

Functional food (functional fermented beverages and edible oils): when science meets bioeconomy and creates health lifestyle — Online Module

Functional edible oils

Cold-pressed edible oils

Virgin oils are very popular as 100% natural products with a deep color, typical taste, and smell, produced only with cold-pressing and without any step of refining [1].

On international scale the Codex Alimentarius Standard for Named Vegetable Oils differentiates between **virgin** and **cold-pressed oils**. According to the international definition, every virgin oil is cold-pressed oil but not every cold-pressed oil is virgin because **roasting of the seeds before cold-pressing is not allowed during production of virgin oils**. Edible oils produced this way are good sources of tocopherols, carotenoids and chlorophylls, polyphenols, and other antioxidants with positive impact on human health [2]. Vegetable oils take a very popular place in human nutrition due to the high level of polyunsaturated fatty acids and tocopherols [3]



<https://www.eatthis.com/affordable-olive-oils-that-taste-expensive/>

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A positive relation between vegetable oil consumption and reduced risk of coronary heart diseases level of LDL, degenerative diseases, and cancer is very well known [4]. The most important virgin oil in the western part of Europe, after olive oil, is rapeseed oil. High levels of monounsaturated fatty acids and lower levels of polyunsaturated fatty acids (below 30%) make this virgin oil suitable for cooking and another with range of applications [5, 6]. The most important compounds responsible for health-promoting activities are:

- mono and polyunsaturated fatty acids,
- vitamin E – active compounds,
- phytosterols and
- polyphenols as a very important minor compounds



<https://www.greendna.in/products/sunflower-oil>

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Cold-pressed edible oils:

Sunflower oil

Classical sunflower oil fatty acid composition is saturated acids 11% (stearic, palmitic), oleic 20% and linoleic acid 69% [7].

Cold-pressed and refined sunflower oils rich in linolenic acid, are particularly susceptible to undesirable changes during deep-frying [8, 9]. Frying oils made from sunflower have lower stability because of their high polyunsaturated fatty acids and low γ -tocopherol content.

Olive oil

Heart Protection: Rich in monounsaturated oleic acid, it helps lower "bad" LDL cholesterol and blood pressure while maintaining good HDL cholesterol.

Anti-Inflammatory Effects: It contains a natural compound called **oleocanthal**, which works similarly to ibuprofen to reduce inflammation in the body

Brain and Cognitive Support: Regular consumption helps protect brain cells from oxidative stress, lowering the risk of cognitive decline and Alzheimer's disease

Blood Sugar Regulation: It improves insulin sensitivity, which helps prevent and manage type 2 diabetes

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Cold-pressed edible oils:

Flaxseed oil

Heart Health: High levels of ALA help lower blood pressure, improve arterial elasticity, and reduce bad LDL cholesterol.

Reduces Inflammation: Regular intake can decrease inflammatory markers like C-reactive protein in the body.

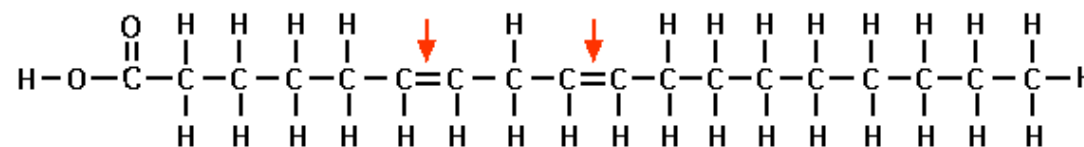
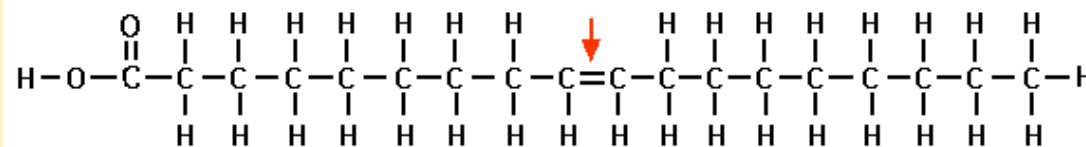
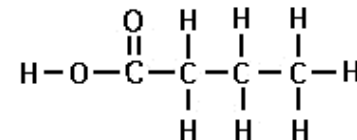
Improves Skin: Essential fatty acids and antioxidants promote skin hydration, smoothness, and help soothe irritation from conditions like dermatitis.

Aids Digestion: Acts as a gentle natural lubricant in the colon to help relieve constipation.



<https://www.midlandsnz.com/health-oils-superfoods/resources/the-science-behind-cold-pressed-flaxseed-oil-why-it-matters-for-manufacturers>

Flaxseed oil is a richest source of α -linolenic acid (ALA) with 55.1% of total abundance.



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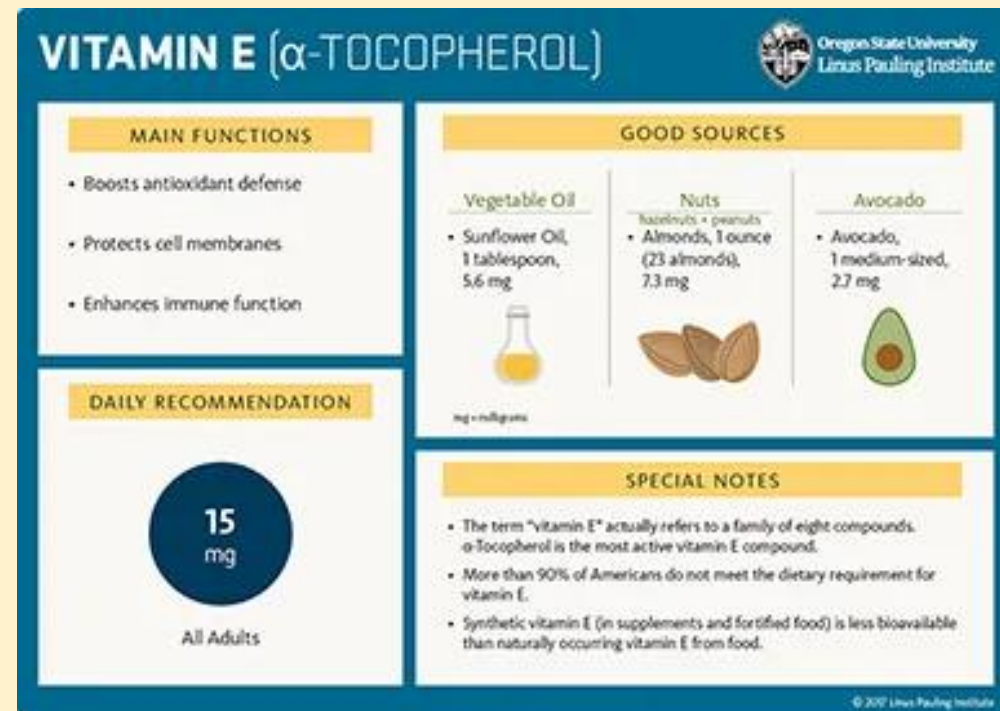
Cold-pressed edible oils

Vitamin-E-active compounds

Sunflower oil **Alpha-tocopherol**: The primary form present (approx. 20–59 mg/100 g depending on the source and seed variety), representing the highest concentration of vitamin E among common commercial vegetable oils.

Olive oil **Alpha-tocopherol** makes up 90% to 97% of the total tocopherol content. Concentrations usually range from 100 mg to 300 mg/kg (or 10 to 30 mg per 100g) in virgin olive oils.

Flaxseed oil **Gamma-tocopherol (γ-tocopherol)** is the dominant form, making up roughly **75% to 98%** of all tocopherols in flaxseed oil.



<https://lpi.oregonstate.edu/mic/vitamins/vitamin-E>

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Phytosterols

Phytosterols are plant sterols with structure similar to cholesterol. They are minor constituents in oils and normal constituents of human diet.

Phytosterols, primarily β -sitosterol, campesterol, and stigmasterol are membrane constituents of plants that effectively reduce serum LDL cholesterol and atherosclerotic risk. Their presence in the oils frequently is connected to higher antioxidant activity [21].

δ 5-avenasterol was found to be the second most abundant sterol in almost all examined oils with exception of sunflower oil.



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QUESTION?! HOW TO PRODUCE FUNCTIONAL EDIBLE OIL?

The answer is: by GERMINATION OF THE SEEDS!



Germination of flaxseeds 1th day

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Germination of flaxseeds 3th day

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Germination of flaxseeds 7th day

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Germination of sunflower seeds 3th day

Analysis of the Influence of Germination on Quality Parameters and the Shelf Life of Linseed Oil and Sunflower Oil

TOBIAS POINTNER^{1,2}, KATHARINA RAUH¹, ARTURO AUÑON-LOPEZ^{1,2}, SANJA KOSTADINOVIK³, MILA MITREVA⁴, SASA MITREV³, MARC PIGNITTER¹

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³ Goce Delchev University, Stip, N. Macedonia

⁴ Agrofila, Stip, N. Macedonia

INTRODUCTION

- Linseeds (*Linum usitatissimum* L.), Sunflower seeds (*Helianthus annuus*)

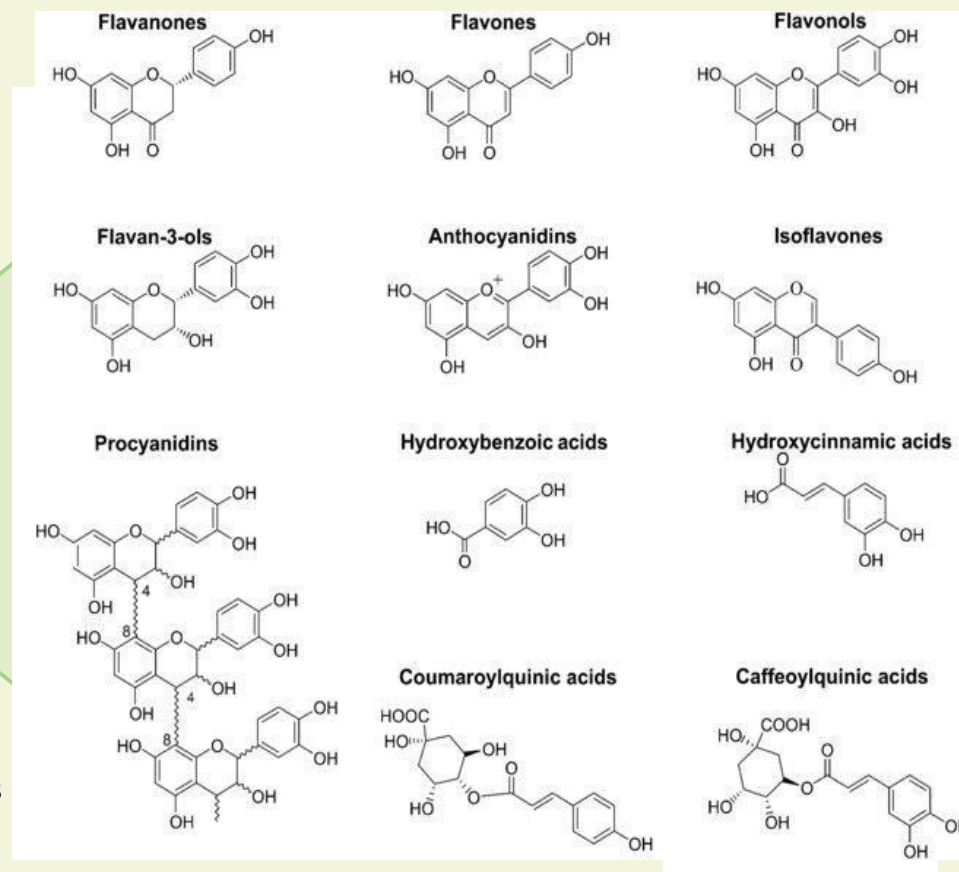
- as food ingredients and oil sources
- nutritional-physiological characteristics
 - important source of unsaturated fatty acids
 - high content of omega-3 fatty acids (linseed oil)
 - Vitamin E

- health benefits

- bioactive substances – Polyphenols
 - anti-inflammatory ¹
 - anti-carcinogenic ²

¹ Hollmann et al. (2011): The Biological Relevance of Direct Antioxidant Effects of Polyphenols

² Limmongkon et al. (2018): LC-MS/MS profiles and interrelationships between the anti-inflammatory activity, total phenolic content and antioxidant potential of Kalasin-2



Germination Process

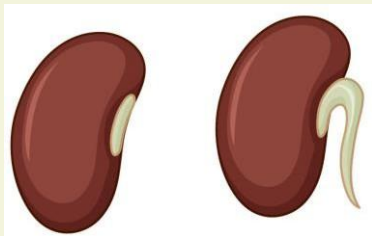
- Traditonell Usage
 - Sprouts, seedlings, bread
- Enzymes and metabolic activities
 - biochemical changes
 - Composition, stability and bioactivity
 - Unsaturated fatty acids ↑
 - Antioxidative capacities ↑



*Swelling, activation
of the embryo*

Germination Process

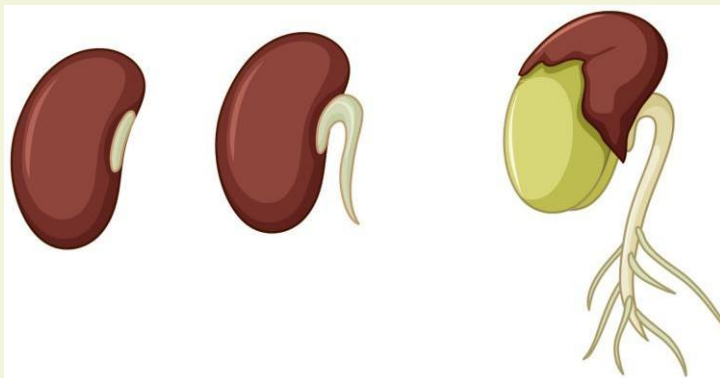
- Traditionally Usage
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Root growth

Germination Process

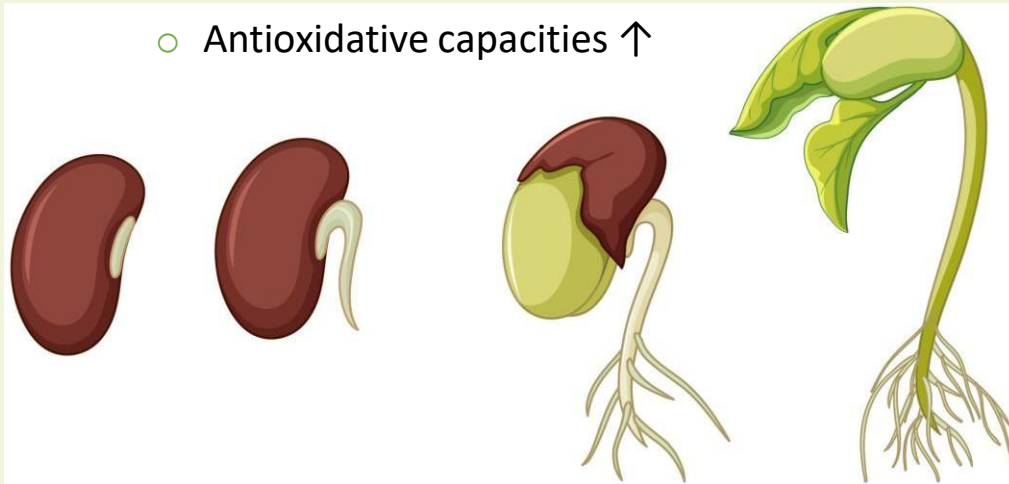
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*Dissolution of the seminal coat by enzymatic reactions
and growth of the embryo*

Germination Process

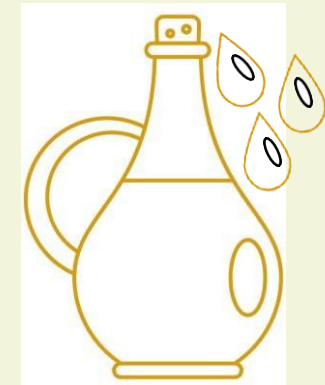
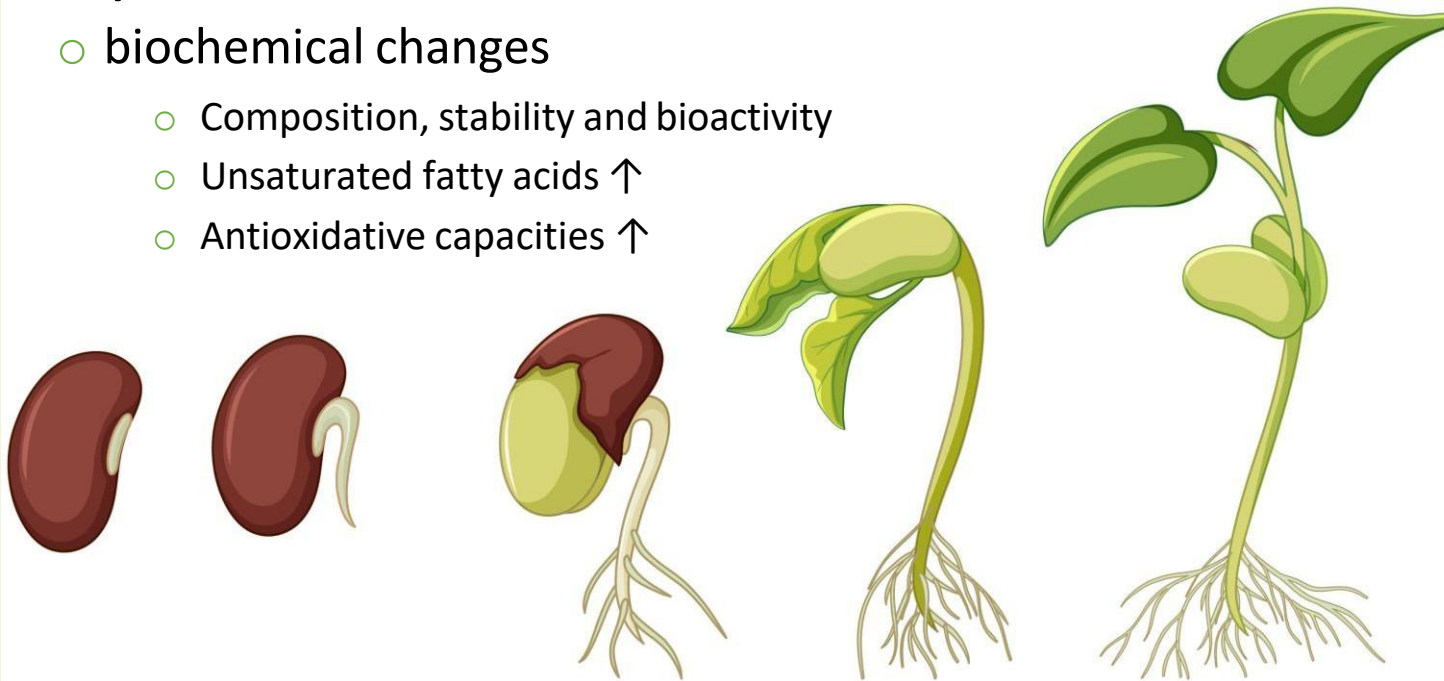
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Cotyledon formation

Germination Process

- Traditionally Usage
 - Sprouts, seedlings, bread
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 - Antioxidative capacities ↑

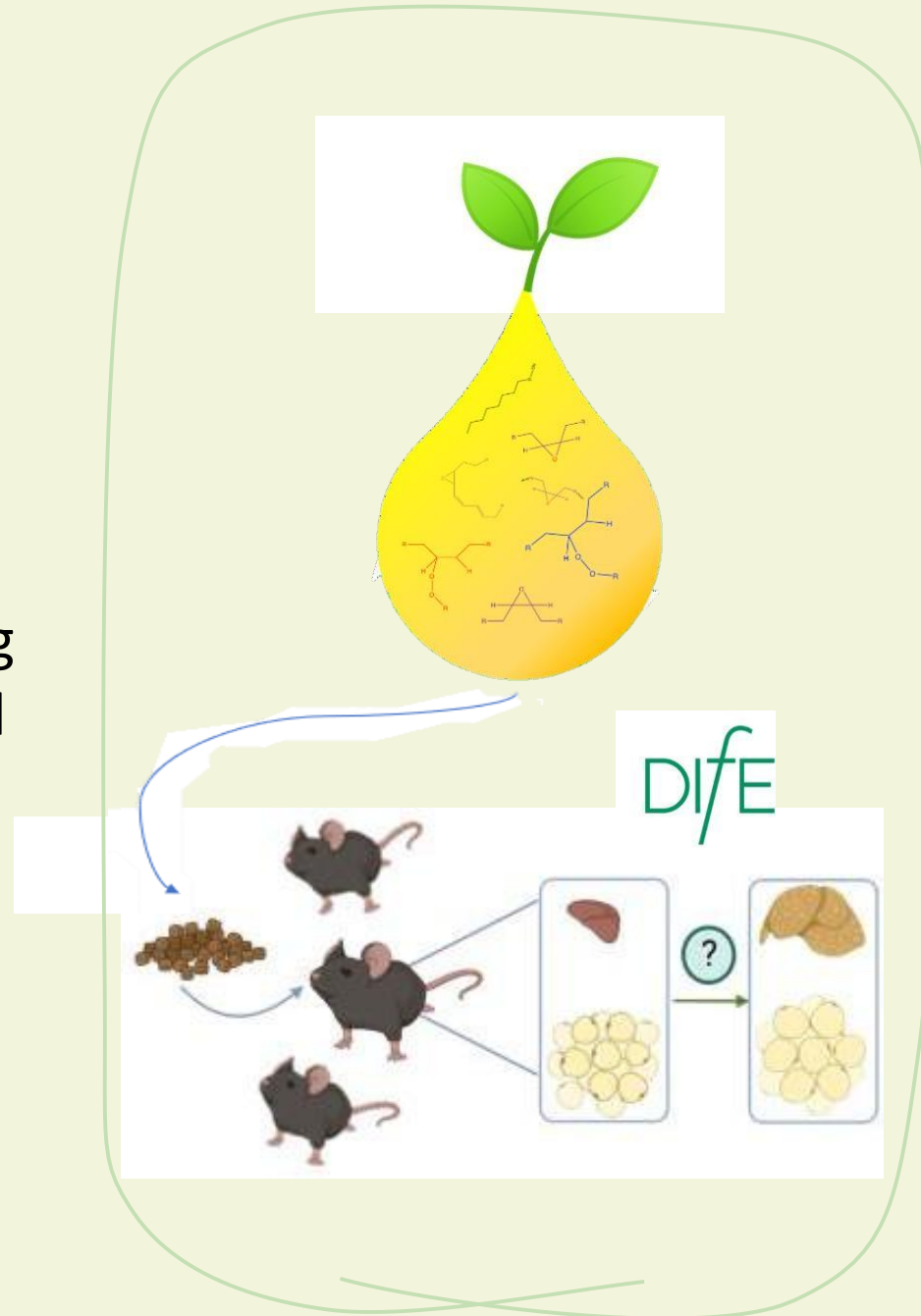


Cold pressing of the seeds to oil

Pajak et al. (2019): Antioxidant properties, phenolic and mineral composition of germinated chia, golden flax and evening primrose

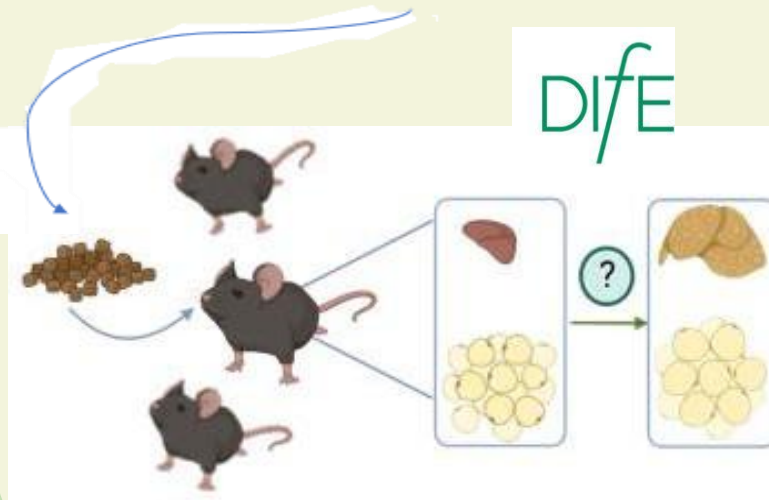
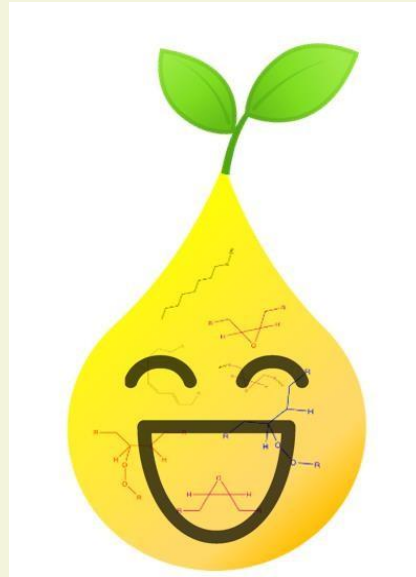
Work Plan

Germinated Oils:
Examining Oxidative
Stability, and Assessing
Health Effects on Lipid
Metabolism

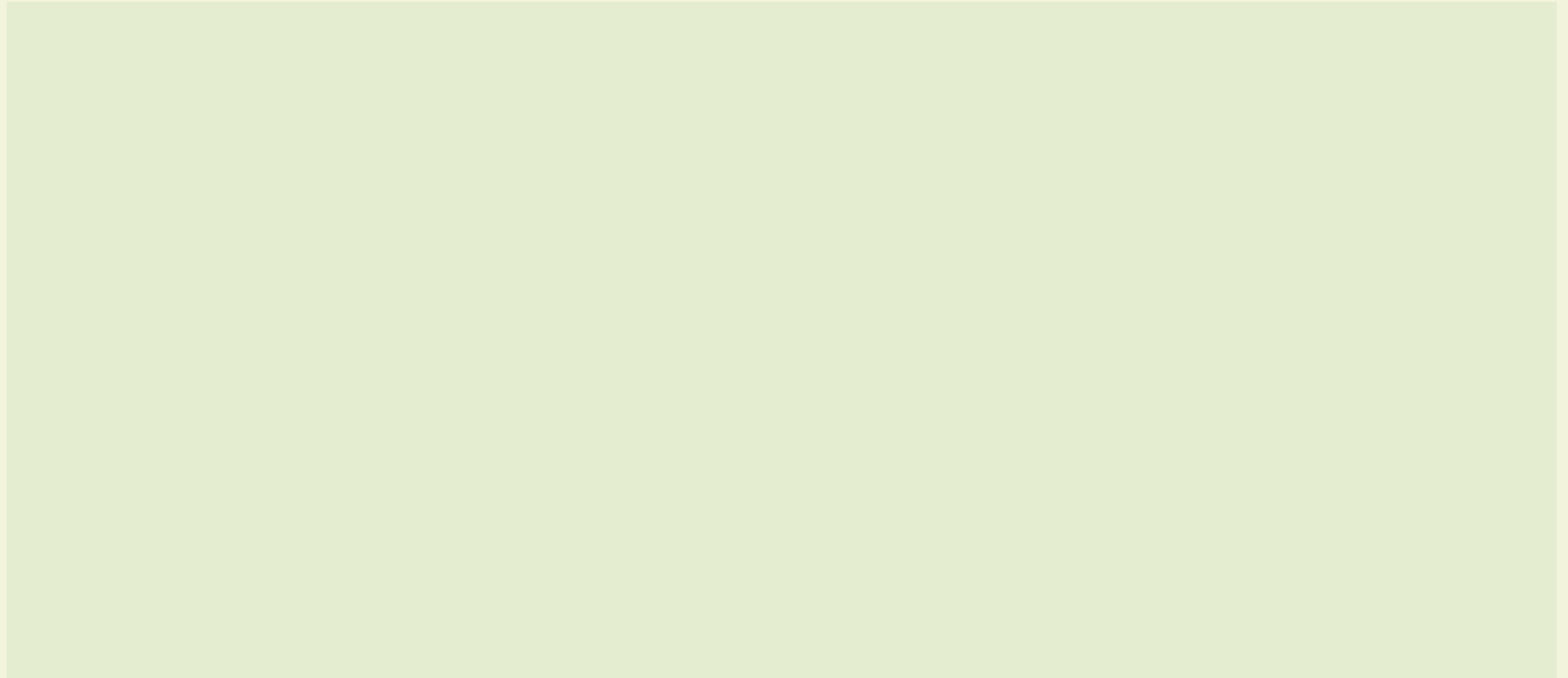
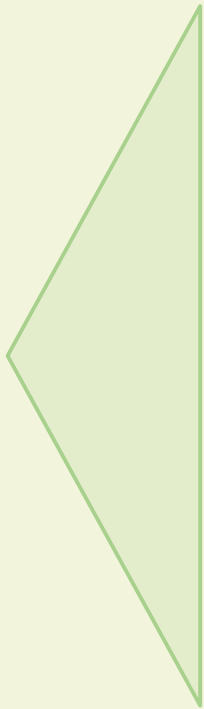
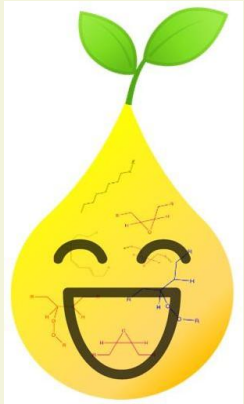


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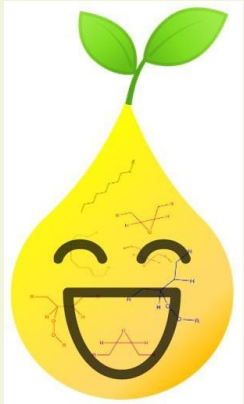
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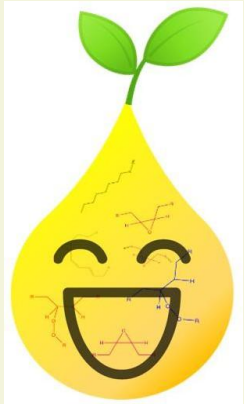


Objectives



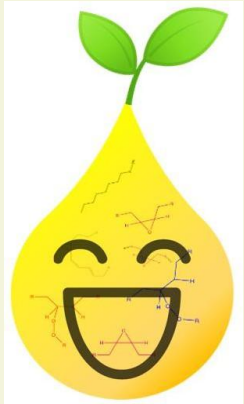
- **positive influence of germination** on physicochemical properties, oxidative stability of cold-pressed oils
 - Unsaturated fatty acids ↑
 - Antioxidants and polyphenols ↑
 - Oxidative stability and longer shelf life ↑
- Promising process to improve oil quality
 - New applications for healthy oils
- Positive effect on lipid metabolism and inflammation
 - Animal study (Lipidomics)

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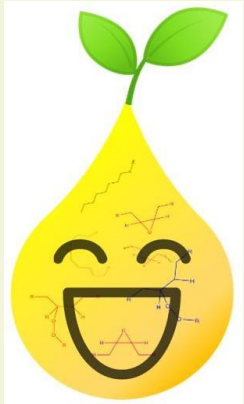
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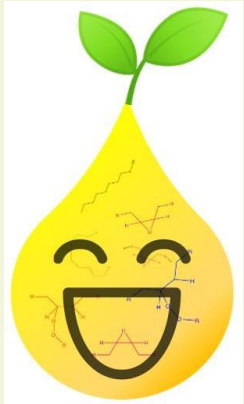
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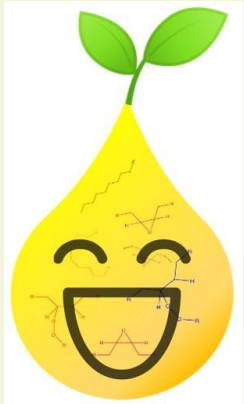
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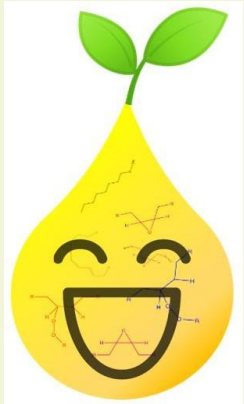
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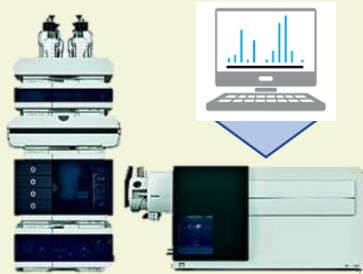
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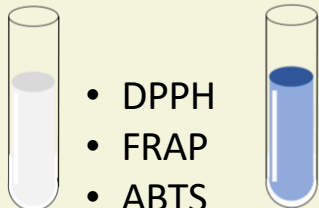


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Methodology



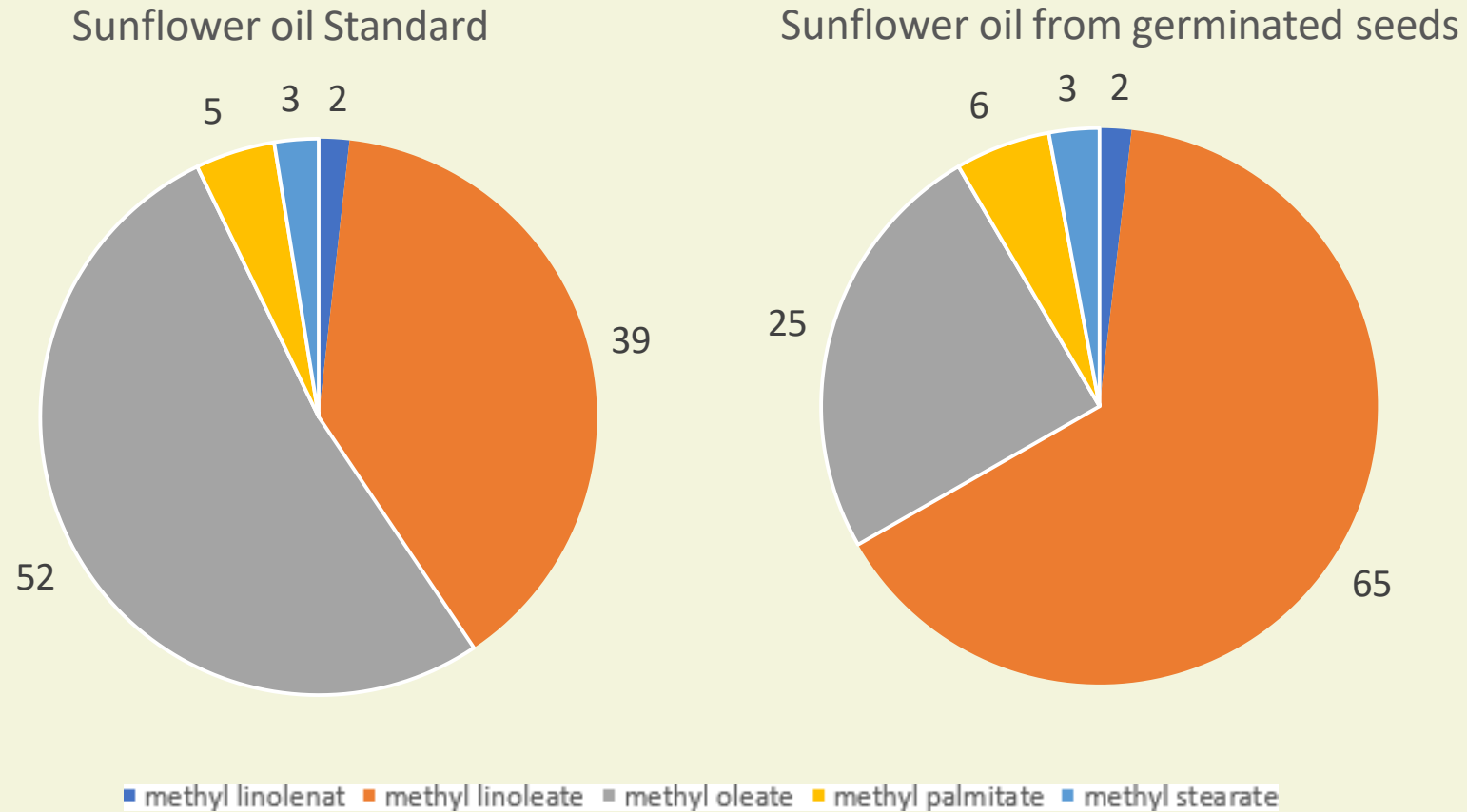
- LC-MS (QTOF, QQQ)
- GC-FID



- DPPH
- FRAP
- ABTS
- Folin–Ciocalteu



Fatty acid profiles

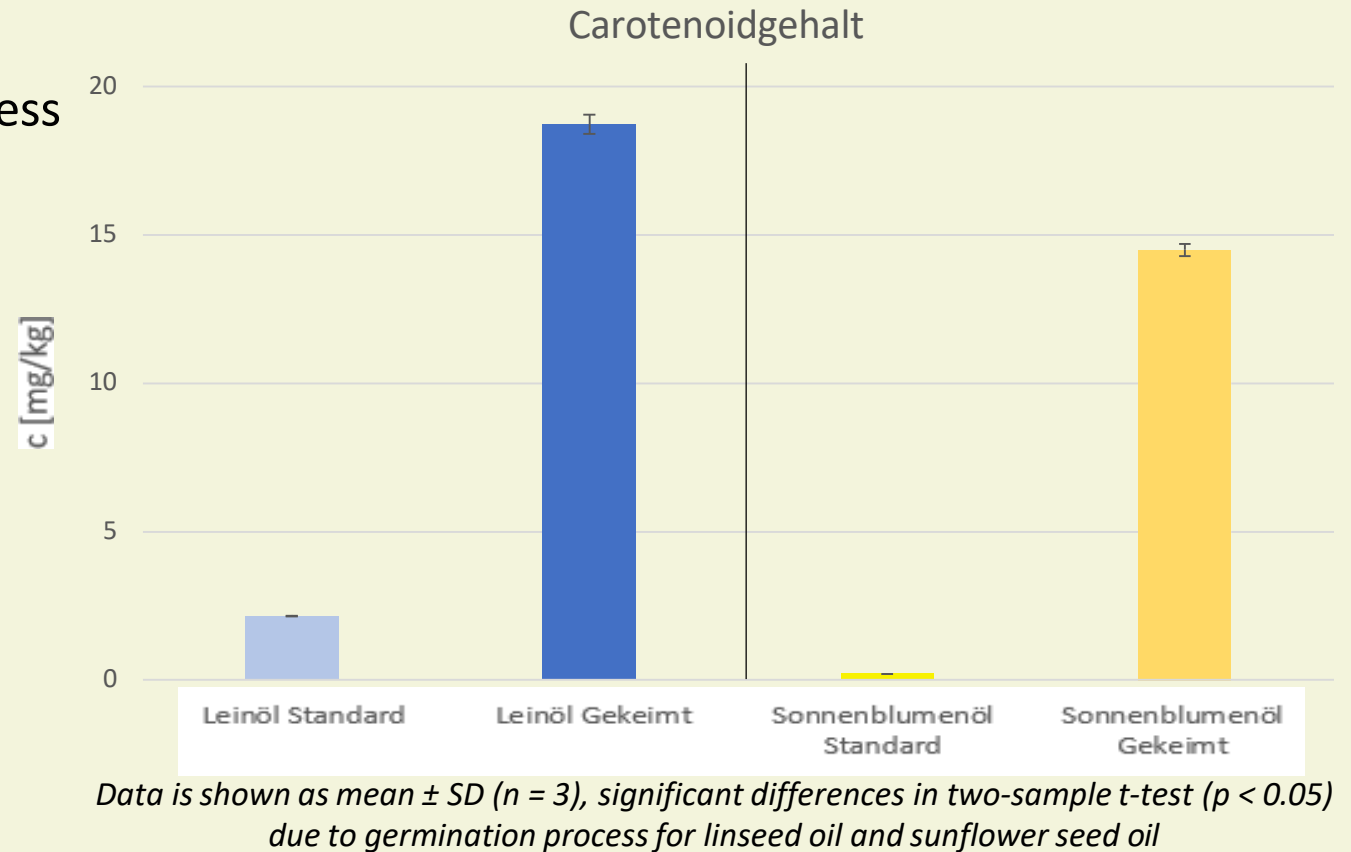


Inhaltsstoffe	
Ölsäure	14-39 % ^[1] (HO-Sorten: 70-92 %) ^[2]
Linolsäure	48-74 % (HO: 2-17 %) ^[1]
Linolensäure	0-0,3 % ^[1]
Weitere Fettsäuren	5-8 % (HO: 3-5 %) Palmitins., 3-6 % Stearins. ^[1]

Bundesministerium für Ernährung und Landwirtschaft (2020): Deutsches Lebensmittelbuch – Leitsätze für Speisefette und Speiseöle

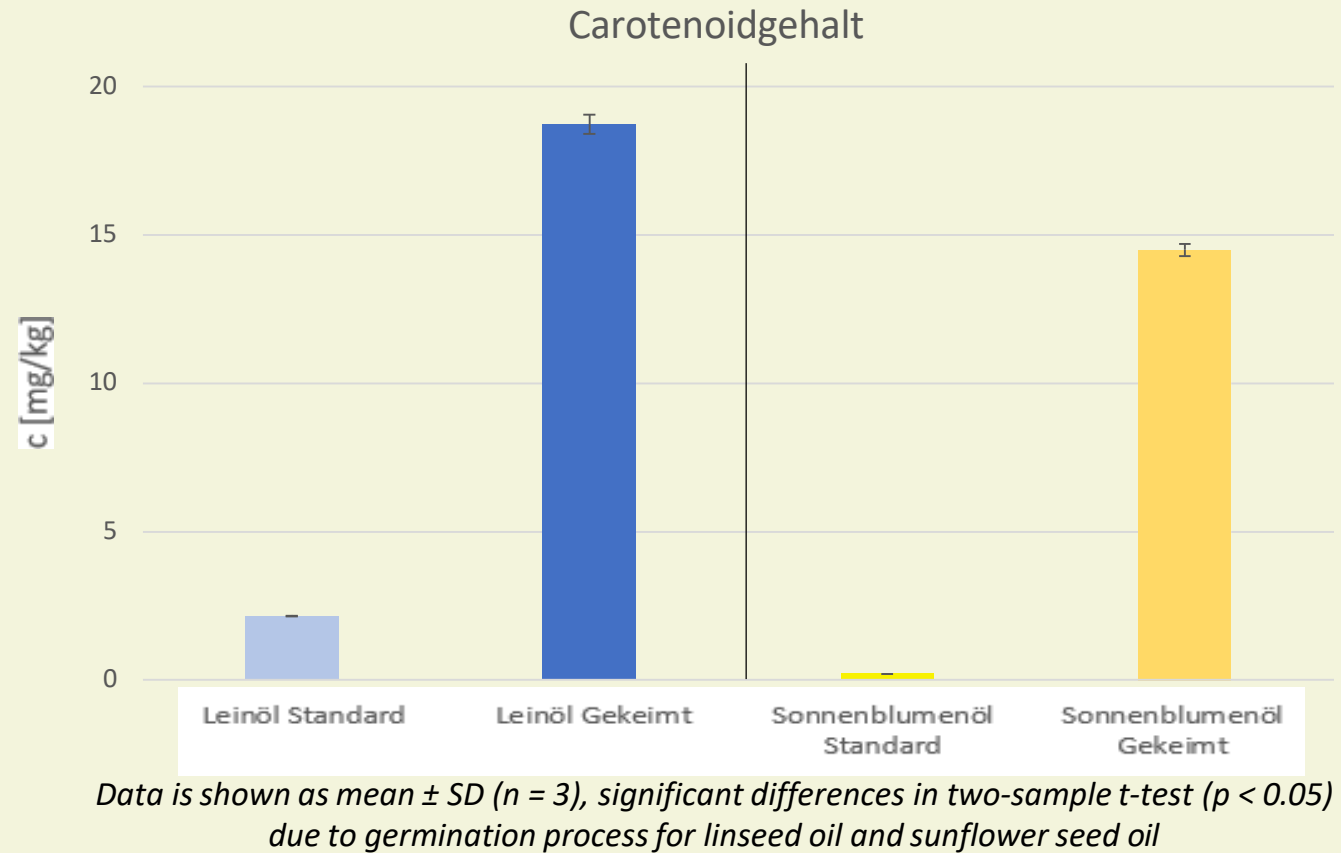
Carotinoid Content

- Strong Antioxidant
 - protection against oxidative stress & cell damage
 - immune system
- Eye Health
 - Lutein and Zeaxanthin
- Heart Health
 - beta-Carotin and Lycopin
- Skin Protection



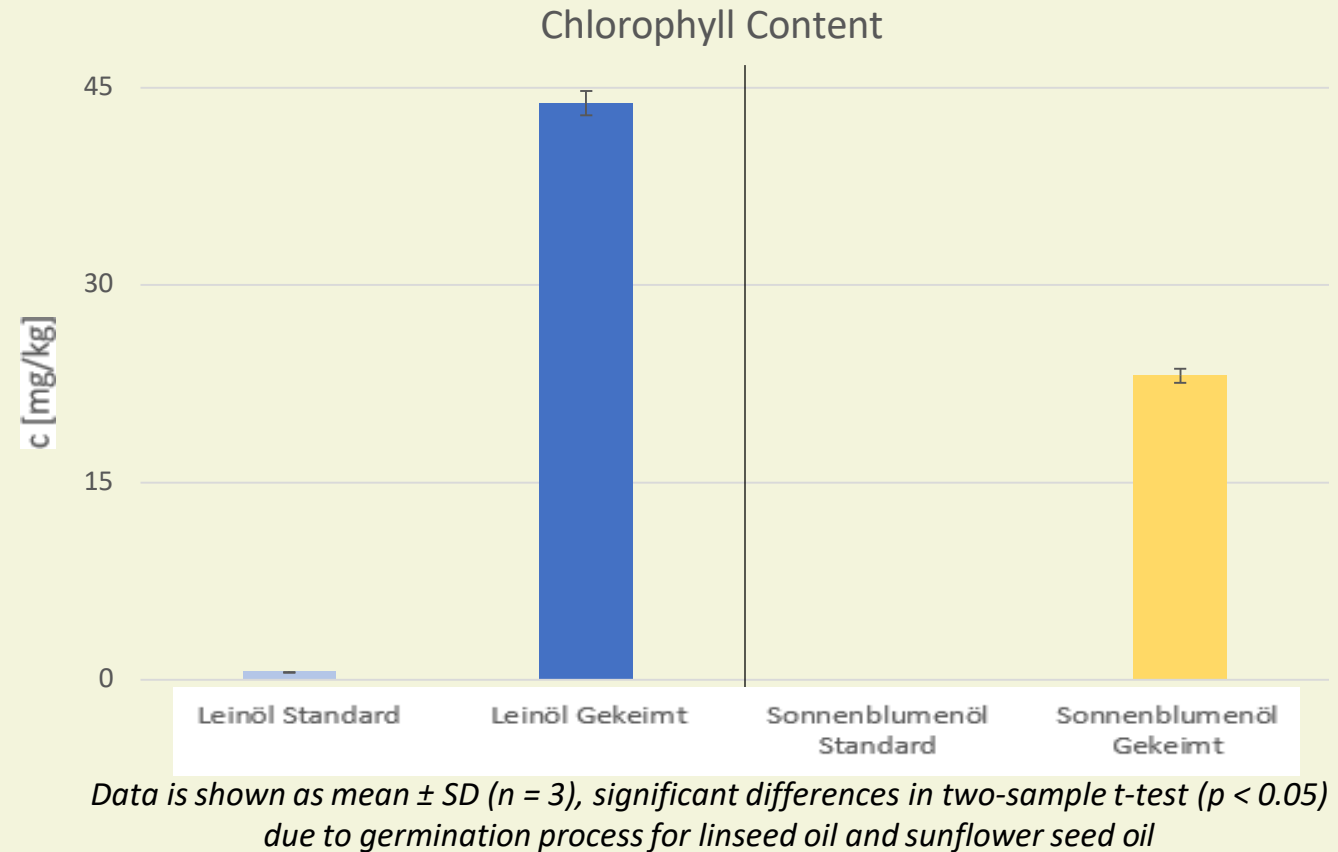
Carotenoid Content

- Extraction with Cyclohexan
- Absorption (460 nm)
- Calculate pigment content via calibration curve



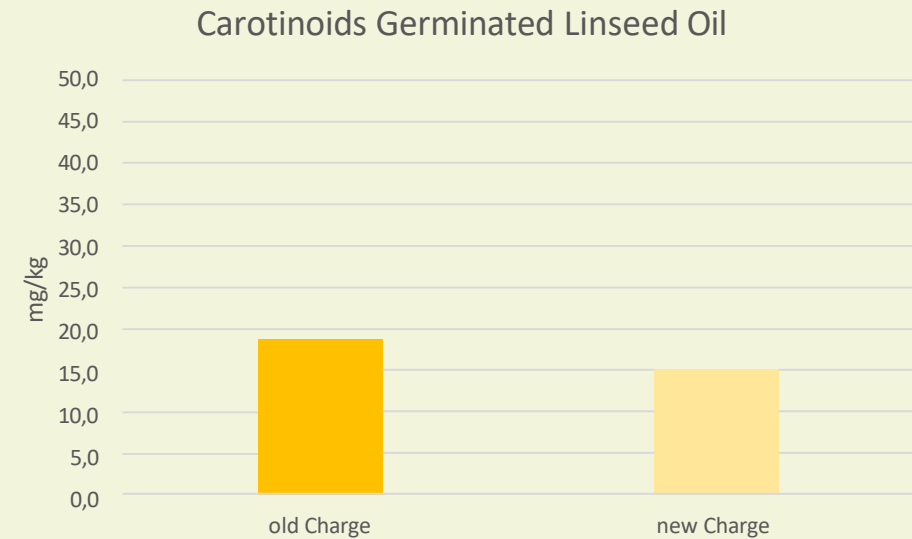
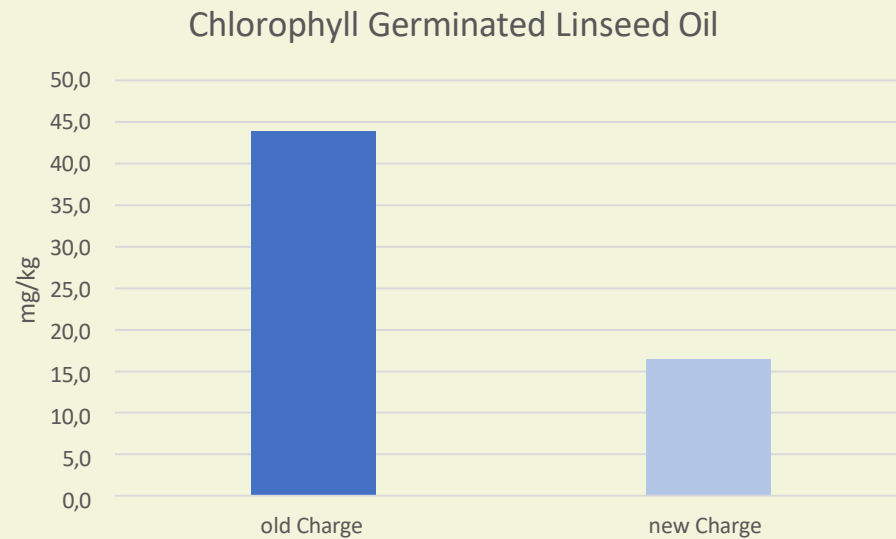
Chlorophyll Content

- Antioxidant Effect
 - binding free radicals
 - anti-inflammatory
- Detox
 - remove heavy metals
 - support liver function
- Digestion
 - beta-Carotin and Lycopin
- Potentially Anti-Carcinogenic

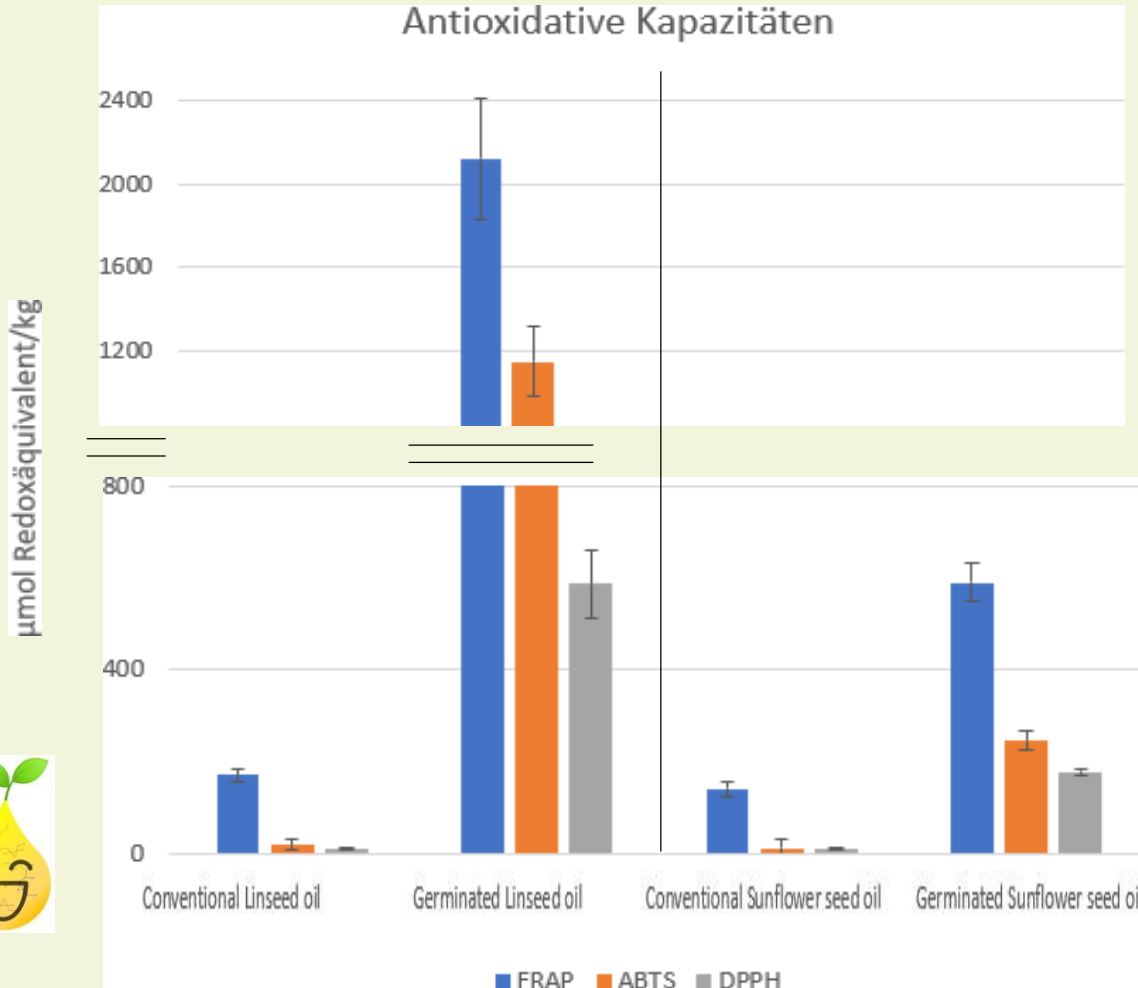


Comparison Batches Germinated Linseed Oils

	old Charge	new Charge
Chlorophyll [mg/kg]	43,8	16,4
Carotinoid [mg/kg]	18,7	15,7



Antioxidative capacities



FRAP: based on electron transfer reactions: color change by reduction Fe^{3+} zu Fe^{2+}

→ Photometric Assay (593 nm)

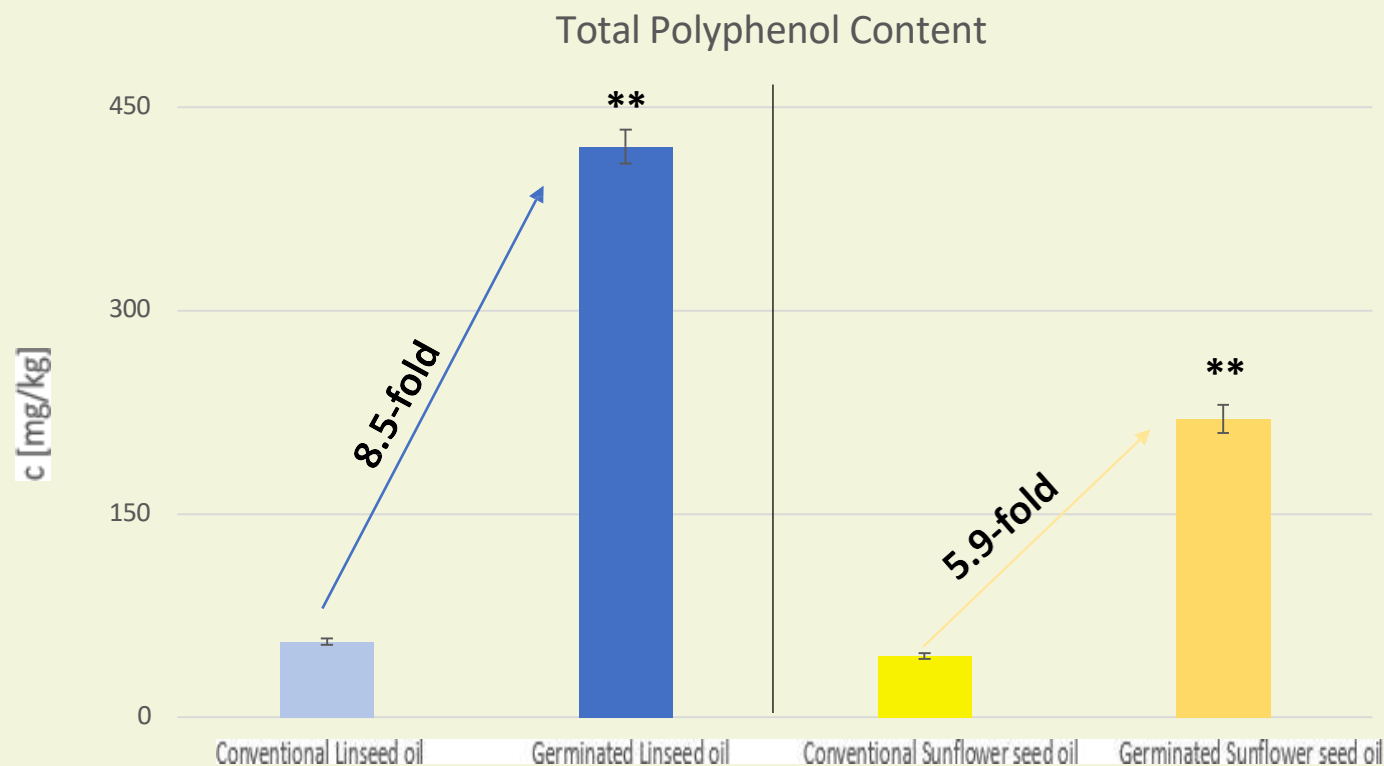
ABTS: based on electron transfer reactions: inhibition of the ABTS radical cation leads to decolorization of the solution

→ Photometric Assay (734 nm)

DPPH: Determination of neutralization/reduction of free radicals: solution decolorizes with increasing number of absorbed electrons

→ Photometric Assay (517 nm)

Total Polyphenol Content



Data is shown as mean $\pm$ SD ($n = 3$), significant differences in two-sample t-test ($p < 0.05$) due to germination process for linseed oil and sunflower seed oil

Folin-Ciocalteu:

→ photometric (765 nm)

Reference Values:

- linseed oil: 15 – 140 mg/kg ¹
- sunflower seed oil: 5 – 21 mg/kg ²
- olive oil: 34 – 360 mg/kg ³

¹Herchi et al. (2011): Changes in the Content of Phenolic Compounds in Flaxseed Oil During Development

²Perretti et al. (2004): Composition of organic and conventionally produced sunflower seed oil

³Manna et al. (2002): Protective Effect of the Phenolic Fraction from Virgin Olive Oils against Oxidative Stress in Human Cells

Polyphenols

○ Untargeted

- HRLC-MS/MS
- Vanquish UHPLC-System, Thermo Fisher Scientific LTQ Velos
- C18 column
(Acclaim 120, 2,1 mm × 150 mm, 3 µm)

○ Targeted

- LCMS-8040, Shimadzu
- C18 column
(Kinetex EVO, 150 × 3,0 mm, 5 µm)
- Triple-Quadrupol-MS + ESI source
- Multiple Reaction Monitoring



Leinöl Standard	Leinöl Gekeimt	Sonnenblumenöl Standard	Sonnenblumenöl Gekeimt
Flavonoide		Flavonoide	
(+)-Catechin	(+)-Catechin	(+)-Catechin	(+)-Catechin
Amentoflavone	Amentoflavone	Amentoflavone	Amentoflavone
Apigenin	Apigenin	Apigenin	Apigenin
	Eriodictyol-7-O-glucoside		Eriodictyol-7-O-glucoside
	Eriodictyol		
Hesperetin	Hesperetin		
Kaempferol-3-7-glu	Kaempferol-3-7-glu		Kaempferol-3-7-sinapoyl-digluc
Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside		Kaempferol-3-glucoside
	Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside	Kaempferol-3-glucoside
	Kaempferol-3-O-hexoxyl-hexoside		Kaempferol-3-O-glucuronic acid
	Isorhamnetin-3-O-rut		
	Luteolin		Luteolin
Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside
Naringenin	Naringenin	Naringenin	Naringenin
Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside
	Quercetin-O-hexose		
Phenolsäuren		Phenolsäuren	
	1,3-caffeoylquinic acid		1,3-caffeoylquinic acid
			4-O-Caffeoylquinic acid
		Caffeic acid	Caffeic acid
Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside
Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid
Chlorogenic acid	Chlorogenic acid		Chlorogenic acid
	Coniferyl aldehyde		Coniferyl aldehyde
cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid
Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer
p-coumaric acid	p-coumaric acid	p-coumaric acid	p-coumaric acid
p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid
Ferulic acid	Ferulic acid	Ferulic acid	Ferulic acid
Gallic acid	Gallic acid	Gallic acid	Gallic acid
Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside
Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid
	Isoferulic acid		Isoferulic acid
Protocatechuic acid	Protocatechuic acid		Protocatechuic acid
	Sinapic acid		Sinapic acid
	Vanillic acid		Vanillic acid
Stilbenoids		Stilbenoids	
Astringin	Astringin	Astringin	Astringin
	Lariciresinol		Lariciresinol
Linustatin	Linustatin		
Pinoresinol	Pinoresinol	Pinoresinol	Pinoresinol
Neolinustatin	Neolinustatin	Neolinustatin	Neolinustatin
Tannins		Tannins	
	Gallocatechol		Gallocatechol
	Procyanidin		
Other polyphenols		Other polyphenols	
	Astraglin		Astraglin
		Digalloyl-glucose isomer	Digalloyl-glucose isomer
Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose
		Rosmanol	Rosmanol
	Umbelliferone		Umbelliferone
			Vanillin



Specific Polyphenols

○ Influence of Germination

○ in both

○ Eriodictyol-7-O-Glucosid

Leinöl Standard	Leinöl Gekeimt	Sonnenblumenöl Standard	Sonnenblumenöl Gekeimt
Flavonoide		Flavonoide	
(+)-Catechin	(+)-Catechin	(+)-Catechin	(+)-Catechin
Amentoflavone	Amentoflavone	Amentoflavone	Amentoflavone
Apigenin	Apigenin	Apigenin	Apigenin
	Eriodictyol-7-O-glucoside		Eriodictyol-7-O-glucoside
	Eriodictyol		
Hesperetin	Hesperetin		
Kaempferol-3-7-glu	Kaempferol-3-7-glu		Kaempferol-3-7-sinapoyl-digluc
Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside		
	Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside	Kaempferol-3-glucoside
	Kaempferol-3-O-hexoyl-hexoside		Kaempferol-3-O-glucuronic acid
	Isorhamnetin-3-O-fut		
	Luteolin		Luteolin
Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside
Naringenin	Naringenin	Naringenin	Naringenin
Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside
	Quercetin-O-hexose		
Phenolsäuren		Phenolsäuren	
	1,3-caffeoylquinic acid		1,3-caffeoylquinic acid
			4-O-Caffeoylquinic acid
		Caffeic acid	Caffeic acid
Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside
Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid
Chlorogenic acid	Chlorogenic acid		Chlorogenic acid
	Coniferyl aldehyde		Coniferyl aldehyde
cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid
Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer
p-coumaric acid	p-coumaric acid	p-coumaric acid	p-coumaric acid
p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid
Ferulic acid	Ferulic acid	Ferulic acid	Ferulic acid
Gallic acid	Gallic acid	Gallic acid	Gallic acid
Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside
Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid
	Isoferulic acid		Isoferulic acid
Protocatechuic acid	Protocatechuic acid		Protocatechuic acid
	Sinapic acid		Sinapic acid
	Vanillic acid		Vanillic acid
Stilbenoids		Stilbenoids	
Astringin	Astringin	Astringin	Astringin
	Lariciresinol		Lariciresinol
Linustatin	Linustatin		
Pinoresinol	Pinoresinol	Pinoresinol	Pinoresinol
Neolinustatin	Neolinustatin	Neolinustatin	Neolinustatin
Tannins		Tannins	
	Gallocatechol		Gallocatechol
	Procyanidin		
Other polyphenols		Other polyphenols	
	Astraglin		Astraglin
		Digalloyl-glucose isomer	Digalloyl-glucose isomer
Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose
		Rosmanol	Rosmanol
	Umbelliferone		Umbelliferone
			Vanillin

Specific Polyphenols

○ Influence of Germination

○ in both

○ Eriodictyol-7-O-Glucosid

○ Luteolin

Leinöl Standard	Leinöl Gekeimt	Sonnenblumenöl Standard	Sonnenblumenöl Gekeimt
Flavonoide		Flavonoide	
(+)-Catechin	(+)-Catechin	(+)-Catechin	(+)-Catechin
Amentoflavone	Amentoflavone	Amentoflavone	Amentoflavone
Apigenin	Apigenin	Apigenin	Apigenin
	Eriodictyol-7-O-glucoside		Eriodictyol-7-O-glucoside
	Eriodictyol		
Hesperetin	Hesperetin		
Kaempferol-3-7-glu	Kaempferol-3-7-glu		Kaempferol-3-7-sinapoyl-digluc
Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside	Kaempferol-3-glucoside	Kaempferol-3-glucoside
	Kaempferol-3-O-glucuronic acid		Kaempferol-3-O-glucuronic acid
	Kaempferol-3-O-hexosyl-hexoside		
	Isohammetin-3-O-rut		
	Luteolin		Luteolin
Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside
Naringenin	Naringenin	Naringenin	Naringenin
Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside
	Quercetin-O-hexose		
Phenolsäuren		Phenolsäuren	
	1,3-Caffeoylquinic acid		1,3-Caffeoylquinic acid
			4-O-Caffeoylquinic acid
		Caffeic acid	Caffeic acid
Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside
Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid
Chlorogenic acid	Chlorogenic acid		Chlorogenic acid
	Coniferyl aldehyde		Coniferyl aldehyde
cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid
Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer
p-coumaric acid	p-coumaric acid	p-coumaric acid	p-coumaric acid
p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid
Ferulic acid	Ferulic acid	Ferulic acid	Ferulic acid
Gallic acid	Gallic acid	Gallic acid	Gallic acid
Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside
Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid
	Isoferulic acid		Isoferulic acid
Protocatechuic acid	Protocatechuic acid		Protocatechuic acid
	Sinapic acid		Sinapic acid
	Vanillic acid		Vanillic acid
Stilbenoids		Stilbenoids	
Astringin	Astringin	Astringin	Astringin
	Lariciresinol		Lariciresinol
Linustatin	Linustatin		
Pinoresinol	Pinoresinol	Pinoresinol	Pinoresinol
Neolinustatin	Neolinustatin	Neolinustatin	Neolinustatin
Tannins		Tannins	
	Galocatechol		Galocatechol
	Procyanidin		
Other polyphenols		Other polyphenols	
	Astraglin		Astraglin
Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Digalloyl-glucose isomer	Digalloyl-glucose isomer
		Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose
		Rosmanol	Rosmanol
	Umbelliferone		Umbelliferone
			Vanillin

Specific Polyphenols

○ Influence of Germination

○ in both

- Eriodictyol-7-O-Glucosid
- Luteolin
- 1,3-Caffeoylquinic acid

Leinöl Standard	Leinöl Gekeimt	Sonnenblumenöl Standard	Sonnenblumenöl Gekeimt
Flavonoide		Flavonoide	
(+)-Catechin	(+)-Catechin	(+)-Catechin	(+)-Catechin
Amentoflavone	Amentoflavone	Amentoflavone	Amentoflavone
Apigenin	Apigenin	Apigenin	Apigenin
	Eriodictyol-7-O-glucoside		Eriodictyol-7-O-glucoside
	Eriodictyol		
Hesperetin	Hesperetin		
Kaempferol-3-7-glu	Kaempferol-3-7-glu		Kaempferol-3-7-sinapoyl-digluc
Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside	Kaempferol-3-glucoside	Kaempferol-3-glucoside
	Kaempferol-3-O-glucuronic acid		Kaempferol-3-O-glucuronic acid
	Kaempferol-3-O-hexosyl-hexoside		
	Isorhamnetin-3-O-rut		
Luteolin	Luteolin	Luteolin	Luteolin
Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside
Naringenin	Naringenin	Naringenin	Naringenin
Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside
	Quercetin-O-hexose		
Phenolsäuren		Phenolsäuren	
	1,3-caffeoylquinic acid		1,3-caffeoylquinic acid
			4-O-Caffeoylquinic acid
		Caffeic acid	Caffeic acid
Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside
Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid
Chlorogenic acid	Chlorogenic acid	Chlorogenic acid	Chlorogenic acid
	Coniferyl aldehyde		Coniferyl aldehyde
cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid
Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer
p-coumaric acid	p-coumaric acid	p-coumaric acid	p-coumaric acid
p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid
Ferulic acid	Ferulic acid	Ferulic acid	Ferulic acid
Gallic acid	Gallic acid	Gallic acid	Gallic acid
Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside
Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid
	Isoferulic acid		Isoferulic acid
Protocatechuic acid	Protocatechuic acid		Protocatechuic acid
	Sinapic acid		Sinapic acid
	Vanillic acid		Vanillic acid
Stilbenoids		Stilbenoids	
Astringin	Astringin	Astringin	Astringin
	Lariciresinol		Lariciresinol
Linustatin	Linustatin		
Pinoresinol	Pinoresinol	Pinoresinol	Pinoresinol
Neolinustatin	Neolinustatin	Neolinustatin	Neolinustatin
Tannins		Tannins	
	Gallic catechol		Gallic catechol
	Procyanidin		
Other polyphenols		Other polyphenols	
	Astraglin		Astraglin
		Digalloyl-glucose isomer	Digalloyl-glucose isomer
Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose
		Rosmanol	Rosmanol
	Umbelliferone		Umbelliferone
			Vanillin

Specific Polyphenols

○ Influence of Germination

○ in both

- Eriodictyol-7-O-Glucosid
- Luteolin
- 1,3-Caffeoylquinic acid
- Coniferylaldehyde
- Isoferulic acid
- Sinapic acid
- Vanillic acid

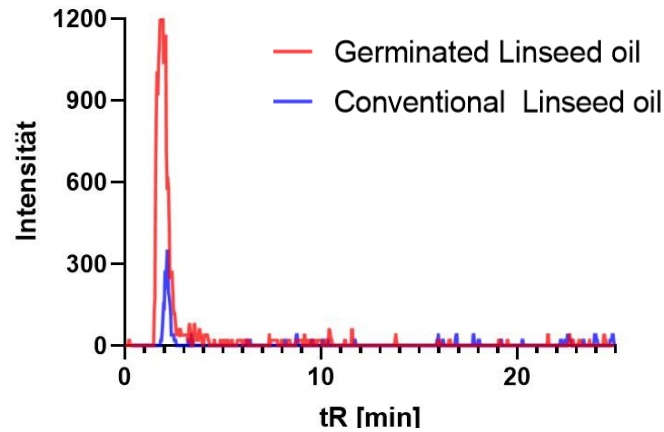
○ only in Germinated Linseed Oil

- Eriodictyol
- Kaempferol-3-O-hexoxyl-hexoside
- Isorhamnetin-3-O-rut
- Quercetin-O-hexose
- Procyanidin

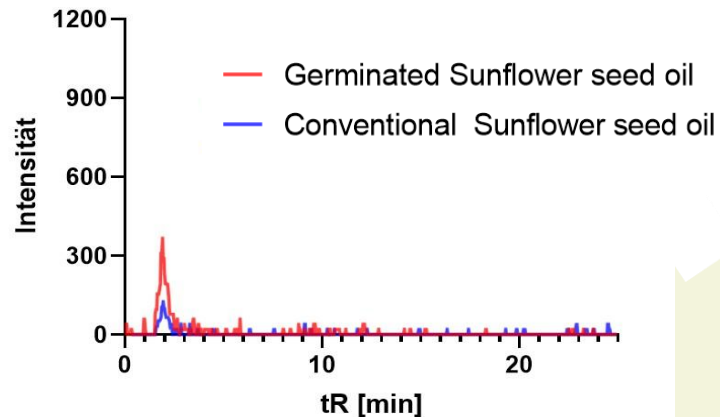
Leinöl Standard	Leinöl Gekeimt	Sonnenblumenöl Standard	Sonnenblumenöl Gekeimt
Flavonoide		Flavonoide	
(+)-Catechin	(+)-Catechin	(+)-Catechin	(+)-Catechin
Amentoflavone	Amentoflavone	Amentoflavone	Amentoflavone
Apigenin	Apigenin	Apigenin	Apigenin
	Eriodictyol-7-O-glucoside		Eriodictyol-7-O-glucoside
	Eriodictyol		
Hesperetin	Hesperetin		
Kaempferol-3-7-glu	Kaempferol-3-7-glu		Kaempferol-3-7-sinapoyl-digluc
Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside	Kaempferol-3-glucoside	Kaempferol-3-glucoside
	Kaempferol-3-O-glucuronic acid		Kaempferol-3-O-glucuronic acid
	Kaempferol-3-O-hexoxyl-hexoside		
	Isorhamnetin-3-O-rut		
Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside
Naringenin	Naringenin	Naringenin	Naringenin
Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside
	Quercetin-O-hexose		
Phenolsäuren		Phenolsäuren	
	1,3-caffeoylquinic acid		1,3-caffeoylquinic acid
			4-O-Caffeoylquinic acid
		Caffeic acid	Caffeic acid
Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside
Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid
Chlorogenic acid	Chlorogenic acid		Chlorogenic acid
	Coniferyl aldehyde		Coniferyl aldehyde
cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid
Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer
p-coumaric acid	p-coumaric acid	p-coumaric acid	p-coumaric acid
p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid
Ferulic acid	Ferulic acid	Ferulic acid	Ferulic acid
Gallic acid	Gallic acid	Gallic acid	Gallic acid
Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside
Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid
	Isoferulic acid		Isoferulic acid
Protocatechuic acid	Protocatechuic acid		Protocatechuic acid
	Sinapic acid		Sinapic acid
	Vanillic acid		Vanillic acid
Stilbenoids		Stilbenoids	
Astringin	Astringin	Astringin	Astringin
	Lariciresinol		Lariciresinol
Linustatin	Linustatin		
Pinoresinol	Pinoresinol	Pinoresinol	Pinoresinol
Neolinustatin	Neolinustatin	Neolinustatin	Neolinustatin
Tannins		Tannins	
	Gallocatechol		Gallocatechol
	Procyanidin		
Other polyphenols		Other polyphenols	
	Astraglin		Astraglin
Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Digalloyl-glucose isomer	Digalloyl-glucose isomer
		Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose
		Rosmanol	Rosmanol
	Umbelliferone		Umbelliferone
			Vanillin

Specific Polyphenols

Apigenin [296.05 > 117.03]

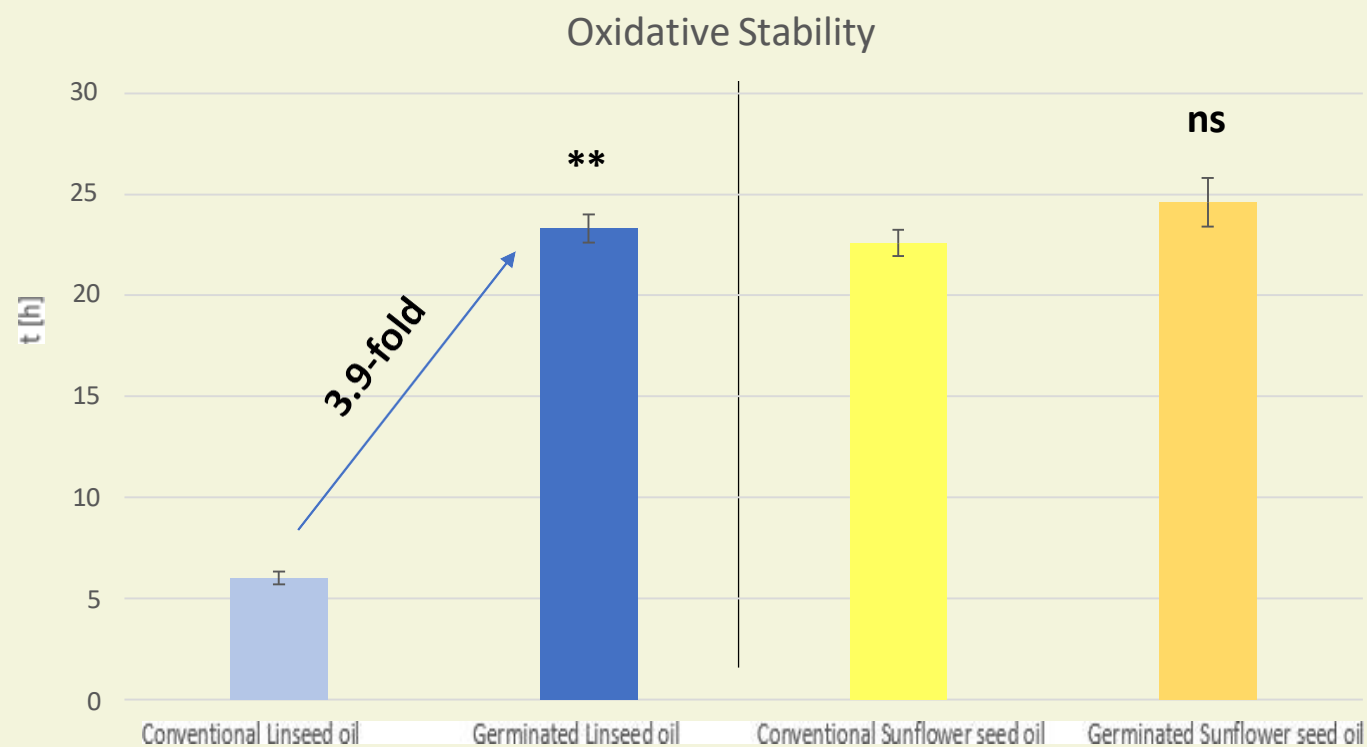


Apigenin [296.05 > 117.03]

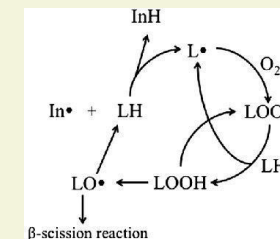
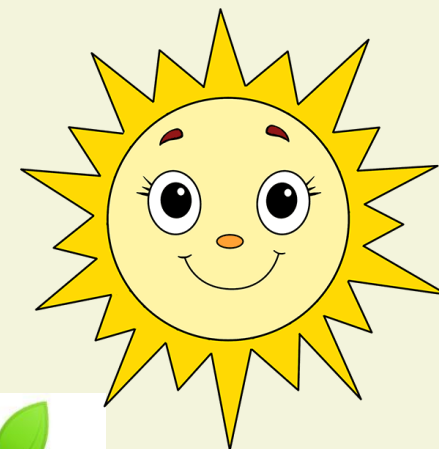


Leinöl Standard	Leinöl Gekeimt	Sonnenblumenöl Standard	Sonnenblumenöl Gekeimt
Flavonoide		Flavonoide	
(+)-Catechin	(+)-Catechin	(+)-Catechin	(+)-Catechin
Amentoflavone	Amentoflavone	Amentoflavone	Amentoflavone
Apigenin	Apigenin	Apigenin	Apigenin
	Eriodictyol-7-O-glucoside		Eriodictyol-7-O-glucoside
	Eriodictyol		
Hesperetin	Hesperetin		
Kaempferol-3-7-glu	Kaempferol-3-7-glu		Kaempferol-3-7-sinapoyl-digluc
Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside		
	Kaempferol-3-O-glucuronic acid	Kaempferol-3-glucoside	Kaempferol-3-glucoside
	Kaempferol-3-O-hexosyl-hexoside		Kaempferol-3-O-glucuronic acid
	Isorhamnetin-3-O-rut		
Luteolin	Luteolin		Luteolin
Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside	Luteolin-7-O-glucoside
Naringenin	Naringenin	Naringenin	Naringenin
Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside	Naringenin-7-O-glucoside
	Quercetin-O-hexose		
Phenolsäuren		Phenolsäuren	
	1,3-cafeoylquinic acid		1,3-cafeoylquinic acid
			4-O-Caffeoylquinic acid
		Caffeic acid	Caffeic acid
Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside	Caffeic acid hexoside
Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid	Caffeoylmalic acid
Chlorogenic acid	Chlorogenic acid		Chlorogenic acid
	Coniferyl aldehyde		Coniferyl aldehyde
cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid	cis Cinnamic acid
Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer	Coumaric acid hexoside isomer
p-coumaric acid	p-coumaric acid	p-coumaric acid	p-coumaric acid
p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid	p-coumaroylquinic acid
Ferulic acid	Ferulic acid	Ferulic acid	Ferulic acid
Gallic acid	Gallic acid	Gallic acid	Gallic acid
Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside	Gallic acid hexoside
Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid	Hydroxyferulic acid
	Isoferulic acid		Isoferulic acid
Protocatechuic acid	Protocatechuic acid		Protocatechuic acid
	Sinapic acid		Sinapic acid
	Vanillic acid		Vanillic acid
Stilbenoids		Stilbenoids	
Astringin	Astringin	Astringin	Astringin
	Lariciresinol		Lariciresinol
Linustatin	Linustatin		
Pinoresinol	Pinoresinol	Pinoresinol	Pinoresinol
Neolinustatin	Neolinustatin	Neolinustatin	Neolinustatin
Tannins		Tannins	
	Gallocatechol		Gallocatechol
	Procyanidin		
Other polyphenols		Other polyphenols	
	Astraglin		Astraglin
		Digalloyl-glucose isomer	Digalloyl-glucose isomer
Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose	Hydroxybenzoyl Glucose
		Rosmanol	Rosmanol
	Umbelliferone		Umbelliferone
			Vanillin

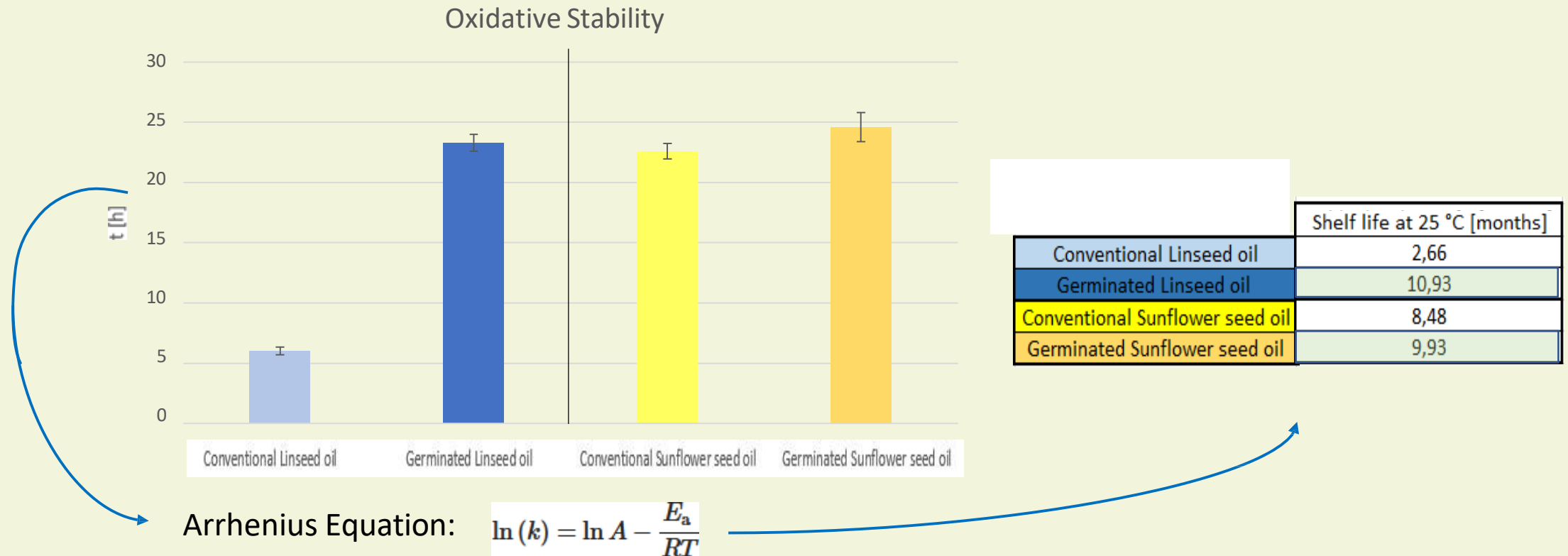
Oxidative Stability - Rancimat



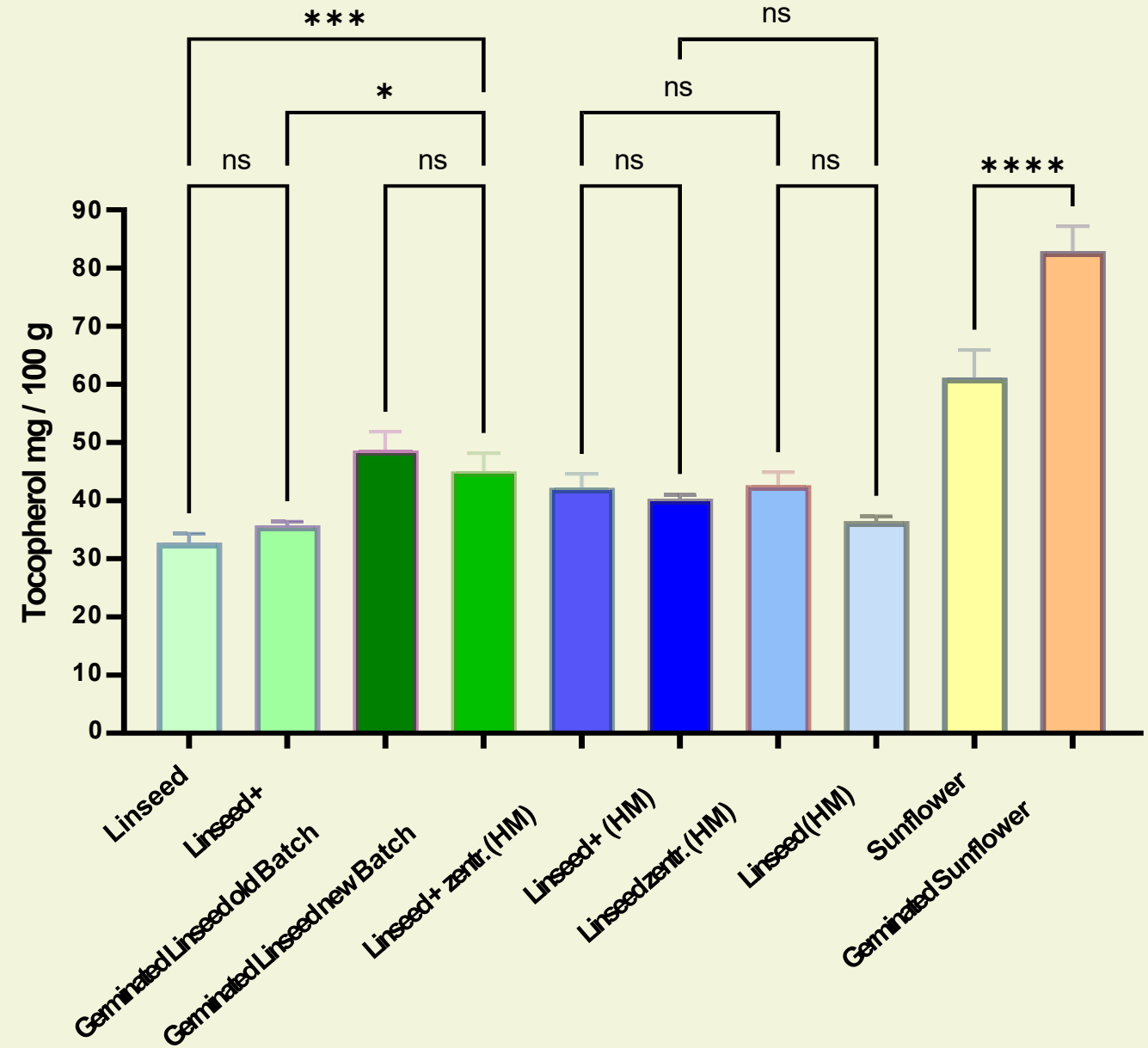
Data is shown as mean $\pm$ SD ($n = 3$), significant differences in two-sample t -test ($p < 0.5$) due to germination process for linseed oil, but not for sunflower seed oil



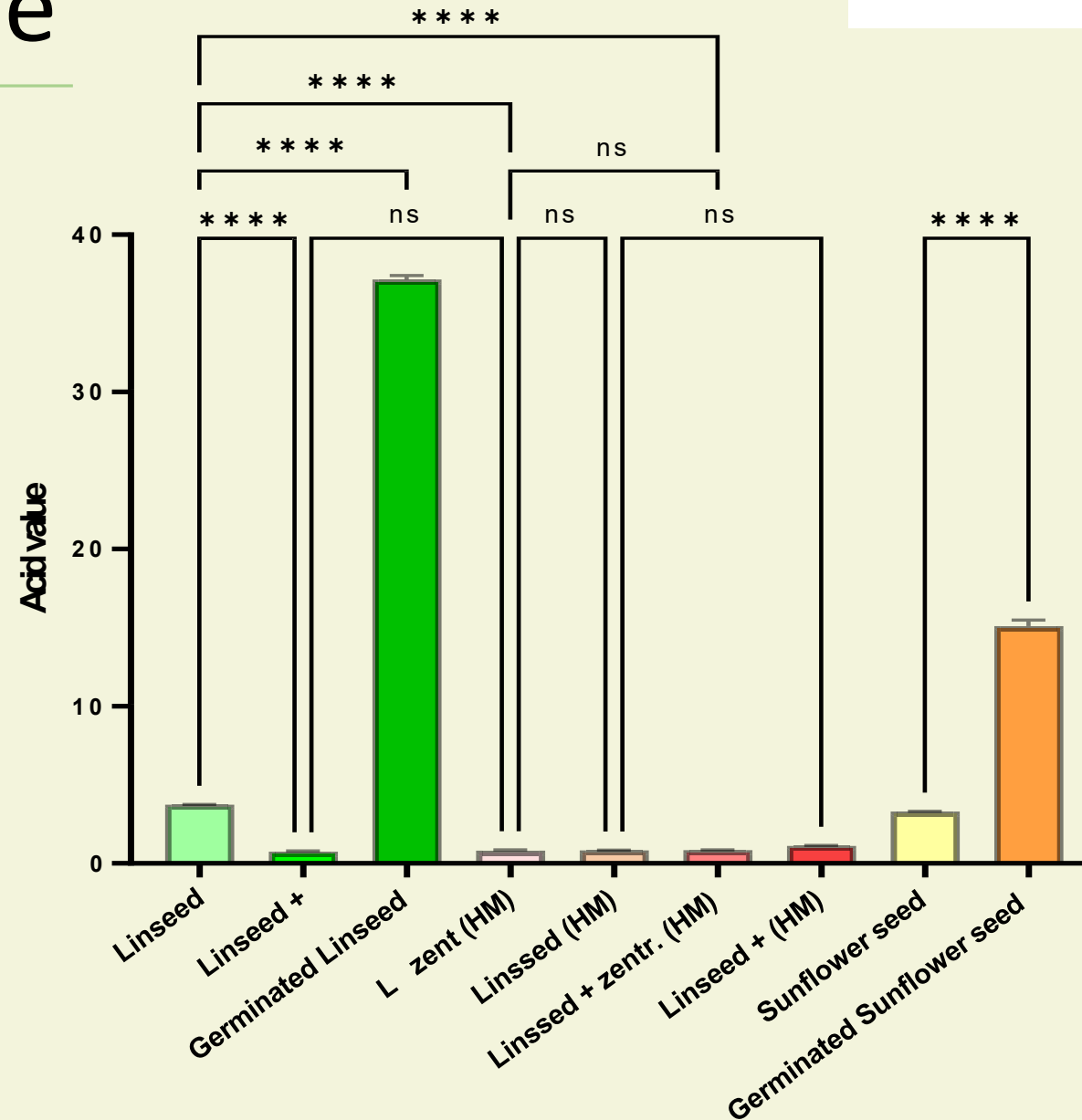
Oxidative Stability - Rancimat



Tocopherols

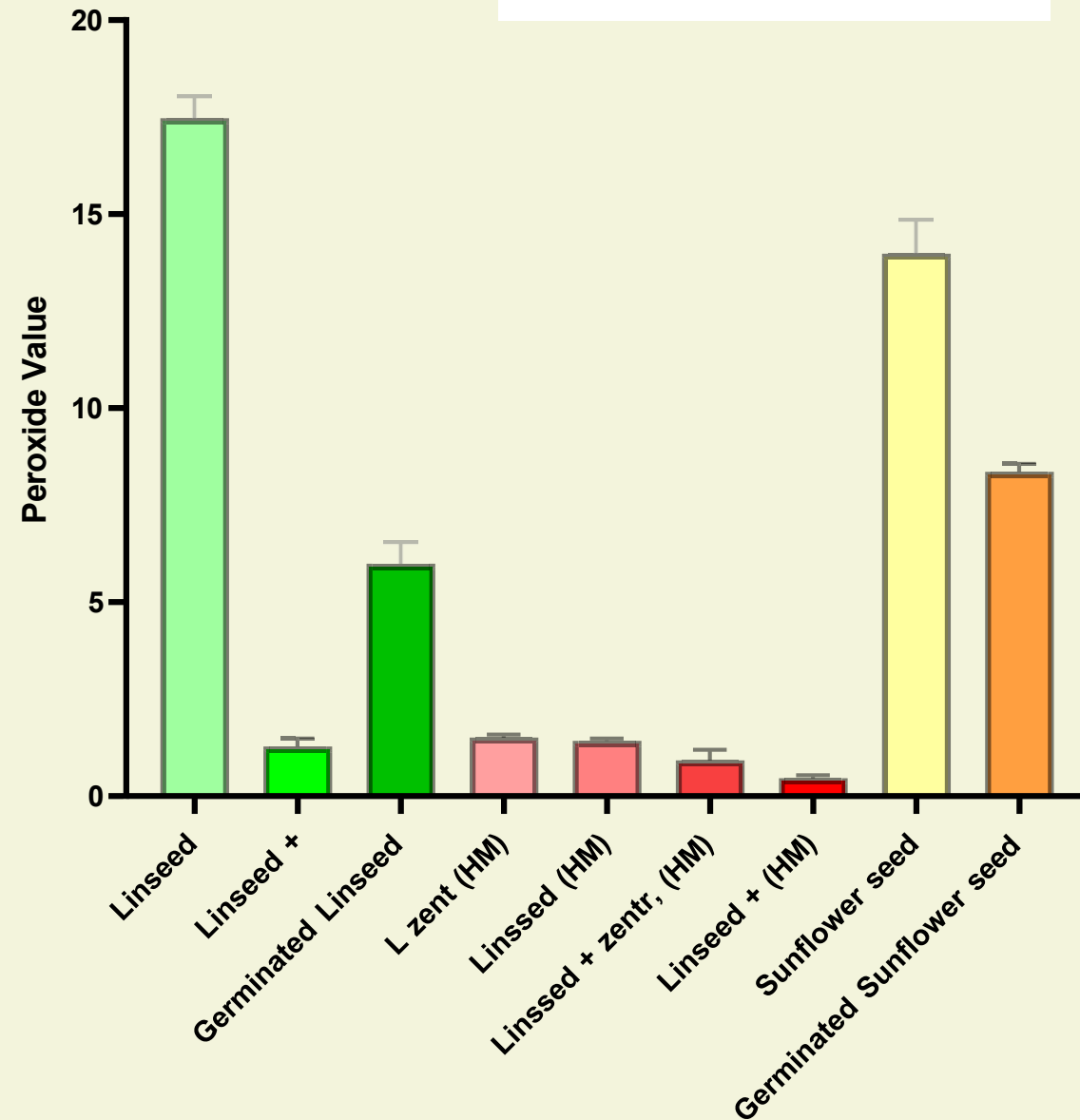


Acid Value



Data is shown as mean $\pm$ SD ($n = 3$). Statistically significant differences between different oils were determined using One-way ANOVA followed by Šídák's post-hoc test, as indicated by **** in the case of significant differences ($p < 0.0001$) and ns in the case of non-significant differences.

Peroxide Value



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Questions and discussion please

