PM Formulation of

Micro Food processing Enterprises (PM-FME) Scheme

Training for Master Trainers

Technical Compendium

On

Fat and Oilseed Processing

(01-06 January, 2021)

Sponsored By

Ministry of Food Processing Industries
Government of India

Editors

Dr. D N Yadav
Dr. Ranjeet Singh
Dr. Sandeep Dawange

ICAR-Central Institute of Post-Harvest Engineering & Technology
PO: PAU, Ludhiana-141004
(An ISO 9001:2015 Institution)

PRODUCE PROCESS PROSPER

Disclaimer

This compendium is a compilation of the lectures which are undertaken during 'Online Training of Master Trainers on Fat and Oilseed Processing' during 01-06 January 2021 at ICAR-Central Institute of Post-Harvest Engineering & Technology, Ludhiana, (Punjab) India with Dr. D N Yadav (Course Director), Dr. Ranjeet Singh and Er. Sandeep P. Dawange (Course Co-Directors). It is understood that the views expressed on various topic are the prerogative and responsibility of concerned authors.

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Editors

D N Yadav
Ranjeet Singh
Sandeep P. Dawange

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भाकृअनुप - केन्द्रीय कटाई उपरान्त अभियांत्रिकी एवं प्रौद्योगिकी संस्थान
ICAR- CENTRAL INSTITUTE OF POST-HARVEST ENGINEERING & TECHNOLOGY
(AN ISO 9001-2015 Certified Institution)
Behind Radha Swami Satsang Ghar, Humbran Road, Ludhiana - 141008 (Punjab)
Corresponding Address - P.O. PAU Campus, Ludhiana-141004 (Punjab) INDIA.

Dr. Nachiket Kotwaliwale,
Director

Massage

India has a wide range of oilseeds crops grown in its different agro climatic zones. Groundnut, mustard/rapeseed, sesame, safflower, linseed, nigerseed / castorseed are the major traditionally cultivated oilseeds. Soyabean and sunflower have also assumed importance in recent years. Groundnut, soyabean and mustard together contribute about 85 percent of the country's oilseeds production. Coconut is most important amongst the plantation crops. Efforts are being made to grow oil palm in Andhra Pradesh, Karnataka, Tamil Nadu in addition to Kerala and Andaman & Nicobar Islands. Among the non-conventional oils, ricebran oil and cottonseed oil are the most important. In addition, oilseeds of tree and forest origin, which grow mostly in tribal inhabited areas, are also a significant source of oils. Until 2002, the olive oil sector in India was predominantly unorganised. The olive oil industry in India is small and largely people use it more for cosmetic purposes than for cooking. Today Indians are moving to better cooking mediums like Olive oil for health and wellness reasons. Olive Oil has always been placed somewhere between food and medicine and the biggest challenge is to educate Indian consumers on the benefits of olive oil as a cooking medium.

The ground realities of Indian vegetable fats and oil sector and the huge untapped potential in edible oil processing bring the role of ICAR-CIPHET into focus. ICAR-CIPHET is serving as a nodal institute in the area of the Post-Harvest Engineering & Technology for more than two decades and has contributed many technologies, which includes tools, equipment/machines, processes and products for postharvest loss reduction and value addition to oil seeds. The role of processing of edible oilseed becomes extremely critical considering the immense and immediate challenge of feeding nutritional fats/oil to the over billion population of India. Therefore, it is the need of the hour to discuss the present status of processing and value addition of oilseeds, explore and work for the future strategies to give oil processing a big boost. Understanding the significance of subject, ICAR-Central Institute Of Post-Harvest Engineering And Technology, Ludhiana is organizing an 'Online Training of Master Trainers on Fat and Oilseed Processing' sonsored by MoFPI, Govt. of India, is being organized at ICAR-CIPHET, Ludhiana during 01-06 January 2021, to assist the master trainers functionaries under PM – FMFPM Scheme throughout the country to enhance the income of farmers in large. I extend my greetings and compliment the team for their determined hard work in timely bringing up this compilation in the form of compendium. I wish this Online training course a great success.

[Nachiket Kotwaliwale]

Mail: director.ciphet@icar.gov.in, ciphet.director@gmail.com; Web: www.ciphet.in
Tel: 0161-2308669(O), 0161-23136103(O); Fax: 0161-2308670 (O), Gram: CIPHET, Ludhiana

‘Online Training of Master Trainers on Fat and Oilseed Processing’
(01-06 January 2021)
List of Experts and Topics

Sr. No	Topic	Expert
1	PMFME scheme: An Overview	**Dr. C. Anandharamakrishnan** Director, IIFPT, Thanjavur
2	Engineering Properties for Quality evaluation of Fats and Oilseeds	**Dr. Nachiket Kotwaliwale** Director, ICAR-CIPHET, Ludhiana
3	Microencapsulation techniques for oils	**Dr. K. Narsaiah** Principal Scientist & Head, ASEC Division, ICAR-CIPHET, Ludhiana
4	Technologies for Refining of edible oils and fats.	**Dr. S. K. Tyagi** Principal Scientist & PC AICRP-PHET, ICAR-CIPHET, Ludhiana
5	Quality aspects of canola and groundnut oil	**Dr. Virender Sardana** Principal Agronomist (oilseeds), Department of Plant breeding and Genetics, PAU, Ludhiana
6	Advanced methods for the fortification of oils and fats	**Dr. Manju Bala** Principal Scientist, FGOP Division, ICAR-CIPHET, Ludhiana
7	Processing of vegetable oil seeds and oils and their nutritional aspects: An overview	**Dr. K. D. Yadav** Senior Vice President (Technical) AAK Kamani Pvt Ltd., Mumbai
8	Technologies for valorization of de-oiled cakes	**Dr. D. N. Yadav** Principal Scientist, FGOP Division, ICAR-CIPHET, Ludhiana
	Innovative trends-in formulation of oilseeds based dairy analogues	
9	Edible oilseeds processing technologies in India	**Dr. S. K. Nanda** Ex PC AICRP–PHET, Ex-Head FGOP Division, ICAR-CIPHET, Ludhiana
10	Opportunities in food processing & considerations in selection of equipment	**Dr. Mahesh Kumar** Professor, Department of Processing & Food Engineering, PAU, Ludhiana
11	Process technologies for extraction of essential oils and oleoresins.	**Dr. R. K. Vishwakarma** Principal Scientist, FGOP Division, ICAR-CIPHET, Ludhiana
12	Role of Oils and Fats in human nutrition	**Dr. Mridula D.** Principal Scientist & Head, FGOP Division, ICAR-CIPHET, Ludhiana
13	Packaging consideration for fats and oilseeds	**Dr. Ranjeet Singh** Principal Scientist, ToT Division, ICAR-CIPHET, Ludhiana
14	Modern Storage technologies for oilseeds	**Dr. Sandeep Mann** Principal Scientist, ToT Division, ICAR-CIPHET, Ludhiana
15	Advances in processing technologies of animal fats and their utilization	**Dr. M. K. Chatli** Dean, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana.

16	Advances in process technologies for fat-rich dairy products	**Dr. S. Siva Kumar** Assistant Scientist – cum - Head, Department of Dairy Tech, GADVASU, Ludhiana
17	Food safety and standards for fats and oilseeds	**Dr. Rahul K. Anurag** Scientist, ASEC Division, ICAR-CIPHET, Ludhiana
18	Problem Management and enhancement of entrepreneurial competencies	**Dr. Ramandeep Singh** Professor, School of Business Studies, PAU, Ludhiana
19	Plant layout and maintenance for oil processing equipment	**Dr. Sandeep P Dawange** Scientist, ToT Division, ICAR-CIPHET, Ludhiana
20	Innovations in production technologies for animal origin fats and oils and their processing.	**Dr. A. K. Singh** Principal Scientist, Dairy Technology Division, ICAR-NDRI, Karnal

Training Agenda
'Online Training of Master Trainers on Fat and Oilseed Processing'
(01-06 January 2021)

Day 1: 01 January 2021, Friday			
Meeting Link: https://us02web.zoom.us/j/87410015707?pwd=bER4cmhucFhWcHhXM3l2RzR4TFNsQT09			
Time	**Schedule**	**Online**	**Speaker**
10:05 am-10:15 am	On boarding of participants	10 min	
10:15 am	ICAR Song	03 min	
10:18 am	Welcome Address	05 min	**Dr. D. N. Yadav** Principal Scientist, ICAR-CIPHET, Ludhiana
10:22 am-10:45 am	Introduction of Participants	23 min	
10:45 am	Address by Director, ICAR-CIPHET, Ludhiana	05 min	**Dr. Nachiket Kotwaliwale** Director, ICAR-CIPHET, Ludhiana
10:50 am	Address by Director, IIFPT, Thanjavur	05 min	**Dr. C. Anandharamakrishnan** Director, IIFPT, Thanjavur
10:55 am	Vote of thanks	03 min	**Dr. Ranjeet Singh** Principal Scientist, ICAR-CIPHET, Ludhiana

Day 1: 01 January 2021, Friday				
Meeting Link: https://us02web.zoom.us/j/87410015707?pwd=bER4cmhucFhWcHhXM3l2RzR4TFNsQT09				
Time	**Schedule**	**Online**	**Demo/Self learning**	**Speaker**
11:00 am - 12:15 pm	Overview of PMFME scheme	75 min		**Dr. C. Anandharamakrishnan** Director, IIFPT, Thanjavur
12:15 pm - 01:30 pm	Engineering Properties for Quality evaluation of Fats and Oilseeds	75 min		**Dr. Nachiket Kotwaliwale** Director, ICAR-CIPHET, Ludhiana
01:30 pm-02:00 pm	***Lunch break***			
02:00 pm - 04:00 pm	Microencapsulation techniques for oils	120 min		**Dr. K. Narsaiah** Principal Scientist & Head, ASEC Division, ICAR-CIPHET, Ludhiana
04:00 pm - 06:00 pm	Technologies for Refining of edible oils and fats.	120 min		**Dr. S. K. Tyagi** Principal Scientist & PC AICRP-PHET, ICAR-CIPHET, Ludhiana
06:00 pm - 07:00 pm	Self-learning on Technologies for Refining of edible oils and fats.		60 min	

Training Agenda
'Online Training of Master Trainers on Fat and Oilseed Processing'
(01-06 January 2021)

Day 2: 02 January 2021, Saturday				
Meeting link: https://us02web.zoom.us/j/86386447434?pwd=ZWQ4TWZrZ0VWaWYzTkFDT2crc1RWUT09				
Time	**Schedule**	**Online**	**Demo/Self learning**	**Speaker**
09:30 am - 11:30 am	Quality aspects of canola and groundnut oil	120 min		**Dr. Virender Sardana** Principal Agronomist (oilseeds), Department of Plant breeding and Genetics, PAU, Ludhiana
11:30 am - 01:30 pm	Advanced methods for the fortification of oils and fats	120 min		**Dr. Manju Bala** Principal Scientist, FGOP Division, ICAR-CIPHET, Ludhiana
01:30 pm- 02:00 pm	***Lunch break***			
02:00 pm - 04:00 pm	Processing of vegetable oil seeds and oils and their nutritional aspects: An overview	120 min		**Dr. K. D. Yadav** Senior Vice President (Technical) AAK Kamani Pvt Ltd., Mumbai
04:00 pm - 06:00 pm	Technologies for valorization of de-oiled cakes	120 min		**Dr. D. N. Yadav** Principal Scientist, FGOP Division, ICAR-CIPHET, Ludhiana
06:00 pm - 07:30 pm	Self-learning		90 min	

03 January 2021, Sunday (Holiday)

Day 3: 04 January 2021, Monday				
Meeting Link: https://us02web.zoom.us/j/83994329141?pwd=UkI3NzV4b0tiNGJsd295ODNrSVcxdz09				
Time	**Schedule**	**Online**	**Demo/Self learning**	**Speaker**
09:30 am - 11:30 am	Edible oilseeds processing technologies in India	120 min		**Dr. S. K. Nanda** Ex PC AICRP–PHET, Ex-Head FGOP Division, ICAR-CIPHET, Ludhiana
11:30 am - 01:30 pm	Opportunities in food processing & considerations in selection of equipment	120 min		**Dr. Mahesh Kumar** Professor, Department of Processing & Food Engineering, PAU, Ludhiana
01:30 pm- 02:00 pm	***Lunch break***			
02:00 pm - 03:30 pm	Process technologies for extraction of essential oils and oleoresins.	90 min		**Dr. R. K. Vishwakarma** Principal Scientist, FGOP Division, ICAR-CIPHET, Ludhiana
3:30 pm - 04:30 pm	Role of Oils and Fats in human nutrition	90 min		**Dr. Mridula D.** Principal Scientist & Head, FGOP Division, ICAR-CIPHET, Ludhiana

Training Agenda
'Online Training of Master Trainers on Fat and Oilseed Processing'
(01-06 January 2021)

04:30 pm - 06:00 pm	Packaging consideration for fats and oilseeds	90 min		**Dr. Ranjeet Singh** Principal Scientist, ToT Division, ICAR-CIPHET, Ludhiana
06:00 pm - 07:30 pm	Self-learning		90 min	

Day 4: 05 January 2021, Tuesday

Meeting link: https://us02web.zoom.us/j/85363955817?pwd=WmJhYUxuZVRyRTJrUU5TQXhHd08ydz09

Time	Schedule	Online	Demo/Self learning	Speaker
09:30 am - 11:30 am	Modern Storage technologies for oilseeds	120 min		**Dr. Sandeep Mann** Principal Scientist, ToT Division, ICAR-CIPHET, Ludhiana
11:30 am - 01:30 pm	Advances in processing technologies of animal fats and their utilization	120 min		**Dr. M. K. Chatli** Dean, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana.
01:30 pm-02:00 pm	***Lunch break***			
02:00 pm - 04:00 pm	Advances in process technologies for fat-rich dairy products	120 min		**Dr. S. Siva Kumar** Assistant Scientist – cum - Head, Department of Dairy Tech, GADVASU, Ludhiana
04:00 pm - 06:00 pm	Food safety and standards for fats and oilseeds	120 min		**Dr. Rahul K. Anurag** Scientist, ASEC Division, ICAR-CIPHET, Ludhiana
06:00 pm - 07:30 pm	Self-learning		90 min	

Day 5: 06 January 2021, Wednesday

Meeting link: https://us02web.zoom.us/j/81317372813?pwd=ZVRid0UzeFM3WVVzWHpTL0JLK1RIUT09

Time	Schedule	Online	Demo/Self learning	Speaker
09:30 am - 10:30 am	Problem Management and enhancement of entrepreneurial competencies	60 min		**Dr. Ramandeep Singh** Professor, School of Business Studies, PAU, Ludhiana
10:30 am - 11:30 am	Plant layout and maintenance for oil processing equipment	60 min		**Dr. Sandeep P Dawange** Scientist, ToT Division, ICAR-CIPHET, Ludhiana
11:30 am - 01:30 pm	Innovations in production technologies for animal origin fats and oils and their processing.	90 min		**Dr. A. K. Singh** Principal Scientist, Dairy Technology Division, ICAR-NDRI, Karnal
01:30 pm-02:00 pm	***Lunch break***			
02:00 pm - 06:00 pm	Evaluation by FICSI			

PM Formalisation of Micro Food Processing Enterprises Scheme (PMFME): An Overview

Dr. C. Anandharamakrishnan

Director, IIFPT, Thanjavur

Introduction

Ministry of Food Processing Industries (MoFPI), in partnership with the States, has launched an all India centrally sponsored "PM Formalisation of Micro Food Processing Enterprises Scheme (PM FME Scheme)" for providing financial, technical and business support for upgradation of existing micro food processing enterprises.

The objectives of the scheme are:

(i) Support for capital investment for upgradation and formalization with registration for GST, FSSAI hygiene standards and Udyog Aadhar;

(ii) Capacity building through skill training, imparting technical knowledge on food safety, standards & hygiene and quality improvement;

(iii) Hand holding support for preparation of DPR, availing bank loan and upgradation;

(iv) Support to Farmer Producer Organizations (FPOs), Self Help Groups (SHGs), producers cooperatives for capital investment, common infrastructure and support branding and marketing.

One District One Program

The Scheme adopts One District One Product (ODOP) approach to reap benefit of scale in terms of procurement of inputs, availing common services and marketing of products. The States would identify food product for a district keeping in view the existing clusters and availability of raw material. The ODOP could be a perishable agri-produce, cereal based product or a food product widely produced in a district and their allied sectors. Illustrative list of such products includes mango, potato, litchi, tomato, tapioca, kinnu, bhujia, petha, papad, pickle, millet based products, fisheries, poultry, meat as well as animal feed among others. Preference would be given to those producing under ODOP approach. However, units producing other products would also be supported. Support for common infrastructure and branding & marketing would only be given for products under ODOP approach.

Upgradation of Individual Micro Food Processing Units

Individual micro food processing units desirous of upgradation of their unit can avail credit-linked capital subsidy @35% of the eligible project cost with a maximum ceiling of Rs.10 lakh per unit. The beneficiary contribution should be minimum 10% and the balance should be loan from a Bank.

Support to FPOs / SHGs / Cooperatives

The scheme would provide support to FPO s / SHG s / Producer Cooperatives for capital investment long the entire value chain with credit linked grant @ 35%.

Seed Capital to SHG

Seed capital @ Rs. 40,000/- per SHG member would be provided to those engaged in food processing for working capital and purchase of small tools. Seed capital as grant would be provided to the SHG federation which, in turn, would be extended to members as loan through the SHGs.

Common Infrastructure

Credit linked grant @35% would be provided to FPOs, SHGs, cooperatives,State owned agencies and private entrepreneurs for development of common infrastructure including common processing facility, lab, warehouse, cold storage, packaging and incubation center.

Branding and Marketing Support

Marketing and branding support would be provided at State or regional level to FPOs/ SHGs/ Cooperatives or an SPV of micro food processing enterprises under the scheme following the ODOP approach for developing common packaging & branding with provision for quality control, standardization and adhering to food safety parameters for consumer retail sale. These organisations would be supported based on DPR prepared by them and recommended by the State Nodal Agency. Support for branding and marketing would be limited to 50% of the total expenditure.

Procedure for applying

Existing food processing units desirous of seeking assistance could apply online on FME portal. The Resource Persons (RPs) engaged for _eld level support would provide handholding support for preparation of DPR, availing bank loan, obtaining necessary registration and licences including food standards of FSSAI, Udyog Aadhar and GST. Applications for support for FPOs / SHGs / cooperatives, common infrastructure and marketing & branding could be submitted to the State Nodal Agency (SNA) along with a DPR. The SNA would appraise the project and recommend it for bank loan. Grant by the Government would be deposited in the account of bene_ciary in the lending bank. If after a period of three years from the disbursement of last tranche of the loan, the bene_ciary account is still standard and the Unit is operational, this amount would be adjusted in the bank account of beneficiary.

Guidelines & Contact

Detailed guidelines of the scheme may be viewed at Ministry's website mofpi.nic.in. Individual entrepreneurs and other stake holders may contact the State Nodal Agencies of their respective State / UT regarding the roll out of scheme and contact points at the district level.

UNIT-2

Engineering properties for quality evaluation of fats and oilseeds

Nachiket Kotwaliwale
ICAR-CIPHET, Ludhiana

WHAT IS QUALITY?

Quality of food is an extremely important aspect of human life. Consumers are becoming more and more concerned about nutrition, food safety and environmental issues that influence their acceptance of food products. In general terms, quality of food relates to desirability of consumer for the particular food. There is general agreement that quality has an objective and a subjective dimension. Objective quality refers to the physical characteristics built into the product and is typically dealt with by engineers and food technologists. Subjective quality is the quality as perceived by consumers. In the subjective realm the holistic approach, equates quality with all the desirable properties, including safety and convenience of consumption, a product is perceived to have. Individual assessments of quality are personal and situational, and that they are often based on incomplete information. Objective evaluation of foods involves instrumentation, and use of physical and chemical techniques to evaluate food quality. Objective testing uses equipment to evaluate food products instead of variable human sensory organs. Such tests of food quality are essential in the food industry, especially for routine quality control of food products. Normally, an objective test measures one particular attribute of a food rather than the overall quality of the product.

WHY MEASURE QUALITY OF FOODS?

- To conform to quality control standards or improve quality
    - Maintaining product safety
    - Maintain a product with same sensorial characteristics so consumers of that product continue to buy it
    - Release or reject production batch for sale because the products inspected meet the standards set by the manufacturer/ buyer/ certifying authority
- To provide input for decision making (new product development)
- To determine the market value of a product
- To determine shelf life of a product
- Ingredient substitution in product formulation
- To compare a product (s) with the competitor's product (s)
- To compare processing conditions and its effect on product
- To determine storage/ packaging conditions

WHO DEFINES QUALITY OF FOOD?

Normally, consumer is at the epitome of the food marketing chain and hence more often, it is the consumer who defines quality, who in turn is influenced by variety of technological, health, sensory, social and psychological factors. Quite often, the quality parameters in the perception of a consumer are vague, inconsistent with time and person and not measurable directly. However, many times the consumer is not aware of the intricacies related to safety and quality features of foods or food ingredients. In such instance, that occurs quite often, buyers (individual, organizations or their country) set the quality standards. Such standards are relatively more objective, measurable, comprehensive, lucid and supported with sufficient procedural and legal documentation. Some important quality enforcing authorities and their standards are listed below:

- Food safety and standards authority of India
  - Food Safety and Standards Act, 2006
    - Prevention of Food Adulteration Act, 1954
    - Fruit Product Order (FPO), 1955
    - Solvent Extracted Oil, De-oiled Meal and Edible Flour (Control) Order, 1967
    - Meat Food Products Order (MFPO)
    - Edible Oils Packaging, 1998
    - Vegetable Oil Products Order, 1998
    - Milk & Milk Product Amendment Regulations – 2009
- Bureau of Indian Standards:
  - Method of analysis for Foodgrain. IS: 4333 (Part-I):1996 and IS : 4333 (Part- II): 2002
  - Terminology for Foodgrains. IS: 2813-1995
  - Method of sampling of cereals and pulses IS: 14818-2000
- ISO standards and food
- Food Safety Act 1990 (USA)
- USDA Quality Standards
- European Food Safety Authority

MEASUREMENT OF QUALITY PARAMETERS

Subjective dimensions of quality are a measured using sensory evaluation technique that applies principles of experimental design and statistical analysis to the use of human senses (sight, smell, taste, touch and hearing) for the purposes of evaluating consumer products. The technique employs trained/ un-trained consumer panellists. Though, the technique is used extensively for food quality determination, it has certain pitfalls such as: Determining the wrong objective for conducting sensory analysis; Choosing the wrong set of participants in the sensory test(s); Asking the wrong questions to the participants; Having biased judgments of the products tested; Lacking scientific control (scientific rigor); Conducting the sensory test in the wrong (inadequate) environment.

MEASUREMENT OF OBJECTIVE QUALITY PARAMETERS

Objective measurement of quality attributes is more dependable and scientific method, it depends heavily on tools and instruments which help in direct measurement in standard units or categorization based on accepted norms. Some important quality parameters for different types of food products are given below:

Type of food product	Quality attribute
Food grains, pulses, oilseeds	Size, shape, weight, density, colour, presence of dockage (unacceptable foreign material, brokens etc.), insect infestation, chemical composition (moisture, fat, carbohydrates, acidity, etc.), microbial presence, other sensory attributes

Processed food products	Textural properties, colour, particle size, shape, moisture content, chemical and microbial quality, other sensory attributes, rheological properties in case of liquids and fluids.

Chemical composition is one of the most important quality parameters and there are many direct and indirect methods for its determination. Microbiological quality assessment is also a well-defined field. The following text defines measurement of some attributes based on some engineering properties of the food materials.

Physical Properties

The physical constituents and engineering properties of food materials are important for the design of machines, processes and analysis of the behaviour of the product in their handling and processing. Post-harvest operations of food materials using various mechanical and/or thermal techniques and devices call for full understanding of size, shape, surface area, volume, particle and bulk density and porosity, static and dynamic coefficients of friction of various food materials.

Spatial dimensions, size, and sphericity – Appropriate for Oilseeds

Engineering properties of biomaterials play an important role in designing the equipment, which are used for post-harvest operations and storage. Shape and size are important parameters that govern design of winnowers, cleaners and graders. In conveying of solid materials by air or water, estimate of the frontal area and related diameters are needed for determination of terminal velocity, drag coefficient and Reynold's number. Further, they are also important in the analysis of problems of heat and mass transfer, pneumatic and hydraulic handling and separation, electrostatic separation of seeds and grains.

Shape defines the form of an object. In defining the shape, some dimensional parameters of an object must be measured. For this, longitudinal and lateral cross sections of the material can be compared with the standard shapes available in various literature.

Instrumentation required for determination of various properties of foods.

Spatial dimensions, size and sphericity

Shape	Shadow graph Charted standard for describing the shape of an object
Spatial dimensions	Travelling microscope (with cross aids and equipped with illuminating device)

Gravimetric properties

Thousand grain weight	Electronic balance Indian Standard: IS:4333(Part-IV)-1968 may also be referred.
Volume	Air comparison pycnometer Liquid displacement specific gravity bottles/ pycnometer General purpose reagent (toluene rectified) and measuring cylinder
Bulk density	Electronic balance and measuring cylinder Indian Standard; IS:4333(Part III)-1967 may also be referred.

Specific gravity	Specific gravity balance Liquid displacement specific gravity bottles/ pycnometer Specific gravity gradient tube General purpose reagent (toluene rectified) and measuring cylinder
Surface area/ projection area	Overhead projector Measurement devices - planimeter
Frictional properties	
Angle of repose	Graduated scale Indian Standard: IS : 6663-1972 may also be referred.
Coefficient of external/ internal friction	Setup for frictional properties Measuring weights or load cells
Aerodynamic properties	
Terminal velocity	Adjustable speed blower Hot wire anemometer or ‘VANE’ type electronic anemometer
Rheological properties – Appropriate for Fats and products	
Deformation load compressive strength, crushing load etc.	Universal Testing Machine (INSTRON) Texture Analyser
Viscosity	Viscometer Rheometer

Texture analysis – Useful for oilseeds and solid products

Texture is an important attribute in that it affects processing and handling, influences habits, and affects shelf-life and consumer acceptance of products. Characterisation of texture commonly falls into two main groups, based on sensory and instrumental methods of analysis. Sensory analysis includes use of the senses of smell, taste, sound and touch. Scientific Texture Analysis provides quantifiable, repeatable and accurate data on the physical properties of food, cosmetic, pharmaceutical and chemical products. It is now an established procedure in research, and a valuable tool in the quest for improved quality control methods. Texture Analysers are used to measure many properties, such as Hardness, Brittleness, Fracturability, Adhesiveness, Elasticity, Bloom Strength etc., on a vast range of products.
Texture analyzer measures three independent variables, i.e. force, distance (deformation), and time. It gives graphical as well as numerical output of desired resolution. Figure 3 shows a typical behaviour of a food material under strain.

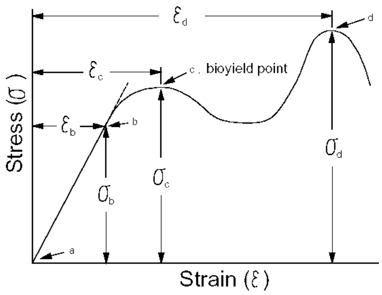


Figure 3: A typical stress strain curve that can be generated by a Texture analyzer.

A food sample can be subjected to multiple cycles of deformation to determine certain rheological properties. The most common of such test is called Texture Profile Analysis (TPA). A sample is subjected to a strain twice with an appropriate time gap between the two cycles and the curve is plotted (Figure 44). Various textural properties are determined from this curve as shown in Figure 44.

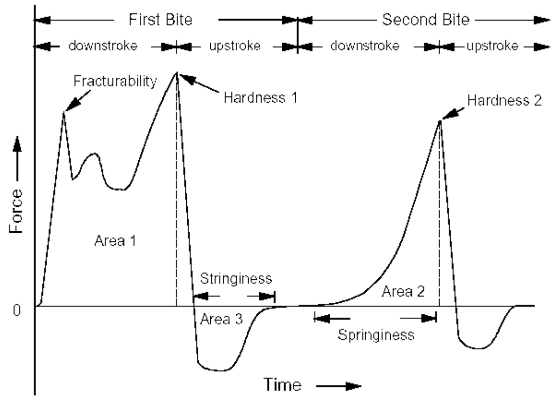


Figure 4: Example of TPA of a food sample

Some other texture related properties which can be determined using a texture analyser are given in table below.

Adhesion	Extensibility	Resilience	Viscoelasticity
Tear Strength	Firmness	Relaxation	Consistency
Brittleness	Flexibility	Setting point	Break Strength
Burst point	Friction	Shear Strength	Tackiness
Cohesion	Fracturability	Springiness	Disintegration
Compressibility	Hardness	Stiffness	Seal Strength
Melting point	Puncture Resistance	Mucoadhesion	Crispness
Creep	Peel Strength	Swelling	Elastic Modulus
Bending	Tensile Strength	Curing	Toughness
Puncture	Flowability		

Rheological properties

Rheology pertains to study of deformation and flow. Rheological properties are determined for liquid as well as solid food materials.

Rheometry

A rheometer is a laboratory device used to measure the way in which a liquid, suspension or slurry flows in response to applied forces. It is used for those fluids which cannot be defined by a single value of viscosity and therefore require more parameters to be set and measured than is the case for a viscometer. It measures the rheology of the fluid.

There are two distinctively different types of rheometers. Rheometers that control the applied shear stress or shear strain are called rotational or shear rheometers, whereas rheometers that apply extensional stress or extensional strain are extensional rheometers. Rotational or shear type rheometers are usually designed as either a native strain-controlled instrument (control and apply a user-defined shear strain which can then measure the resulting shear stress) or a native stress-controlled instrument (control and apply a user-defined shear stress and measure the resulting shear strain). Figure 5 illustrates categorization of liquid rheological instruments.

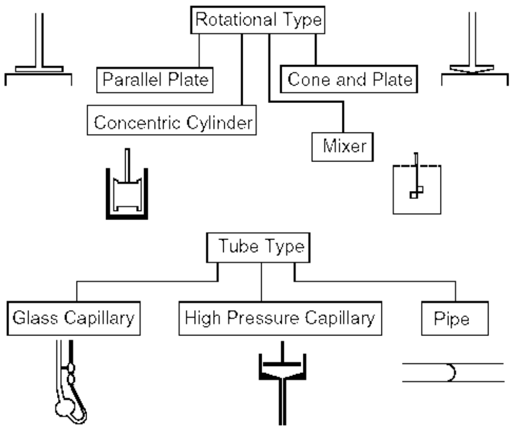


Figure 5: Categories of liquid rheological instruments

Optical properties

The optical properties of a material are defined by the percentage of incident light that is reflected, transmitted or absorbed by each wavelength. Reports of use of optical properties are as old as 1958 when skin color light transmittance could be used to indicate the flesh color of intact fruit. Researchers observed a correlation between wavelength of peak transmittance and loss in firmness occurring during maturation and ripening. They also observed a high correlation between reflectance wavelength and soluble solid/ acid content of freshly harvested fruits, their maturity. Light reflectance techniques have been used to detect surface defects and contamination of dried prunes; mechanical injury, rot, molds scars, mite injury and scrab on oranges and tomatoes.

The green plants which have been irradiated give off light for considerable time after illumination. This phenomenon is known as delayed light emission (DLE). DLE is probably produced by all vegetables, fruits and plant materials undergoing photosynthesis and can be related to chlorophyll concentration or apparent greenness of the product. Researchers have observed an almost linear relationship between chlorophyll content of some fruits and vegetables and their DLE intensity. And thus greens of these commodities could be accurately separated from ripened ones. Moreover, effect of surface treatments such as brushing, brushing and waxing on DLE is observed as negligible.

Measurement of light in the visible range (Figure 6) of the electromagnetic spectrum (approximately 400-700 nm) is used to define colour of an object. Instruments have been designed to quantify colour as humans see it and represent it in terms of some absolute numbers. Some of the popular colour definitions or colour coordinate systems are:

1. CIE-RGB System: Three monochromatic primary sources (Red, Green and Blue).
2. CIE-XYZ System: Provide full gamut of reproducible colors
3. CIE-UVY System (UCS): u,v=chromaticities, Y=luminance.
4. CIE-U*V*W* System (Modified UCS): Good for measuring color difference quantitatively.
5. S, θ, W* system: Polar representation of U*, V*, W* system- S(saturation) , θ(hue), W* (brightness).
6. NTSC Receiver System-RN , GN , BN : Standard for TV receiver.
7. NTSC Transmission (YIQ) System – Facilitate transmission of color images via monochrome TV channels without increasing bandwidth. Y (luminance), I , Q (chrominances).

8. L, a*, b* System: Yield perceptually uniform spacing of colors (classification), L (brightness), a*(red-green), b* (yellow-blue). Graphically, the L-a-b colourspace is explained in Figure 7.
9. CMYK system: Mostly used in printing industry. Colours used to reproduce a specific colour are Cyan (C), Magenta (M), Yellow (Y) and Black (K).

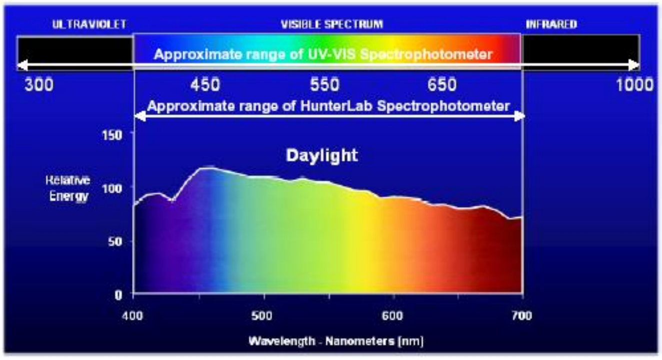


Figure 6: The visible spectrum

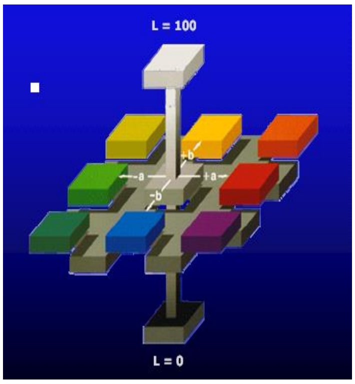


Figure 7: The L-a-b colourspace

CONCLUSION

Quality is value for a food product that depends heavily on the perceptions of consumer. Measurement of quality parameters has been a major subject of interest in the domain of food trade. Though quality itself is a qualitative term, there are many objective methods for determination of quality. Also there are many agencies who define qualitative parameters for variety of food products. The quality parameters are different for different types of food product but they all depend on some kind of property. Scientists and engineers have used engineering properties extensively for determination of quality of food materials. These efforts have resulted into variety of destructive and non-destructive methods based on dimensional, mechanical, chromatic, electromagnetic, magnetic, sonic, and some other engineering characteristics.

UNIT-3

Micro encapsulation techniques for oils

K. Narsaiah

Head (Acting), AS&EC Division, CIPHET, Ludhiana- 141 004

knarsan@yahoo.com

Abstract

With increased awareness on health benefits of functional ingredients, the demand is increasing for the food products that are tasty, healthy and convenient. The addition of bioactive ingredients, especially oils, directly to food and feed products for fortification poses many challenges such as very limited solubility of many interesting ingredients, incompatibility between active ingredient and food matrix. Encapsulation technologies have the potential to meet above demands as well as challenges concerning controlled release of nutraceuticals, essential oils and fats, probiotics, enzymes and food/feed ingredients. Microencapsulation delivery systems induces improved water solubility, thermal stability, oral bioavailability, sensory attributes and physiological performance to the food and feed ingredients. There is gap in basic understanding of electrostatic, short range and long ran range colloidal interactions between delivery system and active ingredients in terms of the basic underlying physicochemical principles for encapsulation and among delivery system particles/emulsions to predict stability with reference aggregation and precipitation. The understanding of these phenomena leads to easy scale up of process. Encapsulation methods are vigorously pursued by researchers to achieve above goals. However, these research efforts are generally focused on influence of process and formulation parameters at lab level leading to qualitative or semi empirical relations which are inadequate for effective process scale up. Different encapsulation methods such as coacervation, spray drying, and interfacial polymerization are adopted/modified to produce micro/nano delivery systems incorporating bioactive/nutraceutical ingredients. Development of equipment and processes for the encapsulation of these ingredients is discussed.

Introduction

Microencapsulation paves way for development of innovative functional foods as well as diagnostic indicators in food safety. With increased awareness on health benefits of functional ingredients, the demand is increasing for the food products that are tasty, healthy and convenient (Zuidam and Nedovic, 2010). However, direct addition of ingredients to food products to add functionality can compromise their taste, color, texture, and aroma. Many ingredients may not be compatible with the food constituents as well. Microencapsulation technology can become saviour of food industry in such situations. It provides viable texture blending, appealing aroma release, and taste-, odor-, and color-masking and can incorporate minerals, vitamins, and essential oils, creating foods in functional foods. With the growing urbanization and increasing quality consciousness, the market for processed foods and functional foods is expected to grow more rapidly. The major segments of functional foods with encapsulated ingredients are dietary supplements, health foods, beverages and confectionaries such as candies and chewing gums. A timely and targeted release improves the effectiveness of feed and food additives, broadens the application range of feed and food ingredients and ensures optimal dosage, thereby improving cost-effectiveness for the manufacturer.

Microencapsulation is a process of entrapping solid particles, liquid droplets or gases in thin polymeric coatings. The outer film (wall) protects the encapsulated material (core) and allows for its controlled release. Application of this technique is wide spread in several industrial fields, including the manufacture of foods, pharmaceuticals, agrochemicals, nutraceuticals, probiotics and cosmetics. Microencapsulation in food industry is aimed at effective delivery of nutrients, bio-active compounds and sensitive ingredients through food systems. Common food ingredients subjected to microencapsulation include probiotic bacteria, acidulents, flavours, colours, sweeteners, minerals and vitamins. A number of coating materials are employed in production of microcapsules, such as gums, starch, and starch derivatives, cellulosic materials, lipids, proteins and inorganic materials.

Actually the development of micro-encapsulates was partially inspired by the nature. Eggs, seeds, grains, nuts, fruits etc. are typical examples of the food encapsulation and encapsulation is natures own way of conserving and protecting natural products against its own deteriorating elements. Taking clue from this, man adopted this technology for protection of some of the foodstuffs as sauces, puddings etc.

Microencapsulation can improve the convenience of food. The shell provides a barrier between reactive components (for instance, delaying the release of leavening agents for fluffier bread products or protecting oxygen-sensitive materials during processing and storage). Microcapsules can help fragile and sensitive materials survive processing and packaging conditions and stabilize the shelf-life of the active ingredient. For effective delivery of functional foods, the carrier systems should have properties such as good uptake, extended circulation time, no/acceptable clinical side effects, high biocompatibility and low immunogenicity (McClements, et al., 2007).

The possibility of controlled release further widens the capabilities of technology and is thus attracting attention of industry players.

In addition, microencapsulation can simplify the food manufacturing process by converting liquids to solid powder, decreasing production costs by allowing batch processing using low-cost, powder-handling equipment. To improve food safety, the technology can be used to indicate product tampering, thermal spoilage, and freeze-thaw cycles.

Reasons for microencapsulation

The reasons for microencapsulation are countless. In some cases, the core must be isolated from its surroundings, as in isolating vitamins from the deteriorating effects of oxygen, retarding evaporation of a volatile core, improving the handling properties of a sticky material, or isolating a reactive core from chemical attack. In other cases, the objective is not to isolate the core completely but to control the rate at which it leaves the microcapsule, as in the controlled release of drugs or pesticides. The problem may be as simple as masking the taste or odor of the core, or as complex as increasing the selectivity of an adsorption or extraction process.

Microencapsulation offers food companies a viable means of penetrating this lucrative growth sector because it has the ability to mask the undesirable tastes associated with some of these ingredients.

This also implies significant opportunities in the highly profitable children's market. While consumers are becoming more health-conscious and are demanding more nutritious products, they are unwilling to compromise on taste.

Microencapsulated ingredients can be used to

- Mask undesirable flavours
- Prevent chemical reactions

- Improve delivery, control delay
- Increase stability of finished product
- Reduce production losses
- Increased quality of finished product
- Increase plant capacity without capital expense
- Improve production yield
- Increase saleable products and increase profit**.**

Although microencapsulation technology was long considered far too expensive for use in the food industry, manufacturers are increasingly adopting this technology to add value to their product range. As food manufacturers consistently track consumer trends and tastes, food ingredients companies must continually look to develop innovative products that help meet end-user needs. Microencapsulation is progressively attracting the interest of food ingredient manufacturers as a way of achieving much-needed differentiation and enhancing product value.

Methods of microencapsulation

A number of microencapsulation methods have been developed over the years for pharmaceutical, agrochemical, textile and cosmetics industries. How these can be adapted for food industry is a good researchable issue. Various methods such as extrusion, spray drying can be used for encapsulation of food ingredients (Karel, 1994). Though there is no clear cut classification of various methods, they can be broadly categorized in to two classes viz. physical and chemical methods.

Physical methods to manufacture microcapsules

Pan coating

The pan coating process, widely used in the pharmaceutical industry, is among the oldest industrial procedures for forming small, coated particles or tablets. The particles are tumbled in a pan or other device while the coating material is applied slowly.

Air-suspension coating

Air-suspension coating of particles by solutions or melts gives better control and flexibility. The particles are coated while suspended in an upward-moving air stream. They are supported by a perforated plate having different patterns of holes inside and outside a cylindrical insert. Just sufficient air is permitted to rise through the outer annular space to fluidize the settling particles. Most of the rising air (usually heated) flows inside the cylinder, causing the particles to rise rapidly.

At the top, as the air stream diverges and slows, they settle back onto the outer bed and move downward to repeat the cycle. The particles pass through the inner cylinder many times in a few minutes.

Centrifugal extrusion

Liquids are encapsulated using a rotating extrusion head containing concentric nozzles. In this process, a jet of core liquid is surrounded by a sheath of wall solution or melt. As the jet moves through the air it breaks, owing to Rayleigh instability into droplets of core, each coated with the wall solution. While the droplets are in flight, a molten wall may be hardened or a solvent may be evaporated from the wall solution. Since most of the droplets are within ± 10% of the mean diameter, they land in a narrow ring around the spray nozzle. Hence, if needed, the capsules can be hardened after formation by catching them in a ring-shaped hardening bath. This process is excellent for forming particles 400-2000μm in diameter. Since the drops are formed by the breakup of a liquid jet, the process is only suitable for liquid or slurry. A high production rate can be achieved, i.e., up to 22.5 kg of microcapsules can be produced per nozzle per hour per head. Heads containing 16 nozzles are available.

Vibrational Nozzle

Core-Shell encapsulation or Microgranulation (matrix-encapsulation) can be done using a laminar flow through a nozzle and an additional vibration of the nozzle or the liquid. The vibration has to be done in resonance of the Rayleigh instability and leads to very uniform droplets. The liquid can consists of any liquids with limited viscosities (0-10000 mPas have been shown to work), e.g. solutions, emulsions, suspensions, melts etc. The solidification can be done according to the used gelation system with an internal gelation (e.g. sol-gel processing, melt) or an external (additional binder system, e.g. in a slurry). The process works very well for generating droplets in the range of 100-5000 micrometer, applications for smaller and larger droplets are known. The units are deployed in industries and research mostly with capacities of 1-10000 kg/h at working temperatures of 20-1500°C (room temperature up to molten silicon). Nozzles heads are available from one up to several hundred thousand are available.

Spray–drying

Spray drying serves as a microencapsulation technique when an active material is dissolved or suspended in a melt or polymer solution and becomes trapped in the dried particle. The main advantages is the ability to handle labile materials because of the short contact time in the dryer, in addition, the operation is economical. In modern spray dryers the viscosity of the solutions to be sprayed can be as high as 300mPa.s. The existing spray dryers can be explored for microencapsulation on large scale with slight modifications. It is mostly used for encapsulation flavours and other functional ingredients with starch derived wall materials such as maltodextrins.

Coaxial air flow bead generator

An easy way for production of small alginate beads in a controllable manner is the use of a coaxial-air-flow bead generator. Low production rate is one of the main disadvantages of these systems. The basic principle of the instrument is the use of a coaxial pressurized air stream which pulls droplets from a needle tip into the gelling bath. The process is capable of producing capsules with diameter 200 µm or more.

Simple droplet generator system for encapsulation of the pancreatic islets employing chitosan-alginate matrix was developed by Hardikar et al. ((1999). The droplet generator system comprised of a needle assembly, a 3-way valve with extended rubber tubing and a filtration unit connected to a pressure pump.

In pursuit of simple and cost effective microencapsulators, microencapsulator with multiple air jet droplet generator for production of microcapsules (Narsaiah and Oberoi 2011) and an autoclavable microencapsulation system with multistage break up two fluid nozzle (Narsaiah et al. 2011) were developed for microencapsulation of sensitive functional ingredients for incorporation in food products at CIPHET, Ludhiana.

Jet Cutting

It is based on the mechanical impact of a cutting wire on a completely filled stream of liquid jet. This jet of polymer is formed by forcing the solution through special nozzles. This jet is broken-up into equal cylindrical segments when passed through a cutting tool consisting of several thin wires fixed onto a holder. Surface tension induces sphericity to these cylindrical segment as they pass through air. The resulting diameter of droplet depends on number of cutting wires, number of rotations of the cutting tool, the mass flow rate through nozzle and the mass flow depending both on nozzle diameter and velocity of the fluid (Prusse et la. 1998).

Spinning disk atomization

The principle of operation is based on disintegration of feed liquid when dropped onto the surface of a rotating disk due to high velocity generated by centrifugal acceleration. The droplets are released from tip of the rotating disk or from ligamentry streams released from the edge of the disk (Ogbonna 2004). The process is capable of producing capsules with diameter 200 µm or more with narrow size distribution and ease of scale up is noteworthy.

Chemical methods to manufacture microcapsules

Interfacial polymerization

In Interfacial polymerization, the two reactants in a polycondensation meet at an interface and react rapidly. The basis of this method is the classical Schotten Baumann reaction between an acid chloride and a compound containing an active hydrogen atom, such as an amine or alcohol, polyesters, polyurea, polyurethane. Under the right conditions, thin flexible walls form rapidly at the interface. A solution of the pesticide and a diacid chloride are emulsified in water and an aqueous solution containing an amine and a polyfunctional isocyanate is added. Base is present to neutralize the acid formed during the reaction. Condensed polymer walls form instantaneously at the interface of the emulsion droplets.

In-situ polymerization

In a few microencapsulation processes, the direct polymerization of a single monomer is carried out on the particle surface. In one process, e.g. cellulose fibers are encapsulated in polyethylene while immersed in dry toluene. Usual deposition rates are about 0.5µm/min. Coating thickness ranges 0.2-75µm. The coating is uniform, even over sharp projections.

Matrix polymerization

In a number of processes, a core material is imbedded in a polymeric matrix during formation of the particles. A simple method of this type is spray-drying, in which the particle is formed by evaporation of the solvent from the matrix material. However, the solidification of the matrix also can be caused by a chemical change.

Application of Micro Encapsulation for Active ingredients

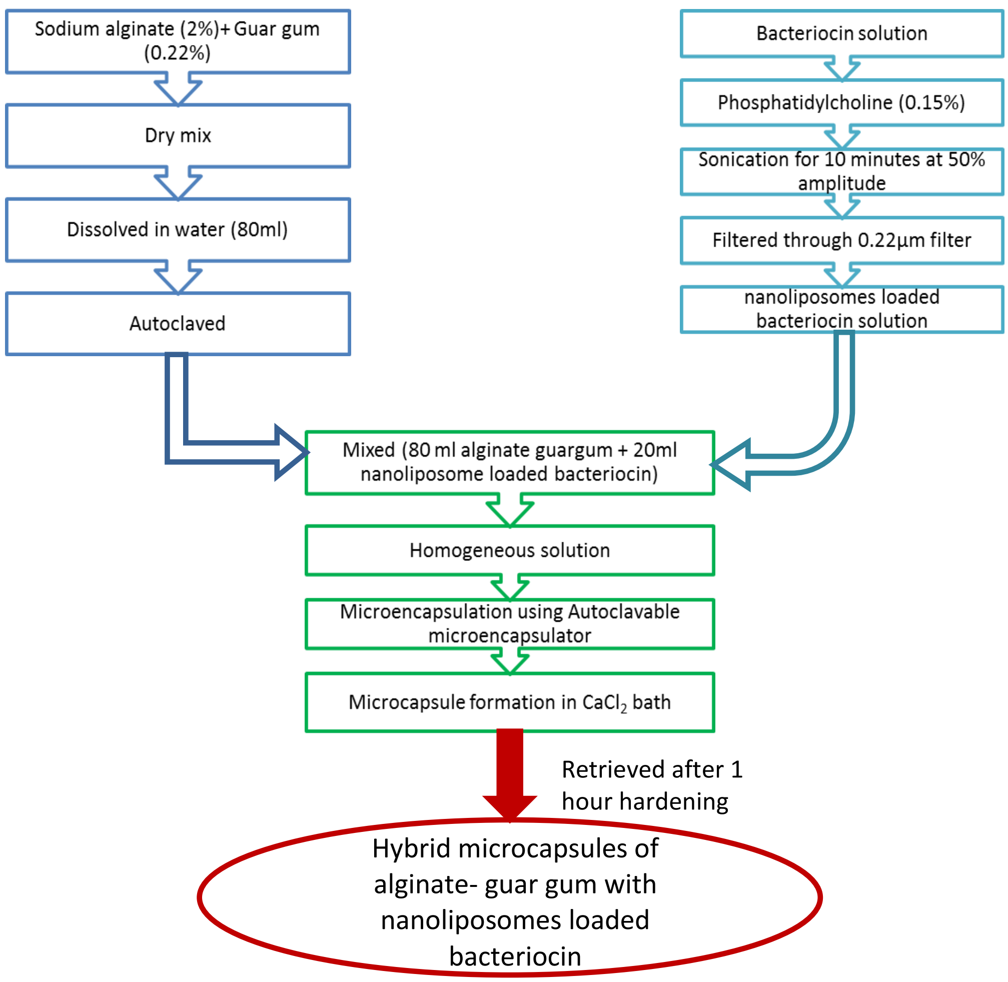
Microencapsulation of bacteriocin

Bacteriocin is of special interest in the food and dairy industry due to its natural antimicrobial properties. It is added in the food formulations as a natural preservative in order to increase the shelf life of food. However, direct addition of bacteriocin in the food causes reduction in the antimicrobial efficacy due to their structural instability, undesirable interaction with the food constituents and inactivation by enzymatic degradation. In addition, it may also result in development of bacteriocin resistant bacteria. Encapsulation or entrapment of bacteriocin may bring about the protection of them from the adverse conditions of the food environment. It may also facilitate the development of controlled release properties of bacteriocin by reducing its transfer rate to the outside environment. Encapsulation of nisin in calcium alginate was purposed for improving its long term effectiveness in food (Narsaiah et al. 2012). Nisin is primarily active against Gram-positive bacteria but when combined with a chelator, nisin can inhibit growth of some Gram-negative bacteria also and is thus potentially effective against a broad spectrum of bacteria. The study optimized the conditions for microencapsulation of nisin at different air pressures using response surface methodology. For this purpose, an autoclavable microencapsulation system was developed with multistage break up two fluid nozzle and programmable pump. Microencapsulation was successfully carried out through this microencapsulator with encapsulation efficiency of 36.65 % and leads to an increase in shelf life and stability of nisin.

Similarly, pediocin, a small antilisterial polypeptide bacteriocin was also encapsulated through this two fluid nozzle system using different wall materials such as phospholipids, proteins, carbohydrate polymers and combinations of these (Narsaiah et al. 2013). The study compared the controlled release behavior of pediocin loaded in delivery systems of different wall materials and found hybrid capsules of alginate plus guar gum incorporated with pediocin-loaded nanoliposomes of phosphatidylcholine as the most effective delivery system for controlled release of pediocin. A recent study conducted by Hosseini et al. (2014) also performed encapsulation of nisin in alginate (Alg) and alginate-resistant starch (Alg-RS) in order to improve its stability. Studies found that more encapsulation efficiency and loading capacity values were obtained when the resistant starch was added to the alginate formulation. The in vitro nisin release from these microparticles followed a controlled-release pattern and the release rate from Alg-RS microparticles was less than that from the Alg microparticles. In another study, a potentially probiotic bacteria was isolated from shellfish digestive gland and screened for activity against different pathogens. The active antimicrobial bacteriocin produced by this isolate was partially purified and encapsulated in 3% of alginate and an alternative using $BaCl_2$ instead of $CaCl_2$ in the hardening bath significantly improved its encapsulation (Fajardo et al. 2014). The coating of alginate (2% (w/w)) with bacteriocin could be used to store minimally processed papaya for 3 weeks without compromising physico-chemical qualities or microbial safety (Narsaiah et al., 2015).

Optimized Process for encapsulation of bacteriocins

Alginate (0.2g) and guar gum (0.22g) were mixed as dry powders. This mixture was dissolved in distilled water (80 ml) and solution was autoclaved. Phosphatidylcholine (0.15g) was added to bacteriocin solution and sonicated at 50% amplitude for 10 minutes to prepare nanoliposomes. Pediocin loaded nanoliposomes solution was filtered through 0.22µ filter. Filtered solution (20ml) was added to alginate guar gum solution and stirred to get homogeneous solution. Mixed solution was atomized through autoclavable microencapsulator into calcium chloride (0.2M) bath to generate microcapsules. Microcapsules were hardened for one hour. Hybrid microcapsules of alginate- guar gum with nanoliposomes loaded bacteriocin were retrieved from calcium chloride bath using muslin cloth. This process was optimized to yield about 65% encapsulation efficiency and good antimicrobial activity with controlled release of pediocin.



Process flow chart

Microencapsulation of vitamins and proteins

Desai, et al (2005) reports the properties of vitamin C encapsulated sodium alginate beads prepared by an alternative approach. The alternative encapsulation process mainly involves immobilization of vitamin C in hydrated zinc oxide layers and encapsulation of prepared immobilized particles in sodium alginate bead. The immobilization of vitamin C in hydrated zinc oxide layers was achieved by a coprecipitation process. Fourier transform infrared (FTIR) spectroscopy showed that the vitamin C was found to be stable after its immobilization. X-ray diffraction (XRD) studies revealed that anionic vitamin C molecules are adsorbed between positively charged zinc hydroxide layers with a 1:1 layer sequence, since well-defined change in basal spacing was observed. Well-defined change in surface morphology was observed by scanning electron microscopy (SEM) when vitamin C immobilized particles are encapsulated in sodium alginate bead. The biological activity of vitamin C was retained, even after its immobilization which was confirmed by 4-dihydroxy-L-phenylalanine (L-DOPA) oxidase inhibition and free radical scavenging activity studies. The release rate of vitamin C from immobilized particles and beads was sustained through an ion exchange process. A higher amount of stable vitamin C was recovered from the bead when compared to neat vitamin C itself.

Katti (1999) described preparation of albumin microspheres by an improved process. In this study microspheres were prepared by the suspension cross linking method for the first time in the absence of any surface active agent, using paraffin oil as the dispersion medium and formaldehyde as the cross linking agent. The microspheres thus obtained were characterized using a Scanning Electron Microscope and found to be spherical and having a particle size distribution in the range 50-400 microns. A preliminary drug release study of chlorothiazide invitro indicated a diffusion controlled release of the drug. This method, being simple and cost effective, could be a promising technique for the large scale manufacture of microspheres.

Taste and odour masking (Prem, 2004) is yet another application of microencapsulation. High protein concentrate from casein, soy protein, fish protein are made palatable by microencapsulation with fats having melting point above 70^{o} F. To overcome the objection, encapsulated garlic oil is strongly recommended , specially in food plant, as its also helps in preventing the cross contamination of the flavour.

Microencapsulation of fish oil

Omega-3 (ω-3) and omega-6 (ω-6) fatty acids found in fish oils are among the most important functional food ingredients. They improve the cardiovascular activity, enhance long-term memory and normal brain function (Kralovec, et al., 2012). However, ω-3 fatty acids are susceptible to degradation releasing unhealthy products such as secondary oxidation products of poly unsaturated fatty acids, aldehydes, ketones, alcohols, volatile organic acids, hydrocarbons and epoxy compounds (Shahidi and Zhong, 2010). Encapsulation is an excellent approach to avoid above problems as it can provide stability and protection, confer targeted and controlled release characteristics. Furthermore, it masks unpleasant odour and taste, extends the shelf life and enhances the bioavailability and palatability of the encapsulated materials. For effective delivery of functional foods, the carrier systems should have properties such as good uptake, extended circulation time, no/acceptable clinical side effects, high biocompatibility and low immunogenicity (McClements, et al., 2007).

Fish oils represent a functional food as it contains important components for maintenance of good health and prevention of a range of human diseases via the beneficial effects on the heart, brain and nervous system (Wu et al., 2009). Fish oil supplements contain significant amounts of omega-3 fatty acids including α-linolenic acid (C18:3, n - 3), eicosapentaenoic acid (C20:5, n - 3), and docosahexaenoic acid (C22:6, n -3) and may be important dietary sources. Nonetheless, fish oil has a strong odour and it is easily susceptible to oxidation of its constituent highly unsaturated long chain fatty acids. These negative attributes could be minimized or eliminated by encapsulation of the fish oil. As well, encapsulation would protect fish oil from auto oxidation of polyunsaturated fatty acid (Jafari, et al., 2008).

Chen et al., 2013 has encapsulated fish oil with phytosterol esters and limonene by milk proteins. Their study has provided some useful insight into the application of the co encapsulation concept to protect spray-dried fish oil microcapsules from oxidation by introducing other lipophilic bioactive components, namely phytosterol esters and limonene as core material. Current finding indicates that co-encapsulation of fish oil with phytosterol esters could effectively prevent polyunsaturated fatty acids from oxidation, and the incorporation of limonene showed good ability to mask the undesirable fishy odour.

A process was standardized at ICAR-CIPHET for preparation of nano emulsion of fish oil and lecithin in water using high pressure homogenizer. Alginate, with either skim milk powder or whey protein concentrate powder, was explored as delivery matrix to further stabilize the nano emulsion of fish oil for incorporation in functional foods. Fish oil emulsion was oozing out in beads of alginate with skim milk powder. Alginate with whey proteins yielded beads with an encapsulation efficiency of 89% and without any oozing fish oil emulsion. These beads were coated with vanilla flavored high melting fat to fully mask the smell of fish oil.

Fig: Beads of alginate, whey protein and fish oil coated with high melting fat

Microencapsulation of Flax seed oil

Flaxseed oil is polyunsaturated oil extracted from the flax plant (Linum usitatissimim) rich in α-linolenic acid (ALA), the essential fatty acid omega (ω)-3, which represents about 57% of its total fatty acids. The high content of ω-3 fatty acid present in this oil allows the attribution of functional food, which means that besides the nutritional functions, its consumption may have beneficial effects on health like promoting eye health, development of brain and nervous system in infants, reducing the risk of hypertension, hypercholesterol and cancer including colon, breast & prostate, improving intelligence and memory, inhibition of aging, reduction of inflammatory bowel diseases & coronary heart diseases, lessening neurodegenerative disorders and controlling diabetes (Goyal et al. 2014; Rodriguez-Leyva et al. 2010; Carraro et al. 2012; Singh et al. 2011).

Helena et al., (2013) obtained encapsulation efficiency values which varied from 62.3% to 95.7% of flaxseed oil microencapsulated by spray drying using different combinations of wall materials. (Narsaiah etal., 2020a)

Microencapsulation of garlic oil for functional bread

Garlic oil as nanoemulsion is incorporated in calcium alginate hybrid microcapsules. Further, the hybrid microcapsules of these bioactive lipids were incorporated in the bread and examined their impact on oxidative stability, texture and sensory characteristics of functional bread. Microencapsulation significantly improved the oxidative stability and final product quality by lowering lipid oxidation in functional bread fortified with garlic oil microcapsules. The rate of increase in TBARS values was similar in both the control and functional bread fortified with hybrid garlic oil microcapsules, whereas it increased by four times higher than the market garlic bread. Whiter crumb was observed in the functional bread fortified with garlic oil microcapsules, which may be due to the presence of microencapsulated garlic oil that indicates protection of colour and oxidation of garlic oil in the hybrid microcapsules as compared to the market garlic bread. Increase in hardness and no change in cohesiveness and springiness with time were observed during storage period for the functional bread. The functional bread fortified with garlic oil microcapsules significantly improved ($P < 0.05$) all the sensory parameters as compared to market garlic bread. The overall view of the developed hybrid MCs suggests that they proved themselves to be suitable delivery vehicles for the encapsulation of garlic oil microcapsules and enhancement of the quality and nutraceutical profile for pan bread (Narsaiah et al., 2019).

Microencapsulation of polyphenols and pigments

Ersus et al (2007) acidified ethanol extracts of black carrots which has a high anthocyanin content (125 ± 17.22 mg/100 g) and were spray dried using a range of maltodextrins [Stardri 10 (10DE), Glucodry 210 (20–23DE) and MDX 29 (28–31 DE)] as a carrier and coating agents, at 3 different inlet/outlet air temperatures with constant feed solid content (20%). Higher inlet/outlet air temperatures caused greater anthocyanin loss during spray drying. The quality attributes of the powders which were produced at optimum drying temperatures (160°C) were characterized by their anthocyanin content, antioxidant capacity, L*, a*, b*, C* and H°values, dry matter content and hygroscopicity. The best dried pigment containing powder was found where the Glucodry 210 was used as wall material. Scanning electron microscope was used for monitoring the structures and size (3–20 μm) of the powders. For determination the stability and half-life period of microencapsulated pigments, samples were stored under different storage temperatures (4°C and 25°C) and light illumination (3000 lx).

Shu et al (2006) investigated the effects of technological parameters including the ratio of core and wall materials, ratio of gelatin and sucrose, homogenization pressure, inlet temperature, feed temperature, and lycopene purity on encapsulation yield (EY), encapsulation efficiency (EE). Lycopene microcapsules were prepared by a spray-drying method using a wall system consisting of gelatin and sucrose. The resulting microcapsules were characterized in terms of lycopene isomerisation, storage stability, PS, PSD, and outer and inner structures. Results showed that EY and EE were significantly affected by the ratio of core and wall materials, ratio of gelatin and sucrose, homogenization pressure, inlet temperature, feed temperature, and lycopene purity. The optimal condition was determined as follows: the ratio of gelatin/sucrose of 3/7 and the ratio of core and wall material of 1/4, feed temperature of 55°C, inlet temperature of 190 °C, homogenization pressure of 40 MPa, and lycopene purity of not less than 52%, at which the microencapsulated lycopene showed some isomerisation, but a good storage stability. SEM and XRD analysis showed that lycopene microcapsules had a regular spherical shape with a PSD of 2–15 µm, mean PS of 5 µm, smooth outer surface, ‘‘bee net’’-like interior structure, and lycopene was embedded in the wall system consisting of gelatin and sucrose.

Shi et. al., (2008) encapsulated the photosensitive resveratrol was successfully encapsulated in yeast cells for the first time, as characterized by FT-IR spectra, fluorescence and confocal micrographs of the yeast cells, resveratrol and microcapsules. The release characteristic of the obtained yeast-encapsulated resveratrol in simulated gastric fluid was evaluated, and its storage stability as a powder was investigated at 25 °C/75% relative humidity (RH), 25 °C/90% RH and 60 °C under the laboratory fluorescent lighting conditions (ca. 300 lx) or in the dark. Also, the scavenging capacity of yeast-encapsulated resveratrol on DPPH radical was compared with that of non-encapsulated resveratrol. It could be demonstrated clearly that no chemical changes occurred during the encapsulation. Besides, the DPPH radical-scavenging activity increased after the encapsulation. In addition, the yeast-encapsulated resveratrol exhibited good stability, and its bioavailability was enhanced as a result of increased solubility of resveratrol and sustained releasing.

Microencapsulation of Flavours and Pigments

Shaikh (2006) reported microencapsulation of black pepper oleoresin by spray-drying, using gum arabic and modified starch as wall materials. The microcapsules were evaluated for the content and stability of volatiles, non-volatiles, total piperine and entrapped piperine for six weeks.

Gum arabic offered greater protection to the pepper oleoresin than modified starch, as seen from the t1/2, time required for a constituent to be reduced to 50% of its initial value.

Jun-xia et al (2011) investigated the coacervation between soybean protein isolate (SPI) and gum Arabic (GA) for sweet orange oil microencapsulation as functions of pH, ionic strength, SPI/GA ratio, core material load and micro molecules. SPI was exposed to ultrasonic to increase solubility before use and microcapsules were spray-dried before analysis. It was found that the optimum pH for SPI/GA coacervation was 4.0. High ionic strength reduced the coacervation between the two biopolymers. The highest coacervate yield was achieved in SPI/GA ratio 1:1 and the core material load for the highest microencapsulation efficiency (MEE) and microencapsulation yield (MEY) was 10%. The addition of sucrose in sucrose/SPI ratio 1:1 increased the MEY by 20%, reaching 78% compared to 65% of control. The microcapsules were spherical without holes on the surface by SEM observation and flavour components were well retained in microcapsules according to GC–MS analysis, indicating good protection for core material.

Shu et al.(2005) prepared lycopene microcapsules by a spray-drying method using a wall system consisting of gelatin and sucrose. The effects of technological parameters including the ratio of core and wall materials, ratio of gelatin and sucrose, homogenization pressure, inlet temperature, feed temperature, and lycopene purity on encapsulation yield (EY), encapsulation efficiency (EE) were investigated. Results showed that EY and EE were significantly affected by the ratio of core and wall materials, ratio of gelatin and sucrose, homogenization pressure, inlet temperature, feed temperature, and lycopene purity. The optimal condition was determined as follows: the ratio of gelatin/sucrose of 3/7 and the ratio of core and wall material of 1/4, feed temperature of 55 °C, inlet temperature of 190 °C, homogenization pressure of 40 MPa, and lycopene purity of not less than 52%, at which the microencapsulated lycopene showed some isomerization, but a good storage stability. SEM and XRD analysis showed that lycopene microcapsules had a regular spherical shape with a PSD of 2–15 μm, mean PS of 5 μm, smooth outer surface, “bee net”-like interior structure, and lycopene was embedded in the wall system consisting of gelatin and sucrose.

Korus et al. (2003) described a method for preparation of microcapsules from granular potato starch by its prolonged (up to 48 h) soaking in water is proposed. The effects of temperature and size of granules is studied. Such treatment removes the amorphous part of the granule interior, forming empty domains inside granules. Material evacuated from the granules was identified as amylopectin together with amylose. The application of such pre-treated granules for microencapsulation of various fragrant compounds (angelicalactone, diacetyl, dibenzyl ether, 2,6-lutidine and myrcene) from their vapours and from their liquid state is described. Depending on pre-treatment of starch and the microencapsulation method applied, the amount of trapped guest molecules is up to 30 wt%.

Soottitantawat et al. (2005) studied about microencapsulation of l-menthol by spray drying, using gum arabic (GA) and modified starch (CAPSUL, HI-CAP 100) as capsule materials. The results showed a higher retention of l-menthol with the increasing of initial solid concentration. HI-CAP 100, showed a higher retention than the other capsule materials. However, it also showed a higher residue of l-menthol on the surface of powder especially at the high concentration of l-menthol in the feed emulsion. That might be from the interaction between the wall materials and l-menthol which can re-crystallize to form whisker after the spray drying. Furthermore, the release characteristics of l-menthol were also investigated. The release rate increased upon elevation of relative humidity and temperature. The activation energies of the release of l-menthol from GA wall matrices at 75 and 83%RH were 140 and 48 kJ/mol, respectively.

Shaikh et al. (2006) reported a method for microencapsulation of black pepper oleoresin by spray-drying, using gum arabic and modified starch as wall materials. The microcapsules were evaluated for the content and stability of volatiles, non-volatiles, total piperine and entrapped piperine for six weeks. Gum arabic offered greater protection to the pepper oleoresin than modified starch, as seen from the $t_{1/2}$, time required for a constituent to be reduced to 50% of its initial value.

Prem (2004) reported a method for coffee aroma encapsulation. Liquefied coffee aroma is passed in to the emulsifying tank that contains the wall material, i.e., an aqueous gelatin material and a modifier, e.g., non –ionic surface reactive agent, such as tween. The mixture is homogenized and an emulsion of the coating substance and aroma. The emulsion is slurred in to the spinning tank, which has the pricess oil, i.e., white mineral oil, such as Nujol. With proper stirring and cooking of the content in the spinning tank, droplets or globules formation occurs in spinning tank. Droplets are formed and remain suspended in the process oil. Globules formation occurs in spinning tank primarily because of aqueous gelation emulsion is insoluble in process liquid. Suspended globules are dried by anhydrous alcohol in the dehydration tank. Dried globules become capsules and are suspended from the process liquid and dehydrating medium by centrifugation or filtration. The capsules are washed free of the process liquid with the aid of a solvent and the solvent is recovered. Last traces of solvent are removed. Encapsulated coffee aroma can be retained for a year.

Prem (2004) stated that chewing gum composition has been found to have prolonged sourness, flavour and juiciness through incorporation of a delivery system comprising a food acid (e.g.malic acid) encapsulated in low molecular weight polyvinyl acetate material. Other process relates to the hydrophobic encapsulation of active material into the chewing gum. Controlled release of flavour together with aspartame gives a long lasting sweetened flavour perception during chewing of the gum.

Souza et al. (2005) studied about chitosan microspheres containing the natural curucum pigment. There is growing trend towards replacing synthetic additives with natural products in the food and pharmaceutical industries. Encapsulation has become an important process to protect natural pigments. This paper reports on the encapsulation of the natural urucum pigment with chitosan using different techniques and its release under different pH conditions. The material loaded with pigment was evaluated by infrared spectroscopy, scanning electron microscopy and thermal analysis. Chitosan was found to be an effective encapsulating agent for urucum pigment.

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UNIT-4

Technologies for Refining of edible oils and fats

Dr. S. K Tyagi (PC-PHET)
ICAR-CIPHET, Ludhiana-141004 Punjab

INTRODUCTION

Oilseed and oil processing are designed to obtain high quality oil with minimal undesirable components, achieve high extraction yields and produce high value meal. Crude fat and oil derived from plant and animal sources are subjected to several commercial refining processes before the final products reach the consumer market**.**During these processes, water, carbohydrates, proteins, pigments, as well as phospholipids**,** free fatty acids**, sterols, waxes and tocopherols** are removed**.**

Fat and oil undergo four processing steps:

1. Extraction
2. Refining (Neutralization or Degumming)
3. Bleaching
4. Deodorization

Prior to extraction, oilseeds undergo various unit operations:

1. Seed cleaning
2. Size reduction and flaking
3. Cooking/Conditioning
4. Expanding

OIL EXTRACTION

- Solvent extraction and mechanical extraction using a screw press are the two common oilseed extraction processes
- Solvent extraction with hexane is the standard practice in today's modern oilseed-processing facilities
- High oil content seeds *i.e.* canola and sunflower, are processed by using a combination of mechanical pressing and solvent extraction
- Seeds are first pressed to reduce the oil content to about 20% and the remaining cake is then solvent extracted
- Supercritical fluid, water and enzyme-aided water extraction processes are of interest for specialty and gourmet oils production

SOLVENT EXTRACTION

- Solvent Extraction is a process which involves extracting oil from oil-bearing materials by treating it with a low boiler solvent as opposed to extracting the oils by mechanical pressing methods (such as expellers, hydraulic presses, etc.)
- The solvent extraction method recovers almost all the oils and leaves behind only 0.5% to 0.7% residual oil in the raw material
- In the case of mechanical pressing the residual oil left in the oil cake may be anywhere from 6% to 14%
- The solvent extraction method can be applied directly to any low oil content raw materials. It can also be used to extract pre-pressed oil cakes obtained from high oil content materials
- Because of the high percentage of recovered oil, solvent extraction has become the most popular method of extraction of oils and fats

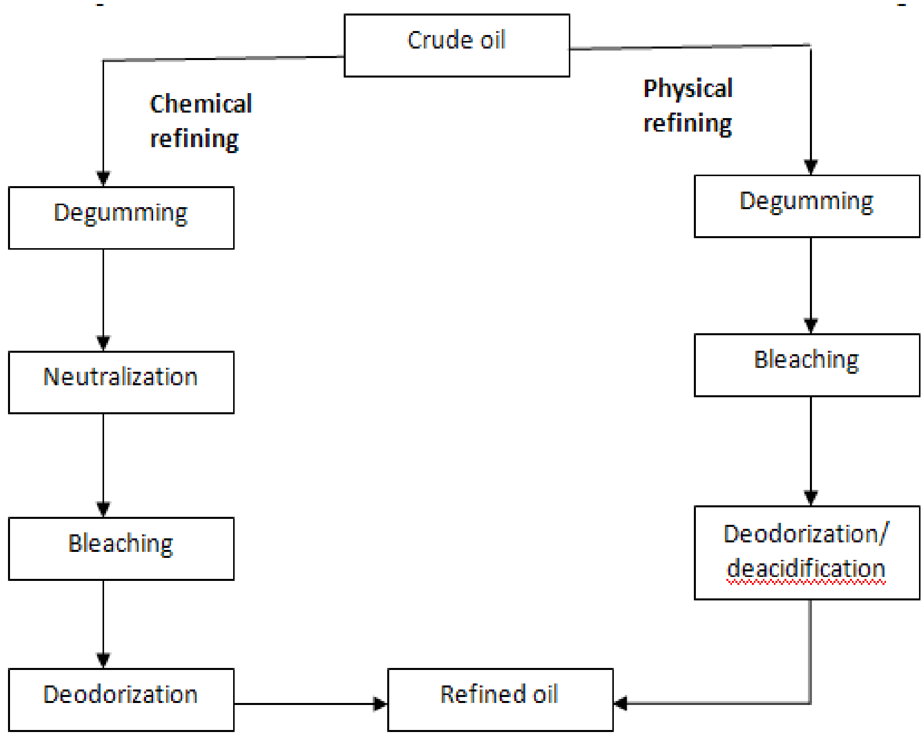
MECHANICAL EXPRESSION

- Oilseeds are mechanically pressed termed crushing or pressing in expellers to obtain maximum yield of oil
- This method is typically used to produce the more traditional oils (e.g., olive, coconut etc.)
- There are several different types of mechanical extraction. Expeller-pressing extraction is common, though the Screw-press, ram press, and Ghani (powered mortar and pestle)
- Oilseed presses are commonly used in developing countries, among people for whom other extraction methods would be prohibitively expensive; the Ghani is primarily used in India
- Not all expeller pressed oils are cold pressed as high pressure extraction can cause temperatures to rise above 120 degrees
- Only if temperature is monitored and kept under 120 degrees, can the oil be called cold pressed

REFINING

- Refining of crude oil can remove the components which may have negative effects on taste, stability, appearance or nutritional value
- To the extent possible, processing should preserve tocopherols and prevent chemical changes in the triacyglycerols
- Non- triacylgycerol fraction constituting about 5% of the crude oil contains various amounts of phosphatides, free fatty acids (FFA), oxidation products, unsaponifiable matter (tocopherols, sterols, hydrocarbons, etc.) and other impurities

PHYSICAL AND CHEMICAL REFINING



Physical Refining/ Steam Refining	Chemical Refining/ Caustic Refining
• Degumming(Removing of Phosphotides) through Enzymes	• Degumming with the help phosphoric Acid
• Bleaching (Color removal through Activated Bleaching Earth)	• Neutralisation (Caustic Based for removal of Free Fatty Acids)
• Dewaxing(Filter Pressing)	• Bleaching
• Steam Deacidification (Removal of Free Fatty Acid)	• Dewaxing
• Winterisation	• Deodourisation
• Bleaching	
• Deodourisation	

DEGUMMING

- It is the treatment of crude oils with water, dilute acids (phosphoric acid or citric acid) and sometimes dilute NAOH to remove phosphotides and mucilaginous material from the crude oil
- The removal of phosphotides during refining is absolutely essential since

1. Phosphotides are excellent emulsifiers and therefore increase refining losses
2. Connected to part of metals especially iron, which is the main cause of a reduced oxidative stability
3. Can cause color inversion and fixation in deodorized oils

WATER AND ACID DEGUMMING

- Oil degumming is usually carried out at the crushing or extraction plant
- Hydratable PLs can be removed from the oil by water degumming
- Hot deionized water (at 65-80 °C) or steam is injected into the warm oil. The amount of water/steam added depends on the amount of hydratable PLs present in the oil
- As a rule of thumb, about 2% water is added to oil and mixed for 30-60 min during a batch operation
- During this process PLs absorb water and lose their lipophilic characteristics (affinity to lipids), become oil insoluble and agglomerate into a gum phase
- Gum is separated by centrifugation and added back to meal or further processed to produce lecithin, which is used as an emulsifier in food and feed applications

MEMBRANE DEGUMMING

- Membrane processing consumes less energy than other degumming techniques, can be carried out at ambient temperature and retains nutrients and other desirable compounds in the degummed oil
- Utilization of ultrafiltration systems equipped with hexane-resistant membranes for degumming hexane-oil miscella
- The microfiltration membranes made of PTFE and PVDF (polyvinylidenefluoride) have also been shown to be effective in rejecting PLs

ENZYMATIC DEGUMMING

- Enzymatic degumming converts non hydratable lecithin (gums) into water-soluble lysolecithin
- This can be removed with the wastewater in a one-step centrifugation stage
- The enzymatic degumming of vegetable oils is an economical alternative to chemical and physical degumming
- It offers higher yields, significant cost savings, and an environmentally friendly process

NEUTRALIZATION

- Also known as deacidification
- It neutralizes fatty free acids in the oil using caustic soda, thereby converting the acids into soaps
- These soaps are easily removed by decantation or by centrifugal force
- The main byproduct of neutralization is the so-called soapstock, which is a mixture of fatty acid soaps, salts, phospholipids, impurities and entrained neutral oil
- the low value of the resulting acid oil and the stricter environmental legislation (making wastewater treatment more expensive) are the main reasons for oil processors to consider physical refining
- Chemical refining (that includes neutralization) is quite forgiving towards crude oil quality and it usually gives a good refined oil quality
- For these reasons, it is still the preferred refining process for many processors, and it is not expected that chemical refining will disappear
- there needs to be serious interest in new developments that make chemical refining more attractive

NANO NEUTRALIZATION

- Nano Neutralization is an add-on process to an existing oil refinery neutralization system which has the potential to improve oil yield, save silica (or wash water), save phosphoric acid, save caustic, and perhaps save steam and electricity

BLEACHING

- Oils are usually bleached after deacidification/refining and before deodorization
- Chlorophyll or pheophytin and their degradation products give oil a greenish color and carotenoids contribute to yellow and red tints that may be undesirable
- Originally bleaching was used to remove color compounds
- Bleaching is designed to remove undesirable oil components, including peroxides, aldehydes, ketones, phosphatides, oxidative trace metals, soaps and other contaminants, such as pesticides and polycyclic aromatic hydrocarbons

DEODORIZATION

- The presence of FFAs in oil correlates well with flavor and odor
- The practical rule is that if an oil has 0.1% FFA it will have an odor which could be eliminated by reducing the FFA content to 0.01-0.03% (zero peroxide value)
- Deodorization is a steam distillation process during which volatile and odoriferous compounds are stripped off with steam
- The objective of deodorization is to produce a bland and stable product by removing FFAs, aldehydes, ketones, and peroxides from bleached oil
- The amount of FFA removed from the oil is inversely proportional to the system pressure and directly proportional to the vapor pressure of the FFA and the sparge steam rate
- Temperature plays a critical role during deodorization

BYPRODUCT UTILIZATION

Byproducts of oil processing are

- Oil cake,
- lecithin sludge,
- Soapstock,
- oil in spent clay and
- distillate

LECITHIN

- Degumming has undergone a number of modifications to achieve better lecithin removal from the oil
- Traditional water degumming is used to recover lecithin gums for manufacturing lecithin products
- Or to remove gums that would interfere with subsequent operations, such as storage or acidulation of the soapstock when non degummed oil is being refined
- The lecithin gums recovered by these methods can be used for making finished lecithin products
- The gums not wanted or unsuitable for making edible or industrial lecithin products can be added back to the meal or used as feed ingredients in conjunction with feed fats
- Feeding studies indicate that lecithin compounds, in addition to giving nutritive value, improve the utilization of feed fats added as an energy source for the animals

SOAPSTOCK

- Caustic refining generates two side streams: soapstock and wash water
- The quantity and composition of the soapstock depend upon the quality and type of feedstock
- The value of the soapstock is determined by its total fatty acid content
- The traditional fatty acid recovery process acidulation-yields acid water for disposal. The location of many refineries has caused environmental problems in disposing of the wash water
- This problem is greatly amplified if strict regulations limit the phosphorus content of the effluent

DISTILLATE

- Deodorization and steam refining generate deodorizer distillate, another important byproduct
- The composition of this byproduct varies according to the refining method used to prepare feedstock
- Caustic-refined fats and oils contain less free fatty acid than those prepared for steam refining.
- Free fatty acid contents as low as 25% and as high as 90% are typical for distillates

- Distillate from caustic-refined soybean oil contains about 25-35% free fatty acid (FFA), while distillate from steam-refined palm oil contains 80-90% FFA
- The low FFA distillate is the preferred starting material to recover tocopherols and sterols from the unsaponifiable fraction of the distillate
- The high FFA distillate might be used in feed fat blends and soaps or by fatty acid distillers
- The most valuable compounds in distillates are tocopherols and sterols
- Gamma- and delta-tocopherols have antioxidant properties; the alpha-tocopherol is vitamin E
- The sterol compounds are used as starting materials for preparation of steroids, such as corticoids, sex hormones, contraceptives and diuretics
- The demand for natural vitamin E has a tremendous effect on the value of distillate.
- The tocopherol content and value determine the price of the distillates
- Sometimes the distillate byproduct is worth three times as much as the finished edible oil product; at other times, it might be worth only as much as the edible oil product

QUALITY ASPECTS OF CANOLA AND GROUNDNUT OIL AND MEAL

Virender Sardana* and Rajiv Sharma**

*Oilseeds Section, Department of Plant Breeding and Genetics
Punjab Agricultural University, Ludhiana
Email: virsardana@pau.edu
**ICAR Central Institute of Post Harvest Engineering and Technology, Ludhiana
Email: sharmapau@yahoo.co.in

Fats derived from vegetable oils and animals (butter, ghee etc) are important sources of energy and nutrition for humans. Edible oils derived from plants of oilseed crops (vegetable oils) are nutritionally superior and cheaper sources of energy than animal fats. On an average, one gram of vegetable oil provides 9 kcal energy compared to 4 kcal energy obtained from same amount of cereals or legumes. The oils/fats are also carriers of fat-soluble vitamins (A, D, E and K) and the essential fatty acids (linoleic and linolenic acids). Human body requires these for several metabolic functions but cannot synthesize these. Vegetable oils are also the primary sources of vitamin E (tocopherols) and phytosterols. The oils and fats present in oilseeds are also used as industrial raw material. Oilseeds also contain proteins, carbohydrates, vitamins and minerals. The proteins present in some oilseeds and their cakes are edible to humans while the others are useful as animal feeds.

Vegetable (edible) oils are essential components of daily human diet and their deficient intake may result in poor general health, poor brain development and premature ageing. About 25 percent of the total energy requirement of an average Indian is met from visible fats (vegetable oils and animal fat). Nutritional guidelines of Food and Agricultural Organization (FAO), World Health Organization (WHO) mandate 30 g/person/day of visible (vegetable oil or animal fat) and the invisible (those obtained from cereals, millets, pulses, vegetables etc.) fat intake. That translates into approximately 20-gram of visible fat/person /day to meet minimum dietary fat requirements. On the other hand, consumption of fats at a rate higher than the recommended intake may cause cardio-vascular damage and chronic inflammation. Quality of fat consumed is equally important as it affects human health in many ways. Quality includes nutritional value, cooking quality, shelf life, market acceptability, consumer preferences etc. An ideal cooking oil is the one that contains healthy fats and nutrients. It should also remain stable during cooking.

Sources of edible oils

Soybean (*Glycine max*), rapeseed-mustard (*Brassica* sp.), groundnut (*Arachis hypogaea*), sunflower (*Helianthus annuus*), sesame/til (*Sesamum indicum*), safflower (*Carthamus tinctorius*) and niger (*Abyssinica guizotia*) are the primary sources of vegetable oils. Though linseed (*Linum usitatissimum*) is considered as non-edible oilseed due to very high proportion of linolenic acid (omega 3, 18:3), its low linolenic forms have been developed in Canada and Australia to be used as edible oil. Low linolenic acid linseed oil is known as linola/solin in the trade. Large quantities of oil are also extracted from rice (*Oryza sativa*) bran, corn or maize (*Zea mays*), cottonseed (*Gossypium* sp.) to supplement the availability of vegetable oils from traditional oilseeds. Oil from several tree borne oilseeds (TBOs) such as coconut (*Cocos nucifera*), palm (*Elaies guineesis*) and olive (*Olea europaea*) is also used for edible purposes, directly or after blending with traditional edible oils. Fatty acid composition of commonly used oilseeds is given in Table 1.

Table 1. Fatty acid composition of important oilseeds

Crop	**Fatty acid (%)**						
	Palmitic (16:0)	**Stearic (18:0)**	**Oleic (18:1) (omega 9)**	**Linoleic (18:2) (omega 6)**	**Linolenic (18:3) (omega 3)**	**Eico-senoic (20:1)**	**Erucic (22:1)**
Conventional rapeseed-mustard	4	3	12	18	10	8	45
‘0’ or ‘00’ (canola) / Indian mustard	4	3	50	28	12	3	<2
‘00’ / Canola oilseed rape (*gobhi sarson)*	5	2	67	18	10	3	<2
Groundnut	12	2	48	32	-	1	-
Sunflower	7	5	19	68	1	-	-
Soybean	11	4	24	54	7	-	-
Sesame/ Til	9	4	41	45	-	-	-
Niger	8	5	35	50	1	-	-
Safflower	10	-	14	75	-	1	-
Linseed	7	4	18	17	53	-	-
Corn	13	1	24	57	1	-	-
Cottonseed	24	3	17	55	Traces	-	-
Rice bran	15	2	42	39	2	-	-
Olive	15	-	75	9	1	-	-
Coconut	91	-	7	2	-	-	-
Palm	51	-	38	10	1	-	-

Oil quality

Nutritive value, chemical and physical characteristics of any fat are regulated by its fatty acid composition. There are three types of fatty acids. These are : saturated fatty acids (SFAs) such as palmitic acid (16:0) and stearic acid (18:0), mono-unsaturated fatty acids (MUFAs) mainly oleic acid (18:1) and poly unsaturated fatty acids (PUFAs) such as linoleic acid (18:2) and linolenic acid (18:3). The PUFAs are also known as essential fatty acids owing to their role in body metabolism and proper functioning of body organs. As these are not synthesized by the human body, these have to be supplied through diet.

Oilseeds differ in their fatty acid composition (Table 1) which determines the quality and end use of particular oil. The proportion of SFAs in plant-derived oils is generally low except in coconut oil (≈ 90%) and palm oil (≈50%). Excess consumption of palmitic acid rich oil increases the risk of cardiovascular diseases. Higher consumption of SFAs is discouraged due to their possible role in increasing low density lipoprotein (LDL) fraction, the so-called bad cholesterol in blood lipid profile. The LDL is carrier of cholesterol from liver to various organs, and its excess can cause thickening of blood vessels (atherosclerosis) and coronary heart disease. The MUFA (oleic acid) acts as cholesterol scavenger. Diets sufficiently enriched with oleic acid (omega 9, 18:1) may slow the progression of atherosclerosis by generating high density lipoprotein (HDL) that is highly resistant to oxidative modification. Oleic acid may also have LDL-lowering effect. Oleic acid reduces the formation of tumour and ameliorates inflammatory diseases. Oleic acid also improves the shelf life and provides thermo-stability to oil and maintains its stability when heated at higher temperatures and, therefore, is best suited for frying. The PUFAs are also important as these are known to reduce blood cholesterols, especially the harmful LDL. These also elevate high density lipoprotein (HDL) fraction of blood lipids. The HDL is important for its role in transporting excess blood cholesterol back to liver for degradation and excretion. Vegetable oils are the main source of PUFAs such as linoleic acid (omega 6, 18:2) and linolenic acid (omega 3, 18:3). World Health Organization (WHO) recommends that the total consumption of saturated fats should be <10% of total energy intake with emphasis on the shift in consumption away from saturated fats to unsaturated fats. However, cooking at very high temperature with oils rich in PUFAs is also not recommended due to rick of producing trans fats. The WHO has also limited the intake of transfats to < 1% of total energy intake.

Greater health awareness coupled with higher consumption of fat rich fast food and increasing number of life style diseases are fueling the quest for high quality edible oils. Consumers are now willing to pay more for quality oils which promise good health.

RAPESEED-MUSTARD

Rapeseed-mustard (*Brassica* sp.) is a group of crops which includes four oleiferous brassicas viz; *Brassica juncea* **(**Indian mustard/raya/laha), *B. rapa* **(**Indian rape/toria, yellow sarson, brown sarson*)*, *B. napus* (oilseed rape/gobhi sarson) and *B. carinata* (Ethiopian mustard/African sarson). *B. nigra* (Black mustard/Banarasi rai)) used as condiment, *B. oleracea* (cabbage/cauli flower) used as a vegetable and *B. pekinensis* (such as Chinese cabbage, broccoli and Brussels sprouts used as leafy vegetables) and *Eruca sativa/vesicaria* (taramira or rocket plant) are also members of rapeseed-mustard family. Globally, it is the third most important source of edible oils after soybean and palm oil. Sunflower ranks next to rapeseed-mustard. In India, the rapeseed-mustard (*Brassica* species) group of crops is next only to soybean in terms of area and production but rank first in terms of contribution (25.2%) and consumption of edible oils. Among different *Brassica* species, Indian mustard (*B. juncea)* accounts for almost 85 per cent of the area occupied by rapeseed-mustard crops in India. Oilseed rape (*B. napus*) has emerged as an important oilseed crop in irrigated areas of north India especially Punjab and Himachal Pradesh due to its better tolerance to low temperature and frost and higher oil content than Indian mustard as well as relative freedom from white rust (a serious disease of Indian mustard). Area under other *Brassica* sp. has declined significantly due to changing cropping patterns and crop intensification in different parts of the country.

Quality of rapeseed-mustard oil

Rapeseed-mustard seeds contain about 36-44 percent oil which is used mainly for cooking and frying owing to its high smoke point (240-250^{o}C), flash points, stability at high temperatures, ability to remain fluid at low temperatures and durability. Rapeseed-mustard oil meets most of the characteristics sought in dietary fats and oils. The rapeseed-mustard oil has low saturated fatty acids (<10%) and relatively a balanced proportion of essential fatty acids such as linoleic acid/omega 6 (18-22%) and linolenic acid/omega 3 (8-12).This is in contrast to very high levels of saturated fatty acids in coconut (91%) and palm (51%) oils. Groundnut, soybean, corn and cottonseed oils also contain about 15 per cent saturated fatty acids. Rapeseed-mustard oil contains higher proportion (20-35 per cent) of poly unsaturated fatty acids than those present in olive, coconut, palm or corn oils (usually 10% or less). Sesame, niger, soybean, sunflower, safflower, corn and cotton seed oils contain 45-70% PUFA (mainly linoleic acid). Soybean and rapeseed-mustard oil are the only common edible vegetable oils that contain appreciable amount of alpha – linolenic acid. Rapeseed-mustard oil has a better ratio of alpha–linolenic acid to linoleic acid (1:2) as compared to soybean oil (1:8). A balanced proportion of linoleic acid to linolenic acid is effective in reducing the risk of heart diseases. Rapeseed-mustard oil is also a rich source of phytosterols (plant sterols) and vitamin E (tocopherols). Phytosterols and vitamin E protect the body from cardio-vascular diseases. It contains higher levels of phytosterol than soybean and sunflower oils. Rapeseed-mustard oil contains higher amounts of alpha-tocopherols as compared to soybean oil or corn oil.

However, rapeseed-mustard oil derived from conventional (traditional) varieties contains high proportion (40-50%)of long chain erucic and eicosenoic (about 8%) fatty acids and low proportion (18-20%) of thermo-stable oleic acid/omega 9 (Table 1). Oil rich in erucic acid is considered undesirable for human consumption by many nutritionists as the regular consumption of oil with more than 20 per cent erucic acid in the diet can cause thickening of arteries which may lead to diseases like myocardial fibrosis, hypocholesterolemia in adults and lipidosis in children. Regular consumption of high erucic acid (22:1) and eicosenoic acids (20:1) rapeseed-mustard oil may result in accumulation of lipids in heart, adrenals and lungs due to slow oxidation and digestion.

Quality of rapeseed-mustard meal

De-oiled seed meal (meal cake) is the major by-product left after extraction of oil. It contains about 30-40 per cent proteins with a superior amino acid composition and about 12% crude fibre. Brassica species contain mainly two types of protein namely cruciferin and napin. These two proteins account for about 60% and 20% each respectively of the total proteins. Rapeseed-mustard meal cake is rich in leucine, isoleucine and sulphur containing amino acids such as methionine and cysteine. Rapeseed protein is balanced with respect to all the amino acids except methionine. The meal is also rich in minerals (inorganic constituents) like calcium, magnesium, phosphorus and potassium and contains vitamin B_4 and vitamin E. It is primarily used in the cattle and poultry feed industries. Rapeseed-Mustard meal is widely used as an inexpensive protein supplement generally as a replacement for soybean meal in animal diet. For monogastric digestive tracts, rapeseed-mustard meal provides better amino acid balance than soybean meal. Defatted dehulled meal contains up to 48% carbohydrates. The main sugars of rapeseed are sucrose. stachyose, raffinose, glucose and fructose. Rapeseed meal contains around 4-6% ash.

However, the quality of rapeseed-mustard meal is constrained by high amount of anti-nutritional sulphur rich compounds called glucosinolates. These are degraded into smaller and more toxic cleavage products (eg. isothiocyanates, nitriles or thiocyanates), following catalytic hydrolysis within the plant tissue in the presence of the plant enzyme myrosinase. Hydrolysis may also occur after its ingestion by animals. It is catalyzed by the gut microflora. Regular consumption of these breakdown products may cause loss of appetite and reduced reproductivity. These may also interfere with iodine metabolism of the consuming animals, causing adverse effects on the thyroid activity leading to thyroid and other goitrogenic problems, liver and kidney abnormalities in livestock. The traditional cultivars of rapeseed-mustard in India contain about 100-130 µmoles glucosinolates per gram of defatted seed meal. This is against internationally mandated limitation of <30 µmoles glucosinolates per gram of defatted seed meal. Adult ruminants like cattle and sheep are normally not affected when they are fed with rations containing ordinary rapeseed meal but pigs and poultry are sensitive to glucosinolate containing rapeseed meal**.** The higher fibre content is another factor which hinders its wider utility.

CANOLA RAPESEED-MUSTARD

This need to have lower erucic acid in oil and glucosinolates in meal has led to the development of low erucic acid (<2%) and low erucic acid-low glucosinolate varieties in rapeseed-mustard crops. Rapeseed-mustard cultivars fulfilling the requirement of low erucic acid (<2%) are known as 'single zero' or 'zero erucic' (0) or 'low erucic' cultivars. The term "double low" or double zero (00) is used to describe rapeseed-mustard varieties with low erucic acid (<2%) in oil and glucosinolates (< 30 µmoles glucosinolates per gram) of defatted seed meal. Double low genotypes are also known as Canola. The term 'canola' was first used in Canada by the Western Canadian Oilseeds Crushers Association (which is now called the Canadian Oilseeds Processors Association). It literally means '*Canadian oil, low acid'*. This term was first registered by Canola Council of Canada in 1978. Ownership of canola trademark was transferred to Canola Council of Canada during 1980. The official definition of canola as per Canadian Food Acts, Feed Acts and the Seeds Act is "An oil that must contain less than 2% erucic acid, and less than 30 micromoles of glucosinolates per gram of air-dried oil-free meal". It is now used as a generic term to describe all rapeseed-mustard varieties in rapeseed-mustard crops.

Quality of canola oil

Canola is now preferred cooking oil in several countries of the world. It possesses a desirable fatty acid profile (Table 1). Decrease in erucic acid in canola oil is also associated with corresponding increase in nutritionally desirable oleic acid (MUFA, omega 9 fatty acid, 18:1). Canola oilseed rape/gobhi sarson (*B. napus*) oil contains high level (62-68%) of oleic acid which is comparable with olive oil (about 70-72%).

Oil from rice bran, corn (maize), cottonseed, palm, safflower, soybean, sesame and sunflower contain less than 50% MUFA. Coconut oil contains only 8% MUFA. Oils from groundnut, soybean, corn, sunflower, sesame, niger and safflower contain higher proportion (32-75%) of linoleic acid (omega 6). Higher proportion of such PUFA makes the oil unstable at higher temperatures and potentially more prone to the production of trans fats. High oleic acid (62%-68%) makes canola oil even better than olive oil which contains highest proportion of oleic acid (about 70%-75%). But olive oil contains higher amounts of saturated fatty acids (≈ 15%) than the canola oil (<10%). Olive oil also possesses lower linoleic acid (8-10%) and negligible amount of linolenic acid (about 1-3%) as compared to canola (18-22%, 8-12%, respectively) oil. The low levels of saturated fatty acids such as palmitic acid and stearic acid and high level of MUFA such as oleic acid and intermediate levels of PUFA such as linoleic acid and linolenic acid coupled with better alpha-linolenic acid to linoleic acid balance make canola oil the most sought after cooking oil.

Nutrition studies have shown that unique fatty acid profile of canola oil helps to mitigate factors associated with coronary heart disease including high blood cholesterol and thrombosis. In developed countries, all rapeseed-mustard genotypes must conform to canola norms for use as edible oil. Oil from non-canola varieties is used for energy production (biofuel) or industrial purposes. The U.S. Food and Drug Administration (FDA) has also supported credible evidence to support a qualified health claim that consuming oleic acid in edible oils, such as olive oil, sunflower oil, or canola oil, may reduce the risk of coronary heart disease. Canola oil may be more heart friendly as it contains lesser amounts of saturated fatty acids as compared olive and sunflower oils. The U.S. Food and Drug Administration (FDA), European Food Safety Authority and Health Canada have banned consumption of rapeseed-mustard oil with more than 2% erucic acid. Japan, Australia, New Zealand have also imposed similar restrictions on consumption of high erucic acid rapeseed-mustard oil.

Quality of canola meal

Significant reduction in glucosinolates in the defatted seed meal from 90-130 µmoles to less the 30 µmoles per gram of defatted seed meal in the canola quality rapeseed-mustard cultivars makes the meal much safer for dairy animals and poultry where is used as preferred source of protein.

GROUNDNUT

Groundnut (*Arachis hypogaea*) is an important legume-oilseed crop cultivated in the tropical, subtropical and temperate zones of the world. It is a valuable source and a unique blend of oil, protein, carbohydrates and minerals. It is used in various forms and, in fact, no part of it goes unutilized. Due to unique blend of oil and protein, kernels are also used for extraction of milk and the kernel residues left after extraction of milk are used in the preparation of cookies.

Quality of oil

Groundnut oil is light yellow in colour with nutty flavour. It is rich in unsaturated fatty acids (Table 1). Oleic and linoleic acids are the two unsaturated fatty acids accounting for 38-56% and 16-38% each respectively. Among the saturated fatty acids, palmitic acid is the major one with about 10-16%. The other fatty acids present in minor quantity are stearic, arachidic, behenic and lignoceric acids (5-10% of the total fatty acids). Raw groundnut oil has very good stability. It can be stored at room temperature for 18 months without any deterioration. Groundnut oil is useful in deep fat frying. Continuous deep fat frying for 10 hours also did not greatly alter its quality. The stability of the oil may be due to the presence of tocopherols (vitamin E) which act as auto-oxidative stabilisers. Higher iodine value and refractive index values indicate its susceptibility to oxidation. Groundnut oil contains a healthy amount of vitamins and minerals, such as vitamin E, vitamin K, vitamin B6, calcium, magnesium, iron, copper, zinc, and potassium. Groundnut oils have higher smoking points and oxidative stability compared to olive oil.

Quality of seed

The protein content of groundnut seed/kernel ranges between 22 and 36% which is more than the meat and about two and a half times more than eggs. It contains ‘lysine’ protein which is lacking in cereals.. Groundnut seed mainly contains globulin type of proteins (87% of total proteins). The protein is easily digestible (97%) with a biological value of 57.9%.The groundnut proteins are richer in acidic amino acids. Aspartic acid, glutamic acid and arginine account for 45% of the total amino acids. Groundnut protein is deficient in lysine, methionine, threorine and tryptophan and therefore is considered as nutritively poor. Conarachin is richer in sulfur containing amino acids than arachin, but poor in phenylalanine and tyrosine.

Groundnut kernel is also a rich source of energy which supplies about 570 kcal per 100 g groundnut kernels. The total carbohydrate content of the kernel is 10-20%. The reducing sugars are low (1.2 to 1.8%). Sucrose is the most important sugar and ranges between 2.86 to 6.35% depending upon genotype. Glucose, fructose and galactose are the other minor sugars present. Oligosaccharides stachyose and raffinose are also present. The latter two sugars are involved in flatulence and bad taste properties of groundnut seed.

Groundnut is a rich source of minerals like phosphorus, calcium, magnesium and potassium. Other elements namely zinc, copper, iron and manganese are also present. However, presence of oxalates and phytates which precipitate the minerals as insoluble salts limit the availability of minerals such as Ca and Fe in spite of their presence in higher quantities. Groundnut is also a good source of 'B' group vitamins. B, B6, niacin. It contains higher levels of tocopherols are present in higher levels. Groundnut is a poor source of vitamins A, C and D.

There are four botanical types of groundnut (*Arachis hypogaea*) under cultivation. They-are Virginia runner, Virginia bunch, Valencia and Spanish bunch. They differ with respect to their chemical composition and oil quality (Table 2). Virginia bunch seeds are richer in oil and energy contents followed by Spanish bunch. Protein content is higher in valencias while soluble sugars are higher in Virginia runner seeds. The runner types contain higher levels of tocopherols than the erect types.

Quality of meal

Groundnut cake is a by-product obtained after extraction of oil. The groundnut cake is mainly utilized as an animal feed and serves as a good nutritious feed for milch animals. The defatted groundnut meal contains about 43-65% protein, 22-38% carbohydrates, 4-6% minerals and 3.8–7.5% crude fibre. About 6% oil remains in cake after oil extraction. The protein digestibility of groundnut cake varies from 88.9 to 92% as against about 90% for soybean meal. In undecorticated groundnut cake the fibre content is very high. It is deficient in lysine, methionine, cystine, tryptophan and also low in calcium, carotene and vitamin D. The cake should be free from aflatoxins which are toxic to poultry, calves and ducklings. Sheep seem to be resistant to aflatoxins.

Advanced methods for the fortification of oils and fats

Manju Bala, Surya Tushir and Poonam Choudhary

ICAR-CIPHET, Ludhiana – 141 004

Vegetable oils mainly comprise triacylglycerides also called triglycerides, or TG. The main nutrient they provide is fat. Fats and oils are complex mixtures of lipid components**.** Fat is a highly valued element of the diet which is important source to provide energy, along with essential fatty acids and fat-soluble vitamins and play critical roles in metabolic functions and nutrient absorption. Moreover, it also serves as a cooking medium flavoring tool and add palatability to dry foods. The main source of fat in the diet comes from vegetable oil, margarine (hydrogenated oil), butter and lard. Fats and oils are necessary for the delivery and absorption of the fat-soluble vitamins (A, D, E and K).These vitamins are required for growth and development of body and

The production of vegetable oils soybean, mustard, canola, groundnut, cottonseed, coconut, olive, palm, safflower, sunflower, corn etc is high throughout the world, and consumption is also increasing, especially among the lower socio-economic groups. A higher consumption of vegetable oils over animal fats is preferable because vegetable oils contain much less saturated fat than animal fats and contain no cholesterol.

Unrefined or crude oils naturally contain vitamin A, D and E or their precursors. When the oil is processed and refined, the precursors of vitamins and or vitamins are lost. Hence, consumers of unfortified refined oil may face health problems due to deficiency of these vitamins if not taken in any other form. Moreover, people now a days are more calorie conscious, avoid high fat diet and as a result it has led to deficiency of fat-soluble vitamins. Changes in life style (indoor staying) have resulted in a reduction in the human body's ability to synthesize vitamin D.There is widespread acknowledgment of the presence of vitamin D deficiency in the community.

Food fortification is the process whereby nutrients are added to food to maintain or improve the quality of the diet of a group, community, or population. Food fortification is required due to insufficient intake of vitamins and minerals, due to the consumption of predominantly processed foods and is increasingly recognized as an effective public health intervention to alleviate nutritional deficiencies. The food to which the nutrients are added is called 'vehicle' for fortification and the added nutrients are called as 'fortificants'.

In order to address the nutritional gaps in vitamin A, D and E consumption and to fighting health problems associated with a deficiency of fat-soluble vitamins, fortification of vegetable oils and fats could be one alternative. They have an advantage in that they are often centrally refined and packed. Moreover, Fat soluble vitamins do not lose potency when heated or cooked and for their fortification no extra technology is required.

Oil Fortification

Addition of one or more essential nutrients to a food, whether or not it is normally contained in the food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups (FAO/WHO 1994). Vegetable oils are consumed by almost everyone; thus, it is possible to improve people's access to fat soluble vitamins through fortification. Vegetable oils are suitable as a vehicle for vitamins A, D, and E fortification due to fat solubility of these vitamins. As vitamins A, D, and E are fat soluble, they can be uniformly distributed in oil. The stability of vitamin A is greater in oils than in any other food and oil facilitates the absorption of vitamin A by the body.

Oils are composed of triglycerides containing polyunsaturated fatty acids (PUFA). PUFAs are long chain fatty acids with more than one double bonds, and hence are susceptible to oxidation. This oxidation can occur when oil is exposed to air and heat. In this sense fortification of oil with vitamin E becomes important when the oil is high in polyunsaturated fatty acids (PUFA). Vitamin E is the general term for all tocopherols and tocotrienols, of which alpha-tocopherol is the natural and biologically most active form. Although gamma-tocopherol makes a significant contribution to the vitamin E content in foods, it is less effective in animal and human tissues, where alpha-tocopherol is the most effective chain-breaking lipid-soluble antioxidant. The ratio of at least 0.6 mg alpha-TE/g PUFA has been suggested, however, higher levels may be necessary for fats with very high PUFA. Antioxidants, such as BHA, BHT, vitamin E (tocopherol) and TBHQ1, are added to reduce the rate of oxidative rancidity. The antioxidant function of vitamin E is critical for the prevention of oxidation of tissue PUFA. Vitamin E is also added to prevent the oxidation of the other vitamins added to the product.

Margarine and fat spreads are still being widely consumed. Margarines lack fat-soluble vitamins. Since margarine was developed to replace butter, which is a good source of fat-soluble vitamins A and D, so they are fortified with those same vitamins at an equivalent level.

Requirements

Vitamin A deficiency (VAD) has been recognized as a public-health issue in developing countries. Vitamin A is essential for normal growth. Vitamin A helps in vision cell differentiation, embryonic development, spermatogenesis, the immune response, taste, hearing, appetite, and growth. Vitamin A deficiency can cause eyesight problems, blindness, reduced resistance to infection, and an increased risk of mortality. Vitamin A activity is expressed in retinol equivalents

(RE) or International Units (IU) (Bagriansky and Ranum 1998). Severe VAD leads to xerophthalmia, the most common cause of preventable blindness among children (WHO, 2009).

Benefits of vitamin A supplementation on serum retinol concentration and hemoglobin levels has been reported in a study on Indian population (Sivon et al., 2002; Das et al., 2013). Studies performed by different workers in India using primarily at large doses of vitamin A supplementation and found little to no impact on linear growth (Bhandari et al., 2001) and no effect on morbidity or mortality (Gupta and Indrayan (2002). However, As per review by Liu et al., 2014 Vitamin A fortification studies are limited on the Indian population. Oil Fortification in Rajasthan and Madhya Pradesh has been reported to be Vitamin A (as Retinyl palmitate) 25,000 IU/kg of Vitamin D-2 to be 2000 IU/kg of oil (Bhagwat et al., 2014). Countries such as Nigeria, Morocco, Yemen, Bangladesh, and Pakistan are implementing national programs to fortify cooking oils with vitamin A. Mandatory fortification of cooking oils with vitamin A has been a focus of the developing societies to combat VAD, e.g. all oils must be fortified at 33 IU/g and 20 IU/g in Pakistan and India respectively (Bagriansky and Ranum, 1998). Further, because of the high efficacy of vitamin A fortification, safety is a concern, and care must be taken not to over fortify.

Vitamin D synthesis in the skin is its primary source, however many people particularly the elderly and those in northerly latitudes rely on dietary vitamin D to maintain an adequate status. Moreover, recent studies show that skin synthesis of vitamin D is insufficient for many people, mainly due to limited sunlight exposure (Ashwell et al., 2010). Therefore, dietary vitamin D may be more important to achieve an optimal serum 25-hydroxyvitamin D (25[OH] D) status in the population (Cashman and Kiely, 2014).

Several recent studies have highlighted the existence of widespread Vitamin D deficiency (about 80%) among the overall population at all ages and in both sexes, residing both in rural and urban

India (Goswami et al., 2008 and Bhandgar and Shah, 2010). Babu and Calvo, 2010 reviwed and reported food fortification as a strategy for improving health, and vitamin D deficiency on Indian populations.

Compared with other feasible food vehicles such as flour and sugar, vegetable oil fortification has been shown to be the most cost effective for vitamin A. In India, hydrogenated oil (Vanaspati) that replaces ghee has been fortified with vitamin A and D since 1953. Current mandate of 700 IU and 56 IU for every ounce of Vanaspati has been a successful program. Margarine is an interesting and effective food vehicle to be fortified with lipid soluble compounds. Many European member states currently require the mandatory addition of vitamins A and D to margarine and fat spreads (Sioen, 2013). For voluntary fortification, one of the main challenges is the cost difference between fortified and non-fortified products and the consumers' willingness to pay for the increased cost due to fortification. This is particularly challenging in countries with a large proportion of poor people, who tend to choose the lowest cost product (Bhagwat et al., 2014). In India, minimal level for vitamin A and vitamin D of 25 IU and 4.5 IU, respectively have been recommended (Table 1).The additional cost due to fortification with Vitamin A and D is 8-10 paise per litre of oil and fortified oil is known to provide 25%-30% of the recommended dietary allowances for vitamins A&D.

Table 1 : Recommendation for fortification of oil by FSSAI, India

Nutrient	Minimum level of nutrient	Source of nutrient
Vitamin A	25 IU per g of oil	Retinyl acetate or Retinyl palmitate
Vitamin D	4.5IU per g of oil	Cholecalciferol or ergocalciferol (from plant source)

(Cited from FSSAI https://ffrc.fssai.gov.in/commodity?commodity=fortified-oil).

Methods involved for oil fortification

Oils can be obtained from either animal fat (lard & tallow) or oilseeds. Heat treatment (rendering process) is used to extract oil from animal tissues, while the extraction of oil from oilseeds is done either through mechanical or solvent extraction. The oil thus obtained is called crude oil which is further subjected to refining processes. Oils can be refined by two types of processes: physical and chemical.

Crude oil

↓

Degumming

(for removal of undesirable components like phospholipids and free fatty acids)

↓

Neutralization

for removal of acidic contents(FFA) in the oil to form soaps

↓

Bleaching for removal of coloring matter (carotene or chlorophyll pigments)

↓

Deodorization

(for removal of undesirable odour such as tocopherols and carotenoids)

↓

Refined Oil

Fig 1.Processes involved for refining of oil

The fortification of fats and oils can be carried out by using fat-soluble vitamins, which can be added either individually (single vitamin) or in the form of a multi-vitamin blend. The addition of these vitamins is generally done after the final refining step of deodorization so as to minimize the loss of the vitamins.

The technology required for the addition of any fat soluble (A, D, E) to refined oil is simple and low cost. The dosing of these micro-ingredients into the oil can be done with the same dosing technology used for the addition of antioxidants, in routine (Nagy, 1995). In order to ensure uniform mixing of these vitamins in the oil, premix is prepared. The term Premix refers to the mixture of a micronutrient and another ingredient, often the same staple that is to be fortified, which is added to the food vehicle to improve the distribution of the micronutrient mix within the food matrix and to reduce the separation (segregation) between the food and micronutrient particles. In case of oil fortification the required amount of vitamins is measured and mixed in a small portion of warm oil (premix) which is then added to the bulk of the oil prior to homogenization. Temperature required assuring uniform mixing for most of the oils is 40-50º C, and for soybean oil it is about 25º C.

Mixing liquids with liquids is relatively easy, a container (a big tank) can be used to put oil (by pump) and to mix the desired quantity of vitamin mix in it by rotary stainless mixer or the tank which can be equipped with a screw or blade adapted for liquid mixing.

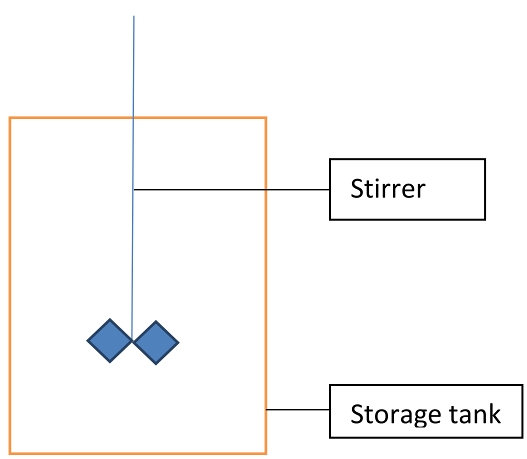


Fig.2. Mixing of Vitamin with oil

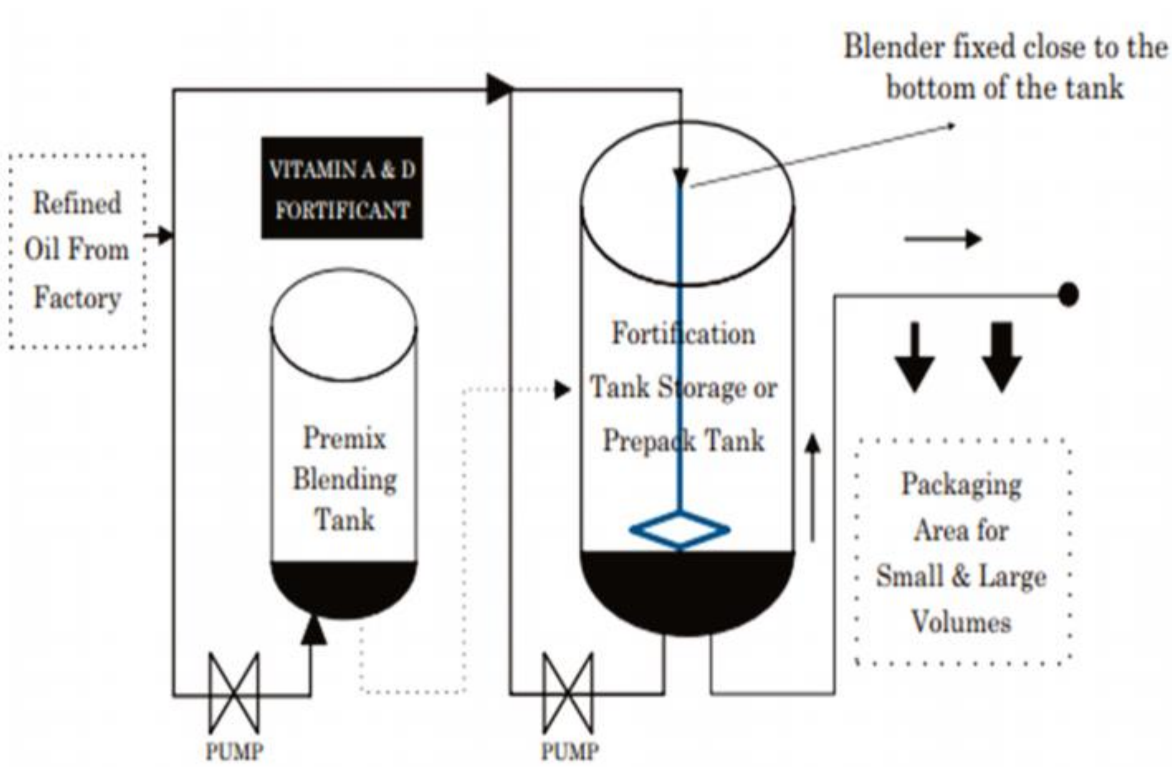


Fig.3. Blending and Holding Tanks for Fortification - Batch Mixing Process (Cited from FSSAI Guide Book on Food Fortification)

Mixing can be performed either continuously in static mixture or in a batch process. Canadian packagers have reported that the mixing is easily accomplished in an agitated tank in one hour (Bloch, 1931). The vitamin A and D blend is measured and mixed with warm oil (1:5) until uniform solution is obtained. This Premix is incorporated in margarine before emulsification.

Stability of fat and oil fortification

The micronutrients used to fortify fats and oils are generally found to be stable. However, the stability of the vitamins used to nutrify fats and oils is dependent on many factors, including the quality of the refined oil, oxidative Stability of oil, exposure to oxygen, storage temperatures, cooking temperature and cooking time and method, and storage time. If the oil is partially oxidized, it will result in the oxidation of the vitamins added to the oil.

Addition of antioxidants in oil, also protect the vitamins from degradation. Gopal, et al. (1955) compared stability of vanaspati with Vanatin (tocopherol and lethicin) with samples that also included BHA. Their results showed improved stability at all temperatures with BHA – although impact at lower temperatures was minimal. At higher temperatures the improvement with BHA was more pronounced. After 5 minutes of frying at 200º C, retention was 71% with BHA and 60% without. Packaging of oil becomes important for the stability of vitamins. Vitamin A fortified oil showed good vitamin retention after 5 months of storage in sealed metal containers at high temperature and humidity .Favaro, et al.1991 found almost no loss through 9 months in sealed containers at 23º C. However, there were significant losses at 18 months.

Akhtar et al., 2012.examined the effect of traditional cooking style on the degree of destruction of vitamin 'A' mandatory fortified in the vegetable ghee/ cooking oils in Pakistan. Some losses of Vitamin A of the fortified oils during cooking were reported. However in case of deep fat frying destruction of added vitamin 'A' was more pronounced. The loss of vitamin 'A' was less than 50%, when the food was cooked in Pakistani style in case of all the cooking oils/ vegetable ghee. In prolonged frying conditions substantial amount of vitamin 'A' (45%) remained in the oil. However, this retention of vitamin 'A' was sufficient to meet the body requirements when oils/ ghee was fortified 33,000 IU per Kg.The fluorescent light commonly used in retail stores and households can also induce a vitamin A loss of more than 80% (Pignitter, et al., 2014). Vitamin A losses of different oils packaged in PET bottles stored under light conditions were reported to be 20- 25% at the 5th week of storage and were more than 80% after 13 weeks, whereas losses under dark conditions and in metal containers were less than 15% (Puysuwan et al., 2007).

Soybean oils with different oxidative status and vitamin E contents were stored in the dark, semi-dark, or exposed to natural light. Lipid peroxidation took place after 3 weeks of storage in dark conditions. After 2 months, the vitamin A and D3 losses reached 60–68% and 61–68%, respectively, for oils exposed to natural light, and 32–39% and 24–44% in semi-dark conditions. The determining factors of vitamin A and D3 losses were (in decreasing order) the storage time, the exposure to light and the oxidative status of the oil, whereas vitamin E content had a protective role (Hemery et al., 2015).

Food fortification is implemented to address vitamins A and D deficiencies in numerous countries. Fortification of widely consumed foods with vitamin A and D could improve consumption of these vitamins and can save the masses from health problems faced due to deficiency of these vitamins. Since the technology requirement for fortification of oil with fat soluble vitamins is not costly so it can be adapted to provide these vitamins to vulnerable groups. Moreover, only selection of efficacious products is not sufficient, successful programs require reliable food enforcement and monitoring systems.

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UNIT-7

Processing of vegetable oil seeds and oils and their nutritional aspects: An overview

Dr. K. D. Yadav
Senior Vice President (Technical)
AAK Kamani Pvt Ltd., Mumbai

- Introduction
- Fatty acids & glycerides
- Physical properties of triglycerides
- Factors determining deterioration of oils and fats
- Oils and fats-processing and refining
- Modification of oils – Hydrogenation, Interesterification, Fractionation
- Importance of oils in the diet
- Trans fats and its implications

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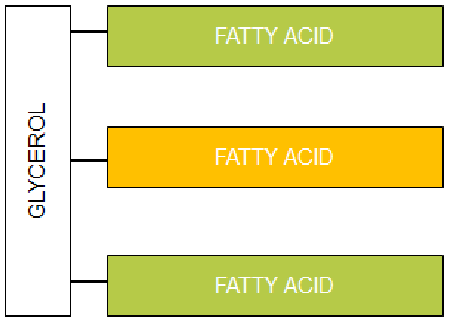
Introduction

- The terms, fats and oils, are commonly used to denote crude mixtures of a class of compounds called ***lipids***.
- They are also called triglycerides (triesters of glycerol and fatty acids)

Triglycerides (TG) are made up of fatty acids

Triglycerides (TGs) are made up of:

- 1 molecule of Glycerol
- 3 molecules of Fatty Acids



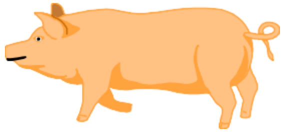
Normally, the simple distinction between oils and fats is:

- FATS are solids at room temperature
- OILS are liquid at room temperature

Fats and oils

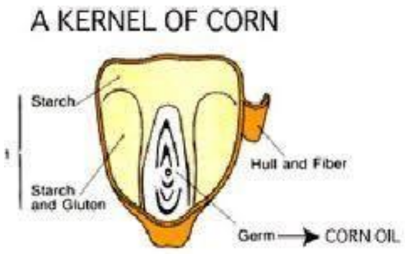
Naturally occurring

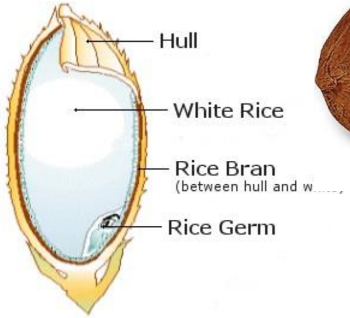
- **Animal fat**
  - **lard**
  - **tallow**
- **Vegetable oil**
  - **sunflower oil**
  - **coconut oil**
- **Marine oil**
  - **cod liver oil**
  - **whale oil**



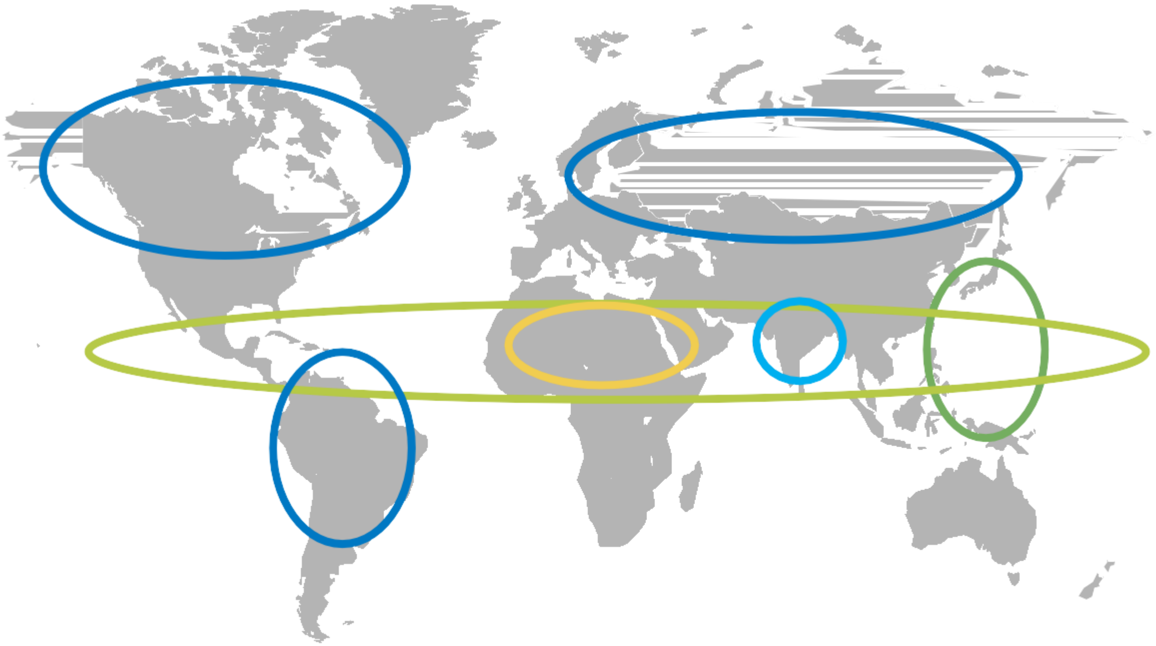


- Plants use stored oil as food/energy for germination and growth
- Oil can be stored in endosperm (castor, coconut), cotyledons (peanut, soybean), germ (corn), fruit pulp (palms and olives).

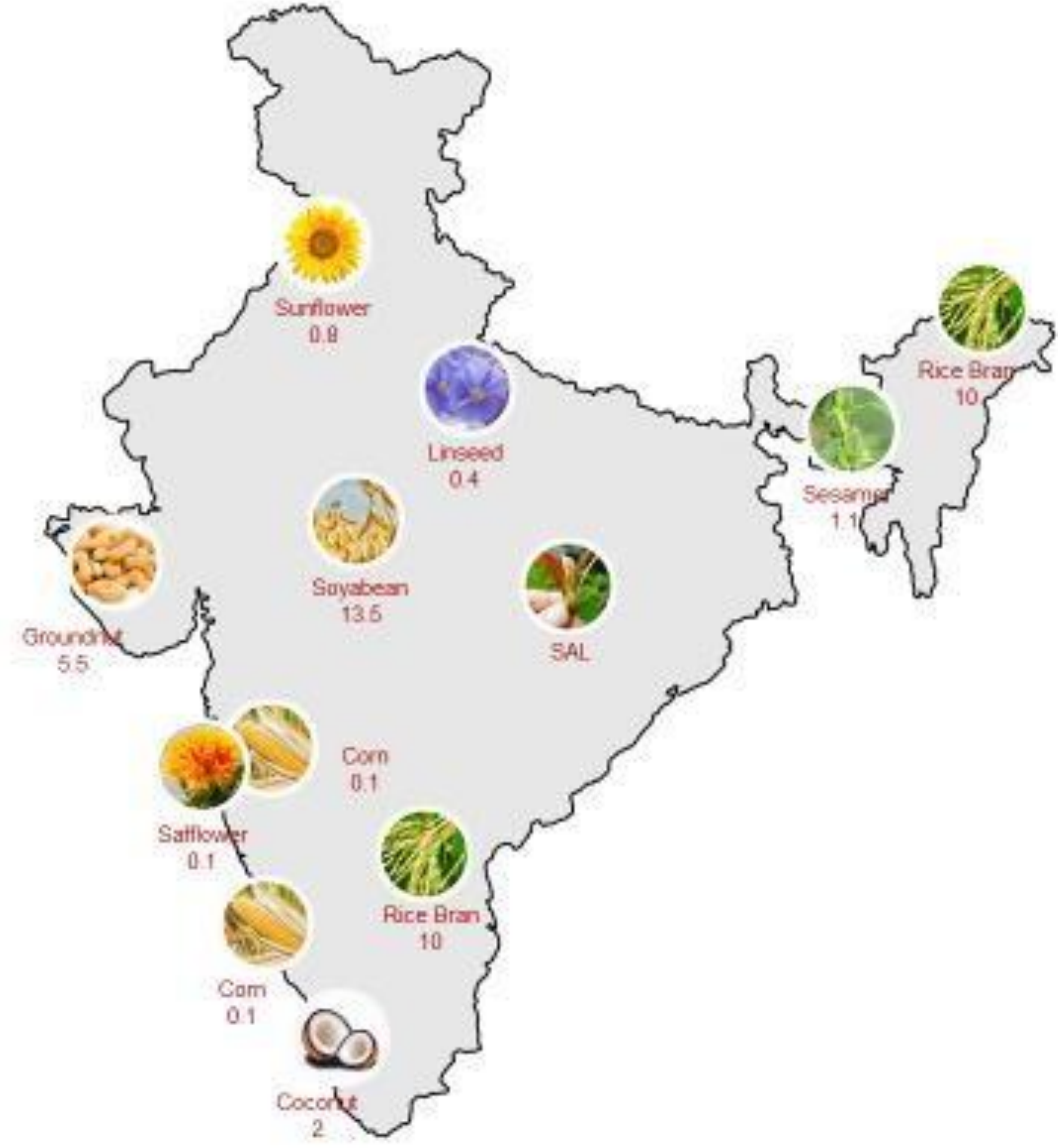





World of Vegetable Oils



- Palm, Palm Kernel
- Shea, Cocoa
- Soya, Rapeseed, Sunflower, Cotton, Corn
- Coconut, Illipe
- Sal, Mango, Kokum



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Vegetable Oils – Consumption pattern

- **Oils vary across different regions in India.**
- **Consumer preferences are influenced by the crops grown in their regions**
- **South and West**

  - Coconut, Sesame and Groundnut oil Sunflower
- **East and North**

  - Mustard oil
- **Other popular oils**

  - Soy, Ricebran, Palm

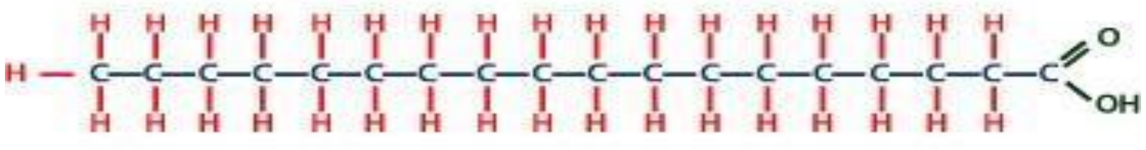
CONTENT

What are Fatty acids and their types

Fatty acids are the building blocks that make up triglycerides (A long chain of Carbon atoms followed by an acid group)

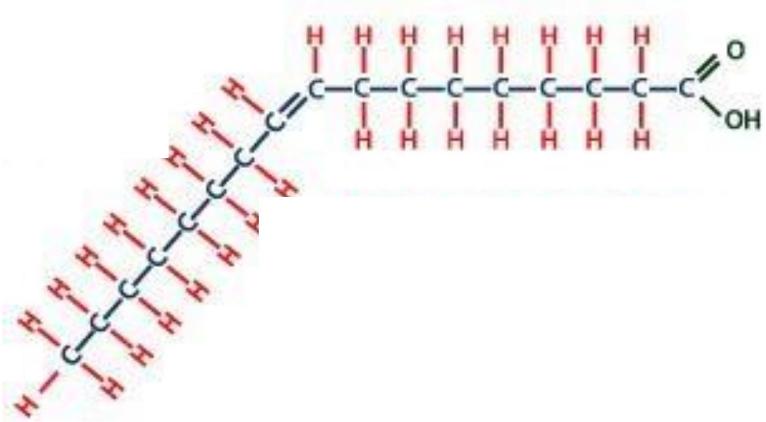
Two types of fatty acids – Saturated and Unsaturated
Unsaturated – Mono-unsaturated and Poly-unsaturated

- Saturated fatty acid



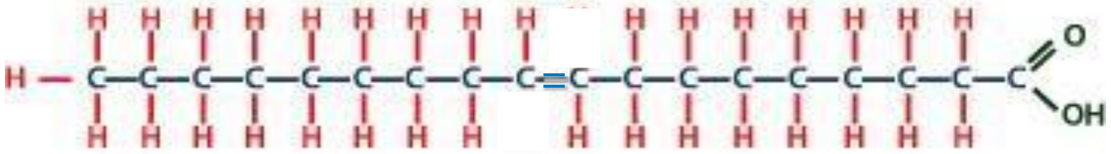
C18:0

- Mono un-saturated fatty acid (One double – bond)



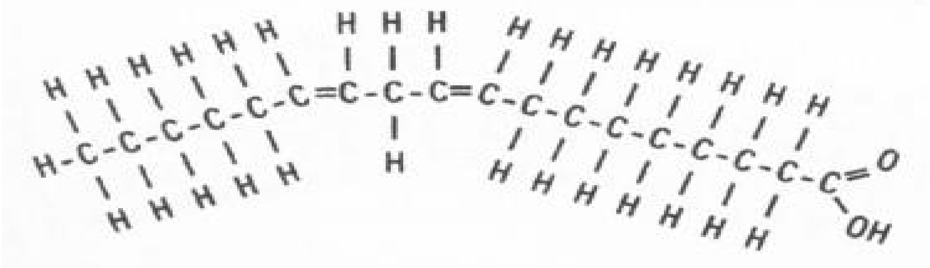
C18:1

- Trans fatty acid



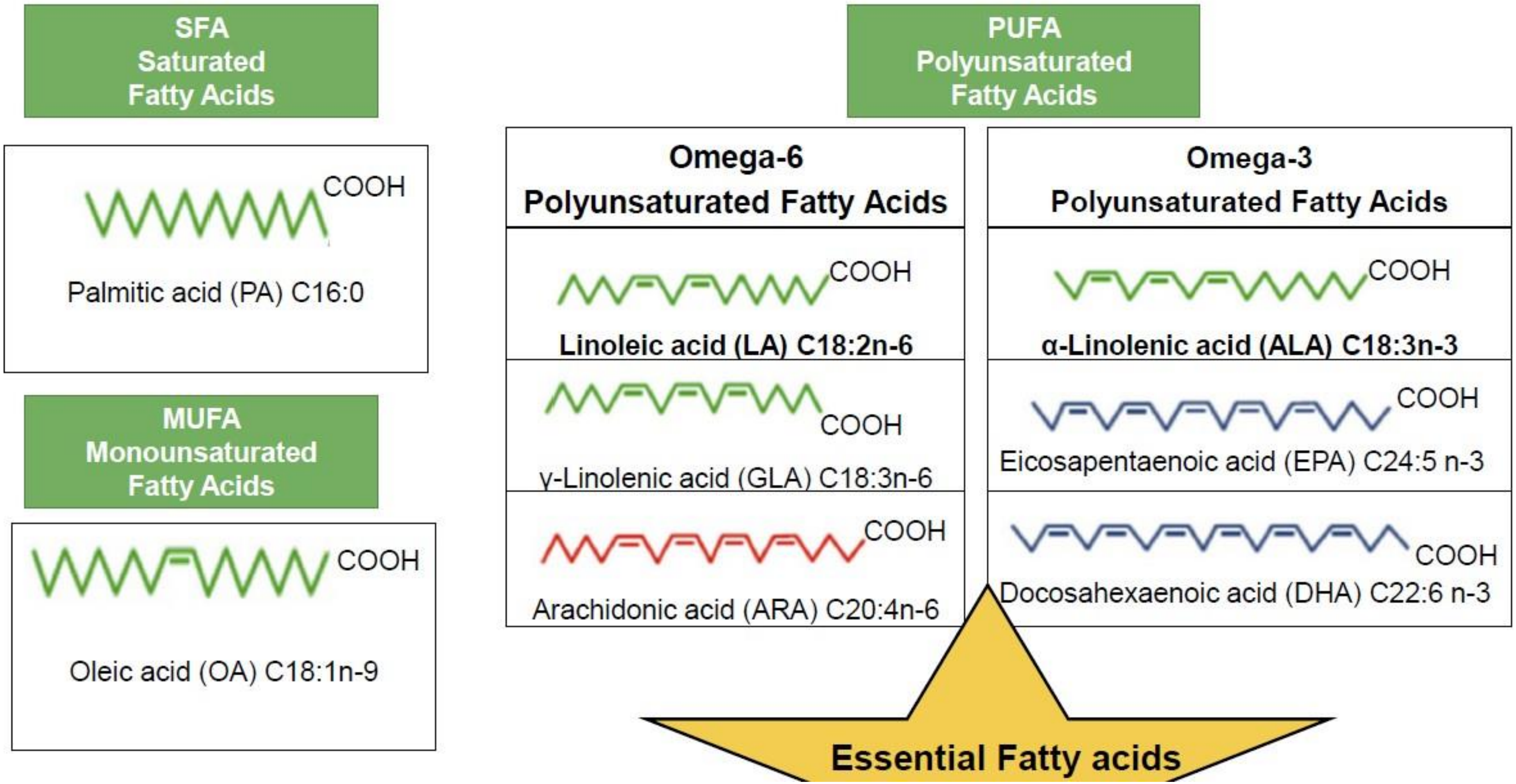
C18:1 trans

- Poly un-saturated fatty acid (2 or more than 2 double-bonds)



C18:2

Some more examples

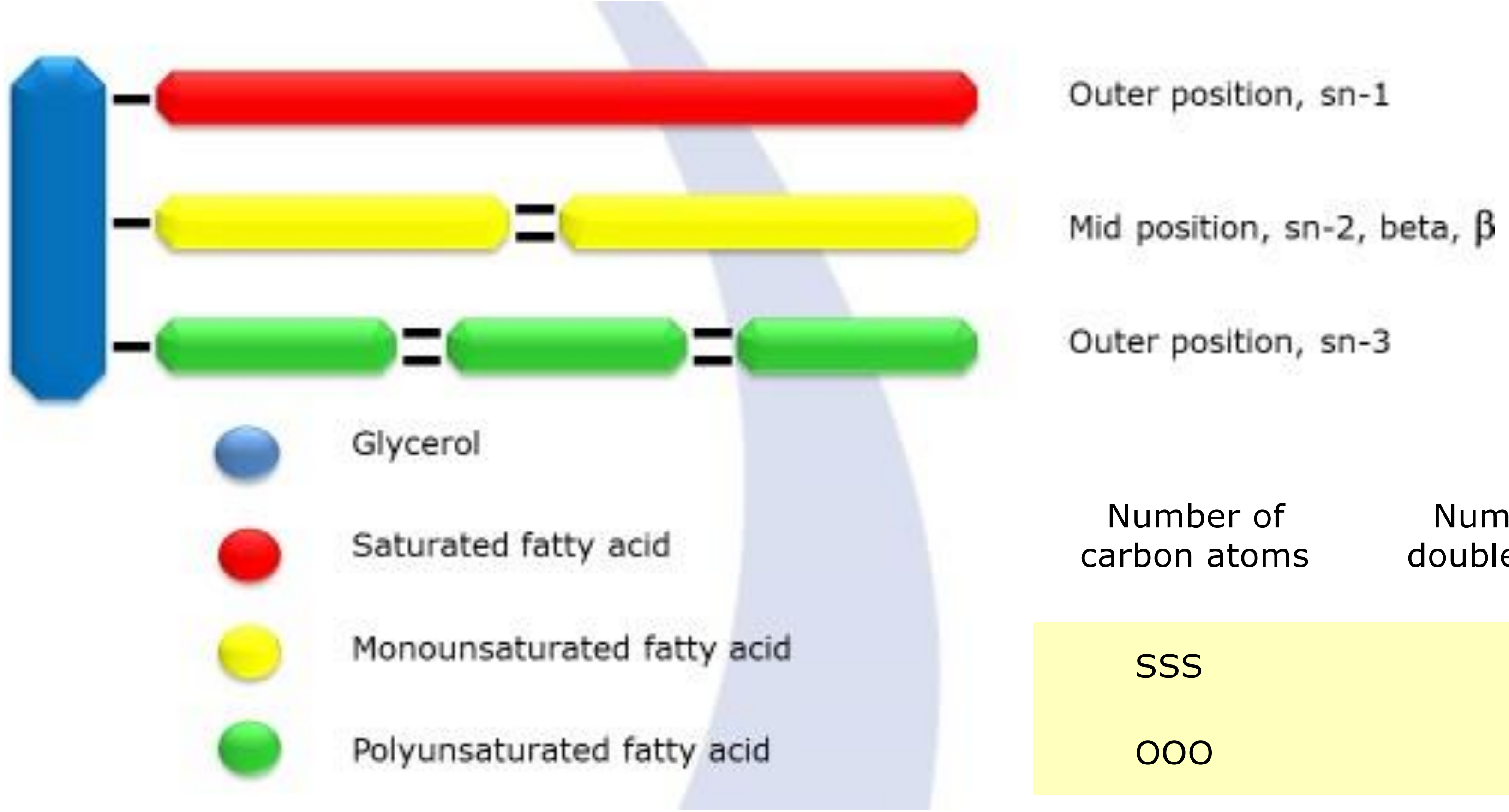


Melting point of certain fatty acids

Common name	Carbon atoms	Double bonds	Source
Butyric acid	4	0	Butter
Caproic acid	6	0	Butter
Caprylic acid	8	0	Coconut
Capric acid	10	0	Coconut
Lauric acid	12	0	Coconut, Palm Kernel
Myristic acid	14	0	Palm Kernel
Palmitic acid	16	0	Palm
Stearic acid	18	0	Exotics (Shea, Illipe)
Oleic acid	18	1	Liquids (Soya, Rape)
Linoleic acid	18	2	Liquids (Soya, Rape)
Linolenic acid	18	3	Liquids (Soya, Rape)
Arachidic Acid	20	0	Exotics, Peanut
Behenic acid	22	0	Rape
Erucic acid	22	1	Rape

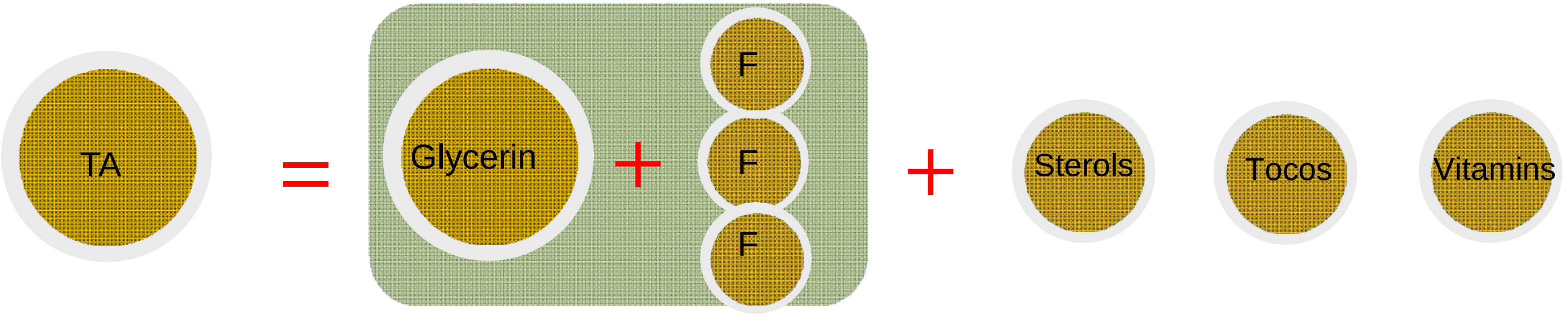
Fatty Acid	Formula	Melting Point °C
Caproic	C6:0	-3.2
Caprylic	C8:0	16.5
Capric	C10:0	31.6
Lauric	C12:0	44.8
Myristic	C14:0	54.4
Palmitic	C16:0	63
Stearic	C18:0	70
Oleic	C18:1	17
Linoleic	C18:2	-7
Linolenic	C18:3	-13

Melting points of some TGs



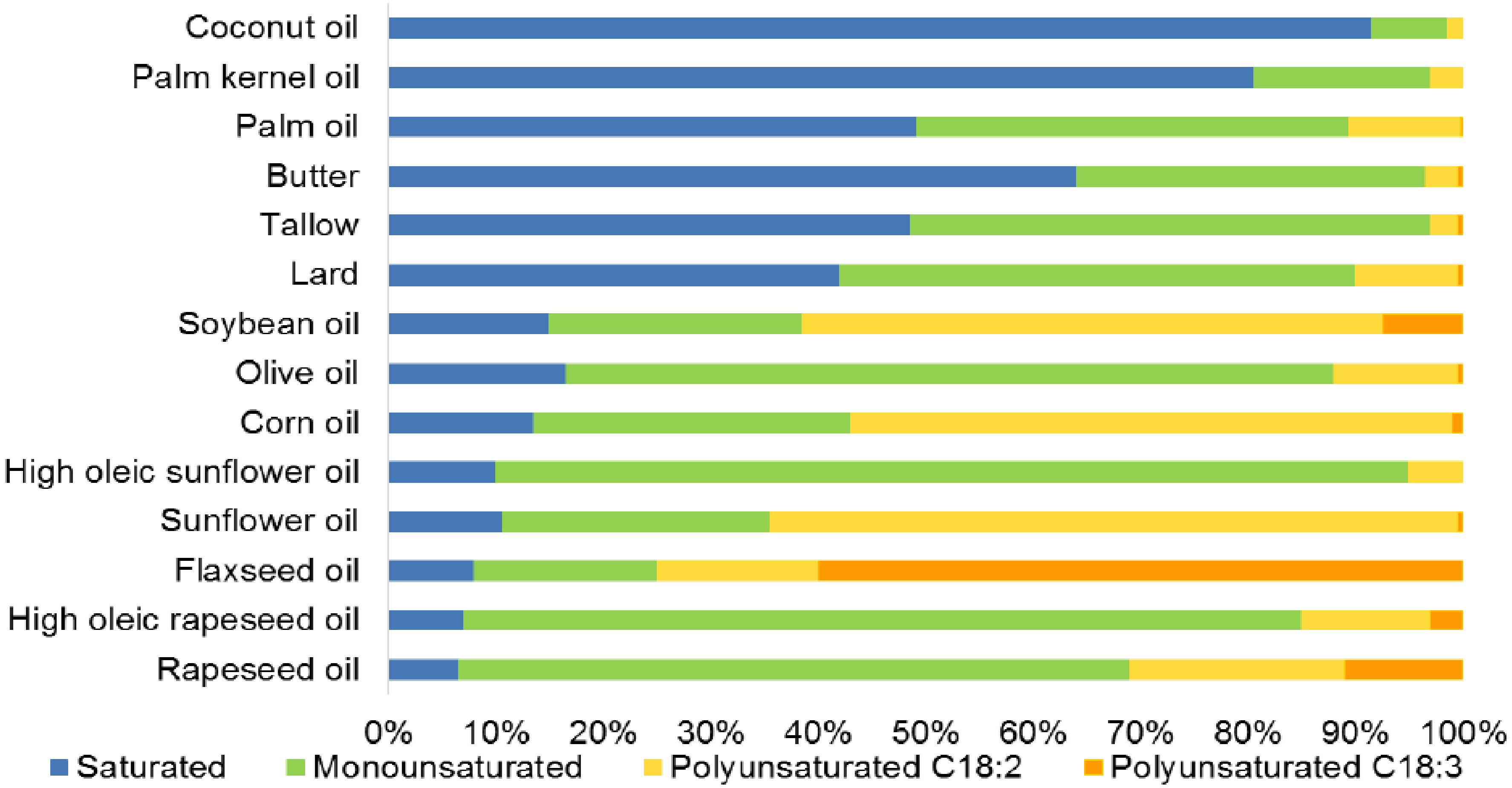
Number of carbon atoms	Number of double bound	Melting point °C
SSS	0	64.3
OOO	3	-10.0
SOS	1	37.0
SSO	1	41.9

Fats & oils and their components



Major Components	Content
Triglycerides	90 - 100 %
Mono-/diglycerides	0 - 5 %
Fatty acids	0 - 1%
Minor components	
Phospholipids	0 - 1 %
Sterols, sterol esters	500 - 15000 ppm
Tocopherols, tocotrienols	0 – 3000 ppm

Fatty Acid Composition of Oils



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Physical properties of triglycerides

- The physical properties, such as melting points, viscosity, density and refractive index depend on:

- the type of fatty acids present in the triglyceride and their location,
- chain length of fatty acids,
- number and location of *cis* and *trans* double bonds on the fatty acid chains.

- ***Melting Point***

- The melting range of fats depends on the triglyceride composition.
- Melting points increase with chain length.
- *Trans* fatty acids always have higher melting points than their *cis* counterparts for any chain length.
- Melting point data are useful in animal fats and processed fats but are of little value for vegetable oils since most oils are liquids at ambient temperatures.

Physical properties of triglycerides- *Polymorphism*

- ***Polymorphism:*** the existence of a substance in two or more crystal forms, which are significantly different in physical or chemical properties.
- Certain pure or mixed fatty acid triglycerides may show as many as five different melting points. Each crystal system has a characteristic melting point, x-ray diffraction pattern and infrared spectrum.
- For example, tristearin can exist in three polymorphic forms with melting points of 54.7°C, 63.2°C and 73.5°C.
- Polymorphism has several industrial implications in use of fats as shortenings, margarines and cocoa butter.

Polymorphism - Ability to crystallise in a number of forms

α→β'→β

- **α Crystals**

–Unstable, Waxy

- **β' Crystals**

–Small, needle like

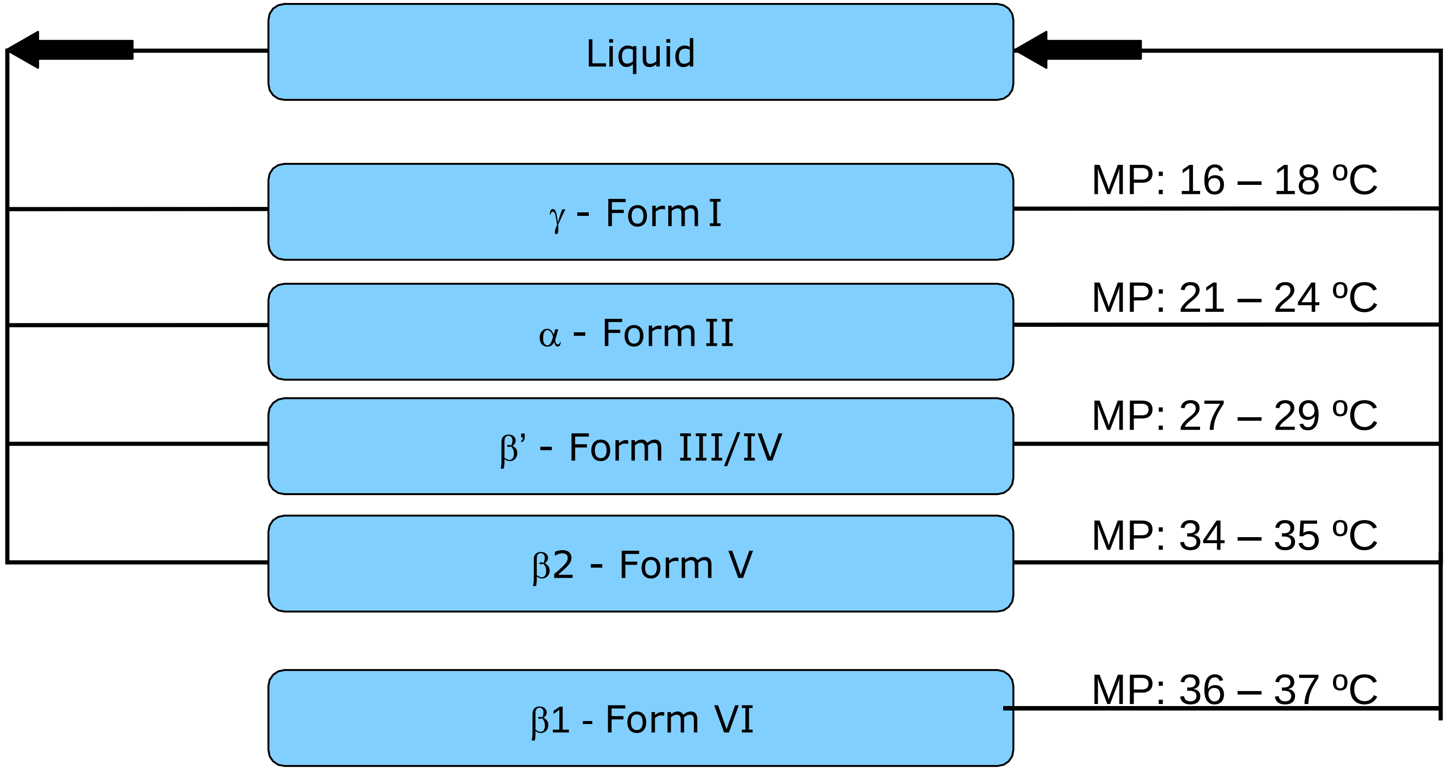
–Smooth texture, better creaming

- **β Crystals**

–Most stable form. Big plate like structure

–Grainy, sandy and oily texture

Crystal forms in cocoa butter



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Why is the deterioration of oils an important factor to consider?

Oxidation

- Decreases nutritional value
- Results in off-flavours
    - rancid, heated oil, fishy, etc

Hydrolysis

- Bitter taste
- Soapy taste

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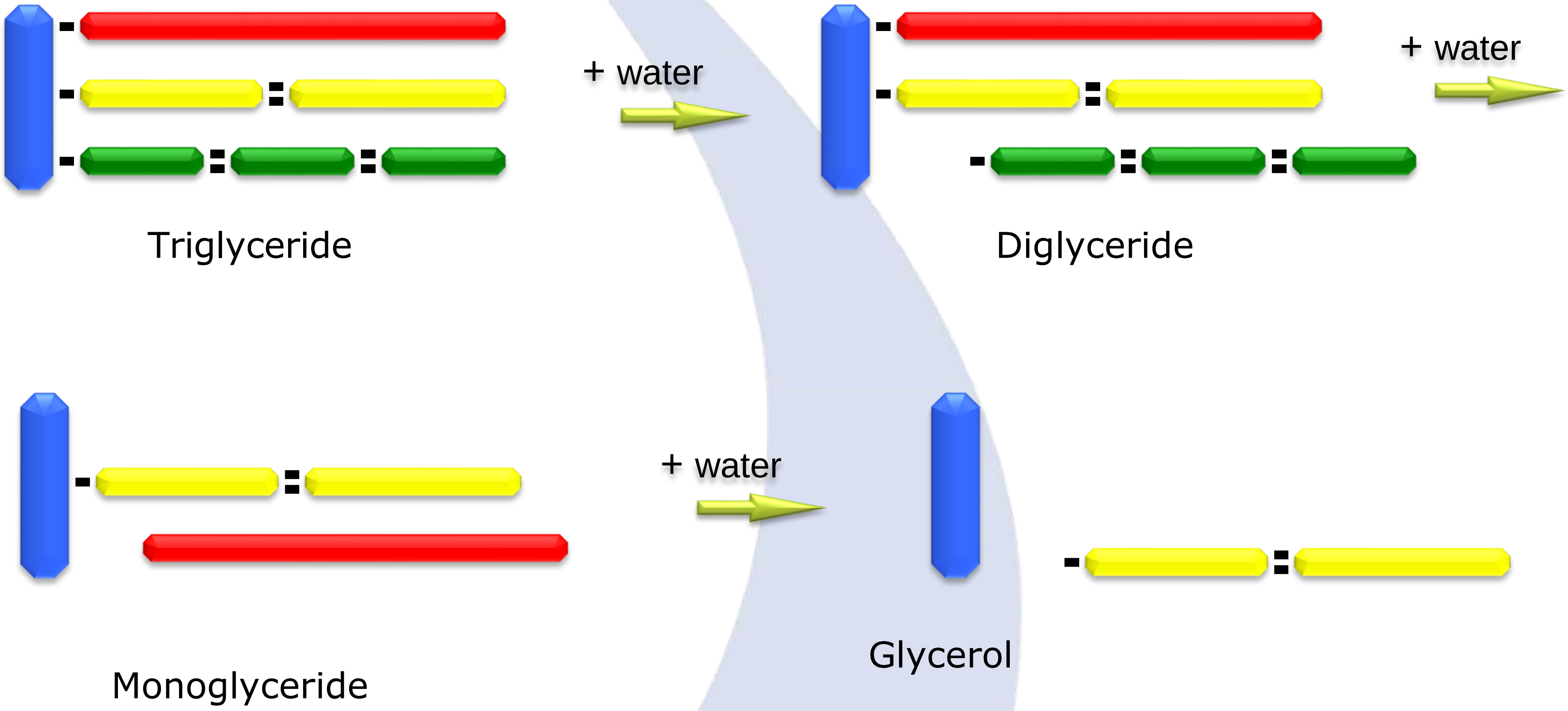
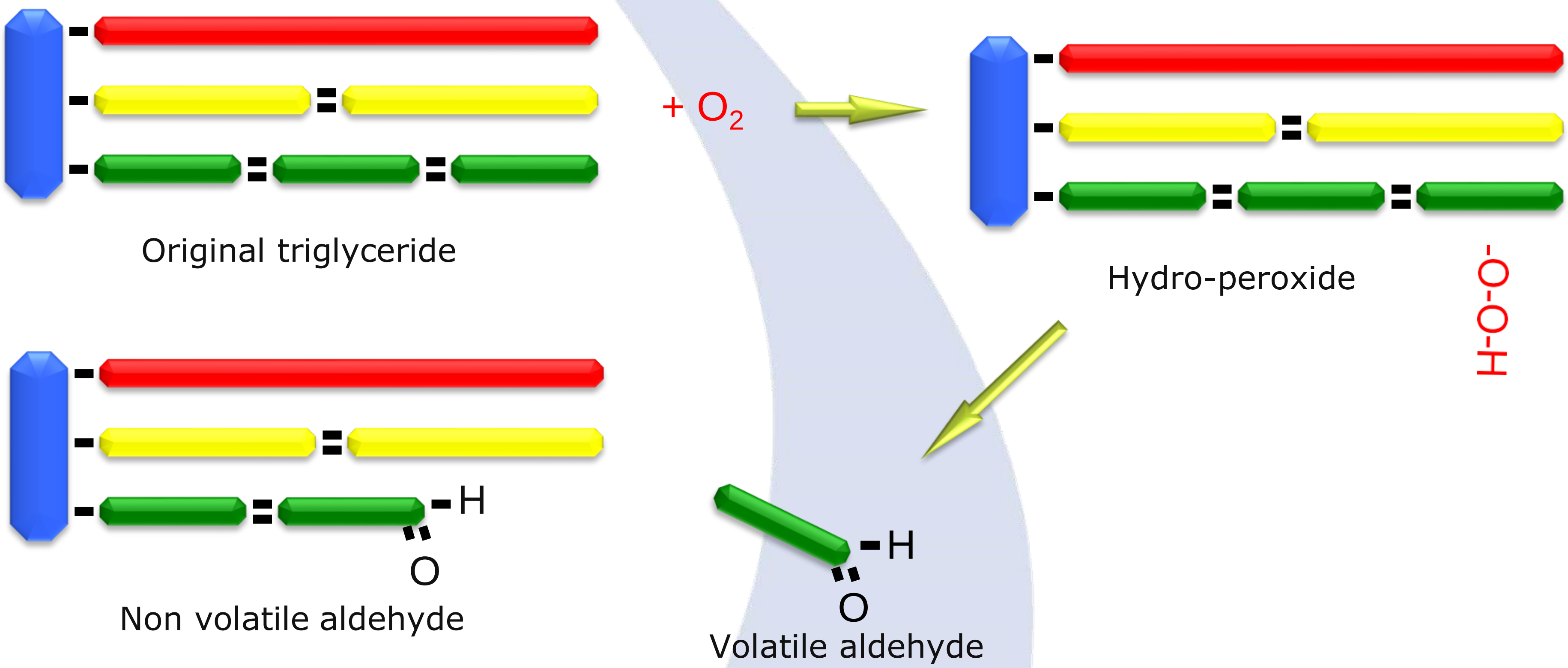
Breakdown of fats - Hydrolysis



Breakdown of fats - oxidation

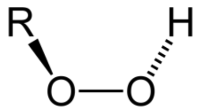


Analyses to monitor lipid oxidation

Peroxide Value

- Primary oxidation products

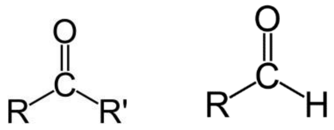
  Hydoperoxides



Anisidine Value

- Secondary oxidation product

  Ketons, aldehydes



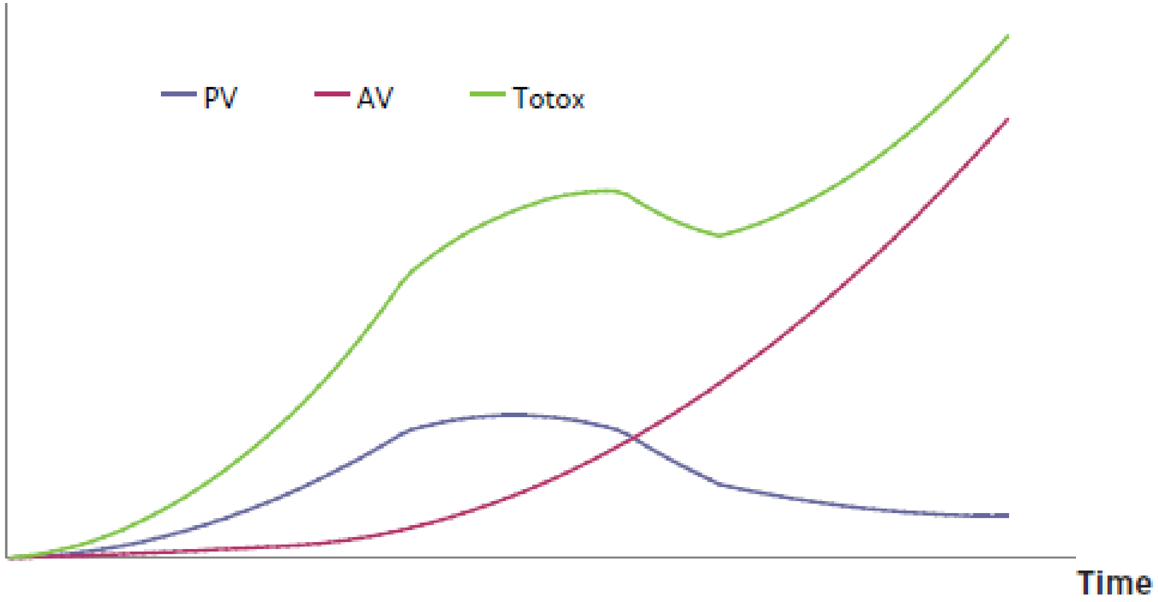


Figure 1 : The oxidation of oil over time as measured by peroxide value (PV), anisidine value (AV) and Totox value. Note: PV can decrease over time so AV and/or Totox calculation is needed to appreciate the whole oxidation story.

Colour

- Oxidation products and coloured contaminants

Oxidation stability Index (accelerated oxidation tests)

- Rancimat

Can hydrolysis and oxidation be prevented ?

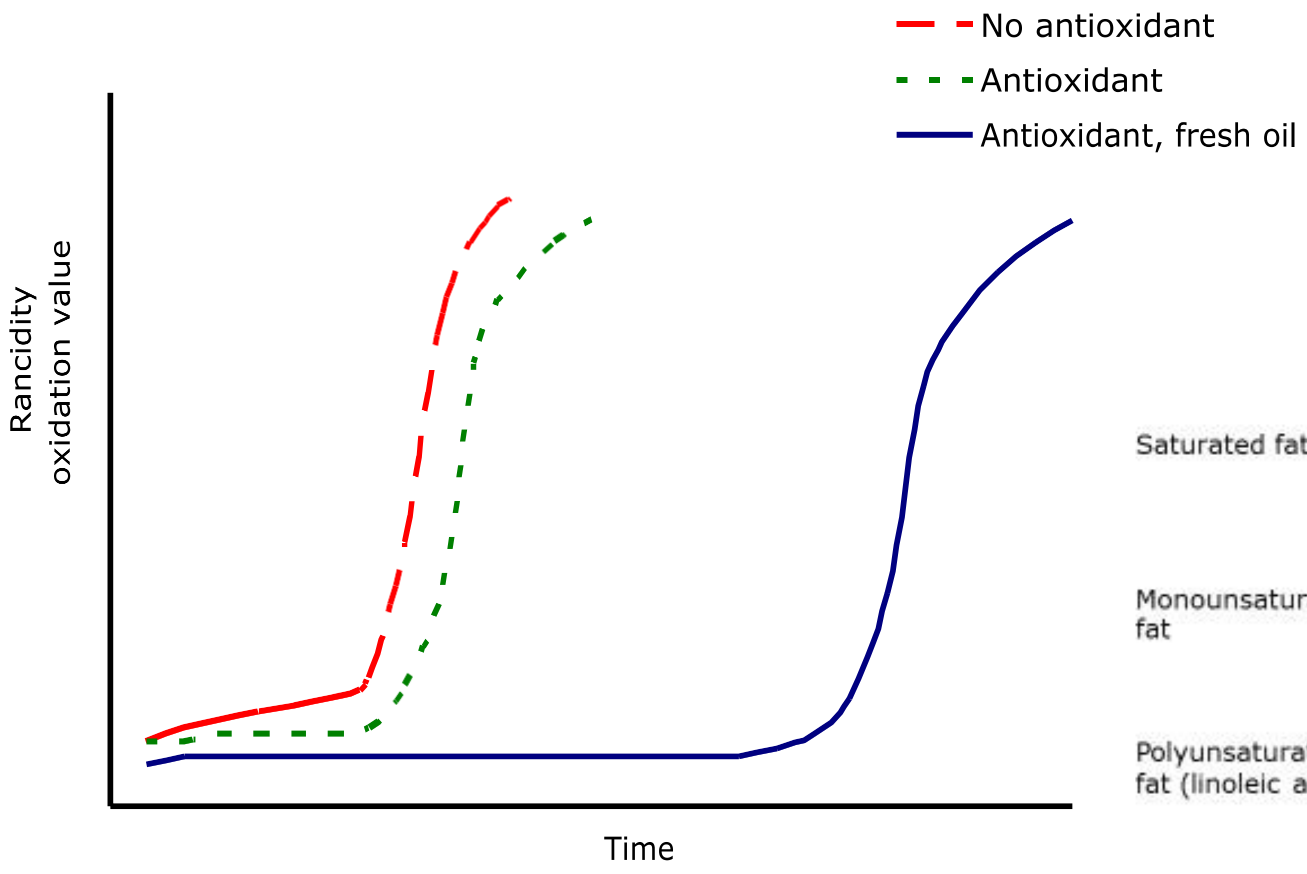
Hydrolysis

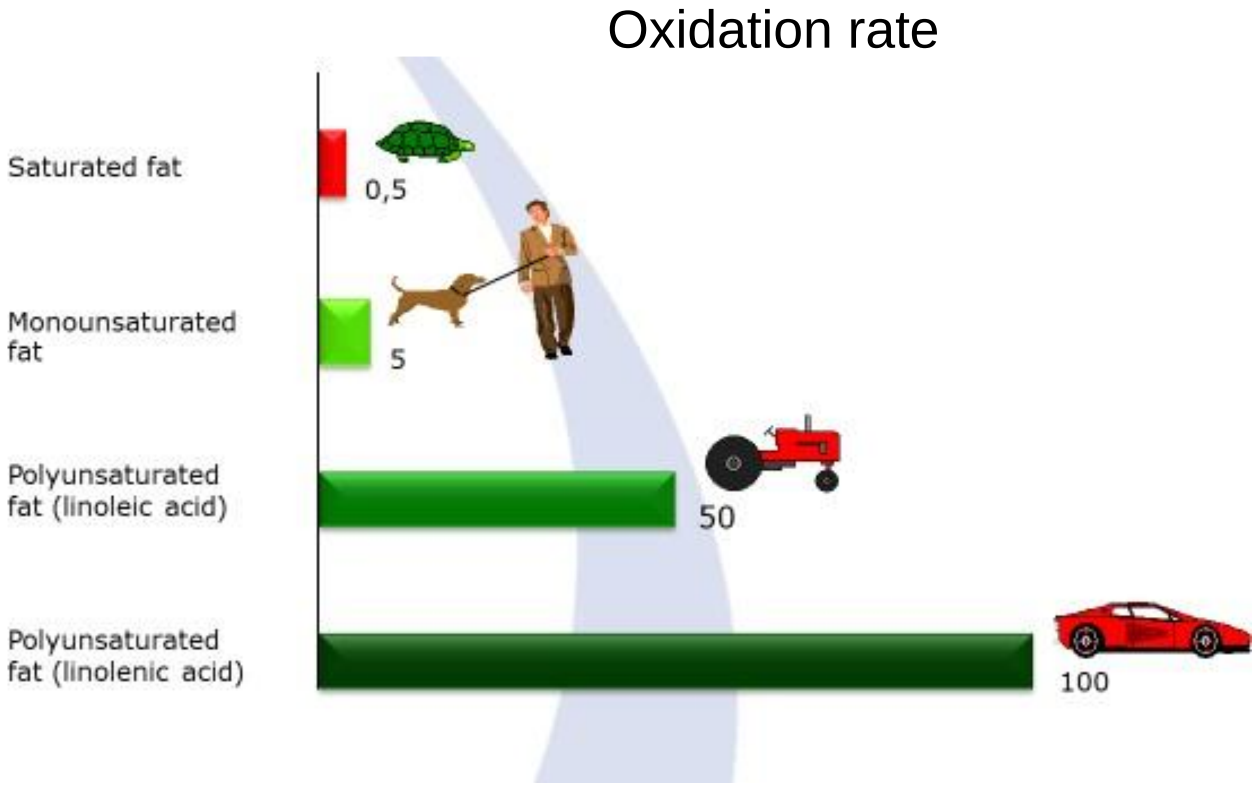
- Avoid water and humidity
- Avoid lipase activity
- Add lecithin
  - Binds water, may inactivate enzymes

Oxidation

- The fatty acid composition is important
  - Degree of unsaturation (High PUFA oils increases oxidation rate)
- Use high quality oils and fats
  - Already oxidised oil catalyses the process
- Add suitable antioxidants (natural/synthetic)
  - Choose oils with a high natural tocopherol content
- Handle the oils carefully
  - Avoid contact with certain metals
  - Avoid high temperature and light (sunlight, UV)
  - No air incorporation

The effects of antioxidants





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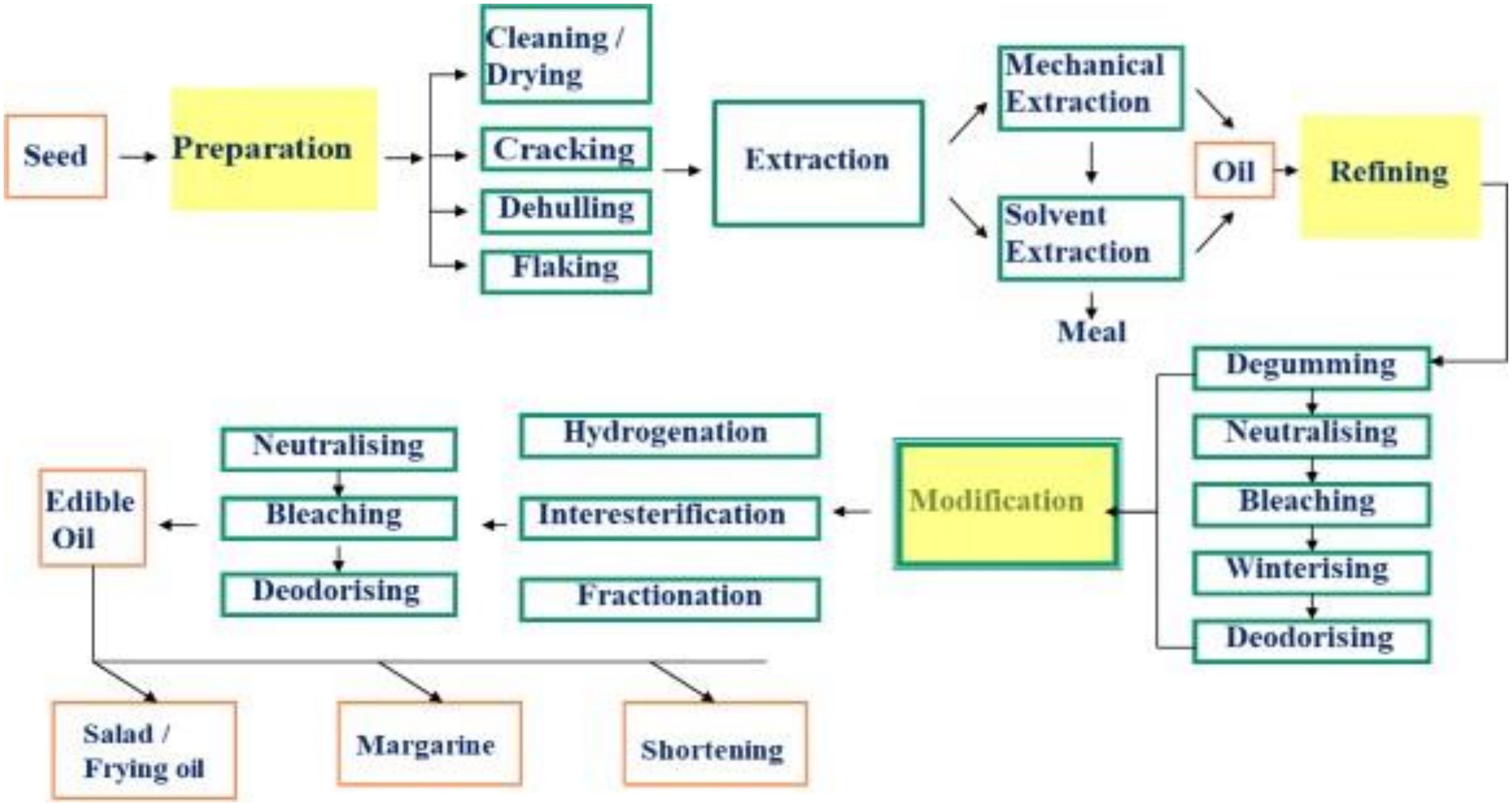
Oils and Fats Processing



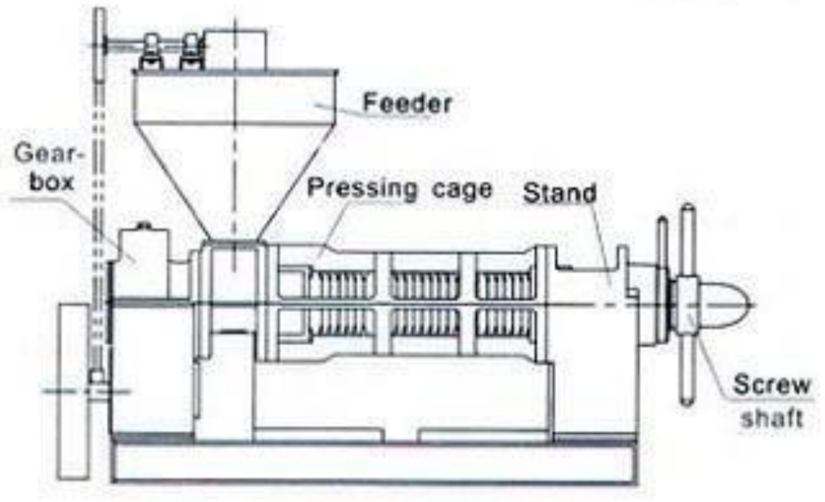
Fats and oils

Oils

Filtered oils | **Refined oils**

Mechanical expelling

- Preparation of the raw material; removal of fine impurities, husks or seed coats from the seeds and separating the seeds from the chaff.
- The seeds are then cracked to expose the "meats" of the raw material.
- Oil is then extracted mechanically with an oil press, an expeller.
- Presses range from small, hand-driven models that an individual can build to power-driven commercial presses.
- Expellers have a rotating screw inside a horizontal cylinder that is capped at one end. The screw forces the seeds or nuts through the cylinder, gradually increasing the pressure.
- The material is heated by friction and/or electric heaters.
- The oil escapes from the cylinder through small holes or slots, and the press cake emerges from the end of the cylinder.
- Oil expressed without heating contains the least amount of impurities and is often of edible quality without refining orfurther processing.
- Such oils are known as cold-drawn, cold-pressed, or virgin oils



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Solvent Extraction

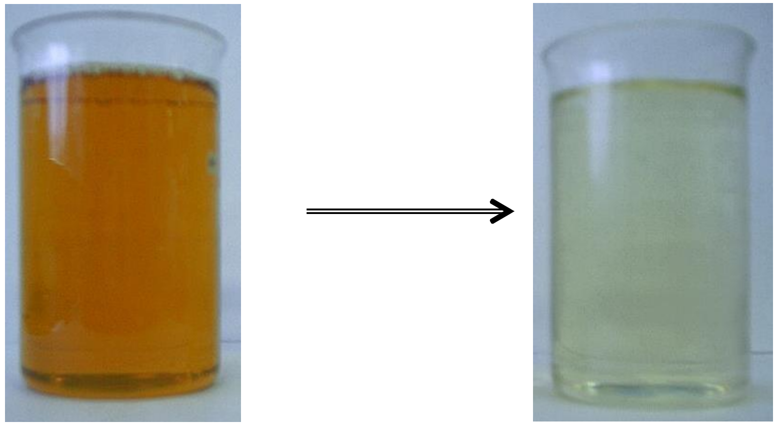
- The press cake emerging from a screw press still retains 3 to 15 percent of residual oil.
- More complete extraction is done by solvent extraction of the residues obtained from mechanical pressing.
- The common solvent for edible oil is commercial hexane
- After extraction, maximum solvent recovery is necessary for economical operation.
- The solvent is recovered by distillation and is reused. The extracted oil is mixed with prepress oil for refining.
- The extracted meals contain less than 1 percent of residual oil

Fats and oils

REFINING OF OILS

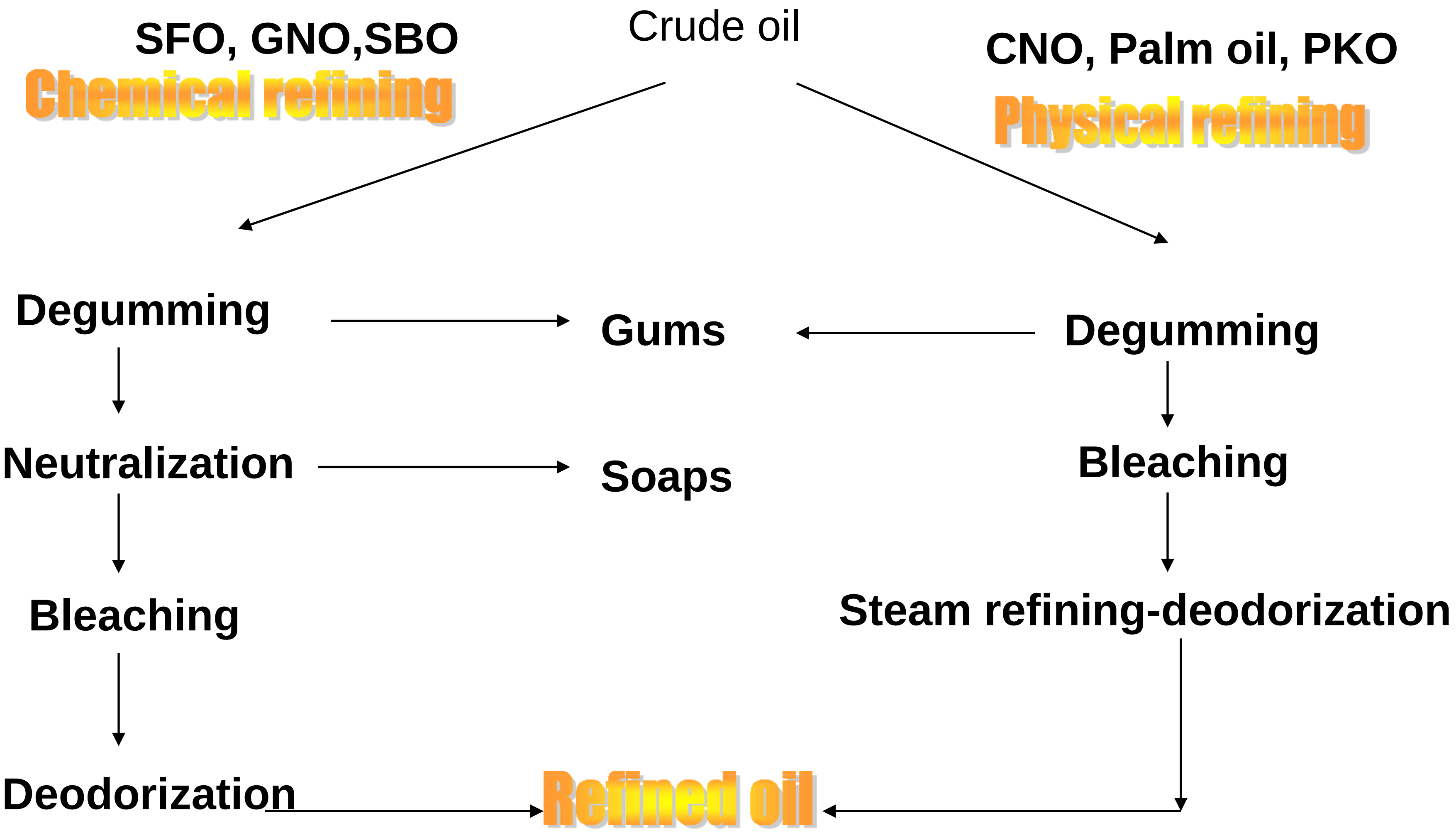
Crude oils have following impurities which need to be removed to make it acceptable

- Free fatty acids
- Phospholipids/gums/waxes
- Colour and Pigments
- Oxidized materials
- Flavour compounds
- Trace elements.



The objective of this process is remove these impurities and to produce oils which are completely free of taste, smell and colour.

Processing steps



Crude oil impurities and analysis

Impurity	Source	Analysis	Typical level
Water	From fruit	Moisture	~0.2%
Waxes	Seed coat	Wax	~500-1000ppm
Free fatty acids	Hydrolyzed oil molecules	FFA	~0.5-5%
Colored compounds	Chlorophyll/carotene in seed/fruit	Lovibond	
Oxidized Oil	Oxidation during processing, storage, transportation	Peroxide Value	10meQ/kg
Gums	Phospholipids	Phosphorous	10-500ppm
Off Flavors	Flavour from seed/fruit	Taste	Strong
Trace metals	Naturally occurring from tanks and processing	Fe, Cu,..	~10ppm

Refining steps

- **Degumming**
- To remove the phosphatides and certain mucilaginous/proteinaeous materials from the oils, which is so called " GUMS".
- Hydrating the phospholipids and mucilaginous gums in order to reduce their solubility in the oil and hence to facilitate their removal with water/acid by centrifuge.

- **Neutralization**
- Removal of free fatty acids(FFA) and residual gums
- Removal by a chemical reaction with alkali(caustic soda)

- **Bleaching**
- Adsorption process to remove coloring pigments(carotene, chlorophylls) and minor impurities like residual phosphatides, soaps, metals and oxidation products.
- Adsorption on acid-activated bleaching clays

- **Dewaxing**
- Process where oil is cooled to low temperature so that waxes become insoluble and separate out.
- Waxes tend to impart haziness to oil when kept at storage temperatures in supermarkets.
- Normally applied to oils like sunflower, corn, sesame etc.
- Wax content of dewaxed oil should be less than 10ppm.

- **Deodourization**
- A steam distillation process in which the volatile odoriferous components like aldehydes, ketones, peroxides and residual free fatty acids is stripped out.
- Steam entrainment of the odoriferous substances that are more volatile than oil under vacuum at a high temperature.

Ref oils vs Filtered oils – remove the myths

Refined	Filtered
Loss of natural nutrients	Natural nutrients retained
Needs addition of anti-oxidants	No addition of anti-oxidants
Aroma is removed, completely bland – wonders for taste	Aroma is retained
Metal impurities are removed	Metal impurities may be present
Utilized for frying and cooking as low in ffa (high smoke point)	Preferable used only in cooking due to higher ffa (Low smoke point)
Soyabean Oil, Sunflower Oil	Groundnut oil, Mustard oil, Sesame Oil, Coconut oil

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Hydrogenation and Interesterification

Hydrogenation

- treat oil with H_2 and catalyst to decrease double bonds and increase saturated bonds
- three important reactions occur simultaneously:

(1) saturation of double bonds with hydrogen,

(2) cis-trans-isomerization of double bonds, and

(3) migration of double bonds to new positions in the fatty acid carbon chain

- Selective or Non-selective

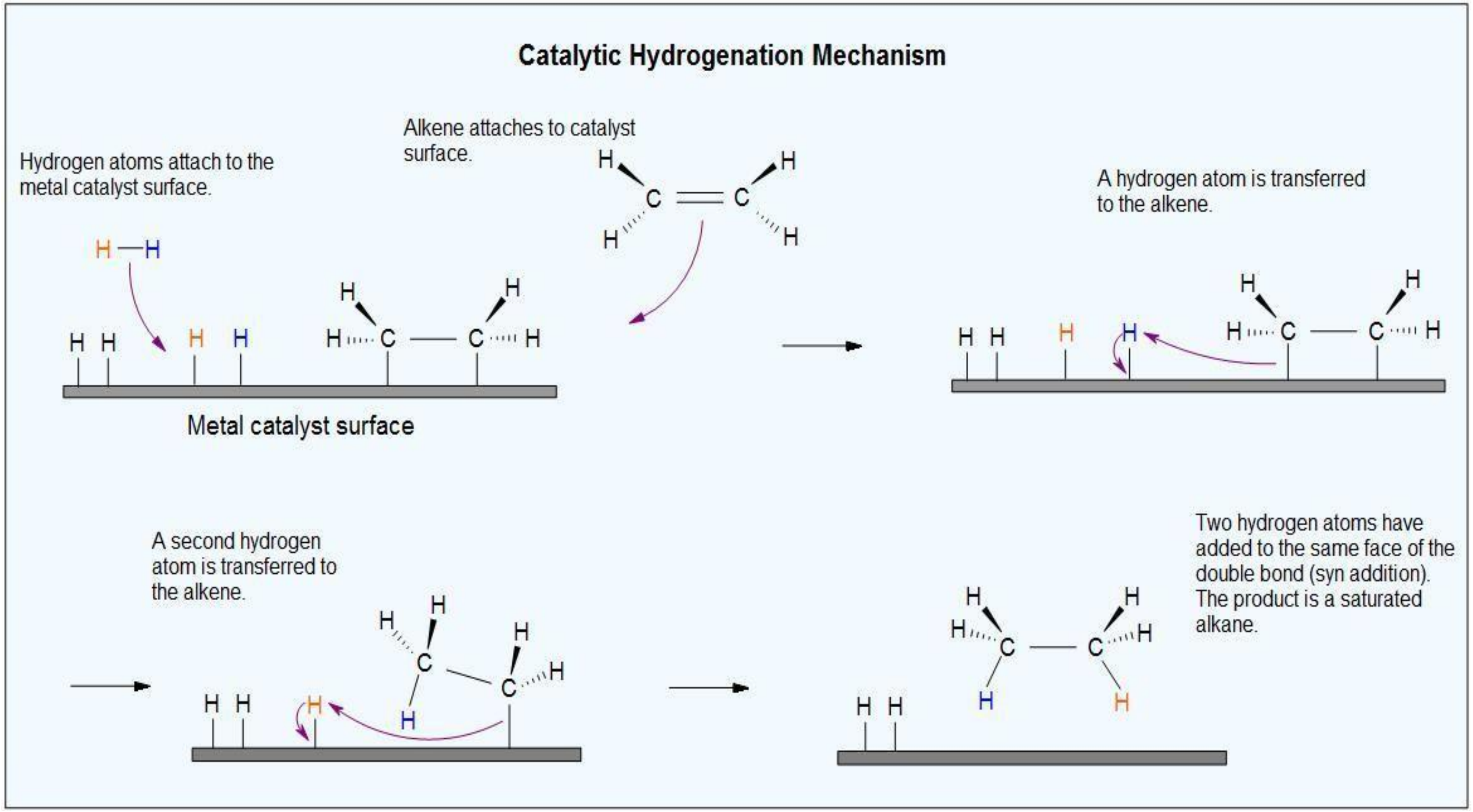
Interesterification

- involves an exchange of acyl group among triglycerides in presence of a catalyst
- Acyl groups may exchange positions within a triglyceride or among triglyceride molecules
- change in the physical properties like melting point, SFC, etc
- Chemical or Enzymatic

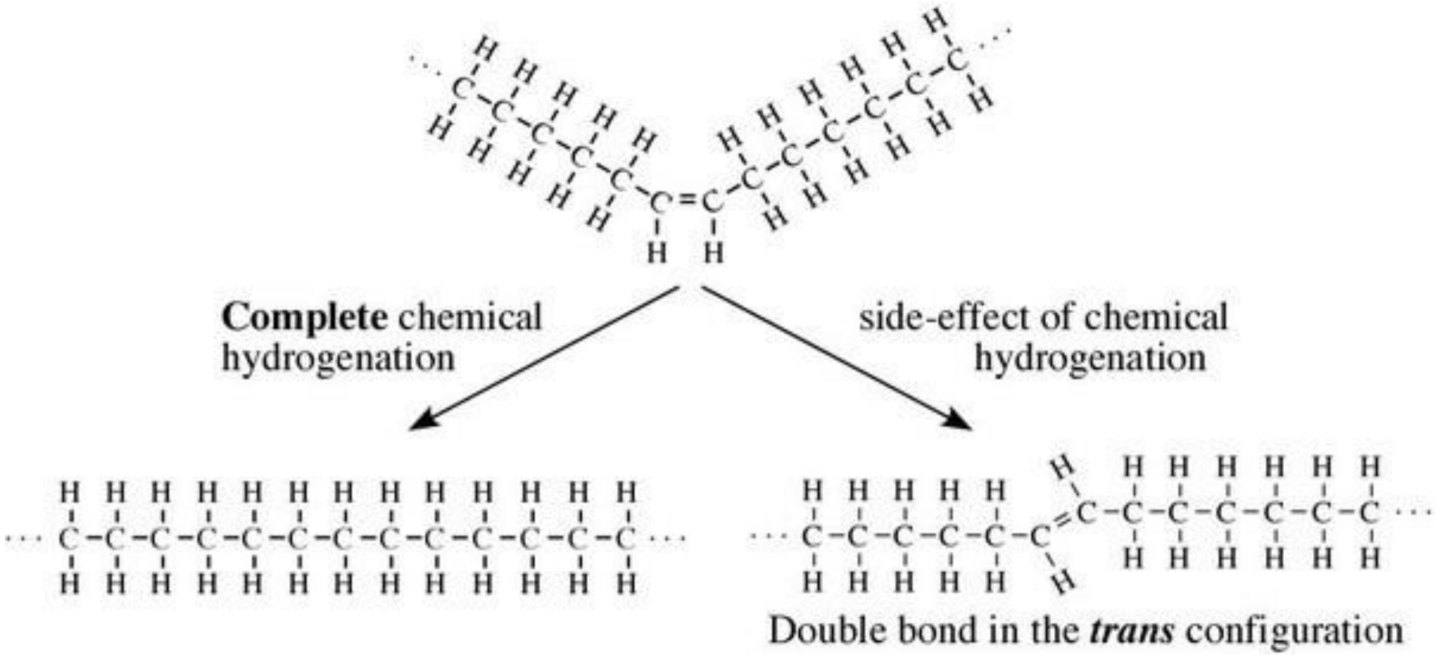
Hydrogenation Methods

- In commercial practice, two types of hydrogenation are performed:
- Nonselective hydrogenation- Conversion of 18:3 to 18:0

- Selective hydrogenation- the preferential conversion of 18:3 to18:2 relative to 18:1 > 18:0. Selective removal of double bonds via hydrogen addition such that saturated fatty acid (stearic) formation is minimized



Trans Fatty acid formation



Cardiovascular Diseases:

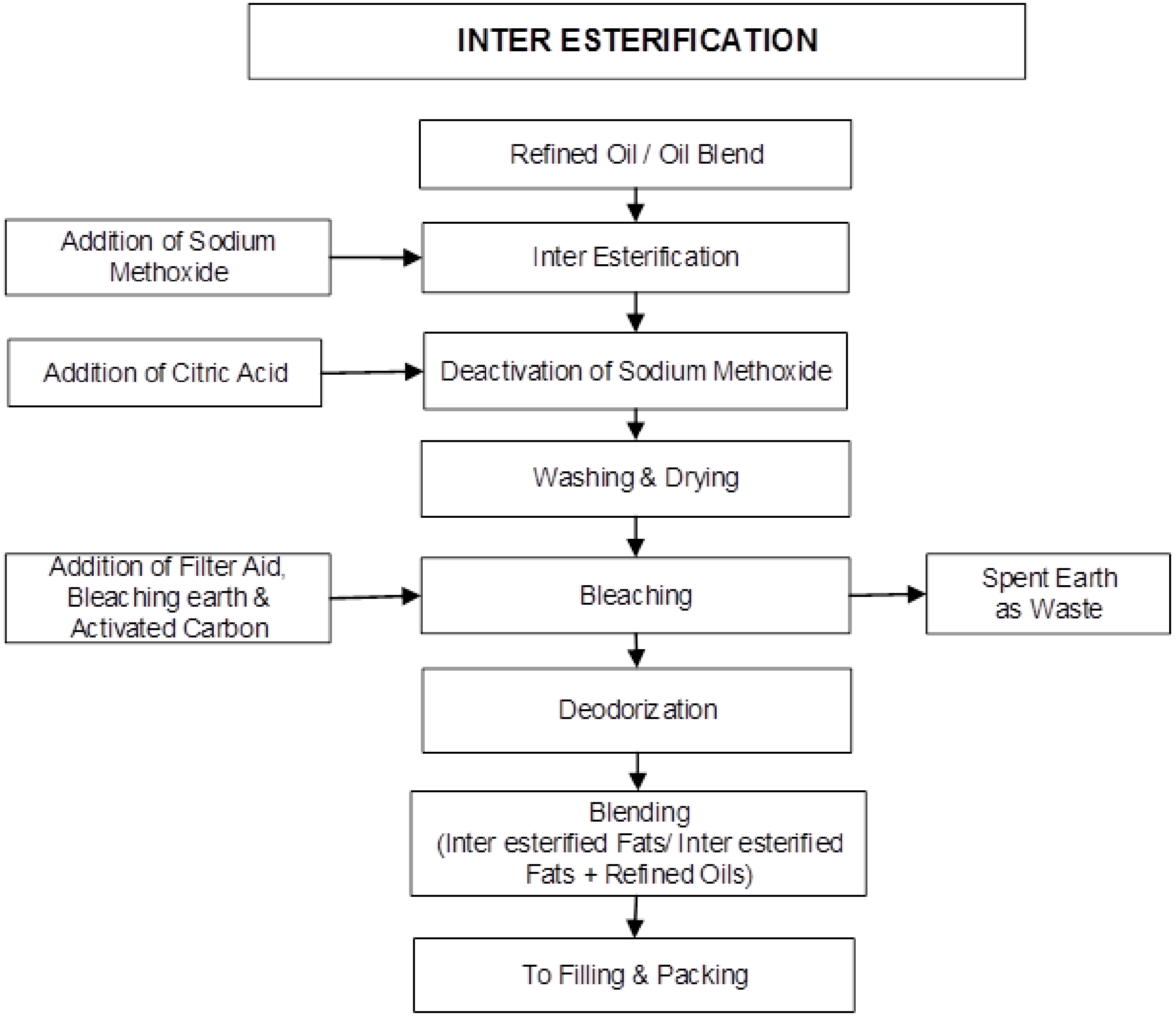
- Trans fat increases LDL and decreases HDL levels.
- Consumption of additional 2% trans fat roughly doubles the risk of coronary heart diseases (CHD).
- Replacing trans fat by unsaturated fat decreases CHD risk by almost 50%.

Factors affecting Hydrogenation

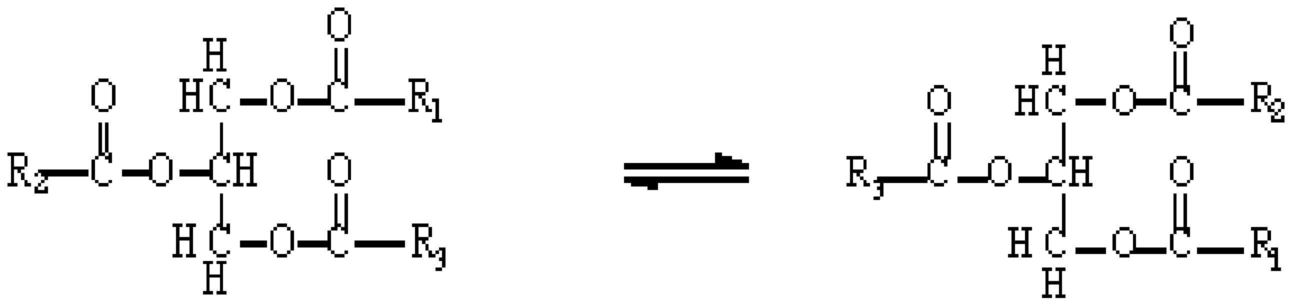
The Relationship between Process Conditions and their Effects on *Trans*-Contents, and the Rates of Reaction

		Trans Content	Reaction Rate
Temperature	↑	↑	↑
Pressure	↑	↓	↑
Agitation	↑	↓	↑
Catalyst	↑	↓	↑

Interesterification Manufacturing Process

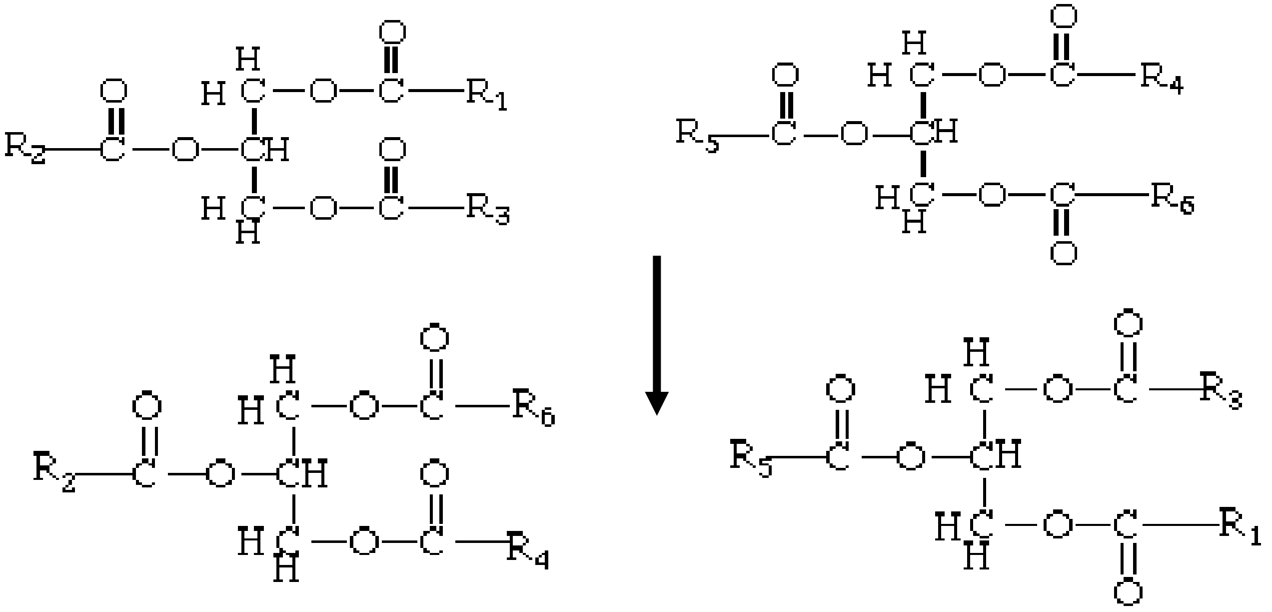


Interesterification



Interesterification within a triglyceride

Or between triglycerides. Start with



End with

Characteristics of Chemical Interesterification

- Random - fatty acyl groups freely move from one position to another in a single TAG molecule or from one TAG to another. This continues until the arrangement of fatty acids in the TAGs is completely random. As the fatty acids rearrange, they reach an equilibrium. A change from ordered to random arrangement results in an alteration of physical characteristics of the starting fats and oils, such as melting profile and melting point

+ CHEMICAL INTERESTERIFICATION

- Fully random
- Highly reproducible and cost-effective
- Easy Process (batch)

- Precautions

- Safe handling of catalyst is a must

Characteristics of Enzymatic Interesterification

- Lipase catalysed and position specific reaction
- Ideally suited for targeted structured TG manufacture
- The catalyst in enzymatic interesterification is a 1,3-specific lipase. The enzyme rearranges the fatty acids in the 1-and 3-positions, by contrast to chemical interesterification where all three positions are shifted randomly.
- No chemicals are used in the process and no trans fats are formed.
- It can be batch or continuous. Reaction conditions are mild

+ ENZYMATIC INTERESTERIFICATION

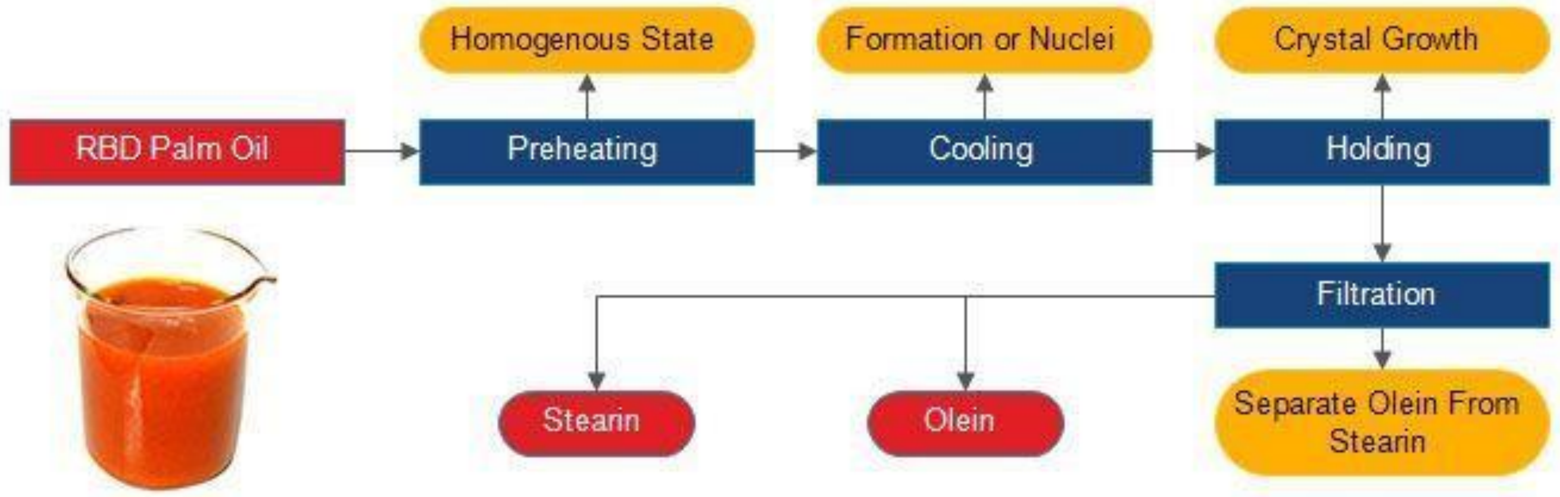
- Cost-effective when running continuously
- Simple, clean & safe – ‘Natural’ process

- ENZYMATIC INTERESTERIFICATION

- High initial capital investment required
- New & still rather unknown
- costly catalyst

Fractionation

- Fractionation is a separation technique wherein solid portion is removed to give liquid oil.
- Liquid oil is called Olein and solid portion is called Stearin.
- Fractionation improves the clarity of oil at ambient temperatures.
- Types - Dry fractionation and Solvent fractionation



Quality Control Parameters in Edible Oil Industry

- Colour
- Free fatty acids - **
- Iodine value
- Peroxide value- **
- Moisture and volatile impurities
- Unsaponifiable matter
- Fatty acid composition - **
- Sensory attributes - **
- Solid fat content - **
- Melting Point - **

** - critical

CONTENT

Importance of vegetable oil in our diet

- Integral part of any traditional Indian diet
- Major source of energy
- carrier of essential nutrients (fat soluble Vitamins)
- source of essential fatty acids
- Protect our brain cells
- Metabolic regulators(hormones and prostaglandins)
- Provide healthier skin

Last but not the least – Taste & Palatability

- Enhances flavor, adds to the mouth-feel
- Making baked products crispier
- Feeling of satiety

Oil and Fats - Most misunderstood

- Excess of fat - culprit for many lifestyle diseases
- Low Fat / No Fat leads to substitution with carbohydrates and high Carb foods.
- These carbs eventually get converted to fat .
- Potentially leading to CVD and other issues
- Right balance of macronutrients (carbs, proteins and fats)

45 - 55 % from carbs, 20-30% from fats, 20 - 25 % from proteins

Oils / Fats in-take – the key is moderation

- The optimum intake of fat for an adult- 30% of its total calorie intake

- For an adult consuming 2000 calories, the upper limit of total fat (visible and in-visible) is 65-67 gm/day

- Invisible fat : amount of fat is present in food items like cereals, pulses, milk, eggs, meat etc

Vegetable oils ….more than a cooking medium

- Current per capita consumption levels – appxx. 17-18 Kg/year
  - global average - 25 kg/year
- Medium for lifestyle correction due to rising health concerns
- Feel good factor - Consumer is prioritizing health but is not ready to compromise on taste
- **Food has to deliver - HEALTH & TASTE**

Choice of cooking oils

Saturated (SAFA)	MUFA	PUFA
(High) Coconut Palmkernel Ghee, Butter Vanaspati	(High) GNO HOSO Canola Olive	(High) Safflower Sunflower Corn Soyabean
	(Moderate) Palmolein Sesame Ricebran	(Moderate) GNO Ricebran Sesame

- SAFA intake should not exceed 8-10% of total energy
- PUFA should be 8-10% of energy intake
- linoleic/ a-linolenic (n-6/ n-3) ratio should be 5-10
- There is a clear shift to Natural oils (thanks to social media)

CONTENT

- Introduction
- Fatty acids & glycerides
- Physical properties of triglycerides
- Factors determining deterioration of oils and fats
- Oils and fats-processing and refining
- Modification of oils – Hydrogenation, Interesterification, Fractionation
- Importance of oils in the diet
- Trans fats and its implications

Trans Fats - History

- **Hydrogenation**

  - Hydrogenation for functional applications in Foods

  - Hardness and shelf life .

  - Primarily from Soft Oils

- **Trans Fats (TFA)**

  - A by-product of Hydrogenation during manufacture of Vanaspati

  - Has some interesting functional applications

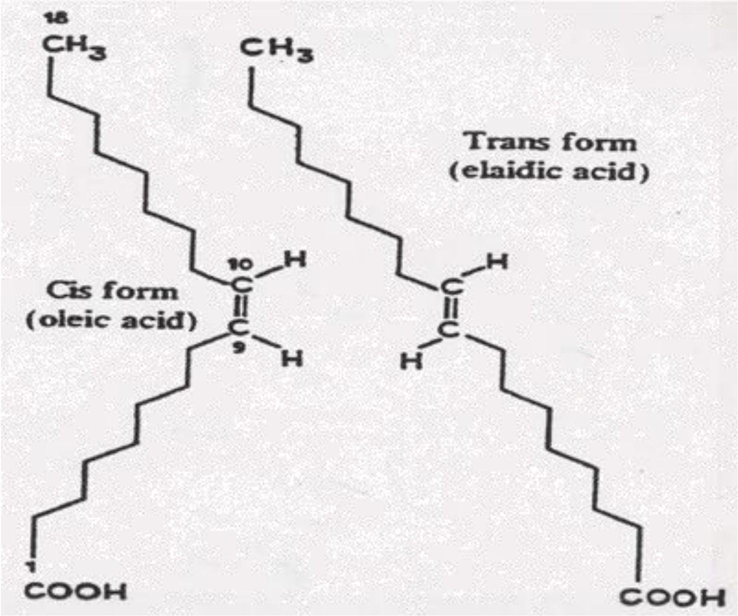
- **1990s – Research on trans fats and its health implications**

- **Industrially produced TFAs – Increases risk of CVD and other non-communicable diseases**

How are trans fatty acids formed?

Trans fatty acids

Hydrogenation of vegetable oils

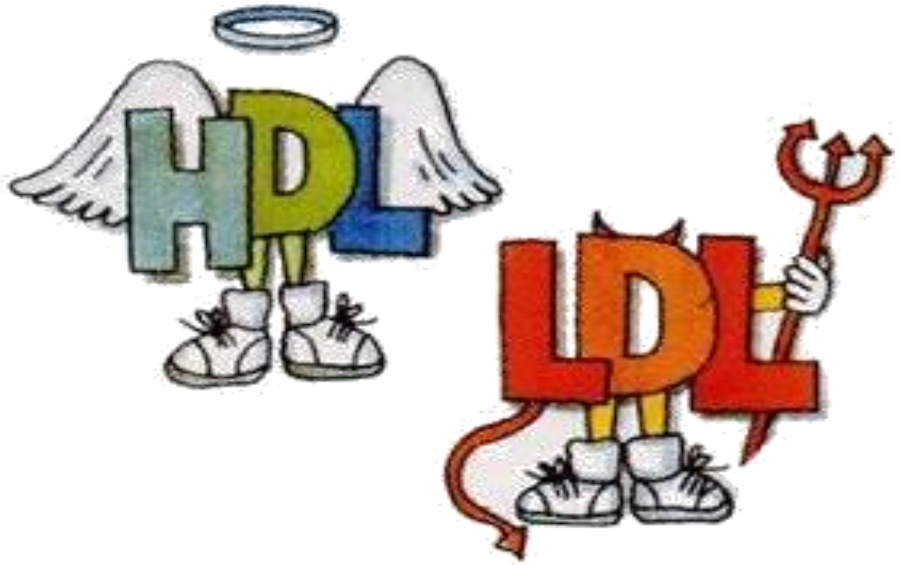


Natural sources

Let’s first understand what are LDL and HDL CHOLESTEROL

- Lipoproteins (LDL, HDL) carry cholesterol throughout the body
- LDL (Low density lipoprotein) has tendency to build up on walls of arteries—harmful, increases risk of heart disease/stroke- Bad cholesterol
- HDL (High density lipoprotein) removes cholesterol from arteries, carries to liver where it is broken down and excreted- Good cholesterol

- **SATURATED FATTY ACIDS** : TOO MUCH OF IT RAISE LDL CHOLESTEROL
- **MONOUNSATURATED FATTY ACIDS** – LOWER LDL CHOLESTEROL AND MAINTAIN HDL CHOLESTEROL
- **POLYUNSATURATED FATTY ACIDS** – LOWER LDL CHOLESTEROL AND TOO MUCH OF IT LOWERS HDL CHOLESTEROL
- **TRANS FATTY ACIDS** – RAISE LDL CHOLESTEROL AND LOWER HDL CHOLESTEROL (As per Indain food laws(FSSAI), trans fat should be less than 3% in oils and fats)



Trans Fats from the Indian context contd….

- WHO/AHA recommendation-

TFA consumption < 1% of total energy intake (< 2.2 gms/day)

- FSSAI limit current : 3% max
- India is not at risk as TFA consumption is well below WHO recommendation
- Low per capita consumption of Vanaspati
- Industry and FSSAI's aim is to make India trans free .
- Pledge by Vanaspati Industry : below 2% by 2022

India@75: Freedom from trans fats by 2022

- WHO has given a call to eliminate industrially-produced trans-fat from the food supply by 2023 and has released an action package ‘REPLACE’ for the same and industry is working hand in hand with regulatory authority to meet these challenges as a common objective to produce and supply trans free healthier fats
- The WHO REPLACE action package provides governments with a strategy to achieve the prompt, complete, and sustained elimination of industrially-produced trans fat from their national food supplies and the authority has been involving all stakeholders in the food chain to achieve the same thru its measures like creating awareness, EAT RIGHT movement, SNF programs
- ***Thus, Vegetable Oils and Fats Industry reaffirms its commitment to achieve these objectives well within the time frame specified by WHO (2023) and fully aligned with FSSAI to make India trans fat free to commemorate its diamond jubilee Independence celebrations in 2022 and ensure supply of healthier – low trans/ trans free Vanaspati products.***


THANK YOU !

Processing of oilseeds cakes/meals into value added products

Deep N Yadav*
ICAR-Central Institute of Post-harvest Engineering & Technology, Ludhiana-141004
***Email:deepyadav18@gmail.com**

On an average, oilseeds contain 40-50% oil and 20-25% good quality protein. The protein content of oilseeds is almost equal to major pulses. The de-oiled cakes left after extraction of oil contain about 35-40% protein, which is two times higher than the protein present (20-25%) in major pulses. The world oil cake market is dominated by eight major edible oil cakes/meals as soybean meal, rape seed cake, cotton seed cake, ground nut cake, sun flower cake, copra cake and linseed cake. Among these soybean meal occupies 54% of the total production volume of the eight cakes followed by rape seed cake (10%) and cotton seed cake (10%). In India, oilseeds meals/cakes are mostly utilized as animal feed or as organic manure. Some amount is also exported. There is need for changing this pattern. Oilseed cake/meal can be made to use for human consumption in the form of full fat/partially defatted/defatted flour, protein concentrates, protein isolates, texturized vegetable protein etc. As a general trend, meals contain anti-nutritional compounds such as oligosaccharides, trypsin inhibitors, phytic acid, and tannins and present low protein solubility, which could limit its food applications. India's total oilseed production has been estimated to 32.2 million metric tons (MMT) (2018-19). Edible oilseeds in India yield about 8.7 million tones of edible oil and 17 million tones of cake/meal containing 30-35% protein. Out of this, it is possible to utilize about 10 million tones of cake/meals for human consumption. This would yield about 3.2 million tones of protein, equivalent to about 13 million tones of additional pulse production.

The general compositions of major oilseeds cakes are presented in Table 1.

The available protein isolate plants in foreign countries are based on their own design with higher capacity, hence cost high. Due to very high cost and higher capacity these are not suitable for small entrepreneurs of our country. An initiative was taken at ICAR-CIPHET, Ludhiana to design a protein isolate plant in order to reduce the cost. As a result, an Indigenous protein isolate plant with small capacity (30-40 kg raw material/day) is established. The plant is suitable for production of protein isolates/concentrates from various oilseeds cakes/meals. The produced protein can be used to produce different protein fortified health foods, so that the cost of protein supplemented foods may be reduced and thus in the reach of large population of the country.

Table 1: Composition of de-oiled cakes/meals

Sample	Moisture (%)	Ash (%)	Fat (%)	Protein (%)
Sunflower cake	9.9	10.9	0.5-1.0	**33.3**
Groundnut cake	9.2	8.5	0.5-1.0	**40.2**
Soy meal	10.1	6.5	0.5-1.0	**50.9**
Mustard cake	10.5	7.0	0.5-1.0	**33.7**

Limitations in utilization of major oilseeds cake:

- *Amino acid availability:* Not all of the protein that is present can be digested and beneficially utilized.
- *Toxic and anti-nutritional factors: C*ertain whole oilseeds contain toxic and/or anti-nutritional factors. The presence of these compounds in the meal must be evaluated and considered
- *Functional considerations:* Physical characteristics can be an issue in certain applications, inappropriate levels of fibre, which limit its practical use in certain applications. Palatability is also a factor.
- *Wholesomeness:* Meals should be free of mycotoxins and other harmful materials. In addition, the residual oil in a meal should not be rancid.
- *Consistency:* When an ingredient is subject to wide fluctuations in composition, it greatly complicates the process and ultimately add cost.

The nutritive value of most of oilseeds proteins are similar or superior than most of the cereal proteins. A comparative data regarding different nutritive values (Biological value, net protein utilization, protein efficiency ratio) are mentioned in table 2. The amino acid profiles are mentioned in Table 3.

Table 2: Nutritive value of proteins of some foodstuffs

Protein source	Protein type	BV	NPU	PER
Animal Protein	Egg	96	96	3.8
	Milk	90	85	2.8
	Meat	74	76	3.2
	Fish	80	74	3.5
Cereals	Rice	80	77	1.7
	Wheat	66	61	1.3
Pulses	Bengal gram	74	61	1.1
	Red gram	72	54	1.7
Oil seeds	Groundnut	55	45	1.7
	Soy bean	62	55	2.1
	Sunflower seed	70	58	2.1

Table 3. Amino acid composition (% of crude protein) of oil cakes.

Amino acid	Ground nut cake	Mustard cake	Soy bean cake	Sunflower oil cake
Arginine	11.0	6.4	7.4	9.1
Cystine	0.9	2.5	1.6	1.8
Glycine	6.0	4.9	4.5	5.6
Histidine	2.5	2.6	2.4	2.8
Isoleucine	3.0	3.8	4.6	4.2
Leucine	6.1	6.3	7.8	6.9
Lysine	3.6	5.4	6.1	3.5
Methionine	0.4	1.7	1.4	2.2
Phenyl alanine	4.9	3.8	5.5	5.1
Threonine	2.8	4.0	3.8	3.4
Tryptophan	-	-	1.3	1.4
Tyrosine	3.7	2.7	3.5	1.4
Valine	3.7	4.7	5.2	5.8

Types of Protein:

The plant proteins are categorized into four groups depending upon their solubility.

Proteins	Solubility Characteristics
Albumins	Soluble in water
Globulins	Slightly soluble in water, very soluble in aqueous salt solution.
Prolamines	Soluble in 70%-80% ethanol, insoluble in water or salt solution.
Glutelins	Soluble in strong alkaline or acid solution.

Characteristics of Plant protein:

Soya protein:

Typical soybean composition is 20% oil, 40% protein, 35% carbohydrate (16% soluble and 19% nsoluble), and 5% ash on dry basis. Soybean mealcharacterized higher content of crude protein- about 40-49%. Soy proteins are composed of a mixture of albumins and globulins, 90% of which are storage proteins with globular structure. Soy protein consists of four major fractions: 2S, 7S, 11S and 15S. It contains all the essential amino acids except methionine and tryptophan. Soy proteins are high in lysine and thus are useful supplements for cereals, which tend to be low in this amino acid.

Rapeseed-mustard protein:

Mustard seeds contain 28-32% protein by weight and 30-35% of oil, although these values can vary slightly between varieties, growing regions and crop. The defatted meal contains 36-38% protein and about 12% crude fibre. Brassica species contain mainly two types of protein namely cruciferin and napin. Rapeseed meal is widely used as an inexpensive protein supplement generally as a replacement for soybean meal in animal diet. Rapeseed protein is balanced with respect to all the amino acids except methionine. Mustard proteins consist of two fractions, a high molecular weight fraction (11S/12S) cruciferin, constituting about 25% and a low molecular weight fraction, napin, constituting about 70% of the total protein.

Sun flower protein:

Sunflower seeds contain~ 20% of protein, whereas protein contents of the oil press cakes and extraction residues range from 30 to 50%. They are low in antinutritional compounds and devoid of toxic substances. An important advantage of sunflower protein product is that, to date, no toxic component has been reported. The techno-functional properties of sunflower proteins are comparable with those of soy and other leguminous proteins. Sunflower proteins have two major salt-extractable fractions (2S, and 11S) that can be isolated on the basis of their sedimentation coefficients.

Ground nut protein:

The defatted groundnut meal contains about 43-65% protein, 22-30% carbohydrates and 4-6% minerals. The defatted meal has higher protein efficiency ratio, net protein utilization and digestibility than the full fat peanut powder. The protein digestibility of groundnut cake varies from 88.9 to 92% as against about 90% for soybean meal. Groundnut seed mainly contains globulin type of proteins (87% of total proteins). Ground nut oil cake, a high protein content solid residue is rich in arginine level,

Limitations:

- In soya protein methionine is the first limiting amino acid and this limitation must be considered when the proteins are added for nutritional purpose rather than simply for functionality
- Proteins from sunflower cake are deficient in lysine. Sunflower seeds are not known to contain significant quantities of anti-nutritional factors or toxicants. However, a precursor of a cyclic trypsin inhibitor in sunflower seeds was detected (Mulvenna et al., 2005). Sunflower kernels and hulls contain phenolic compounds, including chlorogenic and caffeic acids, which are easily oxidised during common processing causing green to brown discoloration in protein isolates and/or concentrates (Sabir *et al*., 1974a; Sabir *et al*., 1974b). These compounds have been studied both for their additive synergistic effect on carcinogenesis and their anti-carcinogenic properties.
- Methionine is the limiting amino acid of mustard protein. Mustard, as well as other brassica oilseeds can be considered an important source of protein, but is most currently used for livestock feeding due to its content of anti-nutritional components and due to protein denaturation during industrial oil extraction, limiting its uses in the food industry. Its use as animal feed is limited by its glucosinolate content, an antinutritional factor. The higher fibre content is another factor which hinders its wider utility. The non-nutritional cake is sometimes used as organic manure.

Approach for Human Consumption:

The de-oiled cakes may be processed as source of protein into protein enriched flour (45-65 % protein), protein concentrate (66-85%), protein isolate (>86 %), dairy analogues etc.

Protein Isolate

Protein isolates contain over 90% protein on moisture free basis and are the most concentrated form of protein products. It is free of objectionable odour, flavour, colour, anti-nutritional factors and flatulence. The high protein concentration provides maximum formulation flexibility for incorporation into food products.

Standard	Minimum Protein (%, db)
IS:8211-1976	$\geq$ 86
Codex Standard 175-1989	$\geq$ 90

Applications of protein isolates: There are numerous application of protein isolates in food products, among them some are listed below:

- Protein supplements
- Texturized vegetable proteins
- Imitation dairy products
- Sea food products
- Beverage industry
- Infant food formulations
- Weaning food formulations
- Pharmaceutical industry
- Bakery products
- Meat analogues

Methods for preparation of protein flours, concentrates and isolates

Air classification:

Air classification is a milling technique that allows the fractionation of grains/seeds into high starch and high protein flours. Milling of pulses results in flours having particles of two discrete sizes and densities. Air classification exploits this phenomenon to separate the light fine fraction (protein) from the heavy coarse fraction (starch). During air classification, whole or de-hulled seed is ground into very fine flour, and the flour is subsequently classified in a spiral air stream to separate the starch from the protein. The process can be repeated several times to improve the separation efficiency, as protein bodies can still adhere to the surface of starch granules after the initial run. Agglomerates present in this initial starch fraction consist of starch granules embedded in a protein matrix, but by repeated pin-milling and air classification, further purification can be obtained.

Alkaline extraction/Isoelectric precipitation:

Aqueous alkaline extraction followed by isoelectric precipitation (IEP) is another frequently used technique for the extraction of legume proteins. The technique takes advantage of the solubility of legume proteins which is high at alkaline pH and low at pH values close to their isoelectric point (pH 4–5). Generally, ground pulse flour (with or without hulls) is dispersed in water using flour: water ratios ranging from 1:5 to 1:20. The pH of the mixture is adjusted to alkaline (pH 8–11) and the mixture is allowed to stand for periods varying from 30 to 180 min to maximize solubilization of the proteins. The mixture is subsequently filtered to remove any insoluble material and the pH of the extract is adjusted to the isoelectric point to induce protein precipitation, followed by centrifugation to recover the protein, washing to remove salts, neutralization and drying.

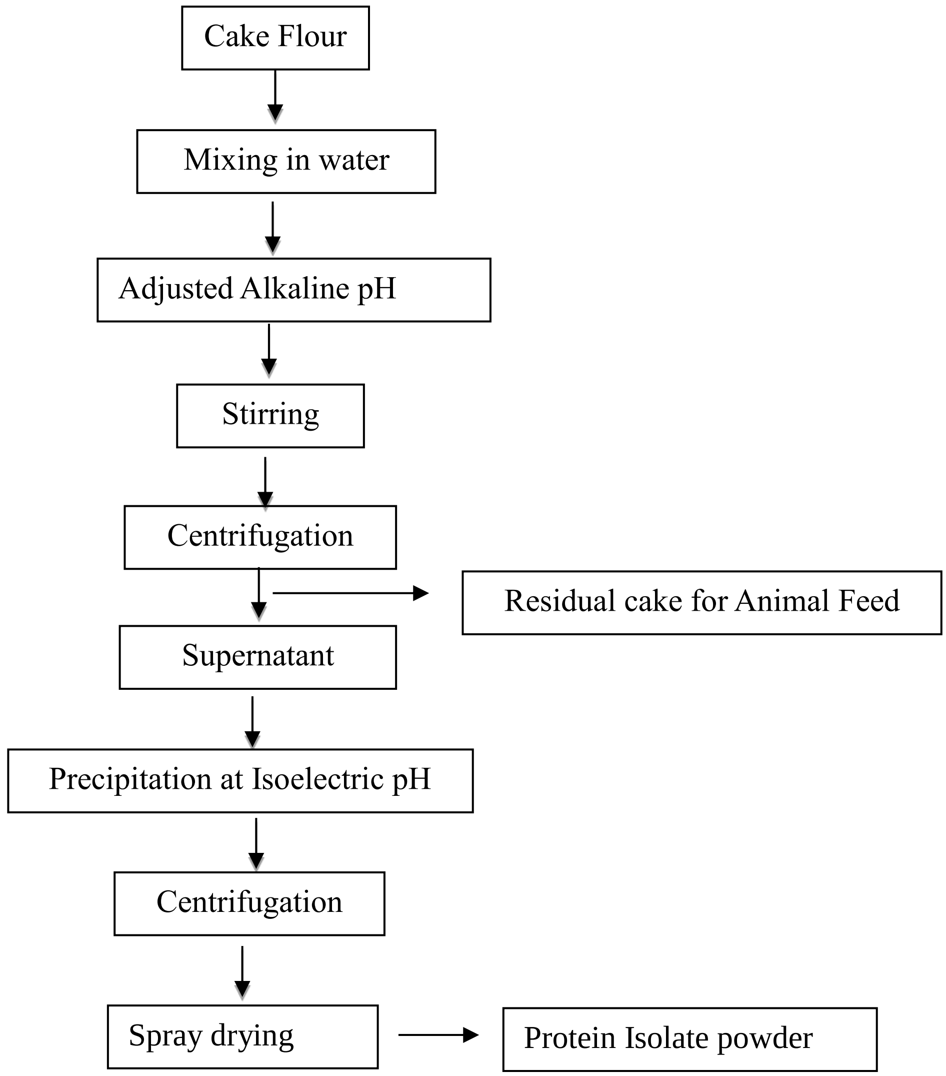


Fig: Typical flow process for production of protein isolates from oilseeds cakes/meals

Acid extraction:

The principle of acid extraction is similar to that of alkaline extraction except that the initial protein extraction is conducted under acidic conditions. Solubility of pulse proteins is also high under very acidic conditions (i.e., pH < 4). This low pH range can, therefore, be used to solubilize proteins prior to their precipitation by IEP, cryo-precipitation (refrigeration) or membrane separation.

Salt extraction:

The salt extraction process, sometimes also referred to as micellization (MI), is slightly different from the previously described processes and is based on the salting-in and salting-out phenomenon of food proteins. In this process, after extraction of protein using an appropriate salt solution at desired ionic strength, the solution is diluted, inducing protein precipitation that can be recovered by centrifugation or filtration, followed by drying.

Ultrafiltration:

Membrane separation is a frequently used alternative to isoelectric precipitation. In this process, the supernatant obtained either after alkaline or acid extraction is subjected to ultrafiltration or ultrafiltration/diafiltration to concentrate the proteins. Membranes with specific molecular weight cut-offs must be carefully selected in order to retain the proteins of interest.

Functional properties:

Functional properties denote those physico-chemical properties of food proteins that determine their behavior during processing, preparation, storage and consumption. Functional properties affect the sensory character and physical behavior of foods or food ingredients. The type of functional properties required in a protein varies with the particular food system. Water binding, solubility, swelling, viscosity, gelation and surface activity areimportant functional properties determining the quality of product in different food systems.

Functional properties	Mode of action	Food system
Solubility	Protein solvation	Beverage
Water absorption and binding	Hydrogen bonding of water	Meat, sausages, breads and cakes
Viscosity	Thickening, water binding	Soups, garvies
Gelation	Protein matrix formation and setting	Meats, curds and cheese
Elasticity	Hydrophobic bonding in gluten, disulfide link in gel	Meats, bakery products
Emulsification	Formation and stabilization of emulsion	Sausage, soup, cake
Fat absorption	Binding of free fat	Meat, sausage
Foaming	Formation of stable films to entrap gas	Whipped toppings, chiffon desert

Conclusion:

Protein malnutrition continues to be a major problem in many places in India, Africa, and in pockets of the developed world. Food manufacturers, as well as consumers, are increasingly searching for food alternatives that offer variety and which provide functional as well as nutritional benefits. This growing trend offers an opportunity to the oil industry to identify novel food uses for at least oil milling by-products as well as to develop ingredients and products that can be used in complement with other grains and cereals.

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Innovative trends-in formulation of oilseeds based dairy analogues

Deep N Yadav

Food Grains and Oilseeds Processing Division
ICAR-Central Institute of Post-harvest Engineering & Technology, Ludhiana-141004
***Email:dnyadav1977@yahoo.co.in**

Abstract

At present, for medical reasons, significant amount of consumers opt for plant based milk substitutes for various medical reasons or as a lifestyle choice. Medical reasons include lactose intolerance as well as milk protein allergies. Plant milk substitutes also serve as a more affordable option. Technologically, plant milk substitutes are suspensions of dissolved and disintegrated plant material in water, resembling cow's milk in appearance. They are manufactured by extracting the plant material in water, separating the liquid and formulating the final product. Homogenisation and thermal treatments are necessary to improve the suspension and microbial stabilities of commercial products that can be consumed as such or be further processed into fermented dairy type products. Groundnut and soybean are two major raw materials used for preparation of plant based milk. The nutritional properties depend on the plant source, processing and fortification. If formulated into palatable and nutritionally adequate products, plant based substitutes can offer a sustainable alternative to dairy products.

Introduction

Plant milk substitutes are water extracts of legumes, oil seeds, cereals or pseudocereals that resemble cow's milk in appearance. There is a wide variety of traditional plant based beverages around the world, for example "tigernut milk" in Spain; Sikhye, a beverage made of cooked rice, malt extract and sugar in Korea; Boza, a fermented drink made of wheat, rye, millet and maize consumed in Bulgaria, Albania, Turkey and Romania; Bushera, a fermented sorghum or millet malt based beverage from Uganda, and traditional soy milk originating from China. The most widely consumed plant milk substitute is soy milk. The first commercially successful product was launched in Hong Kong in 1940 and the market grew rapidly during the seventies and early eighties in Asia after the development of technologies for large scale production of mild flavoured soy milk (Chen, 1989). The demand for soy milk in the Western world was initiated by consumers intolerant to cow's milk (Patisaul and Jefferson, 2010). Soy products are still dominating the market in the Western world, but the emerging of alternative products from other plant sources such as coconut, oat, peanut and almond have decreased its share. Overall, the dairy alternative market is still growing. According to an estimate, 15% of European consumers avoid dairy products for a variety of reasons, including medical reasons such as lactose intolerance (LI), cow's milk allergy (CMA), cholesterol issues and phenylketonuria, as well as lifestyle choices like a vegetarian/vegan diet or concerns about growth hormone or antibiotic residues in cow's milk (Jago, 2011). The main treatment for LI is the avoidance of lactose containing foods and replacing milk and dairy products with lactose free dairy or dairy free alternatives. Functional food market is dominated by dairy based probiotic products mainly yoghurt. There is need to develop dairy alternatives due to allergenic milk proteins, lactose and high cholesterol content (Bansal et al 2016a, 2016b)

Total world production of groundnut in 2012-13 is about 37.2 mt. It is major oilseed crop in India accounting for 45% of oilseed area and 55% of oilseed production. India is rated as the second largest producer of groundnut in the world with annual production of over 5-6 mt. China, India, Nigeria, USA and Myanmar are the major groundnut growing countries. Groundnut contains on an average 40-45 per cent oil and 23-25 per cent protein and is a rich source of calcium, iron and vitamin B complex like thiamine, riboflavin, niacin and vitamin A. In developing countries, it is mainly used for oil extraction and its by product is utilized for animal feed purposes. Animal milk, in India at any rate, has a venerated place as a food for both children and adults. A milk-like beverage, or a re-constitutable powder from which to generate it by adding water, represents an acceptable way of furnishing proteins and other nutrients to all age groups, often at reasonable cost. Plant milks may serve as a boon for the countries where the supply of milk is inadequate. Groundnut and soybean are two major raw materials used for preparation of milk like products.

Process

Plant milk substitutes are colloidal suspensions or emulsions consisting of dissolved and disintegrated plant material. They are prepared traditionally by grinding the raw material into a slurry and straining it to remove coarse particles. Although countless variations of the process exist, the general outline of a modern industrial scale process is essentially the same: the plant material is soaked and wet milled to extract the milk constituents, or alternatively the raw material is dry milled and the flour is extracted in water. The grinding waste is separated by filtering or decanting. Depending on the product, standardisation and/or addition of other ingredients such as sugar, oil, flavourings and stabilisers may take place, followed by homogenisation and pasteurisation/UHT treatment to improve suspension and microbial stabilities. These extracts can also be spray dried to produce powders (Diarra et al., 2005).

Pre-treatments

Raw material pre-treatments include dehulling, soaking and blanching (Debruyne, 2006). Blanching is required to inactivate trypsin inhibitors and lipoxygenase that would produce off-flavours in soy milk and peanut milk (Yadav et al. 2012; Giri and Mangaraj, 2012). Roasting of the raw material enhances the aroma and flavour of the final product, but heating decreases the protein solubility and extraction yield (Hinds et al., 1997a; Chauhan et al 2003).

Extraction

The extraction step has a profound effect on the composition of the resulting product. To increase the yield of the process, the efficiency of this step may be improved by increasing the pH with bicarbonate or NaOH, elevated temperatures or the use of enzymes. Alkaline pH during extraction increases the protein extractability. A higher extraction temperature increases the extractability of fat, but the denaturation of proteins decreases their solubility and yield. Papain and enzymes extracted from *Pestulotiopsis westerdijkii* increased the protein yield of peanut and soy milks (Rustom et al., 1993). In addition to proteolytic enzymes, a mixture of amyloglucosidase and a cellulase cocktail has been shown to increase the carbohydrate recovery of peanut milk (Rustom et al., 1993). Eriksen (1983) used a variety of enzymes in soy milk extraction, and found out that the highest protein and total solids yield was attained using a neutral or alkaline proteinases at their optimum pH. In addition to increasing the extraction yield, proteolytic enzymes improve the suspension stability (Rustom et al., 1991). Also a cellulase treatment after homogenisation has been reported to decrease the particle size and yield a more stable suspension (Rosenthal et al., 2003).

Separation

After the extraction step coarse particles are removed from the slurry by filtration, decanting or centrifugation. When using raw materials high in fat, such as peanuts, the excess fat can be removed using a separator as in dairy processing.

Product formulation

Other ingredients can be added to the product base after the removal of coarse plant material. These include vitamins and minerals used for fortification as well as sweeteners, flavourings, salt, oils and stabilizers. As suspension stability is an issue in plant milk substitutes, hydrocolloids are often used to increase the viscosity of the continuous phase, and also emulsifiers have been proven to be beneficial in some beverages. Mono- and diglycerides, glyceryl monostearate, guar gum and carrageenan can be effectively used for stabilizing peanut and soymilk. The addition of nutrients in food substitutes may be necessary to ensure the nutritional quality of the product. The nutrients used must be bioavailable and sufficiently stable, and not cause excessive changes in product quality. The challenge in mineral enrichment is the reactivity of metal ions with other food components, and the use of sequestrants such as citric acid may thus be necessary (Zhang et al., 2007a). Some mineral sources used in plant milk substitutes include ferric ammonium citrate and ferric pyrophosphate as iron sources and tricalcium phosphate and calcium carbonate as calcium sources (Zhang et al., 2007a; Zhao et al., 2005).

Stability

Plant milk substitutes contain insoluble particles, such as protein, starch, fibre and other cellular material. These particles, being denser than water can sediment, making the product unstable. The suspension stability can be increased by decreasing the particle size, improving their solubility or by using hydrocolloids and emulsifiers (Durand et al.,2003). Many plant milk substitutes coagulate when heating. When proteins unfold as a result of heating, the nonpolar amino acid residues are exposed to water increasing the surface hydrophobicity. This enhances protein-protein interactions that can result in aggregation and sedimentation or gelling (Phillips et al., 1994). The heat stability of proteins depends on the pH, ionic strength and the presence of other compounds such as minerals and carbohydrates (McSweeney et al., 2004). Homogenisation improves the stability of plant milk substitutes by disrupting aggregates and lipid droplets and thus decreasing the particle size distribution (Malaki Nik et al., 2008). Homogenisation in the conventional dairy processing pressure range (20 MPa) increases the suspension stability sufficiently of soy and peanut milk. Ultra high pressure homogenisation (UHPH) of soy milk at 200-300 MPa reduces the particle sizes intensely and improves the stability compared to conventionally processed products. A higher homogenisation temperature has been reported to increase the stability of peanut milk (Hinds et al., 1997a). In soy milk, heat denaturation of proteins is required for suspension stability.

Shelf life

Commercial plant milk substitutes are pasteurised or UHT treated to extend the shelf life. Pasteurisation is carried out at temperatures below 100 °C, and it destroys enough micro-organisms to enable a shelf-life. Rustom et al. (1996) treated a peanut beverage for 4 and 20 s at 137°C. The longer treatment time decreased the suspension stability slightly, but led to higher taste and acceptability scores. Both treatments were effective in increasing the microbial shelf life. In commercial products, pulsed electric fields have been suggested to extend the microbial shelf life (Cortés et al., 2005). Also other non-thermal processes such as ultraviolet sterilisation, high pressure throttling, high pressure processing and ultra-high pressure homogenisation (UHPH) have been explored as methods of soy milk preservation (Bandla et al., 2011; Cruz et al., 2007; Smith et al., 2009; Sharma et al., 2009).

Fermented products

Fermentation with lactic acid bacteria improves the sensory and nutritional properties, and microbial shelf life of foods. Plant milk substitutes can be fermented to produce dairy free yoghurt type products while rendering the raw material into a more palatable form (Bansal et al 2016a, 2016b). The levels of hexanal responsible for the undesired nutty flavour in peanut milk can be efficiently reduced with fermentation (Yadav et al. 2010). Fermentation of soy milk reduced the amount of flatulence inducing oligosaccharides (Yadav at el. 2008). Some authors have used additives such as carboxymethyl cellulose, coagulants (calcium citrate), milk powder and gelatin to enhance the texture and reduce syneresis in the final product (Cheng et al., 2006; Yadav et al., 2010).

Nutritional quality

Plant milk substitutes are often perceived as healthy. In reality the nutritional properties vary greatly, as they depend strongly on the raw material, processing, fortification and the presence of other ingredients such as sweeteners and oil. Also milks produced of legumes other than soy, such as peanut and cowpea can have protein content as high as 4% (Tano-Debrah et al., 2005). Although plant milk substitutes are low in saturated fats and most products have caloric counts comparable to skim milk, some products contain as much energy as full milk, originating mostly from sugars and other carbohydrates. Plant proteins are generally of a lower nutritional quality compared to animal derived proteins due to limiting amino acids (lysine in cereals, methionine in legumes) and poor digestibility. The nutritional value of proteins depends mainly on the amino acid composition and their physiological utilisation, and absorption that is in turn affected by processing. In addition to containing high value protein, milk and other dairy products provide 30–40% of dietary calcium, iodine, vitamin B12 and riboflavin, and population groups with low milk intakes often have a poor status for these nutrients. To combat these shortcomings, some plant milk substitutes are fortified with calcium and vitamins, mainly B12, B2, D and E. However, consumer awareness is important as many of these products are not fortified.

Acceptability

Although the demand for plant milk substitutes is increasing, the unwillingness of the mainstream consumer to try unfamiliar foods that are perceived as unappealing may be a limiting factor. Many modern day soy and peanut milks and related products may have an improved sensory quality, but the product group carries a stigma because of early less appealing products on the market. Legume milks tend to possess "beany" and "painty" off-flavours originating from lipoxygenase activity (Chauhan et al 2003). The presence and intensity of the "beany" flavour depends on processing and storage conditions of soy milks and varieties with less lipoxygenase have less "beany" character (Chambers et al., 2006 and Yadav et al 2003) Another problem is a chalky mouthfeel some products have due to large insoluble particles (Durand et al., 2003). The acceptance of peanut milk has been shown to depend on the colour, mouthfeel, the absence of peanut flavour and similarity to cow's milk (Diarra et al. 2005, Jain et al. 2011) Information can increase the willingness to try novel foods. Taste is the most important purchase criteria of foods, and the information about a good and/or familiar taste increase the willingness to try an unfamiliar food most efficiently. Possible health benefits are also an important criteria and health information may increase both the willingness to try and the perceived liking of a food.

Future prospects

Plant based milk substitutes have a reputation of "health foods" but the products on the market vary remarkably in their nutritional profiles, some having very low protein and mineral contents. If these products are to be portrayed as substitutes for cow's milk, protein content and quality as well as fortification has to be considered by manufacturers. Attention should be brought to the possible ways of improving the nutritional properties by processing means e.g. the use of enzymes and the selection of raw materials based on their protein quality. Also a reconstitution approach may allow a more efficient extraction of protein from the material and the formulation of higher protein products. This would however increase the costs and also the environmental impact of the products. More knowledge is required to overcome the mineral fortification related stability issues.

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Process technologies for extraction of essential oils and oleoresins

R.K. Vishwakarma

Principal Scientist
ICAR-CIPHET, Ludhiana

Introduction: Commercial crops, medicinal and aromatic plants are very important for their industrial application point of view. Very large number of plantation crops, spices, medicinal and aromatic plant species are available worldwide. The spices are known for their characteristic flavor and mainly used in food products. Use of spices in the form of essential oils and oleoresins is increasing day by day. The oils present in the commercial crops, spices and medicinal plants can be divided in to three categories.

1. Essential Oils: The volatile, aromatic fraction of spices and similar plant materials, usually obtained through steam distillation is known as essential oils.
2. Fixed Oils, Pigments, Antioxidants: The non-volatile fractions of spices and plant materials obtained through solvent extraction is known as fixed oils, pigments and antioxidants.
3. Oleoresins: The extracts from herbs or spices or other plant materials. These are complex mixtures obtained by solvent extraction. It constitutes volatile and non-volatile fractions of the spices and plant materials. It contains aroma and flavor of the crops in concentrated form and is usually viscous liquids or semi-solids. Oleoresins are better than essential oils because of the following reasons:

- Instant flavor release
- Standardized flavor and aroma to meet precise specifications
- Uniform dispersion in the product
- Easy handling and storage
- Consistency in flavor
- Not affected by bacterial/ microbial contamination
- Much longer shelf life
- Easier storage and handling
- Full release of flavor during cooking
- Can easily be blended to achieve the desired characteristics

The essential oils and oleoresins are mostly used as flavoring agents in a number of foodstuffs, such as curries, bakery products, pickles, processed meats, beverages, liqueurs, etc. They enhance or vary the flavors of food. These are also flavour disguisers; they help mask the off-flavour of food, which, if un-spiced, have to be thrown away. The world demand of essential oils and oleoresins was of 12 billion dollars in 1994 whereas the production was of Rs. 3200 crores in 1994. The major uses of these oils are in food flavoring purposes with a share of 55-60% (Table 1). The major essential oils and oleoresins produced in india are given in table 2.

Table 1: Uses of essential oils and oleoresins

Uses of oils	**% share**

Food flavors	55-60
Fragrances	15-20
Isolation of aroma	15-20
Pharmaceuticals, other industries	20-30

Table 2: List of essential oils and oleoresins produced in India

Essential oils	Oleoresins
Agarwood, Ajowin, Amberette seed, Basil, Betel leaf, Calamus root, Carrot seed, Cardamom, Cedar wood, Celery seed, Cinnamon bark, Cinnamon leaf, Citronella Java, Clove leaf, Clove bud, Coriander, Fennel seed, Costus root, Dill seed, Eucalyptus, Ginger grass, Ginger, Lemongrass, Lime distilled, Mentha (all types), Nutmeg, Olibanum, Pepper black, Sandalwood, Spearmint, Sugandh, Turmeric, Tagetus	Capsicum, Celery seed, Coriander, Fenugreek, Ginger, Green Chilly, Pepper black, Turmeric

India produces a good quantity of essential oils. Even then india is importing number of extracts from other countries to meet the domestic demand. The major essential oils produced in india with its value are given in table 3 and imported quantity is given in table 4.

Table 3: Esential oils and oleoresins production of India

S. No.	Oils	Quantity, tons	Value in Rs. (crore)
1	Mentha aravensis	13000	720
2	Mentha piperita	400	48
3	Spearmint	300	40
4	Basil	150	12.5
5	Citronella java	250	10.8
6	Lemongrass	200	18
7	Sandalwood oil	25	60
8	Other oils	150	24

Table 4: Essential oils imported by India in bulk

S. No.	Description	Quantity (in tones)
1	Begramot	25
2	Citronella Java	500
3	Clove leaf oil	750
4	Eucalyptus oil globules	100
5	Geranium	50
6	Lanander	25
7	Lavandin	10
8	Lemon	100
9	Lime oil distilled	25
10	Litsea Cubeba	100
11	Orange	5000
12	Petitgrain	15

India ranks sixth in world market share of essential oils with a market share of 6.1%. China ranks first with a market share of 30.7% (Table 5).

Table 5: Market share of different countries in essential oils export

S. No.	Country	Market share (%)
1	China	30.7
2	Brazil	13.1
3	Turkey	10.4
4	Morocco	9.1
5	Indonesia	8.7
6	India	6.1
7	Egypt	3.1

The majority of essential oils and oleoresins are extracted from spices. Spices are obtained from a large number of different plants. They are parts of plants, such as roots, buds, flowers, fruits, barks or seeds. Thus, little can be said in a general way about their composition. Most spices owe their flavoring properties to volatile oils and, in some cases, to fixed oils and small amounts of resins, which are known as oleoresins. In many cases, no single compound is responsible for flavors; a blend of different components, such as alcohols, phenols, esters, terpenes, organic acids, resins, alkaloids and Sulphur-containing compounds contribute to the flavour. In addition to flavour-contributing components, all spices contain the usual components of plant products, such as proteins, carbohydrates, fiber, minerals and tannins or polyphenols. The constituents responsible for the spicy properties of plants are always *secondary metabolism products*; this is, they are not involved in primary metabolism (production of plant tissue and production/use of energy storing molecules); thus, they are not vital for the plant. In some case, it is supposed that the aroma molecules are essentially byproducts of metabolism; in most cases, though, they play an important rôle in attracting pollinators or drive away herbivorous animals. It is somehow paradox that plants are grown and spread word-wide as food enhancers, although their tasty constituents' intention is to discourage the consumtion of the plant.

Essential oils and oleoresins extraction:

Flavoring Extracts: Spices, being agricultural commodities, are prone to spoilage by insect or microbial attack. Hence, the spice oils or oleoresins, which contain all the active principles of spices are extracted and marketed. Spice oils are obtained by the steam distillation of ground spices or, more advantageously, the steam-distilled spice. The spice oils contain only the aromatic principles, while the oleoresins contain both the aromatic and pungent principles. Various solvents like acetone, Isopropanol, methanol, hexane, etc., are used as solvents. According to ISI standards, oleoresins obtained from solvent extraction. The processed products of spices have several advantages as they are convenient to use, free from contamination, have better storage life and are easy to transport. Technology has developed in India to prepare ready-to-use oleoresins from spices.

Spice extracts were developed to meet the new demands of the Food Processing Industry. They have the following advantages:

- Consistency in flavour.
- Not affected by bacterial contamination.
- Much longer shelf life.
- Easier storage and handling
- Full release of flavour during cooking.
- Can easily be blended to achieve the desired characteristics.

The food industry across the globe is turning more and more to spice oils and oleoresins to create newer varieties of food. New flavour systems are being developed to introduce new products in the market and create competitive advantages. The Indian spice oils and oleoresin industry is engaged in continuous innovation and up-gradation of process and products to meet the new global demand.

Essential Oils: Steam distillation is the widely used technique in the extraction of essential oils. In this process, steam is passed through the plant material whereby the constituents that are volatile in steams are carried along with the steam. Steam can be generated in a separate boiler or at the bottom of the still by direct heating. The advantage is that the volatile components can be distilled at temperatures lower than the boiling points of their individual constituents, and that on condensing, the oils, being immiscible in water, forms a layer thereby easing separation. Though the process sounds simple in theory, the actual commercial process for greatest efficiency and quality varies widely, depending on the characteristics of the raw material and the final product.

The essential oil thus obtained is endowed with the major part of the spice flavour and fragrance properties. Spice oils, although characterized on the basis of their physicochemical properties, including GLC and spectrophotometric characteristics, are ultimately judged by sensory and olfactory evaluation. Depending on the final environment of use for the spice oil the standards of quality required will differ and this would demand of the manufacturer to tailor oils to the customer's exact requirements.

Spices Oleoresins: The oleoresins, containing all the volatile as well as non-volatile constituents of the spices most closely represent the total flavour of the fresh spice in a highly concentrated from. The main oleoresins produced in India are from capsicum, celery seed, coriander, fenugreek, ginger, green chili, pepper and turmeric. 55-60% of the oleoresins are used for food flavour purposes, 15-20% for isolation of aroma, and rest for pharmaceutical purposes.

For this reason oleoresins are the preferred spice extract used for flavoring purposes. The oleoresins is produced by extraction of the dry spices with an organic solvent/ solvent is wide; it is usually restricted to the proven solvents such as ethylene dichloride, acetone, hexane, or alcohol. Special attention is always paid to the final stage of preparation to strip of residual solvent to ensure that any residue in the oleoresin is minimal (always less then 30 ppm). The choice of solvent is very important as it governs the ratio of the spice constituents that are extracted. From Table 3 each spice can be seen to yield a range of oleoresins specified by their ratio of constituents. In the case of turmeric, a highly colored oleoresin with little characteristic odor of the spice in solid form can be obtained. Alternatively a very low-colored product having the highly aromatic smell of the ground turmeric in a liquid slate may also be produced. Similarly different products can be obtained by selection of solvents for chilies and black pepper. Decolorized oleoresins are also available. Thus tailored oleoresins can be made to meet most users requirements. The oleoresins containing all the flavour elements of the spices in highly concentrated form provide a very economic method of flavoring products.

Extraction and Isolation Methods: Aromatic components and their precursors are generally present in aqueous solution or as droplets in the cell sap, although some essential oils may exist in oil sacs, glandular hairs, etc. It is necessary to extract or to isolate the odor / flavour complex as completely as possible from the mass of inert cellular matter with the minimum amount of chemical change. The processing of spices to produce oleoresins involves four stages as described below.

a. Extraction with solvents
b. Solvent removal
c. Standardization
d. Dilution through dispersion and emulsifying.

a. Extraction with solvents: The ground/chopped material is dissolved in a solvent. That solvent dissolves the volatile as well as non-volatile fractions of the material. Solvent plays critical role in the extraction process. The selection of solvent is important in obtaining an extract with desired flavor, taste and solubility. Each spice can be seen to yield a range of oleoresins specified by their ratio of constituents. In the case of turmeric, a highly colored oleoresin with little characteristic odor of the spice in solid form can be obtained. Alternatively a very low-colored product having the highly aromatic smell of the ground turmeric in a liquid state may also be produced. Similarly different products can be obtained by selection of solvents for chilly and black pepper.

The extraction can be achieved by several techniques depending on the nature of the start material. These include:

1. **Expression:** The physical extraction of aqueous juices from plant tissues, of particular interest in studies on fruit flavors.
2. **Solvent Extraction:** The solvent used may be either water from which the aromatic components may be recovered by high vacuum vaporization, or low-boiling point nonpolar solvents (e.g., ether, cyclohexane, methylene dichloride, hexane), or liquefied gaseous solvents (e.g., Freons or liquefied carbon dioxide). The solvent depends on the physical nature of the start material and its susceptibility to oxidative.
3. **Steam Distillation at Atmospheric Pressure:** It is the most used method of isolation and recovery of aromatic compounds from plant materials, although precautions must be taken to limit thermal degradation of components.
4. **Vacuum Distillation:** This is used for the distillation of high molecular weight substances, which need high temperatures for their distillation at atmospheric pressures, resulting in chemical decomposition.
5. **High Vacuum Degassing:** It is applicable to the recovery of volatiles from fixed oils and foods having high lipid content.
6. **Headspace Vapor Collection:** This technique is important for the examination of the low volatile components. If the material under examination is allowed to stand in a

suitable vessel, the low-boiling volatile components will achieve the equilibrium in the headspace. These vapors can then be used for direct identification using gas chromatography. The results obtained are, of coarse not representative of the full odor / flavour of the start material.

b. **Solvent removal:** Solvents are removed by heating the mixture at lower temperatures under partial vacuum conditions. However, solvent residues remain with the oleoresins. Removing last traces of the solvents usually results in the loss of some flavor components called "top notes". This is not important if the main use of the oleoresin is for bitterness. However, in the production of oleoresins from spices, such as pepper and ginger, manufacturers leave the solvent residues rather than lose their "top notes" of flavor.

c. **Standardization**: It is necessary with some oleoresins because high level of lipids in certain plants create an extract with a very weak flavor. In order to reinforce the "flavor" and increase the "taste" of the spice, extracts are standardized by addition of essential oils--which are the volatile extracts of the spice. Examples of these "standardized oleoresins" are coriander, bay, nutmeg, mace, and pepper. Because these "standardized oleoresins" are blended with essential oils they are a functional spice--but not a true representation of the plant material. Several manufacturers offer ranges of such standardized spices

d. **Dilution:** The oleoresin contains the aroma and flavor of the spice in a concentrated viscous liquid, or semisolid form. Due to this high concentration, oleoresins cannot be incorporated into food products unless they are diluted. Dilution can be achieved by following methods

1. Dispersing the oleoresin on a dry carrier, such as salt, dextrose, sugar, or starch to produce a dry soluble spice.
2. Dispersing the oleoresin in fats to produce a fat-based soluble spice
3. Dissolving the oleoresin in alcohol, propylene glycol, or another appropriate solvent to yield a liquid soluble spice.
4. Emulsifying the oleoresin with gum acacia, or one of the modified starches, and then spray drying to produce an encapsulated spice.

Areas of uses of the essential oils and oleoresins:

Processed Meats: The use of spices, particularly pepper, in the manufacture of meat products, is traditional to impart flavor and keeping quality to the products. Typical seasoning mix for fresh sausages, for example, consists of pepper, capsicum, ginger, nutmeg, plus herbs. For dry sausages and pickled meats cardamom and coriander are also used. The move to use oleoresins has been accelerated by the increasing size of the manufacturing plants, where the use of spice extracts benefits production quality, as well as easy handling and cost savings. The above spices are used in the dispersed form of their oleoresin, with cardamom and coriander in the form of their oils.

Fish and vegetables: Seasoning mixes for both fish and vegetables, and particularly pickled or brined products such as herrings, contain a wide range of spices and herbs. The use of oleoresins, particularly dispersed oleoresins on a soluble base, will provide a means of easier preparation, reduced handling and costs.

Soups, Sauces, and dressings: The increasing demand for convenience products available in the form of a dry mix for ready reconstitution, has caused a rapid move from conventional seasoning towards dispersed or encapsulated oleoresins and oils. Oleoresins of celery, pepper, capsicum, are used in conjunction with the oils of onion and garlic. Coriander and ginger extracts are used in barbeque sauces.

Cheeses and dairy products: The use of spices in cheeses is established in Germany, including "Quark". Spice extracts are unlikely to be uses in these products as the spices provide the flavoring plus visual impact. However, spice oils and oleoresins will have significance in processed cheeses and savory spreads.

Confectionery: The use of spices and spices extracts in the confectionery area is rare, but demonstration of the use of such material as cardamom oil and other extracts in toffees, chocolates, and others, has shown that they may provide a very novel and pleasing ingredient new to the market.

Baked goods: The use of cardamom in baked goods in Scandinavia and Germany is traditional. The baking industry generally uses ginger, cinnamon, and nutmeg. The move from the spice to their oleoresin has been effectively taking place for many years for ease of handling and simplicity in manufacture. The use of spice extracts in cake fillings, biscuits, and snack products are also increasing.

Snacks: The flavoring is an essential component of the appeal of snack products, and unusual because the flavor is often applied on the surface, either by spray coating or dusting. For this purpose the seasoning mix has to be capable of being applied in spray form, or powder. Oleoresins of pepper, chilly, and celery, are widely used. Turmeric and chili extracts are used to provide color. Beverages Spice oils are used for the preparation of soft beverages, as for example ginger oil in the preparation of ginger beer, etc. Some of the less well-known spice extracts can be used to produce very pleasing soft drink products as yet not widely known outside of local production in countries where they originate.

Cosmetics: The use of spice oils in the preparation of creams, soaps, shampoos, lacquers, lipsticks, etc., is well known. However, some of the materials available from India are as yet not widely used, not recognized as providing means for a new dimension to cosmetic products. The growing preference for herbal, spicy, and spicy coniferous products like shampoos and hair tonics are noted, yet such extracts as those of cardamom and fenugreek are little heard of. The use of lesser-known spice extracts can provide new product appeal.

Perfumes: Perfumery uses a wide range of essential oils and oleoresins from sources far and wide, and yet some of the lesser known oils and oleoresins are hardly used at all. Examination of the wide range of those available from India could well provide a new basis of products of appeal.

Hygiene products: Products like toothpastes, mouthwashes etc., depend on essential oils to provide their pleasing flavor, making them not only acceptable, but pleasant to use. In cleansing materials, detergents etc., spice oils provide the aromatic appeal in otherwise uninteresting and sometimes-offensive notes associated with some of the base products.

Aerosols: The use of aerosols worldwide is increasing at a significant rate in products such as air fresheners, polishes, lacquers and many cleansing agents, as well as waxes etc., All of these are perfumed with essential oils to provide their pleasant and fresh aroma.

Pharmaceuticals: Both oils and oleoresins are widely used in pharmaceutical products, to provide either pleasant taste or aroma to render the medicinal products, which would otherwise be difficult to accept, pleasing and easy to use. These include medications, skin creams, cold remedies, etc.

Issues to be addressed in production of essential oils and oleoresins:

Achieving a consistent quality product: There is wide variation in the level of active ingredients in the plant obtained from different growing conditions. So, techniques should be evolved to produce standardized oils and oleoresins. Types of solvent, extraction temperature, time, degree of fineness of the raw material, moisture content, etc. should be optimized for higher recovery and least losses.

Losses during processing: Active ingredients are very less in the plants. So, during processing, loss of these should be checked. During removal of solvents or water, other undesirable compounds like chlorophyll, from the essential oils and oleoresins, processing conditions like pressure, temperature, etc. should be optimized to reduce the losses.

Research work on value addition, isolation of newer aroma chemicals, and development of analytical procedures to estimate the adulterants should be done. Herbal cosmetics, aromatherapy and quality seed production are other promising areas. Trained manpower availability is very less in this area. Cost of production of essential oils and oleoresins is very high. Production of essential oils and oleoresins should be done from by-products of industries, and plant residues. For example, citrus essential oils are recovered from the peel of the fruits obtained after juice extraction.

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UNIT-12

ROLE OF FATS AND OILS IN HUMAN HEALTH & NUTRITION

Dr Mridula D.

Principal Scientist (F&N)
ICAR-CIPHET, Ludhiana

Oils and fats are the biological substances collectively called as lipids. Lipids are biological chemicals, which are insoluble in water but soluble in certain organic solvents such as ether, alcohol, and benzene. Oils and fats are esters of the tri-alcohol, glycerol (or glycerine). Therefore, fats and oils are commonly called triglycerides, although a more accurate name is triacylglycerols. They form the important dietary constituents due to their high food energy value, the fat soluble vitamins and the essential fatty acids present in them. In the body, lipids are present in the cytoplasm as well as the cell and are also in the specialized areas in the body as depots of fat to serve as the stored energy. Nervous tissues are particularly rich in lipids that appear to serve an important role in their function. The subcutaneous fat plays an insulating role against atmospheric heat and cold and also helps in rounding off the body contours. Lipids are classified as simple lipids (neutral fats and waxes), compound lipids (phospholipids, glycolipids, sphingolipids, lipoproteins) and derived lipids (fatty acids, alcohols and sterols).

Simple lipids

Neutral fats are fatty acid esters of trihydric alcohol-glycerol, also known as triglycerides. Some are solid at room temperature, known as fats while some are liquid at room temperature called oils. Glycerol is a 3-carbon alcohol with three hydroxyl groups, each of which can combine with fatty acid. A simple triglycerides is one in which the three fatty acids are the same. A mixed triglycerides is one in which atleast two fatty acids are different. Mixed triglycerides account for about 98 percent of fats in foods and over 90 percent of fat in the body. Waxes are esters of fatty acids and long-chain or cyclic alcohols. This group includes the esters of cholesterol, vitamin A and vitamin D. The fatty acids commonly occurring in natural fats and oil contains even number of carbon atoms, presented in Table 1.1 &1.2 (adopted from Swaminathan, 1991). Fatty acids are broadly divided into two main groups (i) saturated fatty acids and (ii) unsaturated fatty acids, which contain one or more double bonds. Fats and oils are triglycerides as shown below where R_1, R_2 and R_3 represent fatty acids.

CH_2OH	$HOOCR_1$	CH_2OCOR_1
|	|	|
CH_2OH	$HOOCR_2$	$CHOCOR_2$
|	|	|
CH_2OH	$HOOCR_3$	CH_2OCOR_3
Glycerol	*Fatty acids*	*Triglycerides*

Table 1.1: Saturated Fatty Acids

Molecular formula	Common name	Systematic name	Structural formula
$C_4H_8O_2$	n-Butyric		$CH_3(CH_2)_2COOH$
$C_6H_{12}O_2$	Caproic	n-Hexanoic	$CH_3(CH_2)_4COOH$
$C_8H_{16}O_2$	Caprylic	n-Octanoic	$CH_3(CH_2)_6COOH$
$C_{10}H_{20}O_2$	Capric	n-Decanoic	$CH_3(CH_2)_8COOH$
$C_{12}H_{24}O_2$	Lauric	n-Dodecanoic	$CH_3(CH_2)_{10}COOH$
$C_{14}H_{28}O_2$	Myristic	n-Tetradecanoic	$CH_3(CH_2)_{12}COOH$

$C_{16}H_{32}O_2$	Palmitic	n-Hexadecanoic	$CH_3(CH_2)_{14}COOH$
$C_{18}H_{36}O_2$	Stearic	n-Octadecanoic	$CH_3(CH_2)_{16}COOH$
$C_{20}H_{40}O_2$	Arachidic	n-Eicosanoic	$CH_3(CH_2)_{18}COOH$

Table 1.2: Unsaturated Fatty Acids

Molecular formula	Common name	Systematic name	Number of doubles bonds
$C_{16}H_{30}O_2$	Palmitoleic	9-Hexadecenoic	1
$C_{18}H_{34}O_2$	Oleic	Cis-9-Octadecenoic	1
$C_{18}H_{34}O_2$	Elaidic	Trans-9-Octadecenoic	1
$C_{18}H_{34}O_2$	Vaccenic	11-Octadecenoic	1
$C_{18}H_{32}O_2$	Linoleic	cis, cis-9-, 12-Octadecadienoic	2
$C_{18}H_{30}O_2$	Linoleic	9, 12, 15-Octadecatrienoic	3
$C_{18}H_{30}O_2$	γ- Linoleic	6, 9, 12- Octadecatrienoic	3
$C_{18}H_{30}O_2$	Eleostearic	9,11,13- Octadecatrienoic	3
$C_{20}H_{32}O_2$	Arachidonic	5, 8, 11, 14- Eicosatetraenoic	4

Table 2: Fatty acid composition[#] of dietary fats and oils

consumed in India (% of total fatty acids) Fats/ oils	SFAs*	MUFAs**	LA	ALA
High (medium chain) SFAs				
Coconut	92	6	2	-
Palm kernel	83	15	2	-
Butter/Ghee	68	29	2	1
High SFAs & MUFAs				
Palmolein	39	46	11	<0.5
High MUFAs & Moderate LA				
Groundnut	19	41	32	<0.5
Rice bran	17	43	38	1
Sesame	16	41	42	<0.5
High LA				
Cottonseed	24	29	48	1
Corn	12	35	50	1
Safflower	9	13	75	-
Sunflower	12	22	62	-
LA & ALA				
Soybean	14	24	53	7
Canola	6	60	22	10
Mustard/ rapeseed	4	65	15	14
Flaxseed	10	21	16	53
High TFAs				
Vanasapti	46	49	4	-

Source: Codex alimentarius commission (1996), [#]approximate; * SFAs include <10:0, 12:0 (lauric), 14:0 (myrisitc), 16:0) palmitic), 18 : 0 (oleic); ** mainly cis 18:1 (oleic) other MUFAs when present indicated against superscripts

Physical properties
Neutral fats are colourless, odourless, tasteless substances. The colour and taste of some of the naturally occurring fats is because of the presence of extraneous substances, e.g. carotene in butter. These fats are soluble in organic solvents but insoluble in water and have well defined melting points and solidifying points. They have low specific gravity and float on water, and spread on water to form thin monomolecular layers.
Chemical properties
Hydrolysis: Heating of neutral fats with superheated steam or boiling with acids or alkalies will result in the hydrolysis into glycerol and fatty acids. In case alkali has been used for the hydrolysis, the fatty acids liberated will combine with the base to form soaps.
Additive reactions The unsaturated fatty acids present in the neutral fat will exhibit all the additive reactions (hydrogention, halogenation). Oils that are in liquid state at room temperatures become solidified on hydrogenation. This is basis for the vanaspathi manufacture, where vegetable oils are converted to hydrogenated fat.
Oxidation: Fats rich in unsaturated fatty acids such as linseed oil undergo spontaneous oxidation at the double bond forming aldehydes, ketones and resins that form thin transparent coating on the surface to which the oil is applied. These are called drying oils and usually consider for manufacturing paints and varnishes.
Rancidity: Naturally occurring fats, particularly of animal origin, are contaminated with enzymes like lipase. The action of enzyme, atmospheric moisture and temperature bring about partial hydrolysis of the fat and some degree of oxidation of the unsaturated fatty acids at the double bond and results in a characteristic taste and odour. This process is called rancidity and the fat, that undergo this change is said to become rancid. Vegetable fats contain substances like vitamin E, phenols, hydroquinone, tannins and other substances, which exhibit antioxidant activity and prevent such oils from rancidity. Therefore, vegetable fats preserve for longer duration than animal fats.

Waxes are esters of higher fatty acids with higher monohydroxy alcohols other than glycerol. In the human body, the commonest waxes are esters of cholesterol. Waxes are mainly of three types:

- True waxes are esters of higher fatty acids with acetyl alcohol or other higher straight chain alcohols.
- Cholesterol esters are esters of fatty acid with cholesterol.
- Vitamin A and vitamin D esters are palmitic or stearic acid esters of vitamin A (Retinol) or vitamin D, respectively.

Compound lipids
Compound lipids are esters of glycerol and fatty acids, with substitution of other components such as carbohydrate, phosphate, and / or nitrogenous groupings. Phospholipids or phosphatidic acid is a glycerol ester with two fatty acids and one molecule of phosphoric acid e.g. lecithin and cephalin, which contain a phosphate and nitrogen group. Glycolipids such as the cerebrosides contain a molecule of glucose or galactose in combination with fatty acids. Liporoteins include a variety of lipid molecules bound to protein molecules in order to facilitate transport in the aqueous medium of the blood.
Derived lipids: These include fatty acids; alcohol (glycerol and sterols); carotenoids; and the fat-soluble vitamins, A, D, E and K.
Essential fatty acids
Fatty acid is an organic acid that has an acid group at one end of its molecule, and a methyl group at the other end. Fatty acids are typically categorized in the omega groups 3, 6 and 9 according to the location of their first double bond. The term essential fatty acid refers to a fatty acid, which is not synthesised by the body and must be present in the diet to fulfil the

requirements. Fatty acids which are essential (short chain polyunsaturated fatty acids) for human being are α-Linolenic acid or ALA (18:3n-3) - an omega-3 fatty acid and linoleic acid or LA (18:2n-6)-an omega-6 fatty acid (Whitney and Rolfes, 2008). These two fatty acids are essential because human being can't synthesize them due to lack of desaturase enzymes required for their production. LA and ALA are dietary essential fatty acids, and are metabolized by consecutive chain elongase and desaturase enzymes to long chain (LC) n-6 PUFAs (arachidonic acid (AA) is the predominant LC n-6 PUFA) and LC n-3 PUFAs {eicosapentaenoic acid (EPA) docosapentaenoic acid (DPA) and docosahexaenoic acid (DHA)}, respectively; incorporated into the membrane lipids (Ratnayake and Galli, 2009).

Essential fatty acids are required by the body for formation of cell membranes, proper development and functioning of the brain and nervous system, production of hormone-like substances called eicosanoids (thromboxanes, leukotrienes, prostaglandins) to regulate numerous body functions including blood pressure, blood viscosity, immune and inflammatory responses. Dietary sources of omega 3 fatty acids include vegetable oils, nuts and seeds, flaxseed, shellfish and fish etc. while that of omega 6 fatty acids present in significant proportion in some leafy vegetables, seeds nuts, grains, vegetable oils and meats etc.

Arachidonic acid (AA) and docosahexaenoic acid (DHA) is found crucial in fetal and infant early growth and development. Fetal and early infant development stage, rapid accretion of AA and DHA in infant brain, DHA in retina and AA in the whole body takes place to meet out the demands of rapidly growing tissues/organs. DHA are also present in small proportion in cell membranes throughout the body. DHA and AA have different and specific roles in neural and behavioural functions. DHA is important for the function of rhodopsin for vision and postsynaptic receptors for neurotransmission (Ratnayake and Galli, 2009, Galli and Calder, 2009; Crawford et al., 2009). Fetus depends entirely on maternal source of LA, ALA, AA and DHA (dietary intake and maternal tissues) while infant get these PUFAs through the mother milk (Brenna and Lapillonne, 2009; Koletzko et al., 2007). In view of the high variability in the formation of DHA from ALA and due to its crucial role in normal retinal and brain development, DHA (as provided by human milk) is considered conditionally essential during the early child development.

Digestion and absorption of lipids

Most of the fat in the human diet is present in the form of triacylglycerol.

Emulsification and digestion

Solubility of fats is important for its digestion and absorption. Lipids are hydrophobic, hence poorly soluble in the aqueous environment of the digestive tract. The enzyme for fat digestion i.e. pancreatic lipase- secreted by pancrease, is water soluble and can only work at the surface of fat globules. To a greater extent, fat digestion is aided by emulsification - the breaking up of fat globules into much smaller emulsion droplets. Bile salts and phospholipids are amphipathic (of a molecule, especially a protein) having both hydrophilic and hydrophobic parts) molecules that are present in the bile.As the chyme (partly digested food with gastric juices) enters the duodenum, fat present in the chyme stimulates the release of enterogastrone hormone. This harmone reduces motility and regulates the chyme flow to correspond to the availability of the pancreatic enzymes. The fat presence in the duodenum also stimulates the intestinal wall to secrete cholecystokinin, a harmone. Cholecystokinin stimulates the contraction of gallbladder, thereby forcing bile in to the common duct and thereby in to small intestine. Bile has several important functions in fat digestion and absorption. It (i) stimulates peristalsis, (ii) neutralizes the chyme pH, required for pancreatic enzyme activity, (iii) emulsifies fats present in chyme, thereby increasing the surface area exposed to enzyme action, and (iv) lowers the surface tension to make the contact between the fat droplets and enzymes possible for digestion.

During fat digestion, triglycerides hydrolyzed step-wise by lipase; that is, one of the end fatty acids is removed at the time, yielding a mono-glyceride, with the fatty acid attached in the middle or number 2 position. Only about one fourth to one half of the triglycerides completely hydrolyzed to glycerol and fatty acids. Some of the phospholipids are hydrolyzed by phospholipases. Cholesterol esters are hydrolyzed by cholesterol esterase to cholesterol and fatty acids. The end products of lipid hydrolysis for absorption include fatty acids, glycerol, monoglycerides, some di- and tri-glycerides, cholesterol, and phospholipids. Digestion, absorption and metabolism of dietary fat in the body are briefly presented in Fig. 1 (adopted from Robinson & Lawler, 1982).

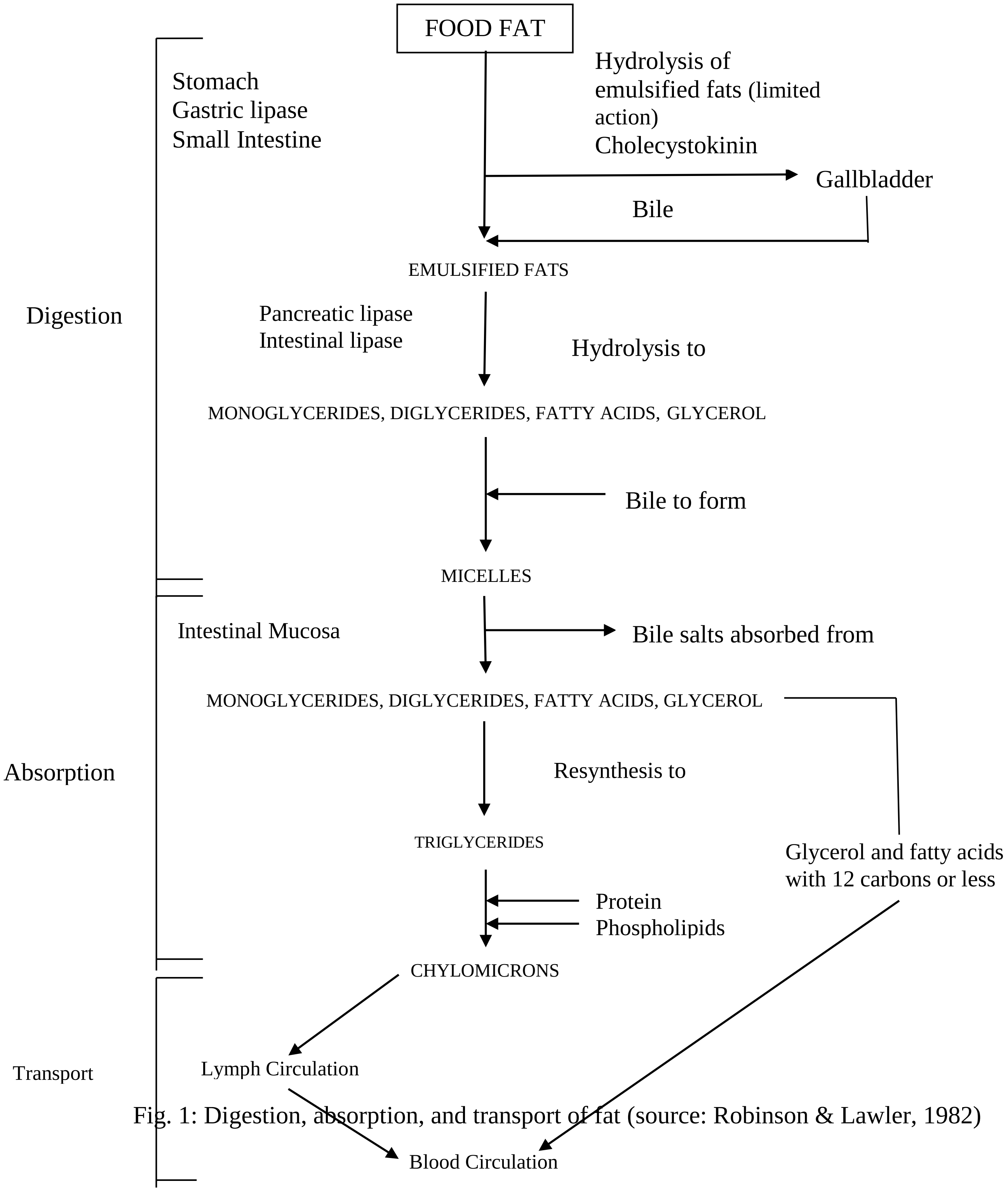

Fig. 1: Digestion, absorption, and transport of fat (source: Robinson & Lawler, 1982)

Importance of fats and oils

Fats and oils are essential food components for good health but require in moderation. Lipids performed several functions in the body.

Functions of triglycerides

Fat (*triglycerides*) has several important functions such as: (i) concentrated source of energy yielding more than twice the energy (9 kcal/ g fat) supplied by carbohydrate per unit weight; (ii) essential for the absorption of vitamin A,D,E and K and carotenoids;(iii) Vegetable fats are good sources of vitamin E (iv) red palm oil is rich in carotene while some animals fats e.g. butter and fish liver oils provides vitamin A; (v) some vegetable fats are rich sources of the essential fatty acid – Linoleic acid; (vi) reduce the bulk of the diet due to higher calories per unit weight of fat as compared to carbohydrates (vii) Fat is deposited in adipose tissue and serves as a reserve source of energy during illness, calorie deficient diets, starvation, etc. (viii) adipose tissue acts as insulating material against cold and physical injury.

Functions of Phospholipids

Important functions of phospholipids are: (i) present in the plasma in combination with proteins as lipoproteins. These proteins involve in the transport of fat and cholesterol; (ii) form a part of certain enzyme, e.g., cytochrome oxidase, succinic oxidase, etc.; (iii present in mitochondria in large amounts and essential for function of the mitochondrial electron transport chain; (iv) important constituents of all cell membranes and influence the permeability of the membranes to different substances; (v) concerned in the selective cation transport across the erythrocyte membrane; (vi) essential components of thromboplastin, a factor in blood couagulation (vii) present in large amount in the nervous tissue and essential for its function.

Function of cholesterol

Cholesterol are important for our body as (i) it act as a precursor for the formation of bile acids; (ii) present in cell membranes and essential for maintaining the membrane in good condition; (iii) a precursor for the formation of some steroid homones; (iv) present in large amounts in the nervous tissue and is essential for its function and (v) it serves as a precursor for the formation of dehydrocholesterol (in the skin and some other tissue) that in turn is converted into vitamin D_3 in the body by the action of ultraviolet rays present in the sunlight.

Complex lipids such as sphingomyelins, glycolipids, phospholipids and cholesterol are present in the tissues particularly nervous tissues; are essential for the functioning of the nervous tissue. They occur in large amount in the brain.

Dietary requirement of fat for Indians

Consumer obtained dietary fats from two major sources viz. the invisible fat , which is present in plant and animal foods; and the visible fat (fats and oils). Fats are the medium for cooking, serve as a vehicle for fat-soluble vitamins and carotenes and important for their absorption, important for satiety, and also a source of essential polyunsaturated fatty acids. But it is important to have good quality fat in adequate quantity having proper proportions of essential fatty acids/ polyunsaturated fatty acids. The type and quantity of fat in the daily diet influence the level of cholesterol and triglycerides in the blood.

The minimal intakes of visible fat in Indian adults range between 20-40 g/p/day, depending upon the physical activity, percent energy from fat and also considering unfavourable effects of low fat-high carbohydrate diets on health, 30 g visible fat by pregnant and lactating and 25-30 and 35-50 g/day, respectively of visible fat for children and adolescents (Final Draft- RDA, 2009). The maximum amount of total fat that can be included in the diet should not exceed 30% of energy i.e. about 60g visible fat/ day. Fat intake exceeding 35%E may increase the risk of diet-related non-communicable diseases (DR-NCD) hence should be avoided. However, dietary fat, including visible as well as invisible fat in one's daily diet can be between 20-30% calories (Final Draft-RDA, 2009). Diets must include adequate amounts of good quality fat and oils particularly in the case of young children to provide concentrated source of energy, required for their growth and development and active and healthy life while adults need to be cautious and require to restrict saturated fat (butter, ghee and hydrogenated fats) and cholesterol in their diet (red meat, eggs, organ meat) to avoid the obesity, diabetes, cardiovascular disease and cancer etc. Recommended dietary allowances for fat for Indians and suggested types of visible fat, may be preferred for different food applications are presented in Table 3 and Table 4 (Final Draft-RDA, 2009).

Table 3: Recommended dietary fat for Indians

Age/Gender/ Physiological groups	Physical activity	Minimum level of total fat (% Energy)[a]	Fat from foods other than visible fats[d], % Energy	Visible fat[9]	
				% E	g/person/ day
Adult Man	Sedentary	20	10	10	25
	Moderate				30
	Heavy				40
Adult Women	Sedentary	20	10	10	20
	Moderate				25
	Heavy				30
	Pregnant women	20	10	10	30
	Lactating women				30
Infants	0- 6 months	40-60	Human milk[i]		
	6-12 months	35[b]	10[c]	25	25
Children	1-3 years & 4-6 yrs	25	10	15	25
	7- 9 years				30
Boys	10- 12 years				35
	13- 15 years				50
	16- 18 years				40
Girls	10- 12 years				45
	13- 15 years				35
	16- 18 years				35

Adopted from: RDA-2020, NIN, Hyderabad

[a]FAO/WHO, 2008; [b]gradually reduce depending on physical activity [c]Human milk/ infant formula + complementary foods ; [d]if higher than 10%E, visible fat requirement proportionately reduces; [g]cooking oils , butter, ghee and margarine; [I]infant formulae/ milk substitutes should mimic contents of fat and fatty acids in human milk including arachidonic and docosahexaenoic acid.

Table 4: Fat and oils (visible) for a well balanced diet

1.	Oils having 2 or more vegetable oils (1:1) *Oil containing LA + oil containing both linoleic acid (LA) and alpha-linolenic acid (ALA)** Groundnut / Sesame[a]/ Rice bran[b] / Cottonseed+ Mustard/ Rapeseed Groundnut / Sesame[a]/ Rice bran[b] / Cottonseed+ Canola Groundnut / Sesame[a]/ Rice bran[b] / Cottonseed+ Soyabean Palmolein[c] + Soyabean Safflower/ Sunflower + Palm oil/ Palmolein[c]+ Mustard/ Rapeseed

	Oil containing high LA + oil containing moderate or low LA Sunflower / Safflower + Palmolein[c]/ Palm oil[c]/ Olive Safflower/ Sunflower + Groundnut / Sesame[a]/ Rice bran[b] / Cottonseed
2.	Replacements for partially hydrogenated vegetable oils Frying using oils having higher thermal stability-- palm oil[c] /palmolein[c], sesame[a], rice bran[b], cottonseed – single/ blends (home/ commercial) Bakery fat, shortening, *Mithai*/ Indian sweets etc -- Food applications which require solid fats : coconut oil/ palm kernel oil/ palm oil/ palmolein/ palm stearin and / their solid fractions and / their blends
3.	Avoid using partially hydrogenated vegetable oils for cooking/ frying
4.	Limited use of butter/ ghee[d]

Adopted from RDA-2020, NIN, Hyderabad; Ghafoorunissa, 1998, 2005 & 2009; Skeaff, 2009; L'Abbe, 2009; [a]sesame lignans, [b]oryzanols + tocotrienols, [c]tocotrienlos, [d]vitamin A & D; *approximately 30-40% PUFAs with >3 %ALA

Effect of dietary fat on food intake

Studies had shown that high dietary fat induce greater food intake and thus weight gain than diets rich in carbohydrates. A number of factors such as energy density of meal, satiety characteristics and post-absorptive factors can contribute to different response to high-fat diets than high carbohydrates diet. Golay and Bobbioni (1997) indicated that the satiating effects after dietary intake with a higher fat : carbohydrate ratio is less than for meal having a lower ratio. They further indicated that dietary density of fat has a poor influence on satiety and that periodic exposure to a high-fat meal, mainly during intense hunger, may lead to over energy consumption as fat in obese patients. High-fat diets promote passive over-consumption, depends largely on the high energy density of high fatty foods and this over-consumption due to overeating has been attributed to as passive over-consumption (Stubbs et al., 1995). Blundell and Stubbs (1999) indicated that short-term studies on appetite of subjects and total energy intake clearly showed that fat is less satiating than carbohydrate and protein, and that high fat diets are more likely to induce passive over-consumption and thus weight gain than less fatty diets with higher protein and carbohydrate contents (Blundell JE, Stubbs, 1999). The source of carbohydrate and glycemic index of foods may have importance for the effect on risk factors. studies show that diet having low glycemic index had more beneficial effects than foods with high glycemic index on LDL- and HDL-cholesterol, insulin resistance and plasminogen activator inhibitor-1 activity (Jarvi et al., 1999; Frost et al., 1999). As a result, low fat diets having high carbohydrate content should contain mainly complex carbohydrates from vegetables, fruit and whole grains that are more satiating with fewer calories than fatty foods and rich in dietary fibre, vitamins, minerals and trace elements. Such diet composition had also been shown to reduce mortality in high risk patients (Singh et al., 1992).

Dietary fat and fat balance

Golay and Bobbioni (1997) reported that energy balance is correlated with fat balance in lean controls and indicated no correlation with either carbohydrate or protein balances; and also reported that carbohydrate and protein reserves in the body is regulated by adjusting oxidation to intake, while dietary fat is almost exclusively used or stored in response to day-to-day variations in the energy balance. This study indicated the positive relationship between fat intake and lipid oxidation seen in lean controls appears not to be present in obese patients. Golay and Bobbioni (1997) reported that on high-fat diets, post-obese women failed to increase the ratio of fat to carbohydrate oxidation appropriately and dietary fat results in preferential fat storage in post-obese women, impaired suppression of carbohydrate and reduction of 24h energy expenditure.

Dietary fat and diseases

Association of fat intake with occurrence of diseases particularly hypertension, heart diseases, diabetes mellitus, cancers (colon, breast, prostate, and ovary cancer) has been debated for many years. Epidemiological studies showed that a high-fat diet promotes the obesity and has a direct relationship between the proportion of dietary fat intake and the degree of obesity. Studies carried out during the past 30 years have indicated the correlation of higher dietary fat intake with higher mortality due to various diseases. Consumption of specific saturated fatty acids raise blood cholesterol levels and, thereby increase the risk of atherosclerosis; higher fat intake is a major cause of obesity, hypertension, diabetes, gallbladder disease and may also increased the risk of breast cancer directly through increased blood estrogen levels and/or secondarily through increased obesity (Kuller, 1997). A number studies have indicated positive correlation between the proportion of total dietary energy intake from fat and body fatness, and inverse associations between carbohydrate intake and body fatness (Astrup et al., 1997; Bray and Popkin, 1998).

Excess bodyweight in overweight (defined as a body-mass index [BMI] of 25 to 29·9 kg/m²) as well as in obese (BMI of 30 kg/m² or greater) people, is becoming an important risk factor for some common cancers (IARC, 2002; WCRF, 2007). In a study carried out by Laura et al. (2002), Conjugated linoleic acid (CLA) intake showed a weak but positive correlation with breast cancer incidence but statistically significant positive correlation with total trans fatty acids and (borderline) with saturated fatty acids. Laura (2002) also observed that anti-carcinogenic property of CLA in animal and tissue culture models could not be confirmed in this epidemiologic study in humans. Andrew et al (2008) indicated that in men, a 5 kg/m² increase in BMI was strongly associated with oesophageal adenocarcinoma and with thyroid, colon, and renal cancers. In case of women subjects, this study further reported a strong association between a 5 kg/m² increase in BMI, gallbladder, oesophageal adenocarcinoma, and renal cancers.

Many researcher documented the association between dietary fats and DR-NCD (mainly CHD), from metabolic studies, clinical trials and epidemiological studies (WHO/FAO, 2003; Elmadfa and Kornsteinera, 2009; Melanson et al., 2009; Sanders, 2009; Skeaff and Miller, 2009; (Willet, 2007; Rastogi et al., 2004; Uauy R, et al., 2009). Elevated serum levels of total cholesterol, low density lipoprotein (LDL) cholesterol and total triglycerides; low serum levels of high density lipoprotein (HDL) cholesterol and increased ratios of total cholesterol : HDL cholesterol are associated with increase in CHD risk and CHD events. The dyslipidemia associated with metabolic syndrome (risk factor for type 2 diabetes) elicits high serum levels of triglycerides (very low density lipoproteins (VLDL) and small dense lipoprotein (sdLDL)) in addition to the above lipid abnormalities. Dietary fatty acids modify the concentrations of plasma triglycerides and lipoprotein cholesterol fractions which affect CHD risk significantly. Lauric (12:0), myristic (C14:0) and palmitic (C16:0) acids increase serum LDL and total cholesterol and the risk of CHD and CHD events. TFAs are similar to SFAs in increasing LDL cholesterol but in addition they lower the protective effects of HDL cholesterol and increase the lipoprotein (a) which further increases the CHD risk (Final Draft-RDA, 2009). Many studies reported that excessive consumption of specific fatty acids (LA, ALA, EPA and DHA) lower the risk/ onset of CHD. Compared to higher fat consumption, high carbohydrate-low dietary fat result in a metabolic pattern that increases the risk of type 2 diabetes and also CHD by way of reducing serum HDL cholesterol and increasing triglyceride concentrations, and show higher responses in postprandial glucose and insulin concentrations. Studies on animals (Ghafoorunissa, 2005) and limited study data in humans indicated that high intakes of either SFAs and / TFAs may contribute to insulin resistance whereas PUFAs may play a preventive role in insulin resistance

(Elmadfa and Kornsteinera, 2009; Melanson et al., 2009; Sanders, 2009; Uauy R, et al., 2009). The Long Chain omega-3 PUFA from fish and other sea foods lower serum triglycerides, postprandial lipemia and have beneficial effects on endothelial function, inflammation, vascular reactivity and ventricular arrhythmias. Many studies indicated a strong inverse relationship between fish consumption or LCn-3PUFA intake and CHD and some types of cancers (Elmadfa and Kornsteinera, 2009, Skeaff and Miller, 2009, Willet, 2007).

Hu et al. (2001) reported that the type of fat, but not total amount of fat, predicts serum cholesterol levels as shown in various metabolic studies. They further reported that controlled clinical trials as well as eidemiologic studies also indicated that replacement of saturated fat with unsaturated fat is more effective in lowering risk of CHD than simply reduction in the amount of daily fat consumption. Hu et al. (2001) further indicated that the prospective cohort studies and secondary prevention trials provided strong evidences that an increasing intake of omega-3 fatty acids (fish or plant sources) significantly lowers the risk of cardiovascular diseases thus mortality by these diseases. Mario et al. (2013) in indicated that the observational evidence not support the hypothesis that dairy fat or high-fat dairy foods contribute to obesity or cardio-metabolic risk, and indicate d that consuming high-fat dairy within typical dietary patterns is inversely associated with the risk of obesity. Mario et al. (2013) suggested that these findings may not be conclusive but may provide a rationale for future research to find out the bioactive properties of dairy fat and their impact on the health of consumers. Type 2 diabetes is mainly determined by lifestyle and genes, even though type and daily food consumption may affect both its development and disease related complications. Dietary fat particularly the fatty acids present in them influence glucose metabolism by altering cell membrane function, enzyme activity, insulin signaling, and gene expression (Risérus et al., 2008). Risérus et al., 2008 reported that among polyunsaturated fats, linoleic acid improves insulin sensitivity whereas long-chain omega-3 fatty acids not appear to improve insulin sensitivity or glucose metabolism.

Fat is an important dietary constituent must be included in the daily diet in adequate amount to fulfil the dietary requirement for growth and development of the body. However care should be taken to avoid the excessive intake of the total fat in general and saturated fat in particular to avoid the onset of obesity and other associated lifestyle related diseases.

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UNIT-13

Packaging Consideration of Oil and Fats

Dr. Ranjeet Singh
Pr. Scientist (ASPE)
ICAR-CIPHET, Ludhiana

Packaging is a very important factor for any food product and, when it comes to edible oils, incorrect storage practices can influence the sensory quality of oil, leading to rancidity and off-flavours. Oils and fats spoil due to environmental factors that affect their stability, namely oxygen, moisture, heat and light. Vegetable oil is derived from seeds of plants. Among the oilseeds cultivated in India, from which edible oil is obtained, are groundnut, rapeseed, mustard, sesame, safflower, sunflower, niger, soyabean, linseed and castor. The other sources of vegetable oil are palm, cottonseed, coconut and rice bran. Generally the two methods employed for obtaining edible oil are pressing and solvent extraction. The crude oil thus obtained may be refined, bleached and de-odourised to remove pigments, objectionable odours and flavours and non-triglyceride material. Oil is liquid at room temperature and contains a large proportion of unsaturated fatty acids.

Vanaspati is refined hydrogenated vegetable oil. It is solid at room temperature, as during hydrogenation, the fatty acids get saturated. Ghee is pure clarified fat with especially developed characteristic physical structure and flavour. Ghee is exclusively obtained from milk, cream or butter from various animal sources by means of processes, which results in almost the total removal of moisture and solid-non-fat contents. In India, different varieties of edible oil are consumed, generally depending on the regional preferences and availability. India is one of the largest producers and consumers of edible oil in the world.

Today, the array and availability of packaging materials, sizes and shapes of package construction are unlimited. Modern packaging technology provides many opportunities to maintain product protection while reducing the cost.

Any packaging system for edible oils and fats should be:

- Non-toxic and compatible (Protect against environmental factors)
- Machineable
- Leak-proof and transport-worthy
- Easy to store, use and handle

The domestic availability of vegetable oil during 2012-2018 is given in Table 1.

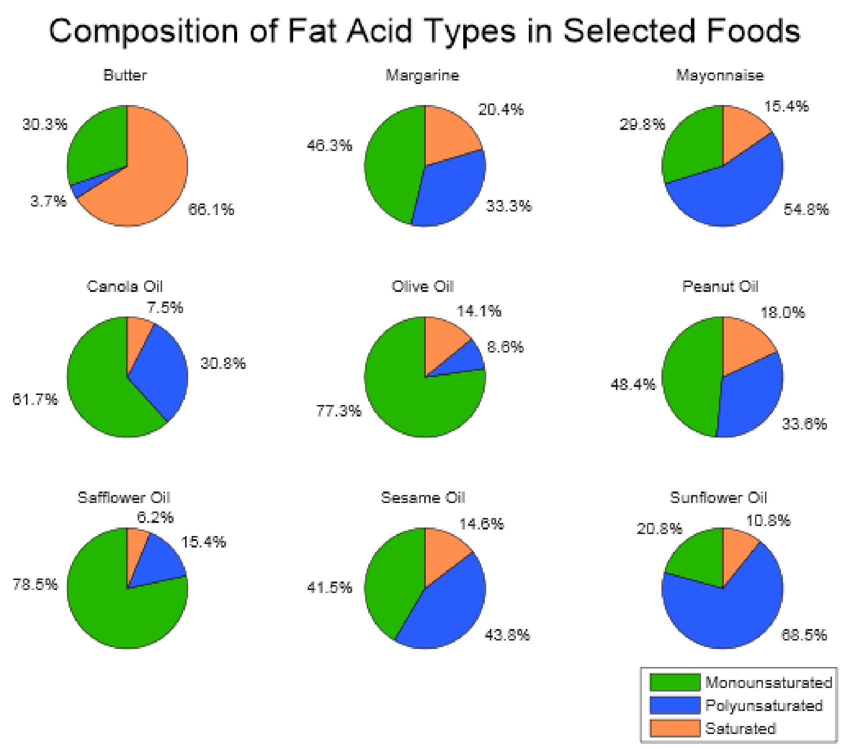
(Million tonne)

Year	Total domestic demand	Domestic availability	Import	Import as % of total domestic demand	Value of import (Rs Cr)	Per capita availability (kg/yr)
2012-13	19.82	9.23	10.81	54.54	53562	15.80
2013-14	21.06	10.08	10.98	52.14	44038	16.80
2014-15	21.71	8.95	12.71	58.54	64894	18.30
2015-16	24.04	9.19	14.85	61.77	68677	19.10
2016-17	24.75	10.75	14.00	56.57	73048	18.75
2017-18	25.88	10.52	15.35	59.31	74996	19.30
Source: Department of Sugar & Vegetable Oils; DG, CI&S, Dept of Commerce, Kolkata						

ICMR recommendation i.e. 30 g/person /day : 10.95 kg/person/year
Per capita requirement by 2022 : 21.55 kg/person/year

Composition of Edible Oil and Fat

The composition of fatty acids in each variety of oil/fat varies considerably. The percentage levels of saturated, mono – unsaturated and polyunsaturated fats in selected foods is given below:



Factors affecting spoilage

Oil and fat are subject to spoilage due to effect of environmental factors that can affect their stability. These factors are mainly oxygen, moisture, heat and light.

- Oxygen is the most critical factor affecting stability. The presence of oxygen leads to oxidation and formation of hydroperoxides and peroxides and then aldehydes and ketones resulting in off-odours due to oxidative rancidity. These reactions increase in rate and intensity in the presence of light and heat. Each oil or fat has a different degree of susceptibility to oxidation. This depends upon the fatty acids composition of each oil and fat. Oil containing high degree of unsaturated fatty acids such as safflower, soya and sunflower are highly prone to oxidative rancidity whereas oil with high degree of saturated fatty acids is less susceptible.

In unrefined oil, natural antioxidants are present and, therefore, these are less prone to rancidity than refined oil, where the antioxidants get removed during the process of refining. Very often, the oil manufacturers add antioxidants to refined oil in order to extend the shelf-life of the product. In vanaspati and ghee, oxygen sensitivity is low as compared to oil.

- Oxygen may gain access to the fat/oil in several ways. Atmospheric oxygen may be present in the oil, it may also be present in the headspace of the package, or may enter the package through the body or the seals.

- Moisture: Another important factor, which contributes to the deterioration of oil is moisture. Very small amount of moisture can be detrimental. Hydrolysis of triglycerides results in formation of glycerol and free fatty acids. Off-flavours occur due to hydrolytic rancidity. This is more common in oil and fats with high levels of saturated fatty acids. Moisture may also gain entry through the body or seams by permeation. Light and heat act as initiators of oxidation reactions, which ultimately lead to degradation and, therefore, control of these factors is also important. Bureau of Indian Standards and Prevention of Food Adulteration Rules – 1955 (PFA), have laid down the specifications of different edible oil and vanaspati. The PFA also lays down specifications for ghee.

The list of standards (BIS) are given as below:

1. 435 : 1973 Castor Oil (second revision)
2. 542 : 1968 Coconut Oil (second revision)
3. 543 : 1968 Cottonseed Oil (second revision)
4. 546 : 1975 Mustard Oil (second revision)
5. 547 : 1968 Sesame Oil (second revision)
6. 548 (Pt 1): 1964 Methods of sampling and test for oil and fat: Part 1. Methods of sampling Physical and chemical tests (revised)
7. 548 (Pt 2) : 1976 Methods and chemical test for oil and fats: Part 2. Purity test (third revision)
8. 548 (Pt 3) : 1976 Methods of sampling and test for oil and fat: Part 3. Analysis by GLC

9. 1780 : 1961 Vegetable Oil
10. 3448 : 1984 Rice Bran Oil (second revision)
11. 3490 : 1965 Nigerseed Oil
12. 3491 : 1965 Safflower Oil
13. 4055 : 1977 Maize (com) Oil
14. 4276 : 1977 Soyabean Oil (first revision)
15. 4277 : 1975 Sunflower Oil (first revision)
16. 8323 : 1977 Palm Oil 8361 : 1977 Palmolein
17. 10633 : 1986 Vanaspati (first revision)
18. 10634 : 1986 Bakery shortening (first revision)
19. 11068 : 1984 Criteria for edibility of oil and fats
20. 11069 : 1984 (RBHWD) soyabean oil
21. 11476 : 1985 Glossary of terms relating to oil and fats
22. 12457 : 1988 Margarine 96

The above standards specify requirements of each oil/grade of oil with respect to characteristics such as:

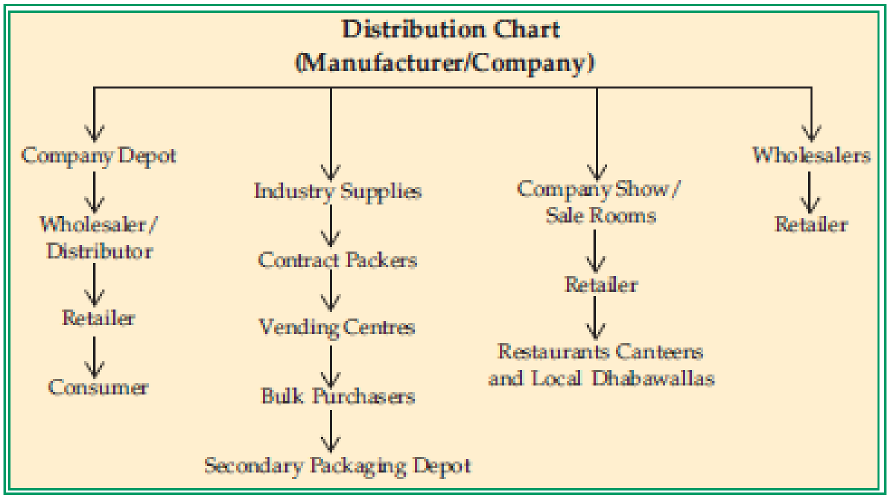
- Moisture and insoluble impurities
- Colour
- Refractive Index
- Specific Gravity
- Saponification value
- Iodine value
- Acid value
- Unsaponifiable matter
- Flash Point

The most significant and critical parameters considered for assessing the storing quality of edible oil are:

- Percentage moisture content
- Percentage free fatty acid
- Peroxide value
- Change in colour/odour

Distribution Pattern

The general distribution pattern followed for these products is shown in the distribution chart given below:



The above distribution pattern indicates that the product passes through a number of hands before it reaches the consumer and therefore it would be ideal to pack the oil at the manufacturers end itself. This would result in a safe and wholesome product to the consumer.

Packaging Systems

Traditionally, oil and fats have been packed in 15kg square tinplate containers. The other types of packages like plastic containers, lined cartons and flexible pouches have been recently introduced. Even though packaging has witnessed many changes, till today about 52% of oil and fats continue to be traded in loose/unpacked form. This includes retail selling of loose oil from 15kg tins as well. This allows a lot of scope to pursue the dangerous practice of adulterating the oil with less expensive and unhygienic varieties. Due to adulteration of oil, deaths have been reported in Spain, Phillipines and India. Consequently, the governments in these countries have taken a step forward to encourage use of inexpensive safe and hygienic plastics packaging for edible oil. Plastic packaging provides safe hygienically packed oil at competitive cost to consumers. It is extremely important that, whatever the packaging material used, it should be food grade and non-toxic. The product package compatibility is the starting point and shelf-life follows compatibility.

Packaged oil and fats offer various advantages such as:

- Ease in quick disposal at retail points
- Ease of identification, tamper evident and therefore chances of mixing or adulteration minimised
- Quality is guaranteed
- No need for consumer to carry own container
- Convenience in storage and use by the consumer
- No wastage due to spillage at retail shops/containers
- Brand identification can be established

Packaged oil, vanaspati and ghee are well accepted and the quantity in packed form is growing steadily. The array and availability of packaging materials, sizes and shapes of package construction are unlimited. In the present day, consumer is willing to try and use new materials.

Modern packaging technology provides many opportunities to maintain product protection while reducing the cost.

The main requirements for a packaging system for edible oil, vanaspati and ghee should be:
• Non – toxic and compatible
• Protect against environmental factors
• Machineable
• Leak-proof and transport-worthy
• Easy to store, use and handle
• Printable

Packaging selection

Marketing and economics are usually the factors driving the selection of packaging. However, proper packaging will provide the conditions to ensure adequate shelf life for distribution and sale. Even though oils are quite stable products, physicochemical characteristics of packaging materials may significantly affect oil quality during their shelf life. In addition, packaging geometry, and filling and closing techniques may also be very important.

Physicochemical characteristics: Oxygen permeability and ultraviolet (UV)/visible light transmission are the major hysicochemical factors,due to the oxidative sensitivity of vegetable oils. Oxygen permeability applies to plastic materials only, whereas light transmission is important for glass and plastic. Many additives are available to reduce UV transmission in both plastics and glass.

Packaging geometry: The geometry of packaging can act in different ways to protect the product. The size and shape of plastic packages can affect the ratio between permeable surface area and product volume. For plastic, glass or metal packages, shape and size can influence the headspace and, therefore, the amount of oxygen available.

Filling and capping: The filling and capping steps are relevant in the process of oil packaging. In order to reduce the residual oxygen inside bottles, the oil is generally stripped with gaseous nitrogen to lower the initial level to below 0.5ppm. Gaseous nitrogen can be pressurised by injecting liquid nitrogen into the headspace prior to closing. The effectiveness of closures is also important in order to reduce oxygen ingress during shelf life. Closure efficiency is related to several factors including material used, design and liner adopted. These factors must guarantee hermeticity, easy opening and the possibility of reclosing. As these goals are sometimes contradictory, efforts to develop new devices is ongoing, including the use of active and intelligent packaging.

Oil-package interactions: Selection of packaging materials may also be made based on their interaction with oils. Oil-package interactions can affect product shelf life, reducing nutritional value and stability – by scalping – or increasing the level of chemical contamination by migration.

Package Material/Type

Metal: Tinplate containers have been used for a long time for oil packaging and are still appreciated because of their many advantages. They provide total protection against light, oxygen, water vapour and micro-organisms. In addition, the inside of the container is protected with food-approved special enamels (lacquers) that protect the metal from the corrosiveness of the product. Edible oils are generally packed in tinplate containers of different capacities, typically from 500g to 15kg. The quality of oil packed in new containers can remain unchanged for a year. However, reuse of containers increases corrosion of the tin coating and the exposed steel base readily reacts with the free fatty acids in oil, leading to oxidative rancidity and organic tin salts with high toxicity. Aluminium is also employed as a packaging material for edible oils as it is light and highly resistant to corrosion. In order to increase its mechanical resistance, aluminium alloys with small amounts of magnesium, manganese, and magnesium silicide are recommended.

Tinplate Containers: Tinplate containers are widely used for packaging of edible oil. They ensure a long shelf-life and are sturdy. They are also suitable for high filling and packaging operations. However, the disadvantages of using a tinplate container are its high cost and uncertainty about availability. Edible oil are packed in tinplate containers of different capacities – 500g, 1kg, 2kg, 5kg and 15kg.

The shape of the container may be round or square. IS – 10339 : 1988 gives the specification for ghee and edible oil tins (500g, 1kg, and 5kg), whereas IS: 10325 – 1989 gives the specification for 15kg square tins for vanaspati and edible oil and ghee. Of late, tinplate containers of 1 kg, 2 kg and 5 kg capacities are being replaced by plastic containers for edible oil and vanaspati, but are still in use for ghee packaging.

It is most unfortunate that reuse of tinplate containers is prevalent even though banned under GSR 575 (E) dated 4/8/95. 15kg tinplate containers used for packaging of edible oil, use not only seconds but also printed sheets, where inks could cause a major health hazard.

Tin plate container for edible oil

Glass: Glass bottles are heavy and fragile but are widely used for bottling olive oils and virgin olive oils in particular. This is not only due to marketing factors but also because glass containers prevent the permeation of oxygen molecules into the bottle, slowing down the autoxidation rate. Transparent glass, however, leads to photooxidation of olive oil and reduction of its shelf life. The use of coloured glass bottles prevents or slows down the oxidation process. Metal and glass are the only packaging materials that provide a virtually total barrier to moisture and gases. The word 'virtually' is used because such containers require a closure that incorporates other materials, such as polymeric sealing compounds in cans and in closures, through which oxygen can easily permeate and promote oxidation. The shelf life of edible oils packaged in metal containers or non-transparent glass bottles is dictated by the initial quality of the oil, processing conditions and filling operations.

Glass bottles for packaging of oils

Plastic: Plastic containers are a relatively new means of packaging edible oil and have been increasingly used in recent years due to their relatively low price and weight and ease of handling. The polymers most frequently used are PET, high density polyethylene (HDPE) and PVC. Although they do not provide as long a shelf life as metal containers, they are economical and suitable for use where a very long shelf life is not required.

PET is one of the most commonly used plastics in food packaging covering a wide range of packaging structures. It satisfies many important requirements including good aesthetic aspect with brilliance and transparency; suitability for colouring; good mechanical, thermal, and chemical resistance; low production cost; good barrier properties against CO_2; suitability for prolonged storage, easy recyclability and low weight. The trend toward incorporating modifier compounds into PET packaging resins has grown in order to produce containers with a high degree of clarity, in a wide variety of custom shapes, and free from residual acetaldehyde.

In addition, the incorporation of antioxidant stabilisers in PET increases its application in the food area, particularly for vegetable oil storage.

HDPE is largely used as a packaging material because of its tensile strength and hardness and good chemical resistance.

Blow-moulded HDPE containers in the form of bottles, jars, and jerry cans are used for packaging edible oils. PVC is a popular packaging material for edible oils in many countries, mainly due to its transparency, adaptability to all types of closures, total compatibility with existing packaging lines, and potential for personalized design features.

Mainly driven by issues such as the protection of the environment, PET has been supplanting PVC in the edible oil market. As with other transparent plastic materials, PVC increases light exposure of the oil, enhancing oxidation. UV absorbers can be added to plastic materials in order to reduce their light transmission.

Rigid, flexible and semi-flexible plastic package

Multi-layer pouches and paper-based cartons: In recent years, the adoption of multi-layer pouches for oil storage has increased due to consumer preference for unit packages. Generally, limited quantities of edible oil are packed in flexible pouches (up to 500g).

Flexible pouches may be manufactured from laminates or multi-layered films of different compositions and the pouches may be in the form of a pillow or stand-up pouch. The selection of a laminate or multi-layer film is governed primarily by the compatibility of the contact layer, heat sealability, heat seal strength, and shelf life required, together with machinability and physical strength parameters.

Multi-layer pouches and paper-based cartons

Active packaging: In order to reduce the diffusion of oxygen into bottled oil, various solutions have been used. The most popular involves the use of 'oxygen scavengers' (OS), which remove oxygen dissolved in the oil and provide a barrier to oxygen diffusion from the atmosphere. These scavengers can be easily incorporated into the packing material without altering its other properties.

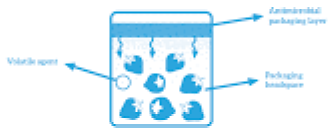


Figure 1. Antimicrobial packaging with volatile agent

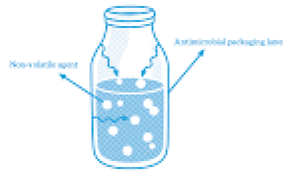


Figure 2. Antimicrobial packaging with a non-volatile agent

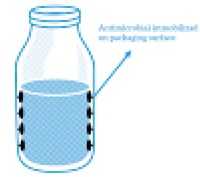


Figure 3. Antimicrobial packaging with the agent immobilized on the surface

Indian Standards for Packaging of Edible Oil, Vanaspati and Ghee

A variety of packaging materials/package types are used by the oil, vanaspati and ghee industries. The Bureau of Indian Standards has drawn up specification details/requirements, method of sampling, tests of different packaging materials/packages used by the industry. Table below gives a list of Indian Standards related to packaging of edible oil, vanaspati and ghee.

Indian Standards Related to Packaging of Edible Oil, Vanaspati and Ghee

Number	Description
IS : 10325 – 1989	Square tins – 15kg/litre for ghee, vanaspati, edible oil and bakery shortenings – specifications
IS : 10339 – 1988	Specification for ghee, vanaspati and edible oil tins
IS : 10840 – 1994	Blow moulded HDPE containers for packing of vanaspati – specification
IS : 12887 – 1989	Polyethylene Terephthalate (PET) Bottles for Packaging of edible oil – specification
IS : 12883 – 1994	Poly Vinyl Chloride (PVC) bottles for edible oil specification
IS : 14129 – 1994	Flexible packaging materials for the packing of vanaspati in 10kg and 15kg packs – specification
IS : 11352 – 1994	Flexible packaging materials for the packing of vanaspati in 100g, 200g, 500g, 1kg, 2kg and 5kg packs – specification
IS : 12724 – 1989	Flexible packaging materials for packaging of refined edible oil – specification (Under Revision)

Legislations

On account of being essential commodities, the edible oil, vanaspati and ghee are subjected to the following regulatory legislations:

- Prevention of Food Adulteration Act
- Directorate of Vegetable Oil Products
- Bureau of Indian Standards

- Directorate of Agricultural Marketing and Inspection
- Food & Drug Administration & Rationing Offices of State Governments in Essential Commodities Act
- Ministry of Civil Supplies
- Package Commodities, Weights and Measures Act
- Occasional interstate transport restrictions imposed by State Government

Conclusion

With such a wide array of packaging materials available to oils and fats manufacturers, the selection of packaging combines marketing, product quality and economic factors. Good packaging will ensure product safety and quality, as well as contributing to low wastage and better logistics. It will also ensure good shelf appeal, branding and visibility.

Over the years, the purchase of oils and fats in loose form is very common practice. This could be due to many reasons, such as a very high percentage of consumers belong to daily wage earning group. Apart from that, many shops have their own expelling units and therefore the oil sold is loose and fresh. Loose sale attributes to real value in terms of quality and quantity. The consequent effect on health and hygiene is often overlooked.

The gradually increasing per capita consumption and growing consumer awareness as well as increased capability to pay, the marketing of oil and fats is set to take a leap. The concept that the product in a pack gives more assurance and psychological advantage overrides that little extra cost. A package thus becomes the vehicle to ensure quality and quantity and the brand assumes relevance and significance. The country has witnessed the introduction of a large number of brands and surely many more will follow. A product of this nature for daily needs, demands a priority in terms of availability and safety.

UNIT-14

Modern Storage technologies for oilseeds

Sandeep Mann[1] & Sachin Mittal[2]

[1]Pr. Scientist (APE) TOT Division, ICAR-CIPHET, Ludhiana
[2]SRF, FFP, TOT Division, ICAR-CIPHET, Ludhiana

The term oilseed is applied to those seeds, including the soybean, which are processed for their oil. These are seeds contain high oil content and widely grown as a source of oil, they are considerably higher in protein and fat content than the cereal grains. These are used for extracting oils for edible purposes and for applications in pharmaceuticals, confectionery, perfumery and cosmetics industries. There are nine oil seeds majorily grown in India such as groundnut, castorseed, sesamum, niger seed, soyabean, sunflower, rapeseed and mustard, linseed and safflower. The coconut also is an important oilseed. In India, the total production of oilseeds in the year 2018-19 was 32.3 million tones. The area and yield of oilseeds in the year 2018-19 was 255 lakh hectare and 1265 kg/ hectare (Source: 4th Advance estimates (2018-19), Directorate of Economics & Statistics, Department of Agriculture, Cooperation & Farmers Welfare). So, to avoid post-harvest losses and to handle this large production there is a need of advance storage technology of oil seeds. Oil seeds are stored because oilseed presses are relatively slow compared to harvest speed, different crops come in at different harvest times thus, one crop may need to be stored while previous crop is pressed. Due to more susceptibility to quality deterioration of oil seeds, the storage of these is more difficult than cereal and pulse grains. They have also limited insect control options. Thus, a planned approach, careful management and a suitable storage system is required for the storage of oil seeds for a long time. Storage of oilseeds on-farm requires a great attention, as there are limited tools available as compared to cereal grain storage.

i) Storage of oilseeds:

Preservation of oil seeds is a complex process and it requires effective interactions among scientific disciplines like biological and engineering groups (White, 1992). Storage of oilseeds is influenced by three important factors viz. i) moisture content of the commodity ii) oil content iii) storage temperature and iv) relative humidity. During storage, oil seeds have increased risk of pest (insect and mould), free fatty acids, heating, cake formulation, discoloration and even fires. High relative humidity increases seed moisture content, leading to biochemical events such as increased hydrolytic enzyme activity, enhanced respiration and increase in free fatty acids. High temperature elevates rates of many enzymatic and metabolic reactions, causing more rapid deterioration. High temperature also accelerates the rate of peroxidation of lipids and free fatty acids. Under extreme conditions, heating leads to the spontaneous combustion of the commodities.

The development of rancidity has been recognized as the predominant cause of oil deterioration and reduction during storage. Due to the presence of double bonds in unsaturated fatty acids these fatty acids are susceptible to oxidation, which is a reaction between unsaturated fatty acids (regardless of whether they are in their free state or esterified in a triacyl glycerol molecule) and oxygen. It is well known that the rate of oxidation increases with the increase in oxygen concentration and the duration of exposure (the length of storage time). The oxidation of oil requires the presence of atmospheric oxygen. The longer the storage time the higher the oxygen availability and vice versa (Singh *et al.,* 2017).

Deterioration of oilseeds is initiated by respiration or carbon dioxide evolution and heat generation by oxidation reactions. The quality of oilseed is generally measured by testing the free fatty acids (FFA), oil colour, oil content, residues of unregistered chemicals, insects or evidence of insect damage, moulds and mycotoxins. Sound, intact seeds may release less than 10 cubic centimeters of carbon dioxide per gram of seed per day, while damaged, high moisture seeds may release 50 cubic centimeters or more of carbon dioxide per gram of seed per day. Further, various oxidation reactions generate heat which may increase the temperature of stored seed, accelerating deterioration even to the point of charring the seeds. Some of the other important factors affecting oil and meal quality during storage are activity of native enzymes present in oilseeds, infestation by insects and mites along with microbial activity. In general, high moisture content (above 14-15 percent moisture) in seeds has an adverse effect on oil and meal quality. Microbial growth (mold and/or bacterial growth) and enzyme activity accelerates the oil splitting and acid generation in high-moisture seeds. Oil in mature seeds may contain about 0.5 percent free fatty acids. However, if seeds are damaged mechanically or by frost or become wet during harvest, handling and storage, then the acidity of oil increases. Another important issue during storage of high-moisture seeds is sprouting. Sprouted seeds may have lower oil and higher free fatty acid content as compared to sound seeds.

Oil seeds are stored either indoor or outdoor. In indoor storage, the commodity is heaped on the floor (flat storage) or held as bag-stacks in warehouses. The outdoor storage may be as bag-stacks under tarpaulins, bunkers, pads etc. Oilseeds are usually stored in vertical cell-like storage bins. Vertical bins are preferred where ambient temperature is low. Copra (dried meat or kernel of the coconut) and undelinted cottonseed do not flow well. Hence, vertical bins are not suitable for this type of seeds. Copra is stored in large flat warehouses. Storage bins can be built of stainless steel, concrete, tile or other material. Concrete bins are used at places where average outside temperature is relatively high (95-113 ^{o}F/ 35-45 ^{o}C). Whole, intact, low-moisture oilseeds (about 8-10 percent moisture) may be stored for an extended time under suitable conditions. Proper handling and storage of oil-containing materials are very important to minimize deterioration and maintain good quality of both contained oil and meal. Ideal storage for oilseeds is a well-designed cone based (depends on size and shape of the oilseed) sealable silo fitted with aeration. The aim is to minimize damage to seed, ease of cleaning / hygiene for empty storages and suitability for effective use of aeration cooling. If seed requires insect pest control, the silo is then sealed (gas tight) for the required period as stated on the label (usually 7–10 days) to enable an effective phosphine fumigation to take place. For all storage types, extra caution should be taken to prevent storm rain / water ingress into storages.

Long term storage of oilseeds allows seeds to be harvested, stored and pressed for oil as the oil is needed. Stored grains that are at proper moisture content for storage need to be monitored as temperatures and outside moisture affect the storage conditions and quality of the grain. Not paying attention to storage can result in seeds that are not fit for pressing into good quality oil. After seeds have been dried to the proper moisture content for storage, they continue to respire and respond to temperature and moisture conditions in the storage container. As temperatures cool, condensation may form on bin or container surfaces or within the grain itself. These moist areas are prime locations for molds to start growth. For this reason, as outside temperatures cool the grain and container should be checked each week for condensation, and if moisture is found the grain should be aerated to reduce the temperature of the grain and remove the moisture so no more condensation occurs. When the grain has cooled to winter temperatures the periods between checks may be lengthened. Problems with moisture occur when outside temperatures are dropping in the fall and winter, not as temperatures increase in the spring.

Today, air dryers are essential components of modern storage facilities to maintain oilseed quality. Most oilseed storage bins are equipped with aeration ducts and ventilation blowers to cool the seeds. Since oxidation reactions are aerobic processes, a low oxygen atmosphere in storage bins helps to slow down oxidation and quality deterioration. Mature seeds can be stored longer than immature seeds because of the lower activity of oil-splitting enzymes in mature seed. Proper storage of harvested oilseeds also may contribute to desirable changes. For example, oil extraction yields from fresh soybeans can be lower than for soybeans stored more than five months. The storage of soybeans also decreases the chlorophyll content of green beans. Chlorophyll is not desirable in edible oils and needs to be removed during the oil refining process. The storage technology should maintain the moisture content, insect pest infestation and also it should be equipped with aeration and drying/cooling system to reduce the heat produced due to respiration load of the stored oilseeds.

ii) Moisture Content of Stored Oilseeds:

Oil seeds will be stored at a moisture content that does not accelerate the enzymatic and oxidative reactions leading to the growth of molds, bacteria or fungi. Thus, the oil pressed from these seeds is unfit for human consumption. This pressed oil may still be tolerable for processing into biofuel but human consumption leads to respiratory hazards. A general rule of thumb recognizes 10 % moisture content as being the high end for long term storage. Storing seeds with lower than 10 % moisture content should produce good results.

Table 1: The maximum moisture content for the safe storage of some oil seeds

Sr. no	Crop	Moisture Content (%)
1.	Copra, canola, mustard	7 %

2.	Palm kernels	8 %
3.	Sunflower	8.5 %
4.	Cottonseed	10 %
5.	Safflower	11 %
6.	Soyabean	13 %

Source: (Rajendran and Devi, 2004)

Table 2: Ideal oilseed moisture content for pressing

Sr. no	Crop	Moisture Content (%)
1.	Canola	7-9%
2.	Soybean	9-11%
3.	Sunflower	7-9%

iii) Ideal Oil seed Storage structure:

The ideal storage for oilseeds is a cone-bottom silo fitted with aeration and sealable for gas-tight fumigation. Generally oilseeds are higher-value grains as well as being prone to mould and insect attack. The ideal oilseed storage will have:

- Aeration cooling, with an automatic controller.
- Aeration ducting suitable for small seeds.
- Easy ways to inload and outload causing minimal seed damage from machinery.
- Access to the top of the grain stack to monitor temperature, moisture and insect activity.
- Quality sealing to meet the minimum three-minute half-life pressure test for gas-tight fumigation with phosphine.
- An easy-to-clean structure so grain can be put into a clean storage, free of insect pests and unregistered pesticide residues.

iv) Drying of oil seeds

The necessary unit operation after harvesting of oilseeds is drying for both storage and pressing purpose. This drying before storage minimizes the handling of seed. Even when moisture content of the seed is acceptable for storage, most seeds do not press well in the oilseed press unless their moisture content is about 7-9 %. After dried storage of seeds, these may be moved directly to storage bin through cleaning process and then, into oilseed press. The seeds may be dried with ambient or heated air. It is dependent on the quantity of seed to be dried and the equipment available. Ambient air is used for lesser quantity of dried material and the time available for drying is more. Hot air drying is necessary to handle the large quantity and more quickly to make room for more of the harvest. Air drying consists of allowing the grain to be in contact with outside air. For a small amount of seed, this can be accomplished by placing the seed in a thin layer outside on a dry day. Larger quantities require a blower mechanism to force air through the seed. Drying can be done in either a grain bin or with grain aerators screwed into the grain stored in a large tote, small bin or small wagon. There are many variables that affect bin drying, such as depth of seed in the bin, diameter and motor size of drying fan, diameter (size) of seeds, initial moisture content and desired moisture content. Bin floor perforation diameter can make a difference in how a given bin will perform with different seeds.

v) Aeration

Aeration is an essential storage tool for oilseeds. Correct management of aeration creates uniform, cool conditions throughout the seed bulk. It helps in slowing most of the quality deterioration processes. It is used to cool and maintain uniform temperatures and moisture in masses of stored grain. In aeration, a fan is used to pump outside air through grain in a storage facility. The grain temperature eventually attains the temperature of air traveling through void spaces in the grain mass. Without aeration, stored grain develops wide temperature differentials, increasing the chances of mold and insect development. Some of the benefits of aeration are listed below:

i. Maintains oil quality – free fatty acid, rancidity, color and odor.
ii. Reduces the risk of 'hot spots', moisture migration and mold development.
iii. Slows or stops storage insect pests breeding cycles by maintaining grain temperatures below 20^{o}C. eg. rust-red flour beetle breeding cycle ceases at 20°C.
iv. Maintains germination and seed vigor for longer when kept cool and dry.

Some of the factors that affect the amount of airflow through the grain are:

- Depth of the grain in storage.
- The amount of un-thrashed and foreign plant material in the grain.
- The size of the motor driving the fan.
- The area and type of ducting must also be adequate to disperse the air throughout the storage.

The power required for aeration increases rapidly as airflow rate and grain depth increase. A doubling of airflow rate or grain depth causes about a four-fold increase in power required. Different grain types have different resistance to airflow. For these reasons aeration fans vary greatly in horsepower. The airflow rate should be chosen according to how the aeration system will be used. If grain will be stored with safe moisture content and the aeration system will be used to prevent moisture migration, a light aeration system may be chosen. When storage will be attempted above one or two percent above safe moisture levels, grain temperature must be controlled more closely and a fast aeration system is desirable. In general, if grain must be cooled quickly, a faster airflow should be chosen.

Airflow Direction: Pressure vs. Suction

Pressure (upward) airflow is preferred by many grain storage managers over suction (downward) airflow because:

(1) Aeration fans are designed to deliver maximum airflow against pressure; fans push more mass of cool dense air than warm light air.

(2) Pressure fans develop more uniform airflow through the grain mass than suction systems.
(3) With pressure airflow, condensation on top of the grain is visible and usually dries up by the end of the aeration cycle; the problem is visible and solvable, whereas bottom condensation damage caused by suction fans cannot be seen until the bin is unloaded.
(4) Pressure fans eliminate winter bin roof collapse (roof vents may freeze over during suction cooling).

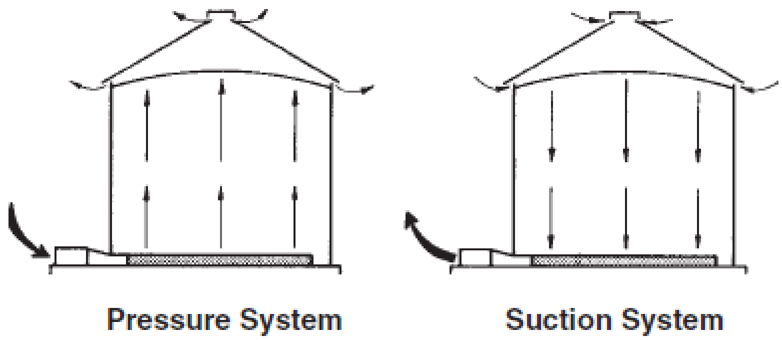


Fig: Direction of airflow in aeration systems.

Aeration Fans: Aeration fans may be either axial (propeller) type or centrifugal (squirrel-cage) type as illustrated in Figure 3. Axial type fans are less expensive and are normally used when static pressure will not exceed 4 or 5 inches of water. Centrifugal type fans with backward-inclined blades give more consistent air delivery over a range of pressures than most axial type fans and, in special designs, can operate at 20 or more inches of static pressure.

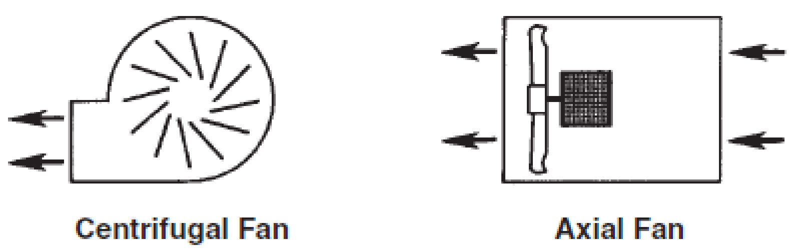


Fig: Centrifugal fan with backward-inclined blades and an axial fan

a) Aeration cooling: Aeration cooling involves an initial period of fan operation to cool grain followed by periodic operation to maintain even temperatures throughout the grain mass. Fan/s operating at low air flow rates around 2-4 litres per second per tonne (L/s/t) can be used for both cool seed and uniform seed temperature and moisture conditions in the storage. Fan's design and capacity is dependent on the type of the commodity dried ex. canola being a much smaller seed adds significantly more back pressure to the aeration fan. Therefore, in canola crop the aeration system is reduced by 40-60 %. Well managed cooling aeration decreases temperature to around 20 °C and below within days. It is advised to make visual inspections, check seed moisture content, use a temperature probe to monitor bulk seed temperature and sieve for insects.

b) **Aeration drying:** In natural air grain drying, damp grain is placed in a bin and the fan is operated continuously for several weeks until all the grain has dried to a safe moisture content. The high flow rates of 15–20 L/s/t are used for aeration drying systems to dry seed reliably. During aeration drying, fans should force large volumes of air through the grain bulk for longer periods of time. Thus, the drying fronts are pushed quickly through so seed at the top. This aeration drying at 30°C ambient air at 30-50% relative humidity is best suited for oilseeds without the risk of heat damage to seed oil quality. Monitor regularly and take preacautions that seed in the silo base is not over dried. Automatic aeration drying controllers are also available to run fans at optimum ambient air conditions. Some controller models provide the option to switch to either cooling or drying functions. Ensure that controller is fitted with a good quality relative humidity sensor.

c) **Heated air drying**: For hot air drying, the driers suitable for reducing moisture content are fixed batch, recirculating batch or continuous flow. As compared to oil seeds, canola seeds dries very rapidly thus, close attention must be given to temperature control and duration of drying time. The air temperatures used for the drying is at 40–50 °C range. For batch dryers when moisture content reading reach 8.5 %, turn off heat source and move to the seed cooling phase with fan only. Use storage aeration fans, before and after the drying process is important.

d) **Automatic controllers:** Often 'aeration cooling' fans are equipped with automatic controllers to turn on & off or a timer clock is used. However there is an automatic controller that selects the optimum run time and ambient air conditions to have fans on. The controller continually monitors air temperatures and relative humidity (RH) and may select air from only 2 or 3 days in a week or fortnight. One unit has the capacity to control fans on multiple silos.

Standard aeration fans operation:

- ✓ Run fans 24 hours per day during the first 4–5 days when grain is first put into the silo. This removes the 'harvest heat'. Smell the air coming from the silo top hatch. It should change from a warm humid smell to a fresh cool smell after 3–5 days. The first cooling front has moved through.
- ✓ For the next 5–7 days set the controller to the "Rapid" setting. This turns fans on for the coolest 12 hours of each day to further reduce the seed temperature.
- ✓ Finally set the controller to the "Normal" mode. The fans are now turned on for approximately 100 hours per month, selecting the coolest air temperatures and avoiding high humidity air.

vi) Insect pest control:

There are a number of insect pests that will cause infestation in stored oilseeds, usually favouring the grain surface. Some of these are rust-red flour beetle (*Tribolium Castaneum*), Indian meal moth (*Plodia interpunctella*), warehouse moths (*Ephestia spp*.) and psocids (*Liposcelis spp*.). These insects tend to favour the top of the grain stack and around silo outlets. These pests multiply rapidly in the food, shelter and warm, moist conditions. They can complete their full life cycle in about four weeks under optimum breeding temperatures of around 30^{o}C. To control the insect pest, phosphine fumigation is recommended to the oil seed crops. The key to successful phosphine fumigation is to apply only in gas-tight, sealed silos. This will ensure to reach the phosphine concentration at lethal dose required to kill insects at all life stages. Fumigation in a non-gas-tight silo is likely to kill only a percentage of the adult insects leaving the eggs, larvae, pupae and remaining adults to reinfest the grain. Most oilseeds absorb phosphine gas during the fumigation so it is vital to use the correct label dose rates and to follow the required ventilation periods stated on the label. The phosphine fumigation exposure period must be extended to 10 days if grain temperature is between 15°C and 25°C. Phosphine fumigation must take place in a gas tight, well-sealed silo. There should be no serious leakage points. Phosphine gas can be held at high enough concentrations in the silo for enough time to kill all the life stages of the pest (eggs, larvae, pupae, adults). Fumigations are likely to fail where there are points of gas/ fresh air leaks in a silo. Pressure testing prior to fumigation is a vital step in identifying and locating gas leaks.

vii) Fire risk:

The dust and admixture (foreign matter, organic and inorganic impurities) attached with the oilseeds leads to a serious fire risk. The operations where constant vigilance required in processing are harvesting and drying. The threat can be reduced by good cleaning, housekeeping in and around equipment and keeping a close eye on problem sites. To control the fire, the plan of action and standard operating procedure is also understood by the operators. Without careful management, high moisture content canola seeds and/or high levels of admixture pose a risk of mould formation, heating and fire through spontaneous combustion.

Summary

The three important unit operations in the oil seeds processing is drying, storage and oil pressing. Due to smaller capacities of oil seed processing plants, different varieties of oil seeds and huge production quantity, the crop is required to be stored. Not paying attention to storage can result in seeds that are not fit for pressing into good quality oil. The oil seeds would continue to respire and respond to temperature and moisture conditions after drying of seeds at proper moisture content for storage. As temperature cools, condensation on the grain surfaces and bin starts the growth of molds. Thus, the grains are required to be aerated to increase the temperature and moisture of the grains. Aeration helps in maintaining uniform conditions throughout the storage period. The oil seeds are also fumigated with phosphine gas to control insect pest during storage. Cleaning silos and storages thoroughly and removing spilt and leftover grain removes the feed source and harbour for insect pests.

Therefore, the most important factors during storage of oil seeds is moisture content, relative humidity and temperature. All the chemical and oxidative reactions initiates from the increase in moisture content. Thus, complete monitoring of inside and outside the storage conditions is mandatory for the oilseeds storage. To retain the market value, care must be directed at maintaining oil quality, visual appearance, freedom from moulds, insect pests and unregistered chemicals.

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Advances in Processing technologies of animal fats and their utilization

Manish Kumar Chatli[a], Jyoti [b] and Radhika Sharma[b]

[a]Dean, College of Veterinary Science, Rampura Phul, Guru Angad Dev Veterinary and Animal Sciences University, **Email:** manishchatlilpt@gmail.com
[b]PhD Scholars, Department of Livestock Products Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Email: jawlajyoti@gmail.com

Animal fat is the fat derived from the fat tissue or fat obtained from the products (milk, meat, carcass, wool) and their byproducts of animals. Fats of land animals are an efficient, low-cost and high energy source for human and animal nutrition. It can be categorised as milk fat, tissue/meat fat (Tallow-cattle and sheep; Lard-pigs). Fat is also classified according to the fat's origin, colour, melting point, the amount of polyunsaturated fatty acids (PUFA), highly unsaturated fatty acid (HUFA), free fatty acids and impurities. In the past animal fats have been primarily used as raw materials for margarine, making soaps and detergents, candles and stearic acid. Annually approximately 10 million MT of animal (milk, meat, wool) fat is being recycled in India.

Since Dwapar yug (Krihan kal), milk fat in the form of butter or *desi ghee* is being used as a part of human diet. Even during Satyug (Rama’s time), the use of desi ghee for lighting of lamps is quoted. Similarly, tallow/lard were probably used prehistorically for lighting and softening, and waterproofing of garments. Tallow candles were in widespread use by the common people before tallow-based soap. Soap may have been made by the Romans, Phoenicians and Babylonians as early as 2800 B.C. Before soap was widely used, candles were the main product made from tallow.

Quality of Animal fat:

Animal fat is broadly classified as edible of inedible fat. However, the quality of animal fat both edible and inedible is judged by titre, free fatty acid (FFA), FAC color (standard set up by the Fat Analysis Committee of the American Oil Chemists Society), or Lovibond color, moisture impurities (insoluble), and unsaponifable matter (MIU).

Titre: It refers to the softness or hardness of a animal fat or the temperature at which fats solidify. Lard has titre <40℃ whereas tallow has titre >40℃. Type of feed can affect the titre. Peanuts fed pigs produces different titre than that of corn fed (higher). The seller shall allow the buyer 0.2% of contract price for each 0.1% titre deficiency, fractions in proportion. The buyer may reject the tender when titre deficiency exceeds

0.5° C (0.9° F).

Free Fatty Acid (FFA): FFA is a percentage of free oleic acid of total sample weight. FFA is considered as an indication of the degree of spoilage. It is directed by cleanliness of material and equipments, microbial load/purification of raw material and processing conditions (temperature & pressure. FFA should not be more than 2%.

Fat Analysis Committee Color: Fats can vary in color from almost white to yellow. Color can be affected by breed, feed, age, condition, and location of livestock. Green color in tallow comes from contact with gut contents, i.e., the chlorophyll in digested plant. Brown coloration occur due to overheating of raw material.

Moisture, Impurities (Insoluble), and Unsaponifiable Matter: Fat and moisture are immiscible. So, pure fat is virtually free of moisture. Water in animal fat (tallow/lard/butter oil) is undesirable because it acts as a medium for the growth of bacteria and the action of fatsplitting enzymes. Moisture is expressed as parts per centum (parts per hundred by weight) and permitted upto 0.2%.

Impurities in fat can be soluble or insoluble. In general, animal fat may contain 95% of fatty material rest are tissue with other foreign materials such as protein fines, finely ground bone, hair manure and gut contents. These insoluble impurities problem is more common in lard/tallow/lanolin. These impurities can be removed by filtration, settling or centrifuging. Oil soluble impurities include trace elements (copper, tin, zinc etc.) and polyethylene. Polyethylene in tallow/lard is allowed as maximum 50 parts per million. The presence of polyethylene in animal fat shows up as black specks in the soap in the settling and filtration processes. The dissolved polyethylene doesn't settle or filter out.

Unsaponifiable Matter: It is the fatty material in a tallow/lard that cannot be converted into a soap by the use of an alkali. Unsaponifiable Matter occur naturally in a fat in minor quantities like cholesterol is natural unsaponifiable fat, lubricating oils and greases are added/contaminants unsaponifiable matter. It can impart objectionable odors and downgrade the market value.

Bleachability: The bleach test is a color test conducted with an activated clay and a Lovibond tintometer. In general, high temperature fixes color in tallow, and the bleach test is a good indication of the temperatures and handling condition to which a tallow has been subjected. The cleaner the raw material and the lower the temperatures and pressures used, the lighter will be the bleach. Soap manufacturers bleach all tallows prior to any recoloring.

Saponification number of iodine value: It is used to identify the types of fats and oils Saponification number indicates the average length of fatty acid chains whereas iodine number indicates degree of unsaturation. Iodine value is low for animal fats and high for vegetable oils. Higher the iodine value, i.e., the more carbon double bonds, the lower becomes the melting point.

Peroxide value: It indicates the rancidity, lower the value better the stability. Fresh fats have a peroxide value of 12, whereas rancid fats have a peroxide value of 15-20.

Smoke point: Smoke point directly related to FFA content in fat. It is the temperature at which the fat may be heated before it begins to smoke. More the FFA lower the smoke point.

Processing: Rendering is the commonest and most acceptable method of processing of animal fat from the carcasses.

Wet Rendering: The name wet-rendering is applied where the raw material is processed with added water or condensate derived from steam. Unlike open pan rendering where rendering was carried out at atmospheric pressure, wet rendering is carried out at pressure under steam in a pressure vessel. The wet-rendering tank is usually a vertical cylindrical boiler, having a cone shaped bottom, with a gate valve outlet of 8-12 inches in diameter. At the top of the tank is a charging hopper through which the material is loaded and a valve through which obnoxious gases escape without reducing the pressure. Higher is the steam pressure used, the quicker is the disintegration process. For this reason, large plants often render the raw materials (offal and condemned carcasses) at a pressure of 60 lbs per sq inch (60 psi). However, such high pressure may reduce the quality of the final product, especially of the fat. Therefore, the steam pressure of 40 lbs is usually recommended and applied. The time required to disintegrate the tissue and to free the fat vary from 5 - 8 hrs depending upon the character of the offal. Blood should not be put into the tank until the fat has been drawn off, as blood imparts a dark colour on fat. Moreover, haeme iron present may act as a pro-oxidant initiating auto-oxidation process resulting in rancidity.

After cooking is complete, the contents of the tank are allowed to settle for about two hours. Then the fat and water are drawn off through the side cocks. After removal of water and grease the digested-mass of meat and bones (slush) is taken out. The slush may contain up to 55% of moisture and about 15% fat. A hydraulic press is used to further reduce the moisture and fat content. Sometime the slush is further dried in a dryer for reduction of moisture which should not exceed 8% of the finished product.

The wet rendering may not be recommended for a bigger and regular working establishment as it requires two pieces of equipment to dry the products completely and also results in loss of soluble proteins in the stick water.

Dry Rendering: This method is commonly applied where the volume of offals is very high. A dry rendering cooker is a horizontal steam jacketed cylinder equipped with a set of agitators which keep the charge in continuous motion. The steam is applied into the jacket only and not to the materials to be processed. In this process all the unwanted moisture is eliminated without the loss of any nutrients. The dry rendering process yields 20% higher than the wet rendering (FAO, 1978) as the water containing water soluble extractives and soluble proteins are not discarded.

The dry heat transmitted from the steam jacket to the raw material converts the moisture present in it into steam, which gradually builds up the internal pressure. This pressure combined with agitation, disintegrates the materials and breaks down the fat cells. In other words the meat is cooked and fried in its own fluids. The sterilized material contains dispersed meat and fat and is called cracklings. The fat in the cracklings may be reduced commonly by mechanical methods. It includes:

a. Hydraulic press, developing pressure up to 4,000 psi

b. Centrifugal turbine fat extractor

c. Fat expeller

However, chemical means can also be used and commonest method is solvent extraction using non-aqueous solvents such as petroleum ether, heptane, perchlorethylene which leave as low as 0.5% fat in the cracklings. The cracklings after fat extraction are milled to a fine powder.

Low Temperature Rendering (LTR): It is a newer method developed to resolve the problem of quality/dark colour of rendered fat (tallow/lard). In this method the energy consumption is reduced by 50%, which reduces the recurring expenses substantially. However, the capital investment required is quite high and trained technical staff is required for regular operations. The melting of the material is carried out at a low temperature of 70°C to 100°C. In this water is removed prior to drying this lead to lower effluent water and lower losses of the nutrients. The quality of fat is very high, therefore fetches more price in the market. The stock feed/meat-cum-bone meal have low fat content and have high nutritional value (protein and mineral content). Meat Industry Research Institute of New Zealand (MIRINZ) provided the guidelines of the method.

Advantages of LTR:

1. Better physical and chemical quality of rendered fat
2. Better nutritional value of meat cum bone meal.
3. Less production of effluents.
4. Less operational costs.

Semi-moist Rendering: This technology has been recommended by Dr Mahendra Kumar Central Leather Research Institute, Chennai for the small units in the book entitled ***'Waste Disposal Systems in Slaughter Houses Suitable for Developing Countries'***. It is known as zero waste technology, simple in operation, economically viable, environmentally clean and require low capital investments. The meat meal produced by this process has protein content around 65% and fat being about 5-7% on moisture free basis.

Steps in the process of Semi-moist Rendering

- Mincing: Soft tissues separated from bones and minced with the help of meat mincer. Mincing helps in loosening the structure and reduction in the size of the tissues resulting in increase in surface area.

- Drying of excess moisture from mince is carried out by any means oven drying, pan drying or open sun drying
- Rendering is carried out at a temperature of 115-145ºC for 30 min. As the raw material was minced so with the rise in temperature above 55ºC and loses 2/3rd of water originally held by it. Depending on the weather one cooking cycle takes about 8-10 hrs.

Biodiesel: Biodiesel is simply a fatty acid methyl ester and can be produced from any oil or fat. It has the same ignition properties as mineral diesel and can be blended in all concentrations. This means it can be used directly in diesel cars and trucks. This resulted in the Biodiesel sector being the fastest growing single market for fats over the last decades. As per Renewable Energy Directive (RED), biodiesel made from animal fats has a greenhouse gas emission saving potential of 81%, compared to soy biodiesel (31%) nearly 2.5 times higher. This is due to the fact that animal fat is not produced for this purpose but a by-product of the meat chain. However, compared to the production of biodiesel from vegetable oil, production from animal fat is more challenging and expensive. This is linked to typical constituents like salts, phosphorus, sulphur, and plastics, which cannot be totally removed in a prior step. Nevertheless, as animal fat is only a by-product of the meat chain, its use for biodiesel is always linked to meat production and cannot be increased as such.

Wool fat/wool wax/lanolin: Wool fat can be separated from water used to wash the wool. Despite the still often used name wool fat it is not a "fat" because it consists of wax. The correct name wool wax should therefore be used. Lanolin may contain paraffin oil and water. Its application is mostly in pharmaceutics/skin care.

Fish or Marine oils: Marine oils are usually by-products of fish caught to be processed as a protein source. However, there are also some fish that are caught with the main purpose of oil production. As a source, a broad spectrum of species from small fish such as sardines to large mammals such as whales is available. Marine oils contain huge amounts of polyunsaturated fatty acids (PUFA), specifically n-3 fatty acids, especially eicosapentaenoic acid and docosahexaenoic acid, which make them a promising source for the supplementation of these nutrients. Generally, the fat nutritional properties of marine fish are largely determined by the advantageous fatty acid profiles that have health-promoting properties. However, the fatty acid compositions of marine fish vary from species to species and can be influenced by many intrinsic and extrinsic factors, such as diet, age, size, and environmental conditions. The fatty acid composition of marine oils is most commonly determined by gas chromatography with flame ionization detection (GC-FID).

Animal fat for Food: Around the globe, the diets of relatively more urbanised populations are characterised by a higher content of animal products than the less diversified diets of rural communities (WHO, 2003). Food fat- the esters of glycerol and three fatty acids plays an important role in the human diet as it contains essential nutrients necessary for health. Fats provide the body with energy, assists in the transport and absorption of fat-soluble vitamins A, D, E, and K by the intestine, act as structural elements of cell walls, plays vital roles as a source of membrane constituents, and metabolic and signaling mediators. In addition it also contribute satiety, flavor, and palatability to the diet. However, a high fat intake is associated with obesity, type 2 diabetes, cancer, and coronary heart disease. Animal fats, which contains a high proportion of saturated fatty acids, are often the focus of attention when it comes to reducing the share of fat in the diet. Lipids are the generic names assigned to a group of fat-soluble compounds found in the tissues of animals that are insoluble in water but are soluble in organic solvents such as ether and chloroform. Lipids that are important to our discussion include fats and oils (triglycerides or triacyglycerols). Physically, oils are liquid at room temperature, and fats are solid. Chemically, both fats and oils are composed of triglycerides. Although many animal parts and secretions may yield oil, in commercial practice, oil is extracted primarily from rendered tissue fats obtained from livestock animals like pigs, chickens and cows. Dairy products also yield popular animal fat and oil products such as cheese, butter, and milk. Hence, animal fats can be categorized as milk fats, rendered fats, and fish oils (marine oils).

Milk fats: The fat present in milk exists as small globules throughout the milk. The fat globules are less dense than water and rise to the top forming a cream layer. The process of "homogenisation" stops this occurring as the fat globules are broken up into smaller globules and therefore do not rise to the top. The fat content of milk varies depending on the product e.g. whole standardised milk has a minimum fat content of 3.5g/100ml or 3.5% fat, semi skimmed milk contains 1.7g/100ml or 1.7% fat, 1% fat milk contains 1g/100ml and skimmed milk contains 0.3g/100ml or 0.3% fat. Milk fats are made from a range of different fatty acids and the composition of the fatty acids varies depending on the breed of animal from which it was produced, the feed given to the cow, the geographical location, the season and the stage of lactation.

Milk fat is primarily triglycerides (98%) containing the glycerides of as many as 400 fatty acids, both saturated and unsaturated. Briefly, about one third of the fat in milk is monounsaturated. The remainder is mostly saturated, but some polyunsaturated fats and other minor fatty acids are also present. Compared with other fats, milk fats contain remarkable amounts of short-chain fatty acids ranging from C4 to C1O. Milk saturated fatty acids are usually associated with increased risk of cardiovascular disease through their cholesterol raising effects; however studies have indicated that this does not apply to all saturated fatty acids in milk. In fact some of the saturated fatty acids in milk may reduce the cholesterol raising effects of other saturated fatty acids. Some are even associated with a direct cholesterol lowering effect which is linked with reducing the risk of cardiovascular disease. Studies have also identified other fats in milk such as Conjugated Linoleic Acid (CLA). Conjugated linoleic acids (CLAs) is a Trans-fat or a series of positional and geometric isomers of linoleic acid (*cis*9, *cis*12-C18:2, n-6) which may potentially protect against several major chronic illnesses. The isomer *cis*9, *trans*11-CLA, named rumenic acid, is the most prevalent—75%–80% of the total CLA content in milk (Schmid et al., 2006). The fat fraction of milk also includes the essential nutrients as vitamins (A, D, E, and K), or vitamin precursors (carotenoids), and essential polyunsaturated fatty acids.

Fat and fatty acid content of meat and meat products: The fat deposition in muscles and the meat fatty acid (FA) composition are factors that affect the meat quality and primarily influence flavor, juiciness, and tenderness Furthermore, fat protects the carcass from the cold; is considered a visual attractive and striking the meat acceptability by the consumer. Therefore, it is important in meat industry. In addition to fatty tissue under the skin (subcutaneous fat) and offal fat, it is visible as depot fat stored between the muscles (intermuscular) and can be detected as marbling within the muscle (intramuscular). Meat fat after processing is called as tallow/lard/grease depending upon the species of the animal, collectively known as rendered fats. Meat and meat products vary greatly in their fat content according to the level of trimming, animal species, age of the animal, part of the carcass used, breed and gender. The fat content and fat composition is also affected by animal feeding (Wood et al., 1999). Meat fat comprises mostly monounsaturated (40–50%) and saturated fatty acids (30-50%), with oleic (C18:1) (30–40% of total MUSFA), palmitic (C16:0), and stearic acid (C18:0) being the most ubiquitous (Diaz et al., 2005). Processed meat products, such as sausages and salami, tend to be high in fat whereas lean meat is generally consist of about 5–10% fat. Food products from ruminant animals also harbor trans fats known as ruminant trans fats. Unlike their industrially-produced counterparts, naturally-occurring ruminant trans fats are not considered unhealthy. The most common is conjugated linoleic acid (CLA), which is found in beef and lamb. Although CLA has been linked to various health benefits including weight loss, still, large doses in supplements may have harmful metabolic consequences. It was observed that meat from grass-fed ruminants contains more CLAs, omega-3 fatty acids, beta-carotene, and vitamins A and E than meat from indoor-fed animals.

Conclusions: Though various studies showed beneficial effects of the animal fat on neoplastic and atherosclerotic processes as well as a cholesterol-lowering effect. In-addition, few epidemiological studies demonstrated that C18:3n3 is associated with a reduced risk of cardiovascular diseases, whereas EPA and DHA have beneficial effects on proper brain and visual development in the fetus, and maintenance of neural and visual tissues throughout life. Animal fat also exert an anti-inflammatory activity and facilitate the action of the digestive enzymes, especially the gastric lipase, making hydrolysis faster and more complete than that of long-chain triglycerides. Not only is body fat an energy reserve, it also constitutes padding for the protection of vital organs as well as acting as an insulator and thus being involved in heat regulation. Various fat components (phosphoglycerides, sphingolipids, cholesterol, glycolipids) are essential components of cell membranes and cell surface structures, and some lipids act as hormones, hormone-similar substances, and second messengers. Therefore, animal fat and lipids can be effectively used as a source of energy in diet to improve the human health as well as to decrease the chances of fat related diseases.

There is a great discussion of use of animal fat as '***food or feed'***. The conversion of animal fat into biodiesel has opened up many opportunities for the fat processor and environmentalists.

UNIT-18

Problem Management and enhancement of entrepreneurial competencies

Dr. Ramandeep Singh

Professor, School of Business Studies, PAU, Ludhiana

What is an entrepreneur?

An entrepreneur is a person who organizes and manages a business undertaking, assuming the risk for the sake of profit. Any person (any age) who starts and operates a business is an entrepreneur.

Agricultural students have been entrepreneurs since the beginning of agricultural education.

The **Smith-Hughes Act** of **1917** (which provided federal funding for agricultural programs) required all students to have an entrepreneurship program but they were not called entrepreneurs back then.

Early entrepreneurship

These early entrepreneurship programs were called different names: Farming program, Productive or production Enterprises and Ownership. The early entrepreneurship programs primarily involved raising livestock and growing crops.

Today agricultural students are involved in different types of entrepreneurial activities. Entrepreneurship in agriculture can still be raising livestock and growing crops, but it can be much more than that.

Agricultural Entrepreneurship (also called Agripreneurship)

The student plans, implements, operates and assumes financial risks in a farming activity or agricultural business. In entrepreneurship programs, the student owns the materials and other required inputs and keeps financial records to determine return to investments

Examples of Agripreneurs

- Lawn maintenance service
- Raise and sell fishing bait
- Custom crop harvesting
- Pet sitting service

- Fishing guide
- Tractor and farm equipment detailing
- Operating a roadside marketing-selling produce

Three aspects of entrepreneurship

1. The identification/ recognition of market opportunity and the generation of a business idea (product or service) to address the opportunity.
2. The marshalling and commitment of resources in the face of risk to pursue the opportunity.
3. The creation of an operating business organization to implement the opportunity- motivated business idea.

Characteristics of successful Entrepreneurs

- **Drive**: Entrepreneurs can expect long hours, high stress and endless problems, as they launch a new business.
- **Thinking ability**: It encompasses creativity, critical thinking, analytical abilities and originality.
- **Aptitude for human relations**: It recognizes the importance of the ability to motive employees, sell customers, negotiate with suppliers and convince lenders. Personality plays a big role in success in this area.
- **Communication skills**: The ability to make yourself understood.
- **Technical ability**: It speaks to the need of the entrepreneurs to know their product and their market. they must consider the long and short term implications of their decisions, their strengths and weaknesses, and their competition. In short, they need strategic management skills.

Advantages

- You are your own boss
- Enjoy the profits from your efforts
- Sense of pride in your business
- Flexibility in your work schedule

Disadvantages

- Need to put in long hours
- Need money to start
- Have to keep up with government rules and regulations

- May have to make hard decisions
- May lose money

Types of entrepreneurs:- ***Clarence Danhof*** classified entrepreneurs into four categories.

1. **Innovative entrepreneurs:** An innovative entrepreneur in one, who introduces new goods, inaugurates new method of production, discovers new market and recognizes the enterprise.
2. **Imitative entrepreneurs:** These types of entrepreneurs creatively imitate the innovative technical achievement made by another firm.
3. **Fabian entrepreneurs:** Fabian entrepreneurs are characterized by very great caution and skepticism to experiment any change in their enterprises. They usually do not take any new challenge.
4. **Drone entrepreneurs:** They are characterized by a refusal to adopt any change even at cost of severely reduction of profit.

Role of competition in Agripreneurship

It may be hard to believe but competition is good for you. It drives innovation, inspires perseverance and builds team spirit. The presence of competition increases the market for everyone. You can develop your own competitive monitoring system by tracking the flow of information about your business and your market. Tracking information is largely a matter of networking. In addition, scan the value chain for your product or service.

Role of cooperation in Agripreneurship

It is important for organizations to identify and cooperate with partners that have competitive strengths in particular aspects of an agripreneurship ecosystem. This cooperative approach is productive, efficient and sustainable method of fostering agripreneurship.

Now-a-days, **Co-opetition** is a neologism coined to describe cooperative competition.

Segments within the Food Processing Industry according to Government of India

- Dairy
- Fruits and vegetable processing
- Grain processing
- Meat – poultry processing

- Fisheries
- Consumer foods including packaged and convenience foods

  We need to develop different products at different levels for promoting agripreneurship in today’s era. These levels are:
- Village level
- Block level
- District level
- At SHGs level
- Individual level
- Cluster form

UNIT-19

Plant layout and maintenance for oil processing equipment

Dr. Sandeep P Dawange
Scientist (Agricultural Structures & process Engineering)
ICAR-Central Institute of Post-Harvest Engineering & Technology, Ludhiana, Punjab

Food Plant Design:

The manufacturing of food products of consistent quality and nutritional value at affordable cost is essential to the success of the food industry today. Plant design refers to the overall design of a manufacturing enterprise / facility. It moves through several stages before it is completed. The stages involved are: identification and selection of the product to be manufactured, feasibility analysis and appraisal, design, economic evaluation, design report preparation, procurement of materials including plant and machinery, construction, installation and commissioning. The design should consider the technical and economic factors, various unit operations involved, existing and potential market conditions etc.

General design considerations:

a. Food processing unit operations
   Food processing involves many conventional unit operations but it also involves many which differ greatly from those usually encountered in the production of industrial chemicals.
b. Prevention of contamination:
   Different measures for avoiding the contamination at all level of processing must be in place for food plant to work effectively.
c. Sanitation:
   Sanitation, which helps prevent contamination, should be facilitated by providing or using: impermeable coated or tiled floors and walls, at least one floor drain per every 40 m2 of wet processing area, special traps for such drains, pitched floors that ensure good drainage, etc.
d. Deterioration of product & raw materials:
   To minimize product and raw material deterioration, provisions should be made for refrigerated and controlled environment storage areas, facilities to carrying out quality assurance tests etc.
e. Seasonal production:
   Food plants have to be sized to accommodate peak seasonal flows of product without excessive delay, and in some cases, have to be highly flexible so as to handle different types of fruits and vegetables.

Plant layout

Plant layout problem is defined by Moore (1962) as “plant layout is a plan of, or the act of planning, an optimum arrangement of facilities, including personnel, operating equipment storage space, materials handling equipment, and all other supporting services, along with the design of the best structure to contain these facilities.

Objectives and advantages

Some of the important objectives of a good plant layout are as follows:

- Overall simplification of production process in terms of equipment utilization, minimization of delays, reducing manufacturing time, and better provisions for maintenance

- Overall integration of man, materials, machinery, supporting activities and any other considerations in a way that result in the best compromise.
- Minimization of material handling cost by suitably placing the facilities in the best flow sequence
- To achieve an optimum effective flow of materials (raw materials, and in-process materials) through the plant.

Advantage of efficient plant layout are as follows:

- Saving in floor space, effective space utilization and less congestion / confusion
- Increased output and reduced in-process inventories
- Better supervision and control
- Worker convenience and worker satisfaction.
- Better working environment, safety of employees and reduced hazardsminimization of waste and higher productivityavoid unnecessary capital investmenthigher flexibility and adaptability to changing conditions.

Types of layout problems/situations

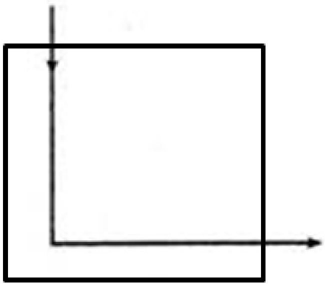
The plant layout problems can be classified into four types as follows:

Planning completely new facility
Expanding or relocating an existing facility
Rearrangement of existing layout
Minor modifications in present layout

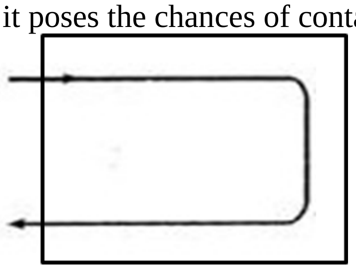
Flow patterns

a. I – Flow / Line flow: In this, Material enters at one end & leaves at other end. This type is economical in space and convenient in I-shaped buildings with long lengths and smaller width. I-Flow is preferred for building automobile Industries.

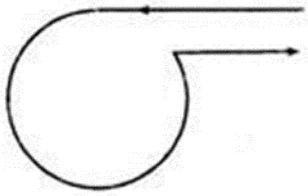
b. L Type Flow:It is similar to the I-Flow and used where I-line cannot be accommodated in the available space



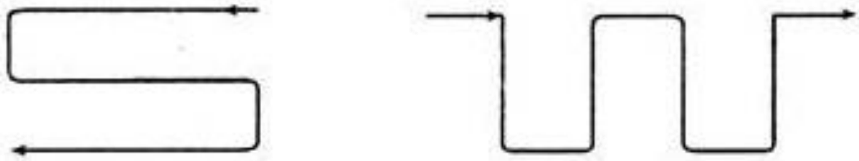
c. U Flow: This type of layout offers easy supervision. In this, raw material entrance & finished product dispatch is located on same side of the plant. This layout is not suitable for food processing industry as it poses the chances of contamination.



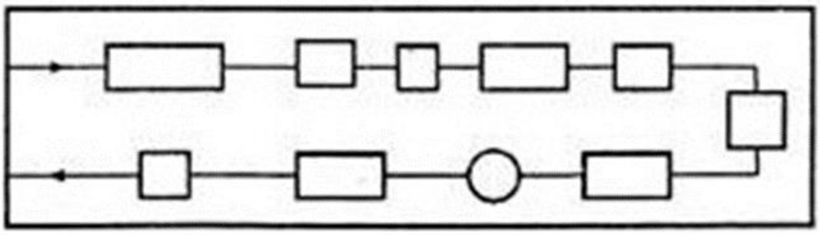
d. O Flow: Operations are performed on rotary table or rotary handling system where the components of final product are inspected at the end stage. This layout suitable for assembly line of bulbs, electric motors etc.



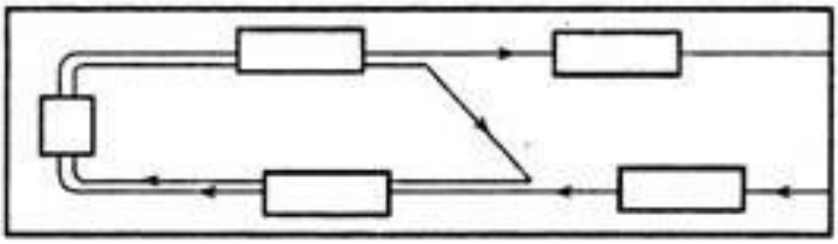
e. S Type Flow: this layout is used for long process lines that requires zigzagging on plant floor. This type provides efficient utilization of space and is compact enough to allow effective supervisionEffective space utilisation and supervision.Separate receiving and shipping area in this layout makes it suitable for food process plant.



f. Unidirectional Flow: in this layout, material is passed from one work station to another without having to re-pass along the same path. This system is suitable for application in food process plants.



g. Retractional Flow: In this, the flow is repeated i.e., two or more non-consecutive op-erations are performed on the same machine. The aspect of flow is decided by consideration of machine utilization. The operations such as dehushking of food grain, peeling of fruits/vegetablesmay require to use this layout to address the issue of incomplete dehusking/ peeling respectively.



h. Upward and downward processing: As apart of vertical flow lines, these line are defined based on movement of material in the plant. In upward processing, materials are fed from the bottom floor while the finished product is received at the top floor. In downward processing, materials are fed from the top floor and gravitational force is used for operation of roller lines, chutes, pipes, buckets, hand operated lifts, etc.

i. Process / Functional Layout: it is a process oriented layout wherein processing units/equipment are organized by their functions into departments/sections. The material moves from one section to other as per the process need. It is economical when flexibility/rerouting of material is the basic system requirement. It offers the advantages such as better equipment utilization, higher flexibility, etc.
j. Product/ Line Layout: in this type of layout, only one product, or one type of product, is produced in a given area in plant. The raw material enters at one end of the line and goes from one operation to another rapidly with minimum of work-in-process, storage and material handling. The equipment are arranged in order of their appearance in the production process. It offers the advantages such as high volume of production for adequate equipment utilization, reduction in material handing & less work-in-progress, better utilization and specialization of labor. The layout reduces congestion and smooth flow of material, effective supervision and control.

Layout for Oilseed processing unit:

The sequence of equipment in layout of oilseed processing plant should be as following

a. **Shelling / Dehusking Equipment:** These category equipment must be close to raw material storage space to enable easy feeding of raw material. The equipment must be accessible by open door for operation as well as ventilation purpose. There should be arrangement for direct outlet for husk/ shells out of the processing plant.
b. **Cleaning / grading equipment:** These equipment must facilitated by continuous manual / automatic feeding as it will ultimately define the plant throughput.
c. **Oilseed roasting equipment:** Oilseed are preheated for easy release of oil from feed material and enhance productivity at given set of working conditions of auxiliary equipment. These equipment requires connection to steam boiler or arrangement for feeding of coal/gas/firewood and efficient Exhaust system.
d. **Oil expellers:**it forms the heart of oil processing / extraction unit and should be installed away from dust generating equipment. Clean working environment can be provided by separating it from rest of the equipment by means of temporary partition.
e. **Refining equipment:**These are required for obtaining good colour & high quality final product. Refining process removes phospholipids, FFA, Pigments, odour and impurities from edible oil.
f. **Edible oil filling and packaging machine:** Filling and packaging station should be installed in clean working environment.
g. **Storage of packaged product:**Cool and dry place should be selected for storage of processed and packaged oil. The storage area should be properly separated from processing area, and well connected with road for transportation.

Maintenance of processing plant & equipment:

The term maintenance is defined as set of action or a combination of the various activities carried out in order to maintain or restore an equipment/ machinery to conditions acceptable to user. This is the common and important issue faced by the industry and affects the productivity of industry. Proper maintenance is instrumental in reducing equipment downtime, and improve product quality. Generally, the budget for plant maintenance costs and component costs is much higher than other processing costs of machines. It is estimated that averagemaintenance costPalm kernel shell processing machine is about 30.21% of total processing cost.

a. **Cleaning:**

Cleaning of processing equipment is a fundamental part of maintenance process. Proper cleaning of equipment enables quick identification of ‘leaks and creaks’ (such as grease leaking from bearing seals) during operation. The detailed cleaning process involved following steps:

- Removal of gross debris from surface, hopper, barrel, outlet of equipment
- Rinsing with water to remove any additional loose debris
- Washing with water containing a detergent or chemical deemed appropriate by the particular industry's standards.
- Followed by a rinse to remove any detergent/chemicals used.

Selection of cleaning method depends on type of processing area, design of equipment, equipment's zone in the facility (e.g., food contact or not) and target concerns (e.g., pathogens and allergens).

Solvent cleaning:

This involves removing contaminants from a surface with an organic solvent without physically or chemically altering the material being cleaned. This can be achived by Vapor degreasing, Ultrasonic vapor degreasing, Ultrasonic cleaning with liquid rinse and Solvent wipe, immersion or spray method.

In case of small processing units, solvent cleaning is undertaken by means of solvent wipe, immersion or spray method. The material used for cleaning should be freshly laundered cotton rags, new cheese cloth, or cellulose tissues, etc.The wiping material should never be immersed in the solvent. General solvents used for cleaning are given in following table:

Acetone	Caustic Soda Flakes / Pearls
Citric Acid	Nitric Acid
D.I. Water	Oxalic Acid
Kerosene	Phosphoric Acid
Lime Powder	Sodium Hypochlorite (Bleach)
Methanol	Sulfamic Acid
Methyl Ethyl Ketone (MEK.)	Sulphuric Acid
Methyl Iso-Butyl Ketone (MIBK)	Trichloroethylene, Perchloroethylene
Muriatic Acid - Hydrochloric Acid 33-38%	Toluene

b. Lubricating system:

Lubricating system of equipment is a key part to reduce mechanical wear and tear. Through cleaning of lubricating system and replacing lubricating oil should be done during overhauling of equipment. The lubricating oil should be changed after about every six months. Condition of all the lubricating points and the oil level height should be checked after 5 h of working of hydraulic press & similar equipment and after 50 h working of Cleaner, graders Screw press, filter equipment etc. following regular tasks should be followed for proper operation of equipment in process plant:

- Temperature of the main bearing lubricating oil is not more than 55 °C
- Paying attention to abnormal noises, strong vibration, or the leakage of oil
- Cleaning of cake inside oil mill, dust and oil dirt

Maintenance of Screw Press/expeller:

Screw of the expeller is subjected to large torque and therefore more prone to wear, breakage and abrasion. As a result, pressure exerted over the meal is lowered and oil recovery from expeller reduces causing economic loss to processor.

General Causes of breakdown:

- In case machine is run on full capacity without initial run-in step, screw press may experience the breakdown due to blockage. This can be avoided by feeding hot oilseeds/ cake with hot water to warm up the screw and other component of expeller.
- Too fast feeding: cage breakdown due to higher pressure build-up. Thin cake is the indication of excessive pressure build-up inside the barrel.
- Idle running of machine without feeding: it causes difficulty in cake discharge & blockage of the machine.
- Foreign material in feed: when the shaft is stuck, blockage need to be cleared by drawing the screw shaft.

Major breakdown of equipment can be avoided by paying attention to machine behaviour during production. Improper functioning of expeller can be identified by using following observations:

- Irregular oil output: results due to small Gap between barrel and screw or the machine body temperature or feed material temperature is too low. Proper screw alignment and initial run-up need to be done
- Uneven thickness of cake: occurs due to improper screw alignment, or when screw surface is not smooth/ polished
- Cloudy oil: The machine body temperature or the material temperature is too low.
- Residue inside screw barrel: result of large gap between screw and barrel
- Overheating bearings: caused due to poor lubrication, blocked oil holes, etc.

Changing of machine components or part should be considered from time to time to avoid major breakdown of equipment. Repairing of faulty bearing seal is quick and inexpensive process as compared to a complete bearing overhaul from a significant bearing failure.
Food contact surfaces should be replaced when excessive abrasions or gouges, discoloration, staining is observed. Screw of expeller should be changed at the most after 1 year of operation. Excessively worn tools should be replaced as they become potential hazard to the user.

Conclusion:

Process plant design and layout is crucial step for development of agro processing enterprise. Selection of appropriate layout allows effective utilisation man machine and other resources. Similarly maintenance of the equipment ensure operation of the unit as per the planned schedule and adds to economic growth of the business. Efficiency of the process plant, quality of final product are largly governed by these factors and hence cruicial for entrepreneurial point of view. is driven by these basic

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UNIT-20

Innovations in production technologies for animal origin fats and oils and their processing

Dr. A. K. Singh
Principal Scientist, Dairy Technology Division, ICAR-NDRI, Karnal

Oils and fats are not only one of the most important elements for human food; they are also a valuable resource for the pharmaceutical and cosmetic industries as well as a source of raw materials for the production of sustainable fuels. The quality of the end product and also the intelligent processing and recovery of by-products, and thus the extent of possible added value, depends very much on the respective production and refining methods.

When animals are slaughtered to produce meat for human consumption, approximately 50% of the animal is turned into animal byproducts. The by-products are further processed and used for variety of applications, thus, adding value to the animals. Traditional uses for the protein rich solids include use in foods, pet foods, livestock feeds, and fertilizers. Fats have been transformed into soaps and oleochemicals (fatty acid derivatives) in addition to being used in food, pet foods and feed applications. The need for new outlets of products has also been realized due to commonly encountered zoonotic diseases. The new outlets include using protein meals and animal fats as energy sources in combustion units for the generation of steam or renewable electricity. Nonetheless, animal by-products contain high levels of water and have a very suitable biological and microbiological composition which, if not stabilized, can lead to decomposition and environmental pollution. The most conventional way of stabilizing raw material is to process the raw material with heat. This serves to both evaporate the water content and sterilize at the same time: this process is known as “Rendering”.

Animal Fat

Animal fats are rendered tissue fats that can be obtained from a variety of animals. Basically, these are the by-products of the meat packing industry, made available as a result of the preparation of meat either for sale as meat percent or from the manufacture of meat product.

Types of animal fat

Tallow: It is hard fat rendered from the fatty tissues of cattle that is removed during processing of beef. There are two types of tallow:

a. Edible tallow: The Codex Alimentarius recognizes standard for this as rendered from certain organs of healthy bovine animals. It is also known as dripping.

b. Oleo-stock: It is high grade tallow that is obtained by low temperature wet rendering of the fresh internal fat from beef carcass. It has light yellow color, mild pleasant flavor and free fatty acid content is less than 0.2%

Lard: It is defined as the fat rendered from clean, sound edible tissues of hogs in good health at the time of slaughter.

Caul fat: It is the fatty membrane which surrounds internal organs of some animals, such as cow, sheep, and pigs also known as the greater omentum. It is often used as a natural casing. It is also known as Lace Fat.

Leaf fat: It is the fat lining the abdomen and kidneys of hog that used to make the lard.

Rendered pork fat: It is the fat other than the lard, rendered from clean, sound carcasses or edible organs from hogs in good health at the time of slaughter, with certain parts of the animal specifically excluded. It includes bacon skins, fleshed skins, cheek meat trimmings, sweet pickle fats and fats obtained from skimming the rendered tanks.

Inedible tallow and greases: These are the main inedible animal fats which are produced in many grades. Inedible tallow and greases produced by meat packing meat industry may contain either hog or beef fat.

Chicken fat: It is the fat obtained (usually as a by-product) from chicken rendering and processing.

It is high in linoleic acids, the beneficial omega-6 fatty acid. Linoleic acid levels are between 17.8- 22.9%. It is used in the production of pet foods and bio-diesel.

Chicken fat is one of the two types of animal fat referred as schmaltz, the other being goose fat.

Blubber: It is a thick layer of vascularized fat found under the skins of pinnipeds, cetaceans and sirenians.

Recovery of fat

Fats are produced by a variety of processes, generally referred to as rendering. Fatty tissues from both beef and pork are composed of essentially three components, viz. water, protein and fat. It is the purpose of any rendering system to obtain as complete a separation as feasible of these materials.

The fat can be obtained from any of the following three methods:

a. Dry rendering

b. Wet rendering

c. Low-temperature wet rendering Lard and Tallow are obtained mainly by dry and wet rendering

Dry renderer: A dry renderer is made up of horizontal stem jacket with raw material or charge load of 8-10 quintals. Two or three stirrers keep the raw material continuously under motion for uniform heat distribution to avoid charring. economize the labor and to increase the keeping quality of material. Removal of fat is done from cracklings inside the centrifugal expeller and fat settling tank. Long bones from settling tank are sent to digester. Dried and nearly fat free cracklings are ground to recover meat meal. A cyclone and sacking unit allows direct filling of bags. Lard and almost all of the inedible tallow is produced by dry rendering.

Bone digester: Long bones are crushed and processed in steam at 60psi for 2 hrs. The steam separates most of the protein and fat. After extractions of fat and gelatin, the digested bones are chalky and soft and can be easily grounded to bone meal which has about 32.5% calcium and 15% phosphorous.

Low temperature wet rendering: This system uses heating, separation and cooling on a continuous basis and is regarded as an ideal purpose. The process involves mincing of the material, melting by live steam injection at 90 degrees, continuous separation of solids from liquid fats in a decanter centrifuge; further heating; centrifugation to remove the fines and cooling in plate heat exchanger to below solidification point.

Characteristics of fat

Fats and oils comprise one of the three major classes of foods, the others being carbohydrates and proteins. Chemically, they may be defined as esters of three carbon carboxylic trihydroxy alcohol, glycerol and various monocarboxylic acids known as fatty acids.

Lard: Lard contains considerable proportions of palmitic acid, stearic acid, oleic acid and linoleic acid. There are small amounts of palmitoleic acid and traces of linoleic acid, arachidonic acid and myristic acid.

Tallow: It typically contains 9 or 10 predominant fatty acids, although approximately 180-200 individual fatty acids, mostly in small or trace quantities are also known to be present. It also contains approximately 6% of trans-oleic acid formed by the action of rumen bacteria on vegetable oils found in food that is ingested by the bovine or ovine anima.

Processing of fat

The treatment involves series of purifying steps followed by modification into more usable products and finally packaging.

Settling and degumming: These are utilized to remove animal or plant proteins, carbohydrates residues, phosphatides and water. Settling involves storing heated fats quiescently in tanks with conical bottoms. The presence of phospholipids will cause the formation of water-in-oil emulsion in fats and oils.

Degumming is a process that removes phospholipids by the addition of water at 1-3% at 60-80 degrees for 30-60 mts.

Neutralization/refining with alkali: It refers to the removal of nonglyceride fatty materials by washing the oils with strong alkaline water solutions (sodium hydroxide). The major impurities in most crude oils are the free fatty acids.

Bleaching: It is a very important step in oil and fat processing. Crude oils often contain pigments that produce undesirable colors (carotenoids, gossypol, etc.) or promote lipid oxidation (chlorophyll).

Deodorization: It is an important oil refining step because of consumer demand for fats and shortenings that have a very bland or practically non-existent flavor. Neutral fats and hydrogenated contain substances contributing to undesirable flavor and odor and these substances must be removed. This is achieved by a technique known as steam distillation under reduced pressure which is designed to remove unacceptable odors and flavors form oils and fats.

Fractionation: Fractionation refers to the partial crystallization of a fat or oil at a specific temperature. The fat is held at the crystallization temperature for a period of time to allow equilibrium or near equilibrium to occur between crystallizing and non-crystallizing triacylglycerols.

Hydrogenation: The physical requirements of many fats used in foods are grossly different those of natural fats or oils. Hydrogenation, the direct addition of hydrogen to double bonds of fatty acids, is used to modify vast quantities of fats and oils. This process alters molecular configuration and changes the geometry, number and location of double bonds. These changes, in turn, alter the physical and chemical properties of fat.

Interesterification: Interesterification, sometimes called ‘ester interchange’ or transesterification involves an interchange of an acyl groups among triacylglycerols.

Quality control

The primary role of the laboratory is quality control. The analytical methods described below are used routinely to control the processing steps and to maintain the constant check on product quality.

Free fatty acid: Free fatty acid is expressed as percentage of free oleic acid of total sample weight. All fat contains some free carboxylic acids, but these are removed by the refining process. The level of these free fatty acids is measured continuously to check the refining efficiency.

Iodine number: It indicates the degree of unsaturation i.e. the number of double bonds present in the length of the chain. The iodine value is low for animal fats and high for vegetable oils. The higher the iodine value, the lower becomes the melting point. In this manner, the presence of pig fats would be detected in tallow allegedly derived from beef sources.

Peroxide test: This test is used to determine the rancidity of tallow. If the peroxide value is low, this normally suggests that the tallow has not become rancid and will have good stability.

Smoke point: It is the temperature to which the fat may be heated before it begins to smoke. It has direct relationship with FFA. Tallow with FFA of 0.2% has smoke point of 225 degrees, Tallow with FFA of 1.0% has smoke point of 145degrees and tallow with FFA of 5.0% has smoke point of 120degrees. Lard has smoke point of 121-218degrees.

Saponification value: It represents the number of milligrams of potassium hydroxide or sodium hydroxide required to saponify 1g of fat under the conditions specified. It is a measure of the average molecular weight (or chain length) of all the fatty acids present.

Refractive index: It indicates the purity and identity of substance. Lard-1.448-1.460, Rendered Pork Fat-1.448-1.461, Premier Jus-1.448- 1.460, Tallow- 1.448-1.460

Melting point: The melting point of a solid is the temperature at which it changes state from solid to liquid. At the melting point the solid and liquid phase exists in equilibrium.

Back Fat: 30-40 degrees, Leaf Fat: 43-48 degrees, Mixed fat: 36-45 degree. Moisture, impurities and unsaponifiable (MIU): Pure fat is virtually free of moisture. Water in tallow is undesirable as it acts a medium for the growth of fat-splitting bacteria and the action of fatsplitting enzymes. Level around 0.2% is desirable.

Conclusion

Lipids play an important role in food quality by contributing to attributes such as texture, flavor, nutrition and caloric density. As knowledge of the nutritional importance of lipids continue to evolve, manufacturers will need to modify the physical and chemical properties of lipids in order to produce healthy foods with high consumer acceptability.

LIST OF CONTRIBUTORS

'Online Training of Master Trainers on Fat and Oilseed Processing' (01-06 January 2021) at ICAR-CIPHET, Ludhiana – 141004, Punjab, India

S. No	Name & Designation	Address
1.	**Dr. Nachiket Kotwaliwale** Director, ICAR-CIPHET	ICAR-CIPHET, PAU Campus, Ludhiana 141004 Contact: 0161-2313117
2.	**Dr. C. Anandharamakrishnan** Director, IIFPT	IIFPT, Pudukkottai Road, Thanjavur, Tamil Nadu 613005
3.	**Dr. Deep N. Yadav** i/C Head ToT Division & Principal Scientist	ToT Division, ICAR – CIPHET, PAU Campus, Ludhiana, Contact: 0161-2313144
4.	**Dr. Ranjeet Singh** i/C ITMU & Principal Scientist	ToT Division, ICAR – CIPHET, PAU Campus, Ludhiana, Contact: 0161-2313135
5.	**Er. Sandeep P. Dawange** Scientist	ToT Division, ICAR – CIPHET, PAU Campus, Ludhiana, Contact: 0161-2313116
6.	**Dr. R K Vishwakarma** Principal Scientist	FG & OP Division, ICAR–CIPHET, Ludhiana, 141004 Contact: 0161-2313120
7.	**Dr. Mridula Devi** i/c Head & Principal Scientist	FG&OP Division, ICAR–CIPHET, PAU Campus, Ludhiana, Contact: 0161-2313127
8.	**Dr. K. Narsaiah** Principal Scientist & Head	PC AICRP-PHET, ICAR-CIPHET, Ludhiana, Contact: 0161-2313127
9.	**Dr. S. K. Tyagi** Principal Scientist & PC	AICRP-PHET, ICAR-CIPHET, Ludhiana Contact: 0161-2313127
10.	**Dr. Virender Sardana** Principal Agronomist (oilseeds)	Department of Plant breeding and Genetics, PAU, Ludhiana
11.	**Dr. Manju Bala** Principal Scientist,	FGOP Division, ICAR-CIPHET, Ludhiana Contact: 0161-2313127
12.	**Dr. K. D. Yadav** Senior Vice President (Technical)	AAK Kamani Pvt Ltd., Mumbai Dr.k.d.yadav@aakkamani.com
13.	**Dr. S. K. Nanda** Ex PC AICRP–PHET, Ex-Head	FGOP Division, ICAR-CIPHET, Ludhiana dr.sk.nanda@gmail.com
14.	**Dr. Mahesh Kumar** Professor	Department of Processing & Food Engineering, PAU, Ludhiana
15.	**Dr. Sandeep Mann** Principal Scientist	ToT Division, ICAR-CIPHET, Ludhiana Contact: 0161-2313125
16.	**Dr. M. K. Chatli** Dean	Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana.
17.	**Dr. S. Siva Kumar** Assistant Scientist – cum - Head,	Department of Dairy Tech, GADVASU, Ludhiana (Punjab)
18.	**Dr. Rahul K. Anurag** Scientist (SS)	ASEC Division, ICAR-CIPHET, Ludhiana Contact: 0161-2313125
19.	**Dr. Ramandeep Singh** Professor	School of Business Studies, PAU, Ludhiana ramandeep@pau.edu, 9814019470
20.	**Dr. A. K. Singh** Principal Scientist	Dairy Technology Division, ICAR-NDRI, Karnal (Haryana)

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(01-06 January 2021)

List of Participants

S. No	Name :	Organization	Email ID
1	Welstar M marak	Department of Agriculture & Farmers' Welfare	welmarak8620@gmail.com
2	Dipali Sahkharam Sangekar	ADT, KVK, Baramati	dipalisangekar01@gmail.com
3	M L Kadam	Department of Food and Industrial Microbiology MGM, College of Food Technology Aurangabad	kadamml09@gmail.com
4	S. Ganpathy	TNAU	ganapathy.s@tnau.ac.in
5	Dr Anupama Sandal	CSK Himachal Pradesh Krishi Vishvavidyalaya	asandal@rediffmail.com
6	Dr. James K. Chawang	Directorate of Agriculture, Government of Nagaland	jkchawang@gmail.com
7	Dr. CK Bakhara	OUAT, Bhubaneswar	ckbbbsr@gmail.com
8	Dr. U.S. Pal	OUAT, Bhubaneswar	us_palceat@yahoo.co.in
9	Sreelakshmi K Unni	Kerala Agricultural University, Thrissur	sreelakshmi090390@gmail.com
10	Dr. Lakshmy P.S	Kerala Agricultural University, Thrissur	lakshmi.ps@kau.in
11	Dr. Dharmendra Khokhar	Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)	dharmendrakhokhar@gmail.com
12	Dr. Abhimanyu Kalne	Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)	abhikalne7@gmail.com
13	Sashi Devi	Community Science College & Research Institute	sashidevig@gmail.com
14	Dr. Udaykumar Nidoni	University of Agricultural Sciences, Raichur	udaykumarnidoni@yahoo.co.in
15	Dr. P.F.Mathad	University of Agricultural Sciences, Raichur	mathad2010@gmail.com
16	Dr. Ambrish Ganachari	University of Agricultural Sciences, Raichur	ambrish001@gmail.com
17	Dr. Suresh Chandra	Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250110 (UP)	chandra21778@gmail.com
18	Dr Vishakha Singh	CCAS, MPUAT, Udaipur	vishakha.udaipur@gmail.com
19	Dr V K Chahar	CTAE, Udaipur	4387vijay@gmail.com
20	Dr. Rakesh Kumar Rajgar	College of Agricultural Engineeringand Post Harvest Technology	rakeshiitkgp07@gmail.com
21	Sandhya	Punjab Agriculture University	sandhya7819@gmail.com

@www.ciphet.in