tallowy, green	0.21	0.018	
Decadienal (2t,4c)	Frying odor		0.02	
Decadienal (2t,4t)	Deep-fried	2.15	0.1	
Ketones and furans				
1-Pentene-3-one	Sharp, fishy		0.003	
1 -Octen-3-one	Metallic			
1 -Octen-3-ol	Moldy, mushroomy	0.077	0.0001	0.00009
2-Pentylfuran	Buttery, beany	2		
2-(1-Pentenyl) furan	Licorice	2 to 6		

Belitz, 1986

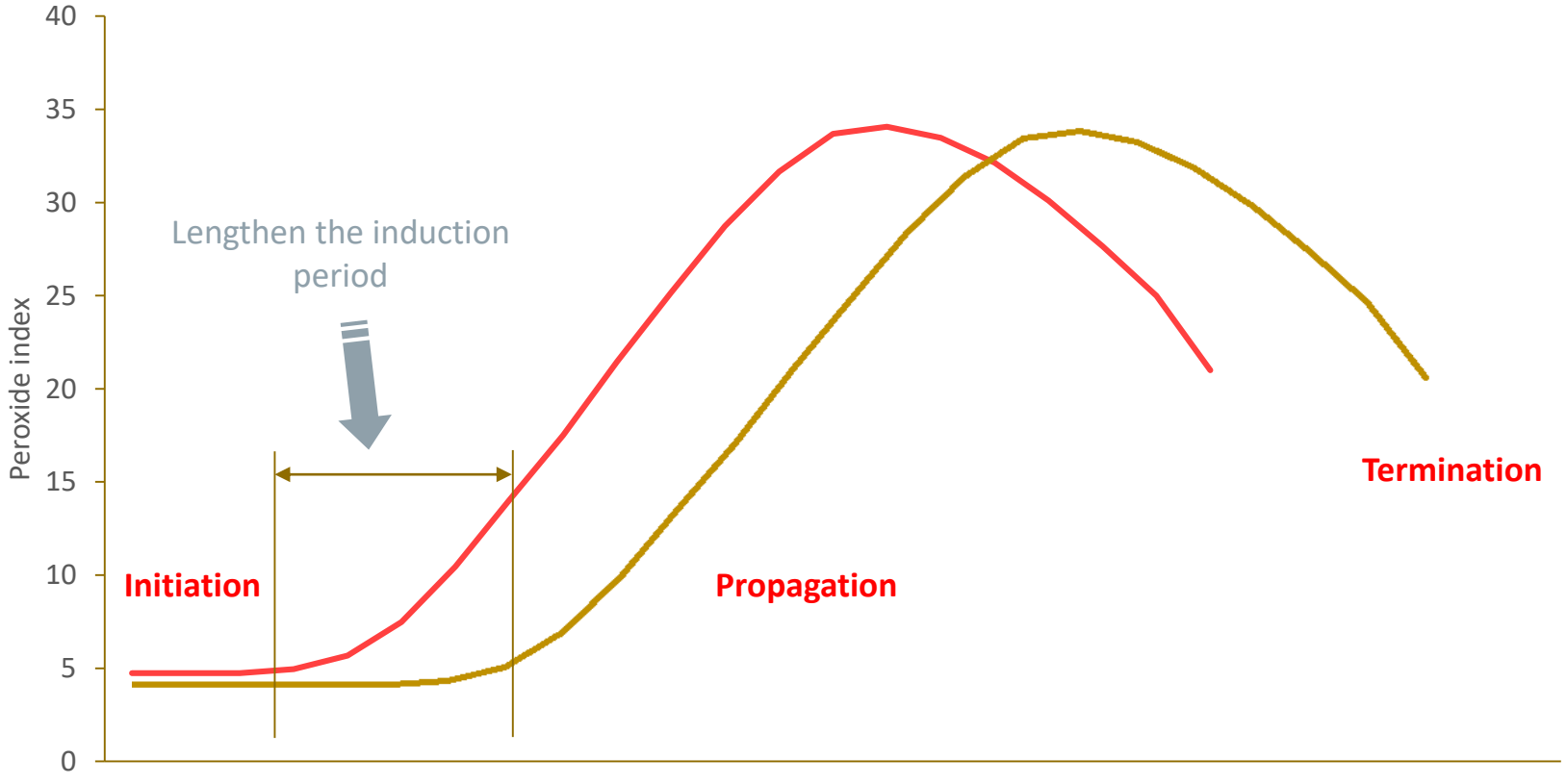
EFFECTS OF OXIDATION IN FOOD AND FEED INGREDIENTS



Schaich, 2014

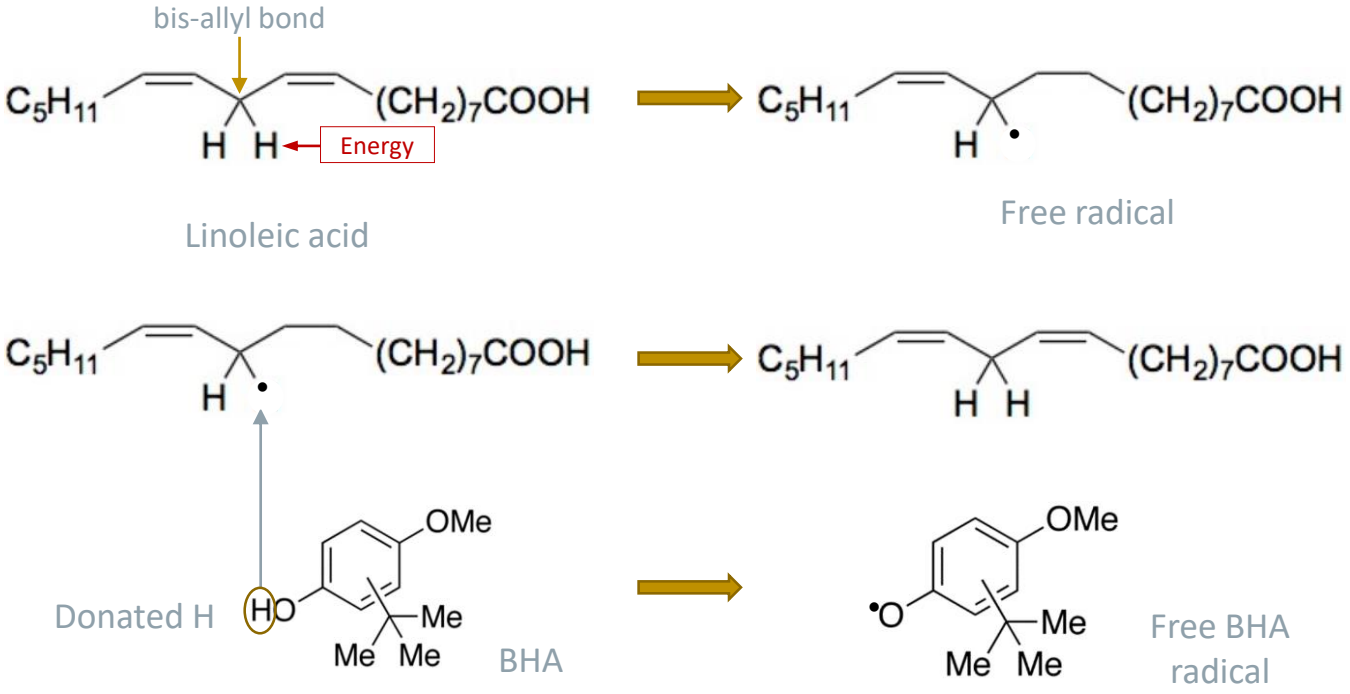
TECHNOLOGY OF ANTIOXIDANTS

THE ROLE OF ANTIOXIDANTS



RADICALARY REACTIONS AND ANTIOXIDANT MECHANISM

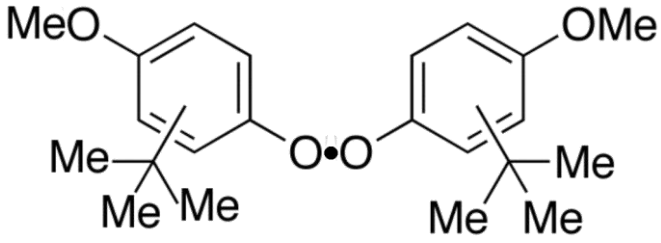
C=C-C=C: 75 kcal/mol
C=C: 88 kcal/mol
C-C: 101 kcal/mol



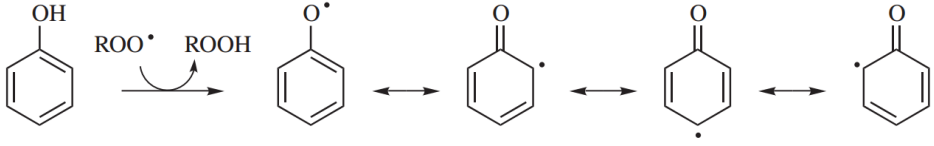
Choe, 2009

ANTIOXIDANT RADICAL NEUTRALIZATION

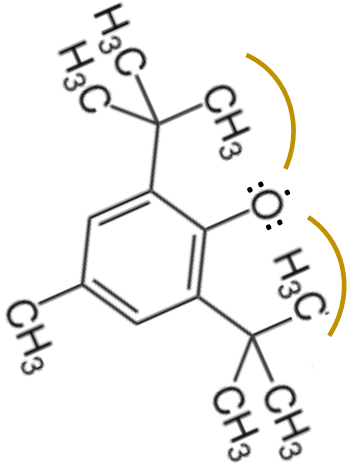
- Neutralization systems
  - Dimerization: two radicals together block the active site.
  - Resonance: delocalization of electron in phenol molecules
  - Steric hindrance: physical occupation by tert-butyl groups



Dimerization



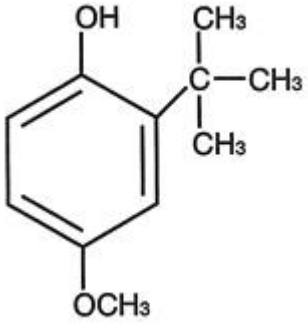
Resonance



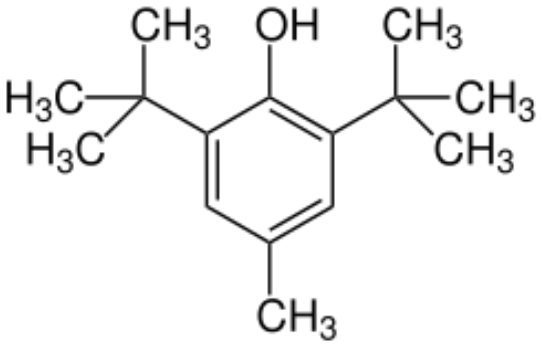
Steric hindrance

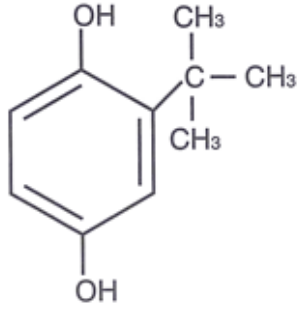
TYPES OF ANTIOXIDANTS: SYNTHETIC

BHA

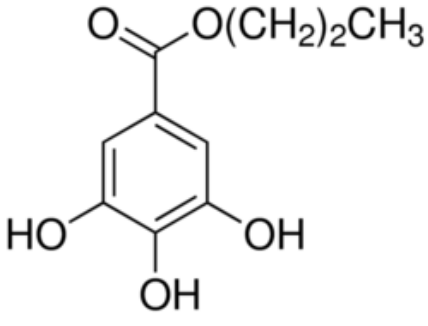


BHT

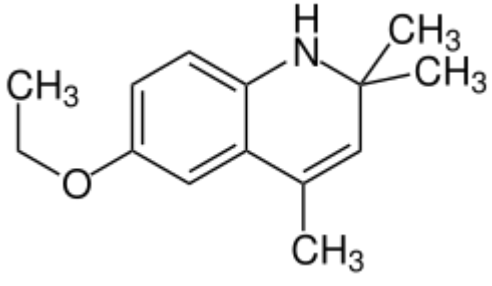




TBHQ

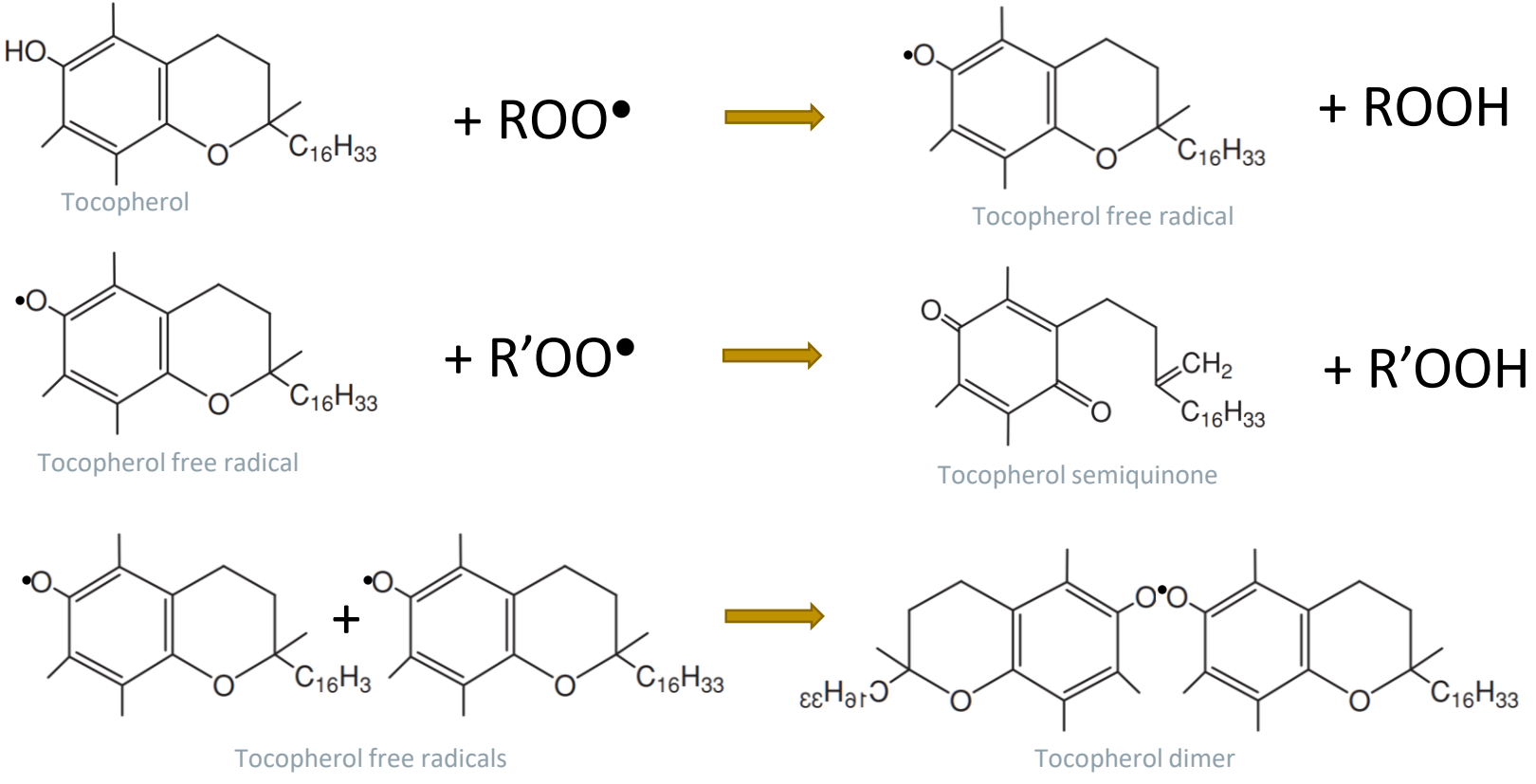


Propyl gallate



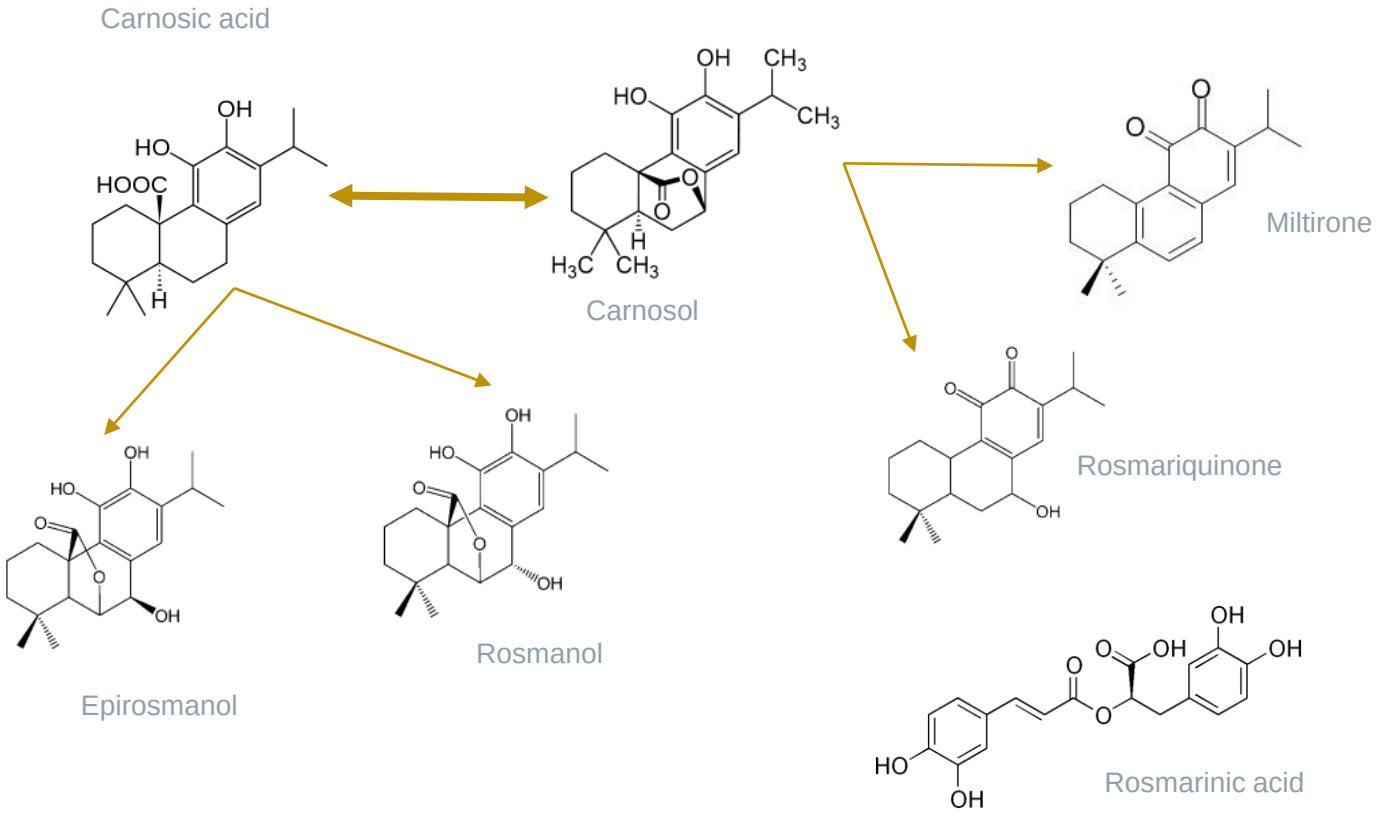
ETQ

NATURAL ANTIOXIDANTS: TOCOPHEROLS

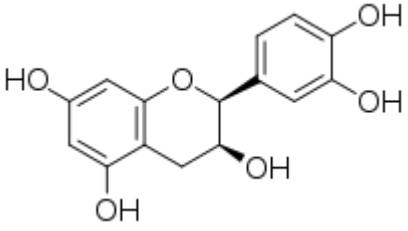


 Adapted from Choe, 2009

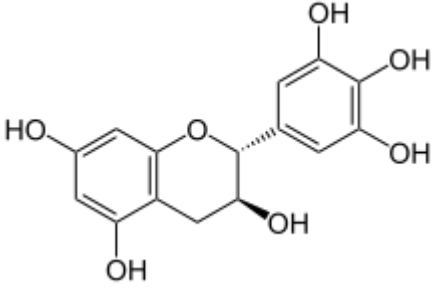
NATURAL ANTIOXIDANTS: DITERPENES FROM ROSEMARY



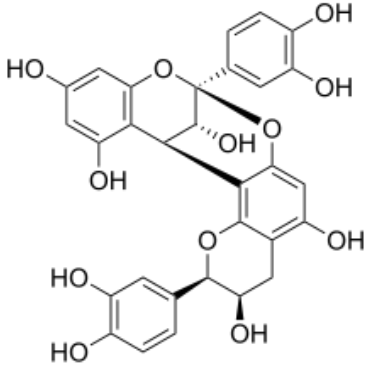
NATURAL ANTIOXIDANTS: CATECHIN AND GALLIC ACID DERIVATIVES



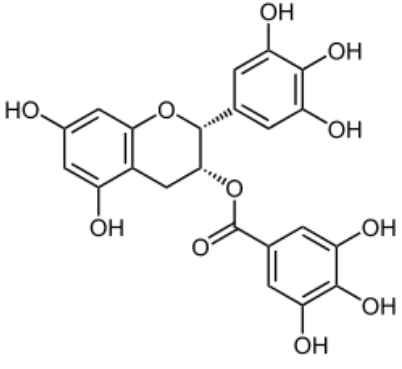
Catechin



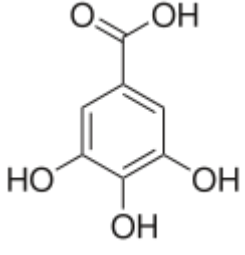
Gallocatechol



Procyanidin A2

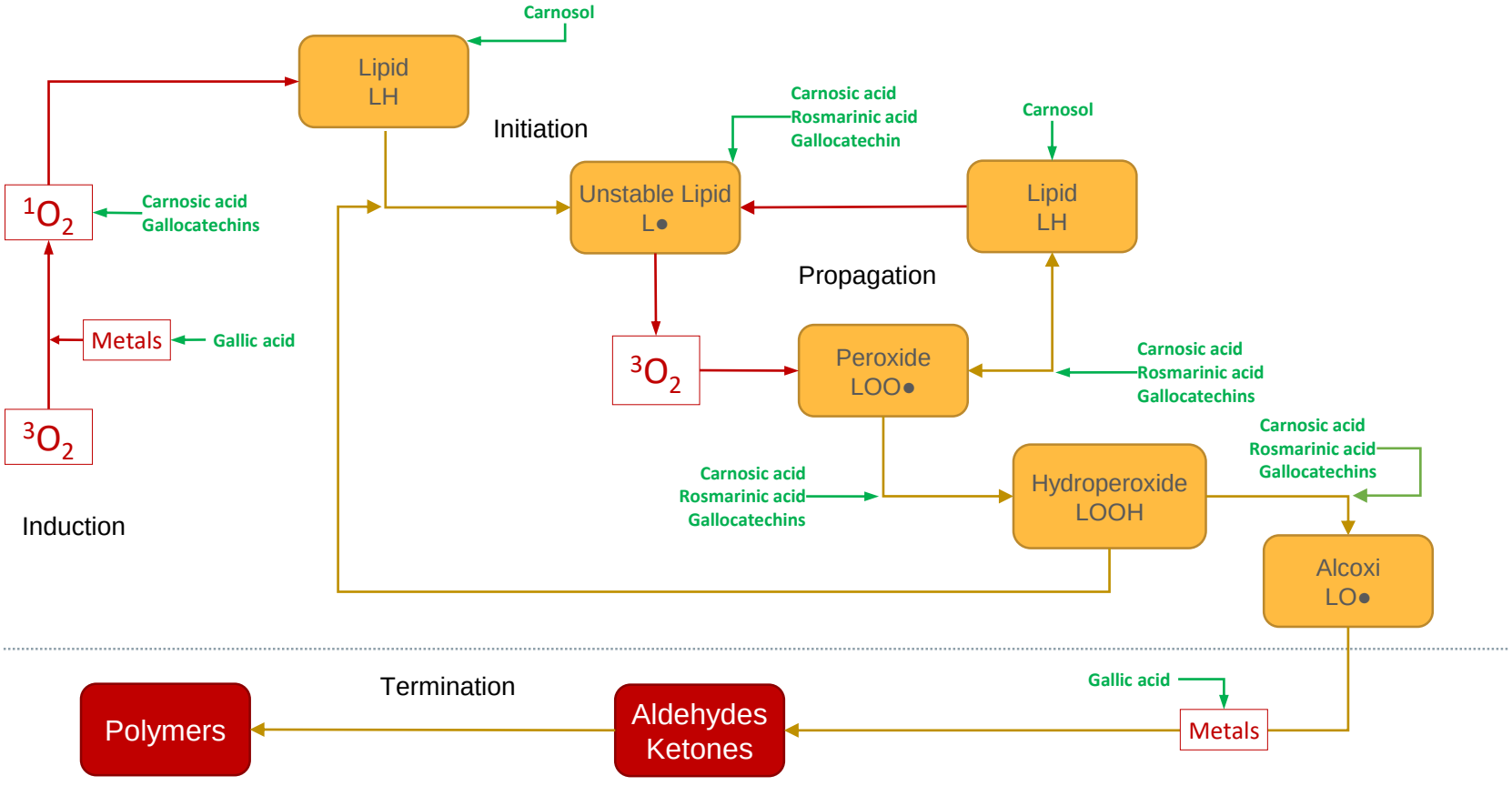


Epigallocathechin gallate



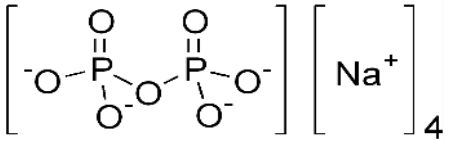
Gallic acid

ANTIOXIDANT FUNCTIONS OF POLYPHENOLS IN LIPID OXIDATION

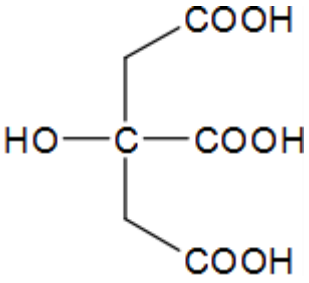


CHELATING AGENTS

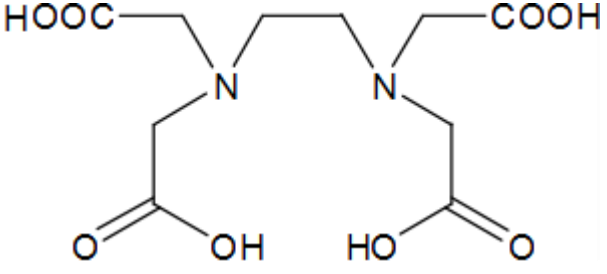
- Block metals and avoid their activity upon the antioxidant
- Reversible: release metal ions in the gut
  - Citric acid
  - Ascorbic acid
  - Tartaric acid
  - Phosphates
- Irreversible: do not release metal ions
  - EDTA



Trisodium phosphate

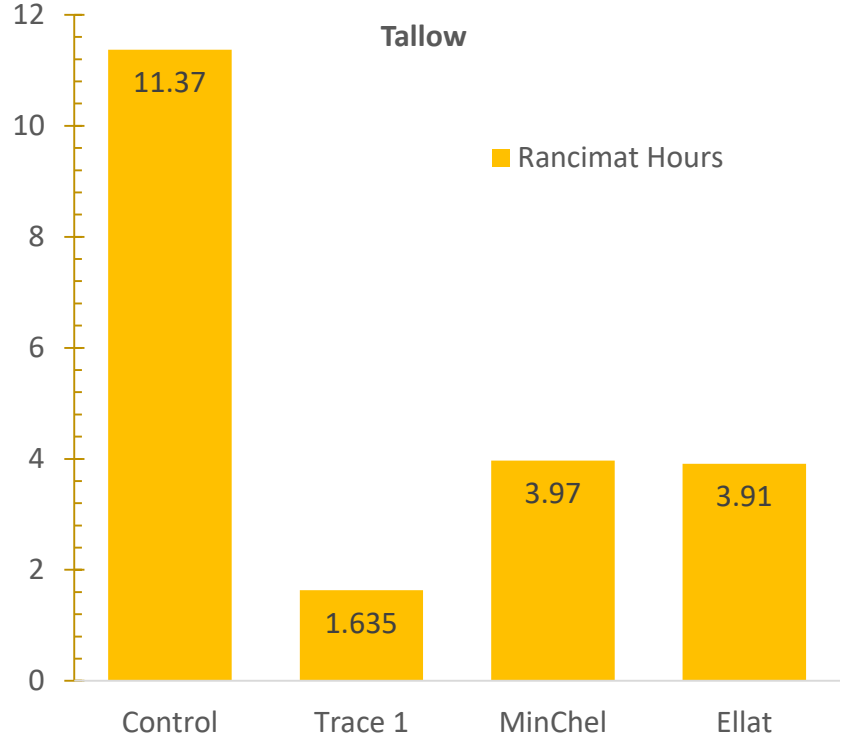


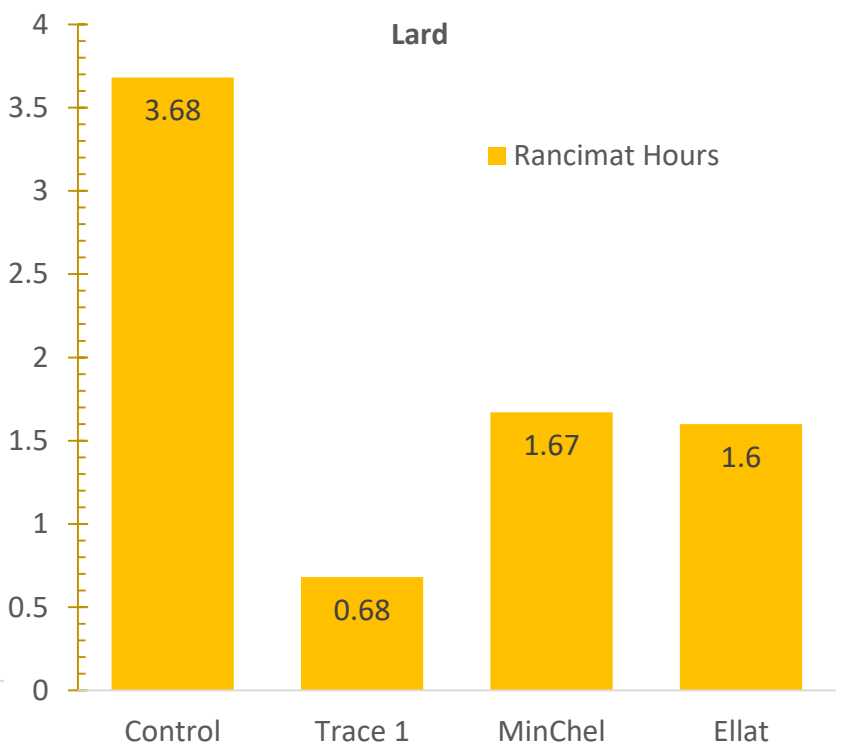
Citric acid



EDTA

TRACE MINERALS AND CHELATING AGENTS ON LIPID STABILITY





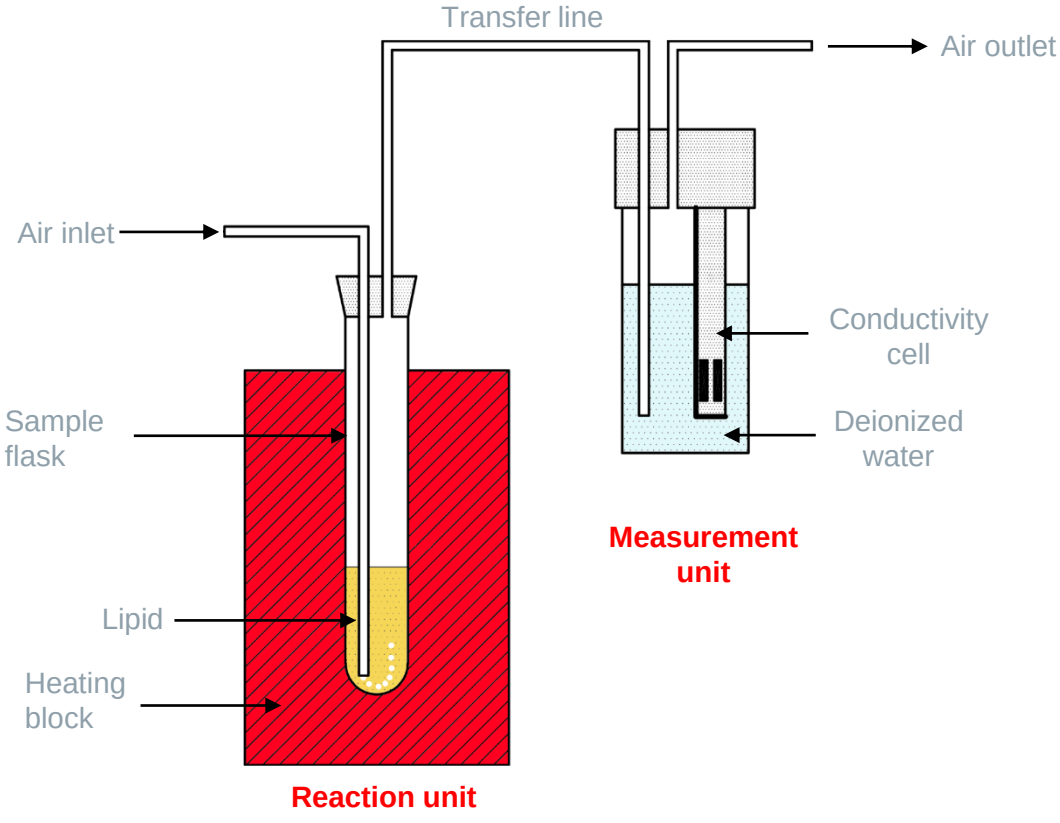
Trace 1: 1.8 ppm Fe + 1.5 ppm Cu. Minchel: citric acid + sodium phosphate, 64 ppm. Ellat: ellagitannins, 60 ppm. Layn, 2019

TruGro® AOX ASSESSMENT

PROCEDURE FOR EVALUATING TruGro® AOX IN FATS AND OILS

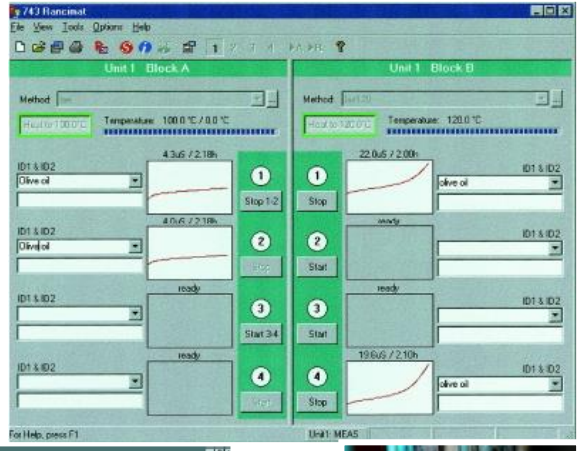
- Indicator: Oil Stability Index (OSI)
- Technology: Rancimat
- Substrate: several types of lipids
- Reference: synthetic antioxidants
    - BHA 150 ppm
    - BHT 150 ppm

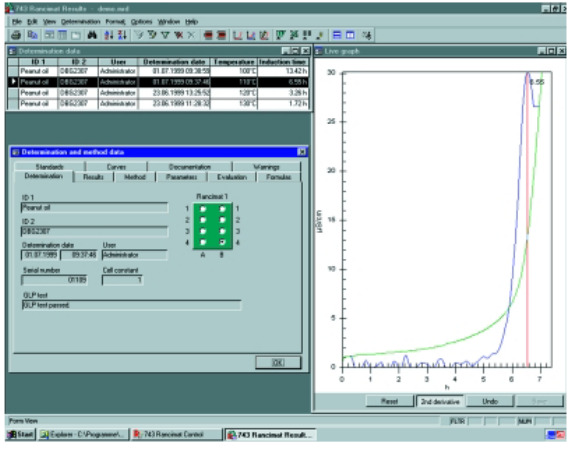
RANCIMAT BLOCK DIAGRAM



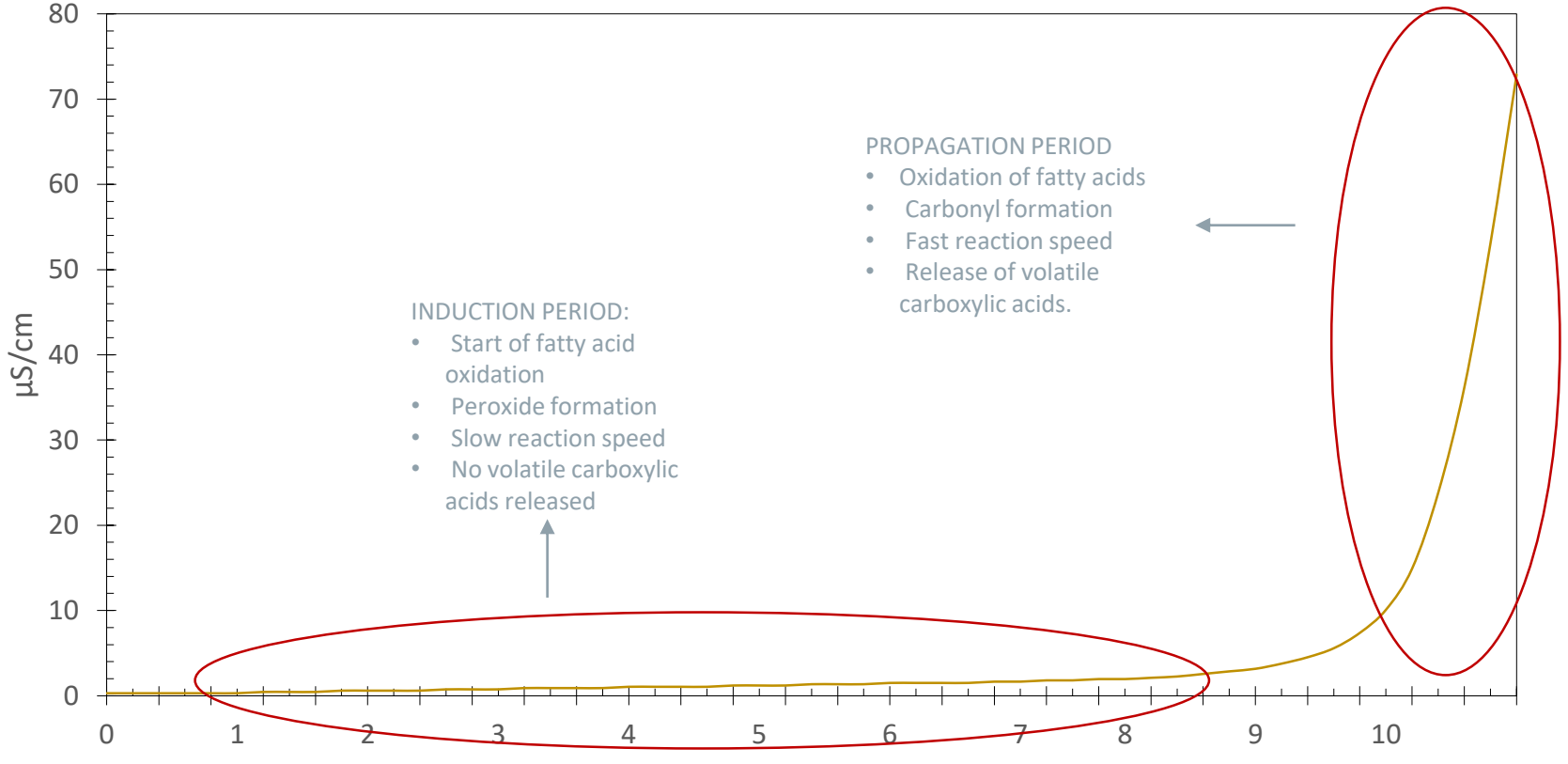
Adapted from En ISO 6886:2006.

RANCIMAT DEVICE





RESULTS PLOT



SUBSTRATE CHARACTERISTICS

Fatty acid, %	Sunflower	Soy	Palmolein	Lard	Tallow
Caprilic	0.04		0.05		
Capric	0.03		0.04		
Lauric	0.22	0.01	0.42	0.11	0.09
Myristic	0.13	0.08	0.83	1.4	3.24
Myristoleic		0.01	0.0	0.02	0.64
Pentadecanoic	0.02	0.13	0.05	0.07	0.62
Palmitic	3.87	10.58	37.2	25.23	25.5
Palmitoleic	0.12	0.12	0.2	1.79	3.46
Margaric	0.03	0.09	0.09	0.41	1.52
Margaroleic	0.04	0.05	0.03	0.41	0.59
Estearic	3.4	3.53	4.98	17.62	17.79
Oleic	78.35	26.52	43.88	35.63	36.29
Trans C18:1 isomers	0.02	0.04	0.11	0.25	5.08
Linoleic	11.51	51.18	10.83	14.08	2.92
Trans C18:2 isomers	0.16	0.19	0.26	0.07	0.57
Linolenic	0.01	5.67	0.05	0.084	0.28
Saturated fatty acids, %	7.74	14.42	43.66	44.84	48.76
Unsaturated fatty acids, %	90.21	83.78	55.36	52.33	49.83
U/S ratio	**11.66**	**5.81**	**1.27**	**1.17**	**1.02**

RESULTS FROM RANCIMAT DETERMINATIONS

Polyphenol-based antioxidants against industry-standard synthetics				
	Run 1	**Run 2**	**Mean**	**% stability increase**
Soy oil				
Blank	5.65	5.60	5.63	
BHA 150 ppm	5.74	5.62	5.68	0.89
BHT 150 ppm	6.24	6.05	6.15	9.24
AOX 1112 150 ppm	6.68	6.94	6.81	20.96
AOX 1113 150 ppm	6.32	6.53	6.43	14.21
Tallow				
Blank	18.56	17.60	18.08	
BHA 150 ppm	36.78	36.44	36.61	102.49
BHT 150 ppm	21.35	21.41	21.38	18.25
AOX 1112 150 ppm	45.12	43.22	44.17	144.30
AOX 1113 150 ppm	47.90	48.52	48.21	166.65
HO Sunflower				
Blank	15.04	14.56	14.80	
BHA 150 ppm	16.62	16.55	16.58	12.03
BHT 150 ppm	17.32	17.27	17.29	16.82
AOX 1112 150 ppm	20.96	21.18	21.07	42.36
AOX 1113 150 ppm	19.09	19.19	19.14	29.32

COMPARISON WITH NATURAL ANTIOXIDANTS IN UNSATURATED AND SATURATED LIPIDS

Effect of several antioxidants on sunflower oil stability				
	Run 1	**Run 2**	**AVG**	**% stability increase**
Blank	2.61	2.54	2.58	
Rosemary extract 1, 650 ppm	2.88	2.93	2.91	12.82
Rosemary extract 2, 650 ppm	2.82	2.79	2.81	8.93
Rosemary extract 3, 650 ppm	2.94	2.99	2.97	15.15
Layn Green Tea extract OS, 1000 ppm	5.09	5.08	5.09	97.48

Effect of several antioxidants on bovine tallow stability				
	Run 1	**Run 2**	**AVG**	**% stability increase**
Blank	9.90	9.87	9.88	
Rosemary extract 1, 650 ppm	29.6	29.2	29.40	397.4
Rosemary extract 2, 650 ppm	30.51	30.11	30.31	406.6
Rosemary extract 3, 650 ppm	30.62	30.30	30.46	408.1
Layn Green Tea extract OS, 1000 ppm	44.23	44.74	44.48	550.0

CONCLUSION

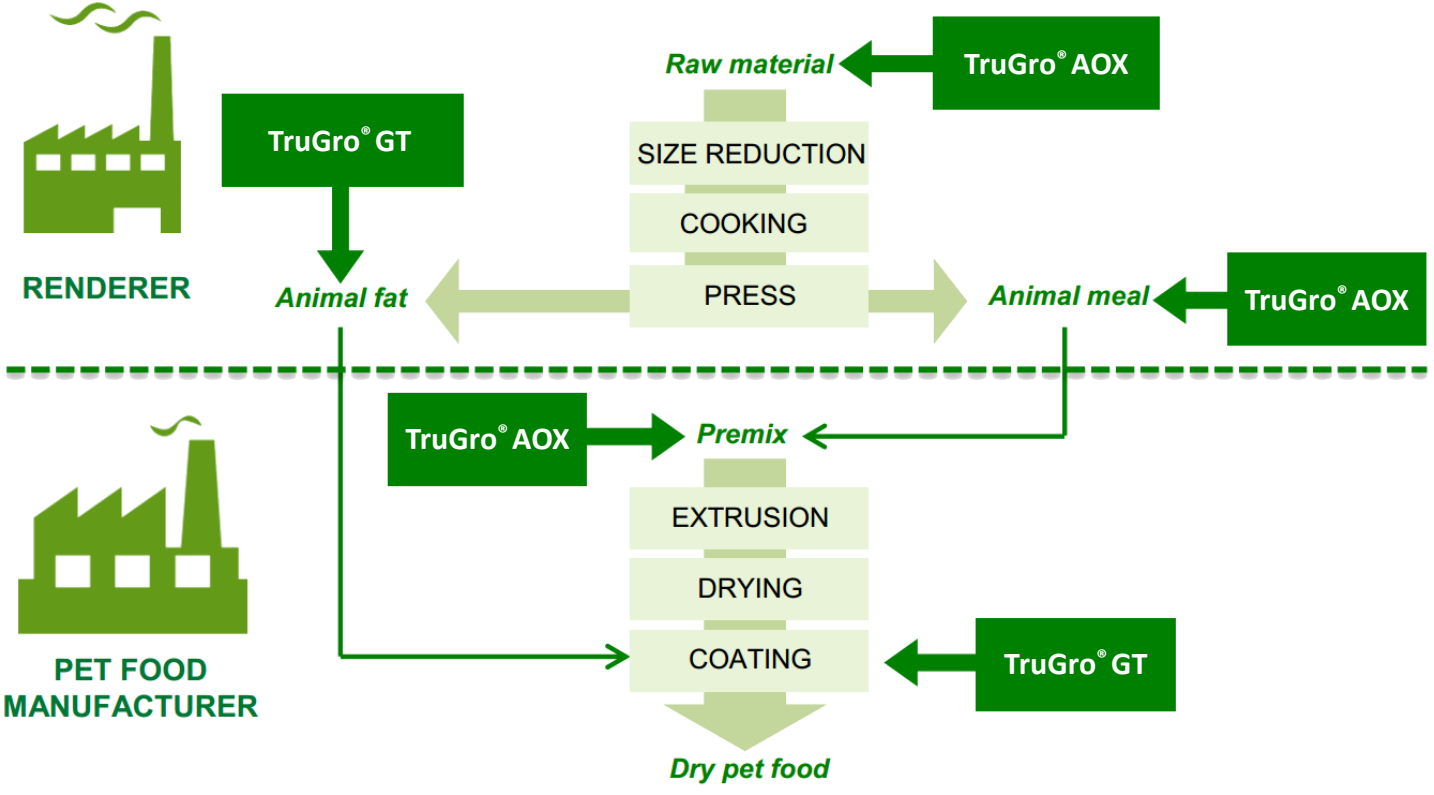
ATTRIBUTES OF POLYPHENOL-BASED LIPID ANTI OXIDANTS

- Adequacy
  - By using a selected combination of standardized botanical extracts with high polyphenol content, it has been possible to increase lipid stability under the analytical conditions used.
  - This research shows selected polyphenol combinations improves on the antioxidant protection afforded by two synthetic compounds.
- Specificity
  - This research shows the lipid's unsaturation index influences the efficacy of polyphenol combinations. In practical terms, this means the knowledge of the U/S ratio would modulate usage for a particular application, mandating different ingredient combinations for maximum response.
- Implications
  - When consumer choice forces the level of synthetics being reduced or altogether removed, polyphenol antioxidants constitute an alternative solution to lipid stability in pet food systems.

RECOMMENDED PRODUCTS

- TruGro® AOX 1112
  - A selected combination of standardized botanical extracts being the choice antioxidant product for lipids with high unsaturation index: soy oil, canola oil, peanut oil, sunflower oil or palmoleins.
  - Add to dry feed at a rate of 30 ppm/1% fat, for 18 months shelf life
- TruGro® AOX 1113
  - A selected combination of standardized botanical extracts being the choice antioxidant product for lipids with low unsaturation index: lard or tallow
  - Add to dry feed at a rate of 30 ppm/1% fat, for 18 months shelf life
- TruGro® GT OS
  - A selected combination of standardized botanical extracts being the choice antioxidant product for lipids with high unsaturation index for external kibble coating: soy oil, canola oil, peanut oil, sunflower oil, or chicken oil.
  - Add to cover lipids at a rate of 10 ppm/1% fat, for extended shelf life.

ANTIOXIDANT APPLICATION PATTERN IN THE INDUSTRY



THANK YOU

Questions?

Enquiries?

Sample requests?