Cotton Seed Oil: Nutritional and Health Benefits

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NIFTEM K

1. Overview of cotton seed oil
2. Properties of cotton seed oil
3. Health benefits of cotton seed oil
4. Stability enhancement using novel technology
5. By-products

Cotton seed oil

COTTON SEED

COTTON PLANT

COTTON SEED OIL

Varieties : *Gossypium hirsutum, Gossypium arboreum, Gossypiumherbaceum, Gossypium barbadense*

It is **by-product of cotton manufacturer**; extracted from the decorticated and delinted cottonseed for their used as edible oil and industrial applications.

Uses: production of crackers, biscuits, mayonnaise, pastries, potato chips, salad, margarine, shortening, dressing, doughnuts, ice cream substitutes, baking, frying, oriental dishes and for industrial applications

Oil yield- 15-22% depending on varieties and extraction technology

Phytochemicals

Pan et al., (2019); Yang et al., 2019

Phenolics compounds
Gossypol (Toxic at higher levels)

Flavonoids
Quercetin

Tocopherols
α, β, γ, δ-Tocopherols

Phenolic acid
Caffeic acid, ferulic acid, p-coumaric

Sterols and Policosanols
Campesterol-874.2mg/100g
Stigmasterol-255 mg/100g
β –sitosterol-272.9

Fatty acid composition

Yang et al., 2019; Zia et al., (2022)

Linolenic acid (n-3)
Reported value-0.2%

Linoleic acid (n-6)
Reported value- 47-58%

Oleic acid (n-9)
Reported value- 14-17%

Palmitic acid Reported value- 19-23%

Stearic acid Reported value- 2-5 %

These phytochemicals collectively contribute to the oxidative stability and shelf-life of cottonseed oil, making it more resistant to rancidity.

Commonly used edible oil

Fatty Acid (%)	Cottonseed Oil	Coconut Oil	Mustard Oil	Sunflower Oil	Olive Oil	Rice Bran Oil
Capric Acid	--	3.91	--	--	--	--
Lauric Acid	--	41.21	--	--	--	--
Myristic Acid	1.0	23.90	0--	0.07	--	0.35
Palmitic Acid	23.7	16.50	2.19	6.62	10.27	19.34
Stearic Acid	3.4	3.14	1.17	3.27	3.15	2.0
Oleic Acid	19.4	9.14	10.16	30.4	77.86	43.42
Eicosanoic Acid	--	--	5.48	--	--	--
Erucic Acid	--	--	51.18	--	--	--
Linoleic Acid	53.2	1.61	15.58	58.25	6.17	11.23
Linolenic Acid	0.5	--	11.70	0.05	0.63	0.30
SFA	26.9	88.66	3.36	9.96	13.42	22.78
MUFA	19.4	9.14	66.82	30.4	77.86	43.42
PUFA	53.7	1.61	27.28	58.3	6.8	32.63
MUFA:PUFA	0.361	5.677	2.449	0.521	11.450	1.331

Properties of Cottonseed Cooking Oil (RBD)

Refined, Bleached, and Deodorized

Parameter	Value
Lovibond Colour (Red Max.)	2.0 – 6.0
Free Fatty Acid (as Oleic % Max)	0.05
Peroxide Value (Meq/kg. Max.)	1.0
Iodine Value	103-116
AOM Stability (hrs.)	15
Cloud Point (°F)	30 – 38
Melting Point (°F)	50 – 60
Smoke Point (°F)	**430**
Flavour	Bland

Properties of CSO

High omega-6 content

High in Unsaturated fatty

Decrease in stability

Blending

Addition of saturated FA-rich oil

High Smoke point

High thermal properties

Good for frying

Rich in tocopherol and antioxidant

Scavenge free radicals

Better stability

Multiple Benefits Associated With Cottonseed Oil

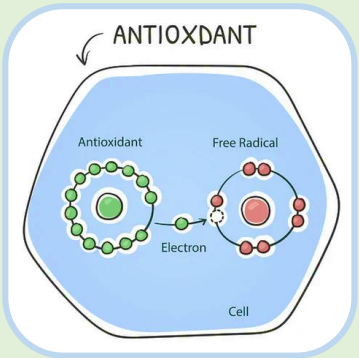
Nutritional and Health Benefits of Cottonseed Oil

RICH NUTRITIONAL PROFILE

- Naturally Hydrogenated: Contains stearic, palmitic, and oleic acids, reducing the need for artificial hydrogenation.
- High in Tocopherols: Abundant in vitamin E, which is beneficial for overall health.
- Beneficial Fatty Acids: Contains Polyunsaturated fatty acids and monounsaturated fatty acids (MUFAs).

CARDIOVASCULAR HEALTH

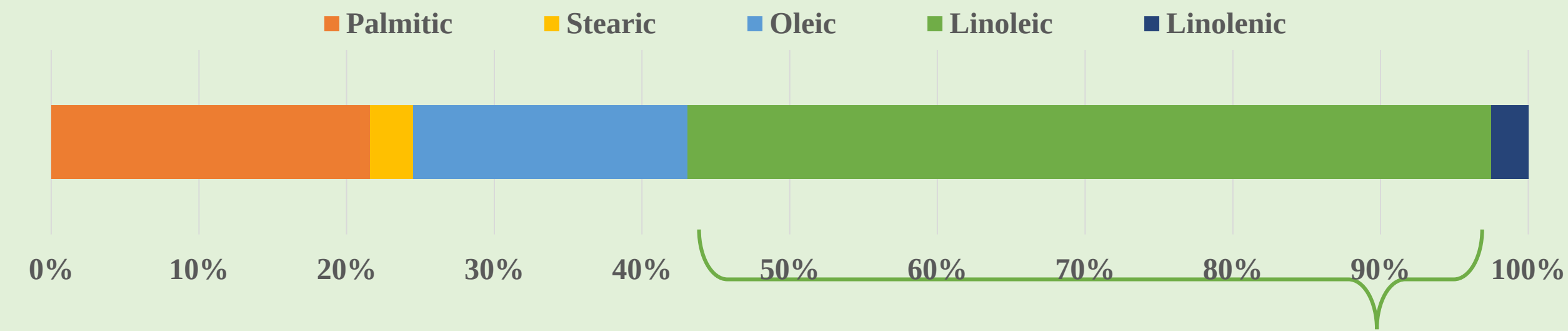
- Cholesterol Management: Rich in polyunsaturated fatty acids (PUFAs), which help lower bad cholesterol (LDL) and increase good cholesterol (HDL).
- Heart-Friendly: MUFAs reduce plasma cholesterol, while PUFAs lower the risk of cardiovascular diseases.



ANTIOXIDANT PROPERTIES

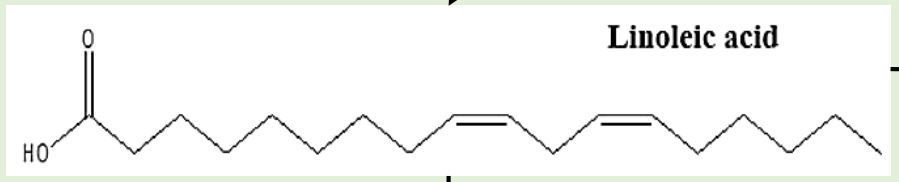
- Vitamin E: Acts as a powerful antioxidant, combating oxidative stress and reducing the risk of chronic diseases.
- Reduces Reactive Oxygen Species (ROS): Protects against cell damage caused by free radicals.

Cottonseed Oil's Polyunsaturated Fatty Acid Rich Profile

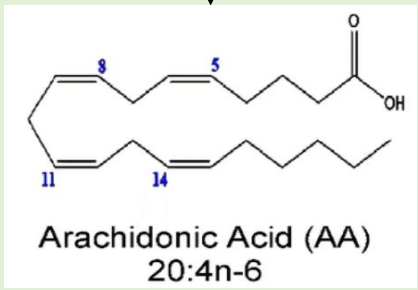


Nearly 50% of composition is made up of Linoleic Acid (C18:2) PUFA

American Heart Association (AHA) has included it in the "OK FOOD" products and **approved it as a nutritious and "Heart Oil" food.**



Metabolic Conversion



Essential for body's

1. Muscle Growth
2. Immune Support
3. Brain Function
4. Cell Membrane Integrity
5. Inflammatory Response Regulation

Therapeutic and Healing Properties of Cottonseed Oil

ANTI-INFLAMMATORY EFFECTS

- Fatty Acids and Phenols: Linoleic acid and terpenes help reduce inflammation, alleviating redness, dandruff, and acne.
- Vitamin E: Promotes healing of scars and epithelium cells.

ANTI-CANCER POTENTIAL

•Gossypol exhibits anti-proliferative and pro-apoptotic effects on various cancer cells, including breast and prostate cancer.

•Gossypol in limited amounts can inhibit adipogenesis and reduce obesity-related cancer risks.

HEALING AND RESTORATION

Promotes Cell Proliferation: Encourages the growth of healthy cells and repairs dermal tissues.

Lipid Barrier Restoration: Enhances the cell's lipid barrier, aiding in faster healing.

Research supporting the benefits of Cottonseed Oil

ELSEVIER

The Journal of Nutrition

Volume 152, Issue 9, September 2022, Pages 2060-2071

Blood Lipid Responses to Diets Enriched with Cottonseed Oil Compared with Olive Oil in Adults with High Cholesterol in a Randomized Trial

Prater M Catherine [1], Scheurell Alexis R [1], Paton Chad M [1 2], Cooper Jamie A [1]

The study concluded that Cotton seed oil, but not Olive oil, diet enrichment caused substantial improvements in fasting and postprandial blood lipids and postprandial glycemia in hypercholesterolemic adults.

ELSEVIER

Nutrition Research

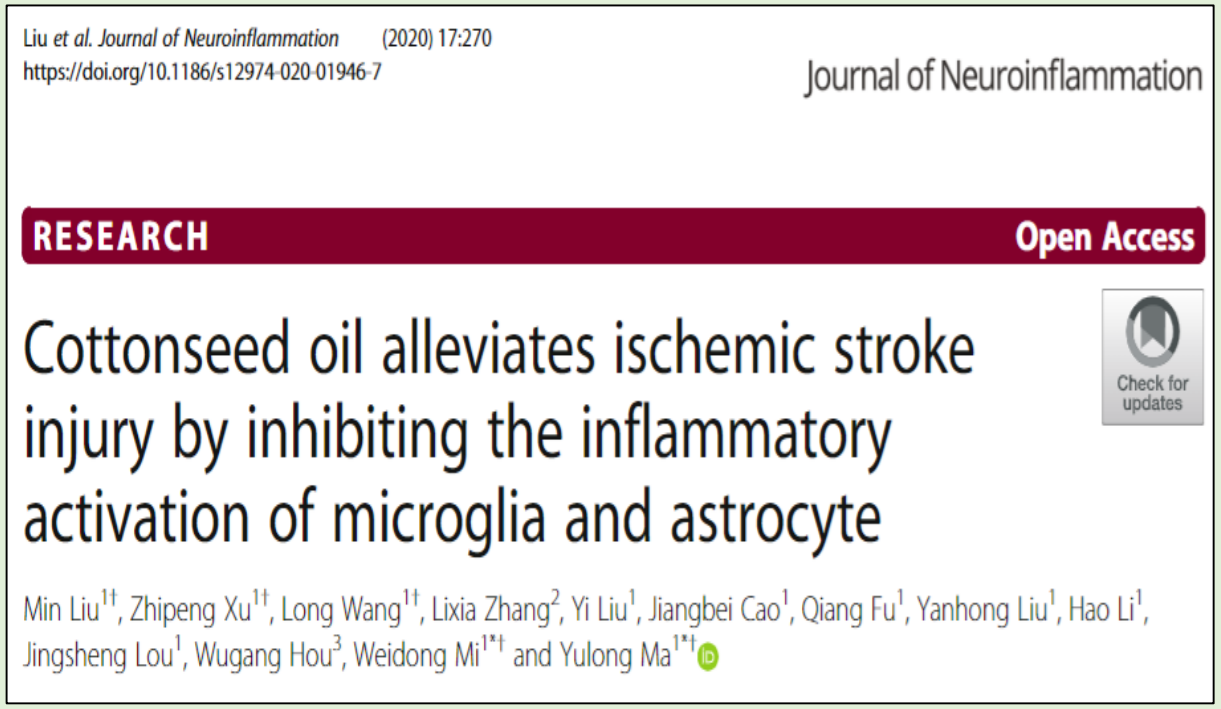
Volume 60, December 2018, Pages 43-53

A 5-day high-fat diet rich in cottonseed oil improves cholesterol profiles and triglycerides compared to olive oil in healthy men

Kristine R. Polley [a], Natalie J. Oswell [b], Ronald B. Pegg [b], Chad M. Paton [a b], Jamie A. Cooper [a]

A 5-day Cottonseed oik-rich diet led to reduction in CVD risk factors. Total cholesterol, LDL, serum triglyceride were lower following CSO diet intervention. Moreover, HDL cholesterol increased following CSO diet intervention. All while no change was observed in blood lipids where participants followed Olive Oil based diet.

Research supporting the benefits of Cottonseed Oil (cont.)



Liu *et al. Journal of Neuroinflammation* (2020) 17:270
https://doi.org/10.1186/s12974-020-01946-7

Journal of Neuroinflammation

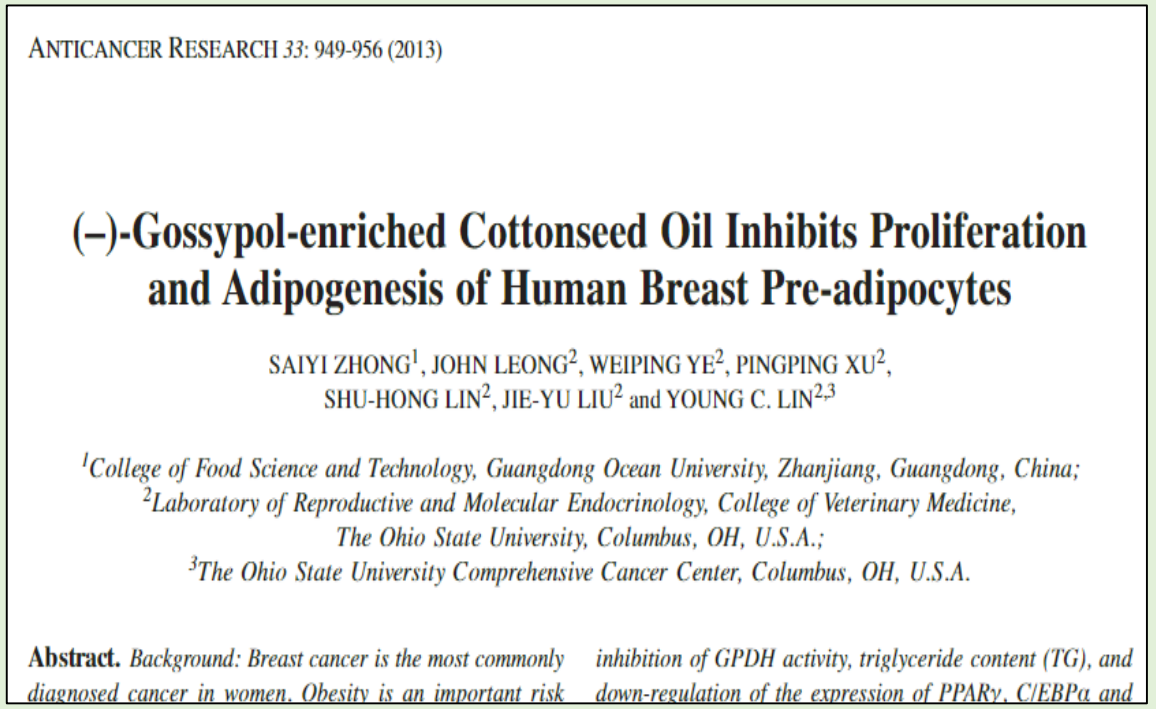
RESEARCH Open Access

Cottonseed oil alleviates ischemic stroke injury by inhibiting the inflammatory activation of microglia and astrocyte

Check for updates

Min Liu[1†], Zhipeng Xu[1†], Long Wang[1†], Lixia Zhang[2], Yi Liu[1], Jiangbei Cao[1], Qiang Fu[1], Yanhong Liu[1], Hao Li[1], Jingsheng Lou[1], Wugang Hou[3], Weidong Mi[1*†] and Yulong Ma[1*†]

CSO treatment alleviated ischemic stroke injury by reducing microglial and astrocytic activation and inflammation, which was related to the inhibition of TLR4/NF-κB pathway and the reduction of A1 phenotype neurotoxic astrocyte activation, suggesting that CSO could be a new strategy in the prevention of ischemic stroke.



ANTICANCER RESEARCH *33*: 949-956 (2013)

(–)-Gossypol-enriched Cottonseed Oil Inhibits Proliferation and Adipogenesis of Human Breast Pre-adipocytes

SAIYI ZHONG[1], JOHN LEONG[2], WEIPING YE[2], PINGPING XU[2], SHU-HONG LIN[2], JIE-YU LIU[2] and YOUNG C. LIN[2,3]

[1]*College of Food Science and Technology, Guangdong Ocean University, Zhanjiang, Guangdong, China;*
[2]*Laboratory of Reproductive and Molecular Endocrinology, College of Veterinary Medicine, The Ohio State University, Columbus, OH, U.S.A.;*
[3]*The Ohio State University Comprehensive Cancer Center, Columbus, OH, U.S.A.*

Abstract. *Background: Breast cancer is the most commonly diagnosed cancer in women. Obesity is an important risk ... inhibition of GPDH activity, triglyceride content (TG), and down-regulation of the expression of PPARγ, C/EBPα and*

Gossypol enriched CSO inhibited proliferation of pre-adipocytes and also significantly decreased adipogenesis. Findings suggest that gossypol enrichment in CSO has the potential as a food supplement to inhibit adipogenesis, and therefore, reduce obesity.

Enhancing nutritional profile of cotton seed oil

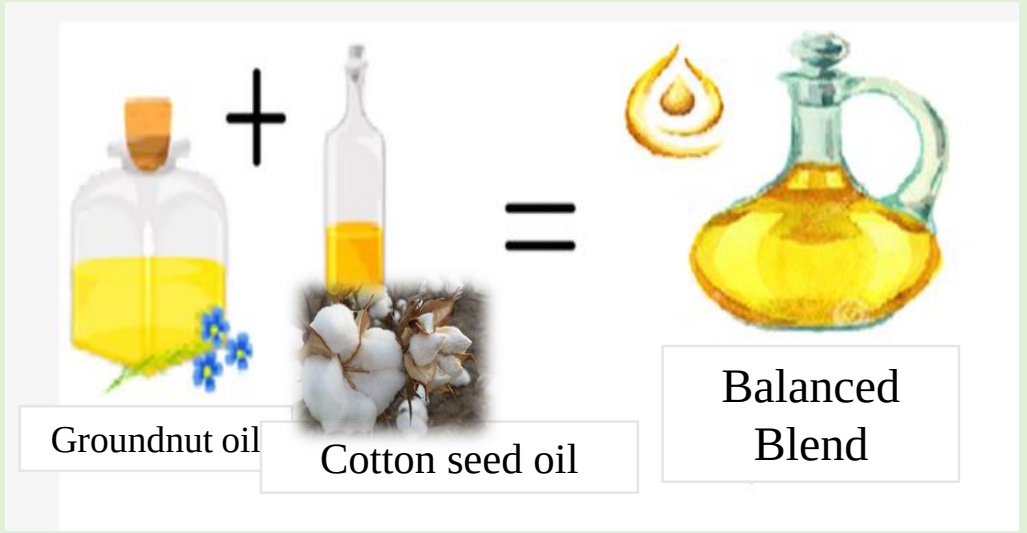
Antioxidants

- **Natural**
  - **Polyphenols**
  - **Flavonoids**
  - **Plant derived antioxidants**
- **Artificial**
  - **Negative long term implications**

Altering fatty acid profile

Balanced S:M:P/n-6:n-3 ratio

high-oleic (HO) and high-stearic (HS) oils can be blend to obtain Balanced binary il blend



Oxidative stability enhancement: Blending and addition of antioxidant

Triglyceride polymer

Polymerization

Oxidized TG

Hydroperoxide

Decomposition

Ketones, aldehyde

Balanced SMP ratio

OR

Antioxidant

Oxidation of oil during frying

- Physico-chemical properties
  - Color↑
  - Viscosity ↓
  - PV↓
  - FFA ↓
  - CD&CT ↓
  - P-AV↓
  - TOTOX↓
  - TBA↓
  - Fatty acid composition
    - SFAs↓
    - USFAs ↑
    - MUFAs↓
    - PUFAs ↑
    - TFAs↓
  - Volatiles compounds ↓
- Harmful compounds
  - TPC ↓
  - Acrylamide ↓
  - TFAs ↓
  - 3-MCPD ↓
  - HAA ↓
  - TAG polymers ↓
  - PAHs↓

Interesterification

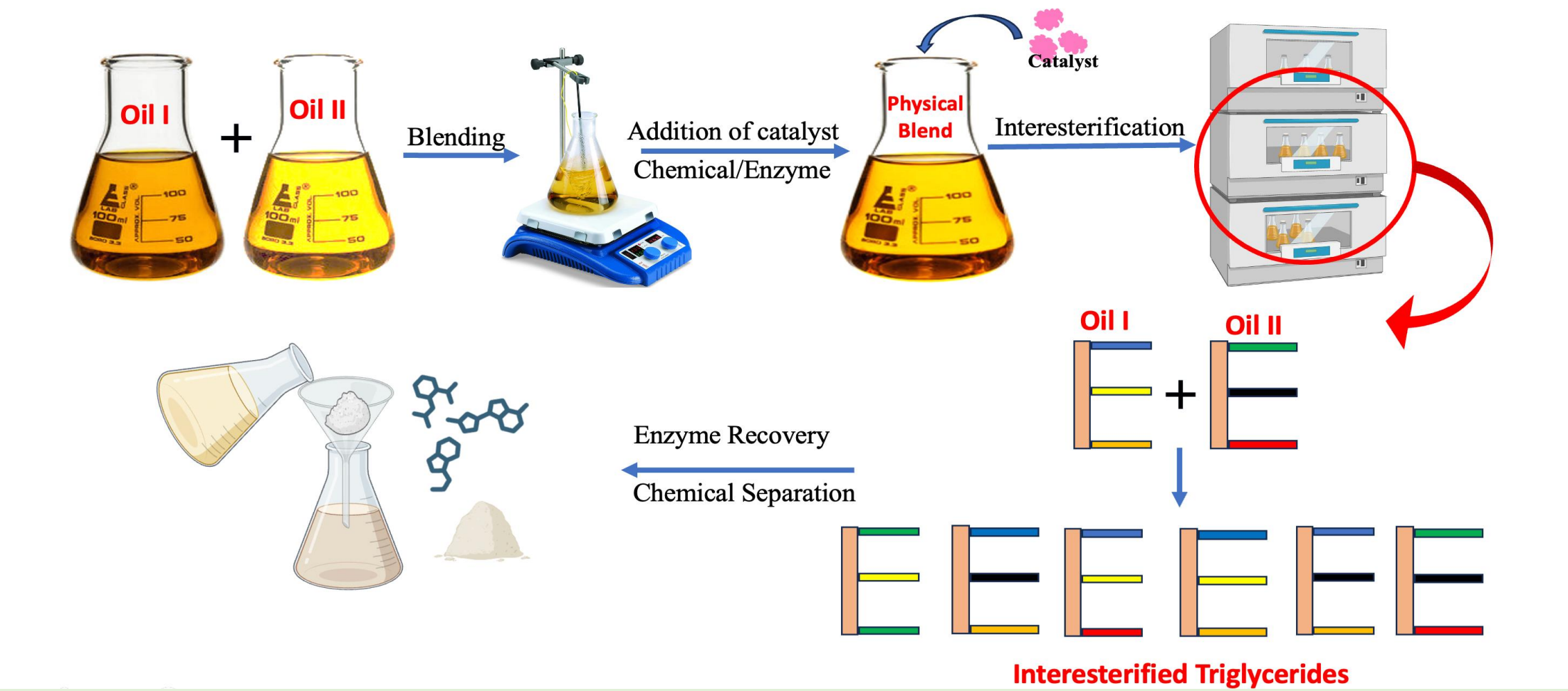


Figure: Interesterification Process

Interesterification

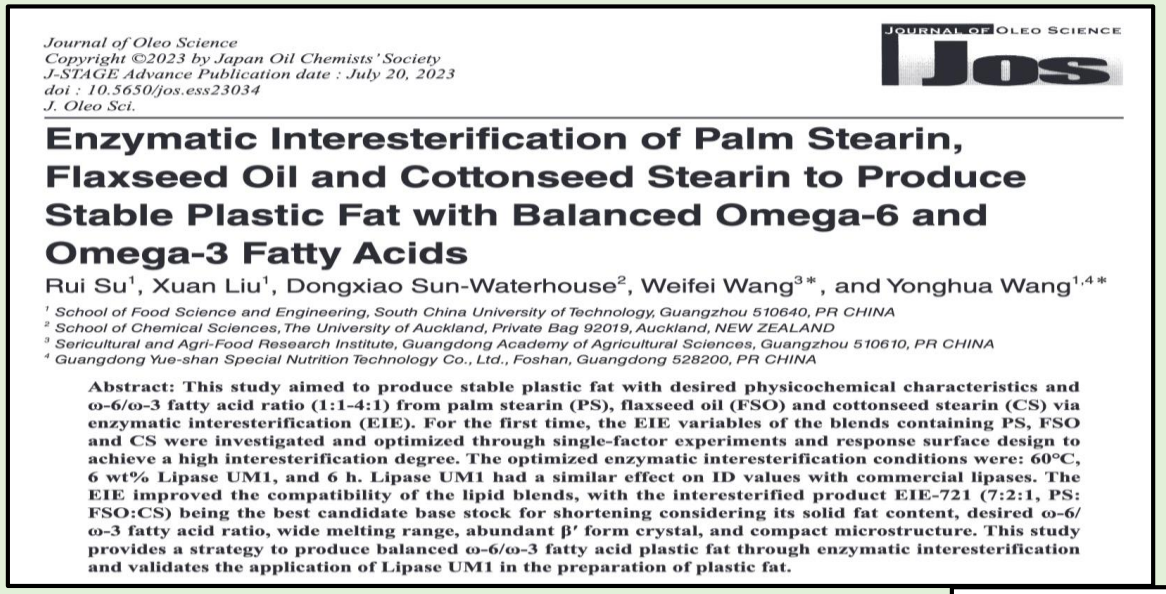
Chemical vs Enzymatic Interesterification

Characteristic	Chemical	Enzymatic
Catalyst	Chemical	Enzyme
Specificity	✗	✓
Temperature	↑ 	↓ 
Cost	Low cost	Expensive
By-product	High	Low
Environment concern	Hazardous	Environment Friendly

Why interesterification of cottonseed oil is required?

- Balance the SMP ratio of fatty acids.
- Balance the omega-6 to omega-3 fatty acid ratio.
- Enhancing the shelf life of PUFA.
- Improving the functionality and applicability.

Studies related to interesterification of cottonseed oil



Journal of Oleo Science
Copyright ©2023 by Japan Oil Chemists' Society
J-STAGE Advance Publication date : July 20, 2023
doi : 10.5650/jos.ess23034
J. Oleo Sci.

JOS JOURNAL OF OLEO SCIENCE

Enzymatic Interesterification of Palm Stearin, Flaxseed Oil and Cottonseed Stearin to Produce Stable Plastic Fat with Balanced Omega-6 and Omega-3 Fatty Acids

Rui Su[1], Xuan Liu[1], Dongxiao Sun-Waterhouse[2], Weifei Wang[3]*, and Yonghua Wang[1,4]*

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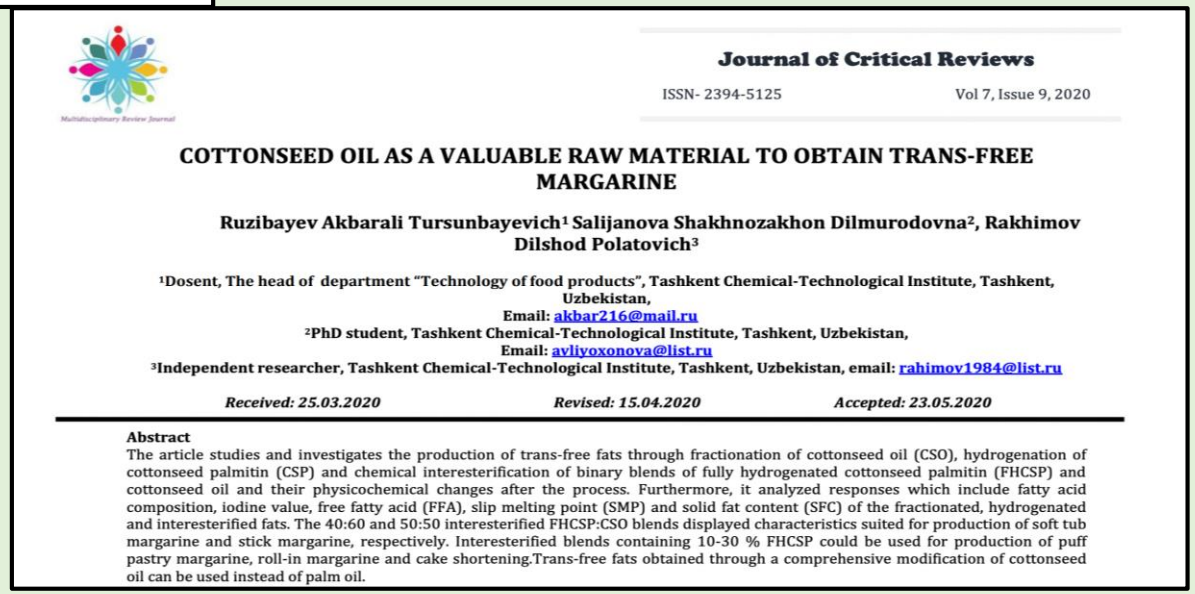
[3] Sericultural and Agri-Food Research Institute, Guangdong Academy of Agricultural Sciences, Guangzhou 510610, PR CHINA
[4] Guangdong Yue-shan Special Nutrition Technology Co., Ltd., Foshan, Guangdong 528200, PR CHINA

Abstract: This study aimed to produce stable plastic fat with desired physicochemical characteristics and ω-6/ω-3 fatty acid ratio (1:1-4:1) from palm stearin (PS), flaxseed oil (FSO) and cottonseed stearin (CS) via enzymatic interesterification (EIE). For the first time, the EIE variables of the blends containing PS, FSO and CS were investigated and optimized through single-factor experiments and response surface design to achieve a high interesterification degree. The optimized enzymatic interesterification conditions were: 60°C, 6 wt% Lipase UM1, and 6 h. Lipase UM1 had a similar effect on ID values with commercial lipases. The EIE improved the compatibility of the lipid blends, with the interesterified product EIE-721 (7:2:1, PS: FSO:CS) being the best candidate base stock for shortening considering its solid fat content, desired ω-6/ω-3 fatty acid ratio, wide melting range, abundant β′ form crystal, and compact microstructure. This study provides a strategy to produce balanced ω-6/ω-3 fatty acid plastic fat through enzymatic interesterification and validates the application of Lipase UM1 in the preparation of plastic fat.

- Cottonseed oil, being rich in omega-6 fatty acid has been used with a source of omega-3 fatty acid (flaxseed oil) and palm stearin to develop a plastic fat with balanced omega-6 to omega-3 fatty acid ratio.
- The enzymatic interesterification was carried out using Lipase enzyme.
- The fat exhibited desirable techno-functional properties.

- Cottonseed oil, was chemically interesterified develop a trans-fat free margarine.
- Traditional margarine is rich in saturated fatty acids and also comprise trans fats
- The fat exhibited desirable solid fat content, slip melting point, and texture with 50:50 ratio of fully hydrogenated cottonseed palmitin and fractionated cottonseed oil.



Journal of Critical Reviews
ISSN- 2394-5125 Vol 7, Issue 9, 2020

COTTONSEED OIL AS A VALUABLE RAW MATERIAL TO OBTAIN TRANS-FREE MARGARINE

Ruzibayev Akbarali Tursunbayevich[1] Salijanova Shakhnozakhon Dilmurodovna[2], Rakhimov Dilshod Polatovich[3]

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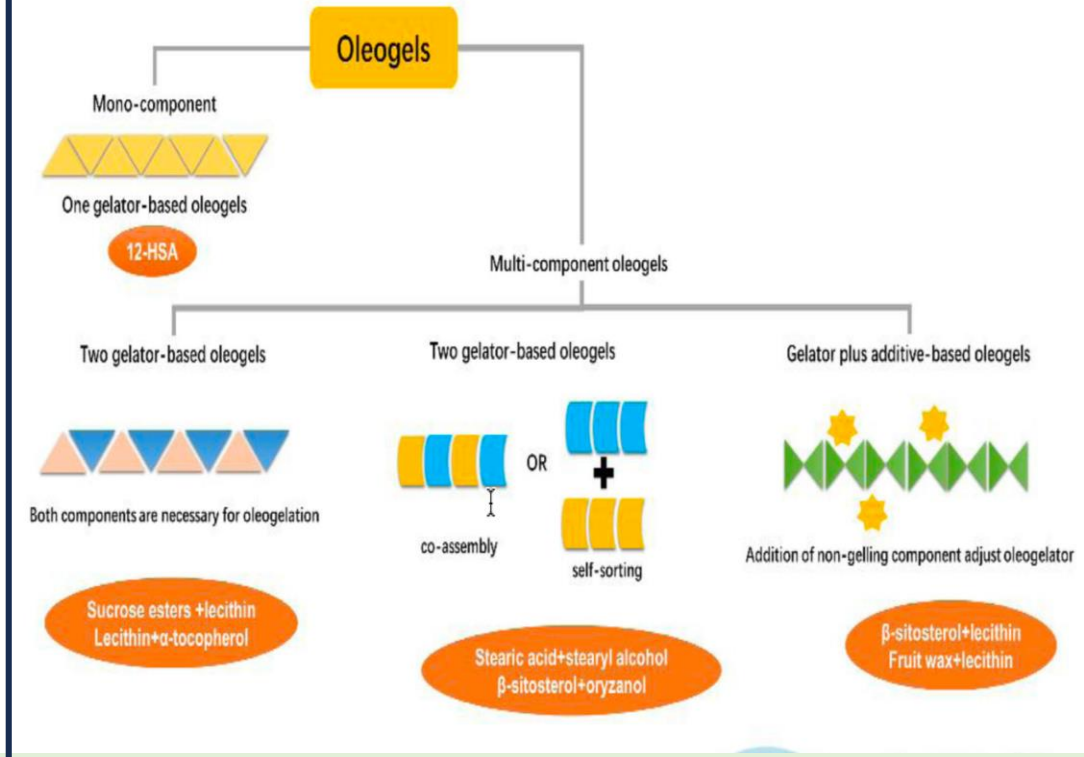
Received: 25.03.2020 *Revised: 15.04.2020* *Accepted: 23.05.2020*

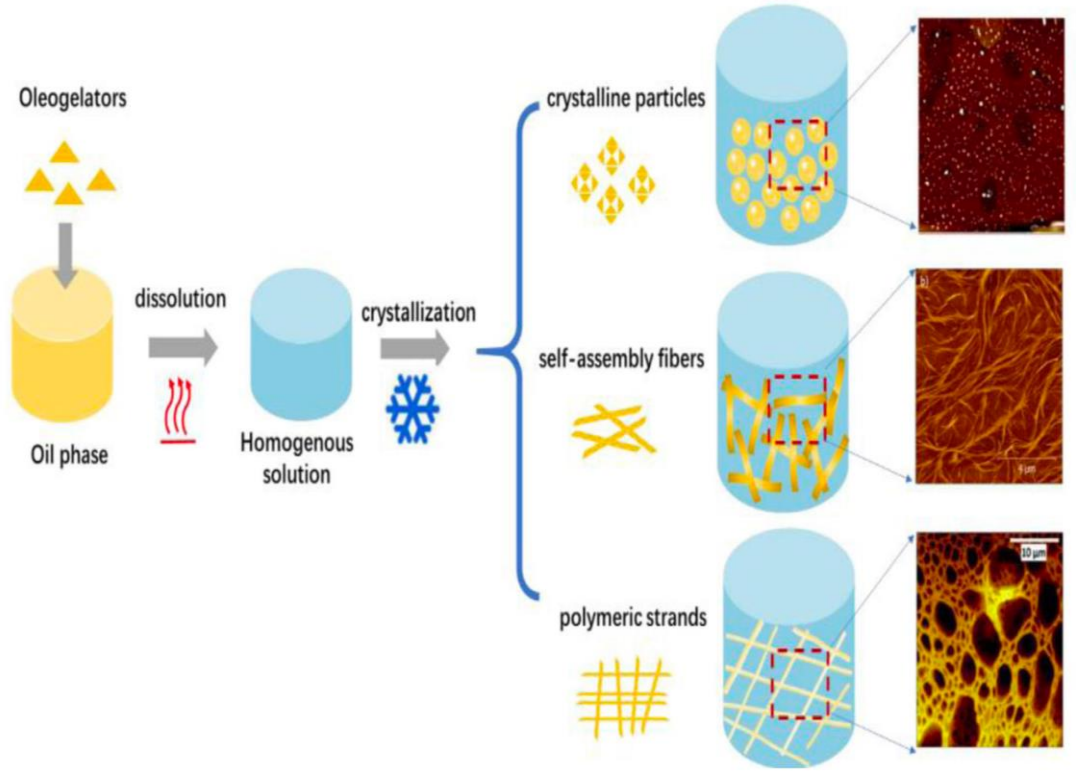
Abstract
The article studies and investigates the production of trans-free fats through fractionation of cottonseed oil (CSO), hydrogenation of cottonseed palmitin (CSP) and chemical interesterification of binary blends of fully hydrogenated cottonseed palmitin (FHCSP) and cottonseed oil and their physicochemical changes after the process. Furthermore, it analyzed responses which include fatty acid composition, iodine value, free fatty acid (FFA), slip melting point (SMP) and solid fat content (SFC) of the fractionated, hydrogenated and interesterified fats. The 40:60 and 50:50 interesterified FHCSP:CSO blends displayed characteristics suited for production of soft tub margarine and stick margarine, respectively. Interesterified blends containing 10-30 % FHCSP could be used for production of puff pastry margarine, roll-in margarine and cake shortening.Trans-free fats obtained through a comprehensive modification of cottonseed oil can be used instead of palm oil.

Oleogelation

Classification of Olegels



Mechanism of oleogelation



Studies related to oleogels based on cottonseed oil

DOI: 10.1111/jfpp.13621

ORIGINAL ARTICLE

WILEY Journal of Food Processing and Preservation Institute of Food Science + Technology ifst

Investigating the usage of unsaturated fatty acid-rich and low-calorie oleogels as a shortening mimetics in cake

Halime Pehlivanoglu[1] | Gorkem Ozulku[2] | Rusen Metin Yildirim[2] | Mehmet Demirci[1] | Omer Said Toker[2] | Osman Sagdic[2]

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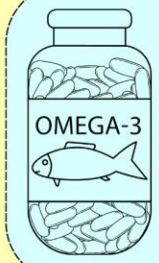
Abstract

In the present study, two purposes were aimed: (a) Reduction of fat content of cakes using watery oleogels and (b) Reduction of saturated fatty acid contents of cakes using oleogels rich in unsaturated fatty acid composition instead of shortening. For this aim, five different oleogels were produced using different percentages of high oleic sunflower oil, cotton seed oil, and blend fat and they were used in the cake formulation instead of shortening. Some physicochemical properties of oleogels (solid fat content and fatty acid composition) were determined. Specific volume, color, textural, and sensory properties of cakes containing prepared oleogel were also analyzed and compared to those of control sample. In addition, rheological properties of the batters were also determined. Color properties of the oleogel-containing cakes were found to be very similar to those of control sample. Oleogel formulation significantly affected the textural characteristics. Sensory scores showed that cakes including oleogels were found to be consumable level and the most acceptable sample was detected as the one including oleogel which was produced from high oleic acid sunflower oil and cotton seed oil at equal amounts (50/50). The results indicated that oleogels could be used in the formulation of cakes as a shortening replacer; thus, it might be possible to produce cakes rich in unsaturated fatty acids and cakes with lower calorie value, which is important for consumer acceptability of the products.

- Reduction of fat in cakes was aimed by formulating oleogels with sunflower, cottonseed and blended fats.
- Physicochemical and sensory analysis compared with control prepared with shortening
- The sensorial analysis indicated that the panel considered the oleogel cakes acceptable.
- The most preferred were the cakes containing oleogel of sunflower oil and cottonseed oil in equal amounts.



Sources

- Fish Oil
- Chia Seeds
- Garden Cress Seed
- Rapeseed Oil
- Microalgal Oil
- Flax Seeds
- Canola Oil
- Soybean Oil

Omega 3 Rich Oils

Benefits

- Cell protection
- Brain development
- Heart health
- Inflammation reduction
- Mental Wellness
- Body balance
- Lipid profile control

Low Stability

Encapsulation

Encapsulation Techniques

- Emulsification
- Spray-drying
- Extrusion
- Freeze-drying
- Coacervation
- In situ polymerization
- Coaxial electrospray system
- Fluidized-bed-coating
- Supercritical fluid technology
- Nanoliposomes

Increased Stability

- Enhanced stability prevents oxidation.
- Prolongs freshness and usability.

Improved Bioavailability

- Higher intestinal absorption
- More availability of Omega-3 Fatty Acid in systemic circulation
- Enhanced bioactivity of Omega-3 Fatty Acid

Higher Functionality

- Functional Foods
- Nutritional Supplements
- Bakery and Confectionery
- Dairy Enrichment
- Infant Nutrition
- Salad Dressings
- Snack Enrichment
- Medical Applications
- Oxidation Protection
- Customised Health Product

Oil Powders

- These are powdered forms of oils created through the **process of microencapsulation**, particularly used for PUFA (Polyunsaturated Fatty Acid) rich oils.

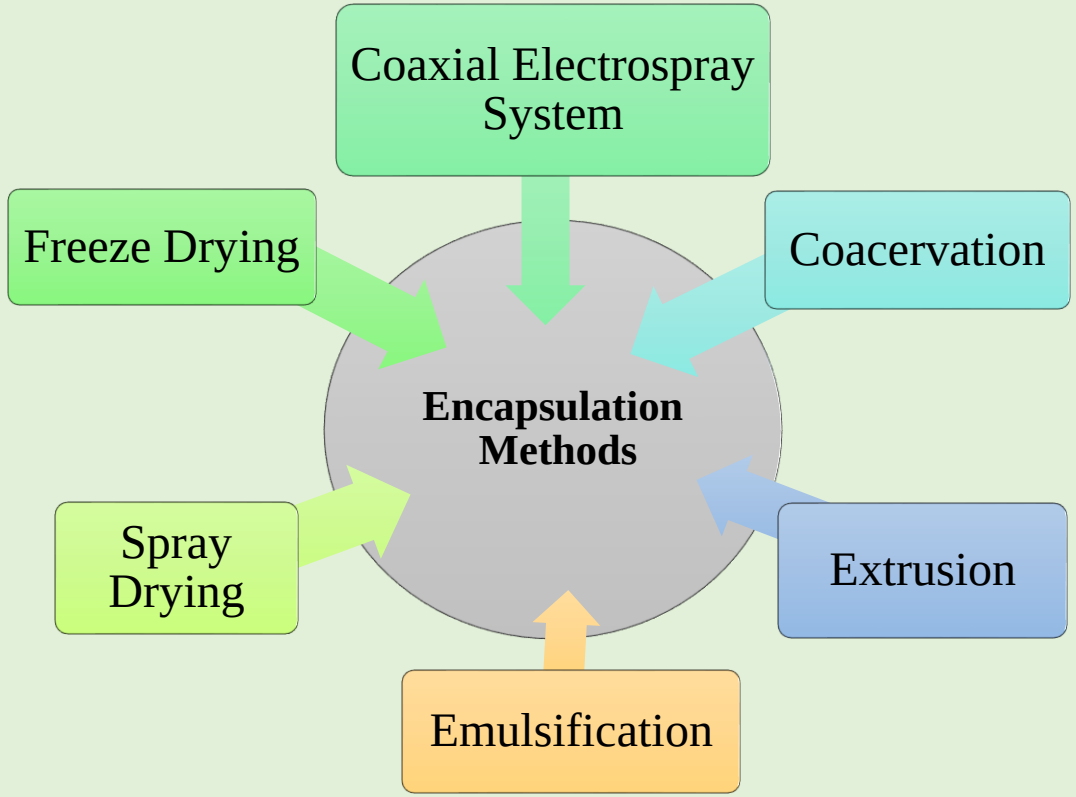
- PUFA rich oils are encapsulated within a matrix, often composed of polymers like Carbohydrates, protein, and solid fats, to **protect them from degradation.**

- After encapsulation, the **emulsion containing the oil and matrix is dried**, typically through techniques like freeze drying or spray drying, to remove water and create a powdered form of the oil encapsulate.

Methods of Encapsulation

- Encapsulation is widely adopted across food, pharmaceutical, and cosmetic industries due to its versatile applications.
- Structures for entrapping omega-3 PUFA include
    - nano- or micro-sized capsules
    - crystals
    - fibers
    - gels

  with carriers based on proteins, carbohydrates, or lipids.
- The encapsulation technology and matrix selection depends on the product's processing conditions and intended use.
- Encapsulation techniques and process parameters effect the properties and functionality of encapsulated components.



Methods of Encapsulation

Functionality

Better control of hygroscopicity, flowability and solubility

Masking

Unacceptable odors and tastes masked or reduced

Handling

Easier industrial handling and convenience in packaging of PUFA-rich powder

Stability

Improved oxidative stability and shelf life

Digestion

Controlled release and improved bioavailability of PUFA molecules

Form conversion

Liquid lipids change into solid microcapsules

Cottonseed: A sustainable source for meeting global protein needs

- Cottonseed has proven to be a sustainable source of plant protein.
- The protein requirement of half a billion people globally can be fulfilled by cottonseed meal.
- Gossypol, is the major polyphenol which acts as an anti-nutrient in cottonseed meal.
- USFDA (United States Food and Drug Administration) and WHO (World Health Organization) have set the limits for free gossypol in cottonseed meal-based protein products for utilization by nonruminants is 450ppm

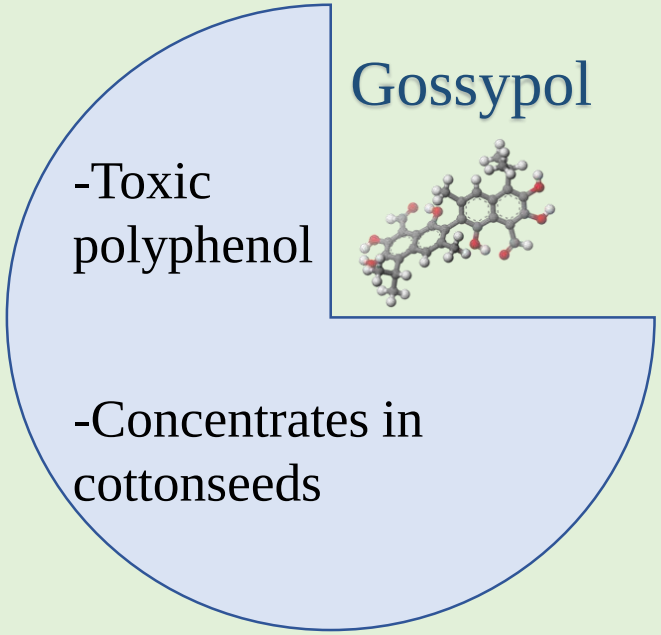
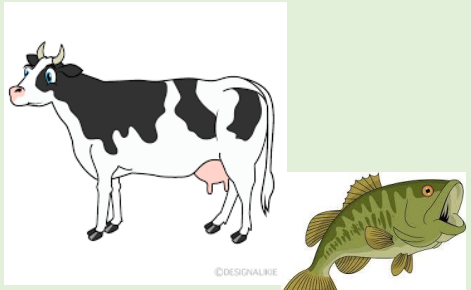


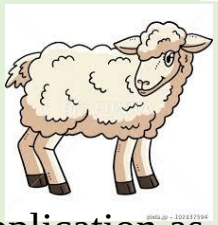
Figure: Flow chart depicting the steps needed for the application of cottonseed protein in food and feed.

Cottonseed

18% oil

Cottonseed Meal
(After oil extraction)





Application as cattle feed

Physical/chemical/
biological treatments for
degossypolization

Cottonseed Meal with high protein content and permissible gossypol limits

Protein extraction from cottonseed meal

Application in food industry

Various treatments used to remove gossypol

Type of cottonseed meal	Treatment used	% Gossypol Removal	References
Solvent extraction			
Defatted meal	Pure ethanol	61.55%	Saxena et al. 2012
Defatted meal	Aqueous butanone (90% v/v)	79.54 (FG%*)	Dechary et al. 1952
Flakes	Isohexane and alcohol	70% (FG*) 45% (TG*)	Kuk and Hron et al. 1998
Meal	Ethanol(acidic), Ethanol:water (95:5)	94.53%	Pelitire et al. 2014
SSF (Solid state fermentation)			
	Organism used		
Meal	Bacillus subtilis GH38	78.86%	Zhang et al. 2018
Meal	Candida tropicalis	88.6%	Khalaf et al. 2008
Meal	Saccharomyces cerevisiae ZD-5	88.51%	Zhang et al. 2007

*FG-Free gossypol, TG- Total gossypol

Conclusion

Cottonseed Oil Characteristics:

- High in omega-6 fatty acids
- Rich in antioxidants
- High smoke point, making it suitable for frying

Enhancing Thermal and Oxidative Stability:

-Blending: Mix with oils rich in saturated fatty acids

- Antioxidants: Add natural antioxidants
- Novel Technologies: Use encapsulation techniques

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