Chapter 9

PACKAGING ASPECTS OF OILS, FATS & VANASPATI

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Edible oils and hydrogenated fats (vanaspati) are extensively used in human diet as they impart textural qualities, taste and palatability to food apart from contributing calories, fat soluble vitamins and essential fatty acids for human nutrition. About 55% of vegetable oil domestically consumed, is imported (10.6 million tonnes in 2002-03) making India the world's leading importer ahead of the European Union and China. Bulk quantities of oils are packed and transported in expensive tin containers and galvanized iron drums and sold in loose form by retail vendors. This practice gives scope to adulteration with less expensive oil, which has been a cause of ill health in India and many other parts of the world. As a consequence, the governments of these countries have been trying to enforce compulsory packing of edible oils in inexpensive plastic unit packages. Distribution of oils/fats in unit consumer packs is increasingly becoming popular as it assures quality product packed under hygienic conditions in unadulterated forms. In view of their logistic advantages such as light weight, low cost and convenient shapes and tailor made functionality, plastics in rigid, semi-rigid and flexible forms are replacing conventional bulk packages. Only a small percentage of the oil consumed is being packed in units of ½ kg to 15 kg in lined folding cartons, HDPE, PET and PVC bottles, HDPE jars, bag-in-boxes and tin containers. In some regions, adoption of oil pouch is going on slowly in unit packs of 200 ml to 1 litre capacity. If this has to reach every consumer, a suitable package has to be designed to ensure variety, quality and safety of the product until it reaches the ultimate consumer and also satisfy the legal requirements. Knowledge of the nature and deteriorative characteristics of the product is very important in order to design a suitable package.

Nature and Deteriorative Characteristics of Oils and Fats

Fats and oils are triglycerides of different fatty acids and glycerol. Oils contain higher content of glycerides of unsaturated fatty acids and therefore are liquids, whereas fats are solids at room temperature. Vanaspati, which is a hydrogenated oil, falls under the category of fat. Oils and fats are adversely affected by humidity, oxygen, temperature, light, tainting and traces of metals and are prone to various types of deteriorations.

1. **Hydrolytic rancidity :** Moisture is one of the chief causes of spoilage of oils and fats. Even though fats and oils are hydrophobic in nature, even small variations in moisture content can be detrimental to the keeping quality of the product as it alters the equilibrium relative humidity of the product. Unlike other common foods, water holding capacity increases with temperature in oils and fats (Fig. 9.1).

   Hydrolytic rancidity is caused by moisture due to hydrolysis of fats and oils to glycerol and free fatty acids which are responsible for the off odour. This is catalyzed by enzyme (lipase) activity and increases with time. Oils and fats containing higher amount of saturated fatty acids like lauric and palmitic acids are more prone to hydrolytic rancidity. Rate of hydrolytic rancidity is higher at above 65% RH corresponding to a moisture content (MC) of 0.1% which is the critical limit for refined oil as per different specifications for fats and oils. Therefore, oil needs to be protected from moisture above 65% RH with a high barrier packaging material. However, at below 65 % RH, the equilibrium moisture content of oils never exceeds 0.1%. Therefore, moderate moisture proof materials are sufficient.

2. **Oxidative rancidity :** This is caused by oxygen resulting in oxidation of oils and fats. The extent of oxidation is also affected by moisture content. Aldehydes and ketones are the final products of oxidation responsible for the rancid odour of oils and fats. The rate of oxidation is accelerated by the degree of

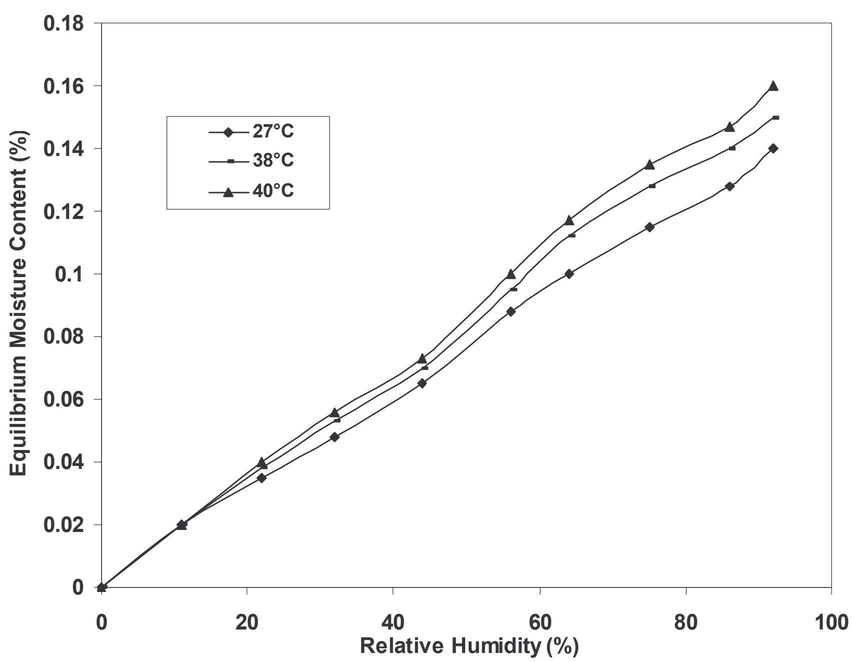

Fig.9.1. Moisture sorption isotherms of palm oil at different temperatures.

unsaturation of oils and fats, temperature and humidity and catalysed by UV-light, traces of metals and degradation products of oxidation. Oils containing higher content of unsaturated fatty acids undergo maximum oxidation whereas fats like vanaspati with higher degree of saturation are affected least. Unrefined oils are less prone to oxidation than refined oils due to the presence of natural antioxidants and pigments.

3. **Tainting by extraneous sources and from packaging materials and components:** Even though vanaspati is chemically stable due to hydrogenation, it is equally susceptible to odour pickup from external sources and therefore requires to be protected.

4. **Growth of microorganisms due to increase in water activity:** This can occur at moisture content corresponding to above 65% RH.

5. Colour and vitamin degradation in oil occurs due to exposure to UV light and further accelerated by oxygen. Therefore, oil needs to be protected from light by using opaque and pigmented packaging materials.

Proper packaging plays a vital role in the marketing system by retardation of deterioration and prevention of social hazards of adulteration and possibility of under-weighing.

Packaging Material Requirements

To prevent or retard chemical deteriorations of fats and oils, and for easy handling, transportation and to ensure that the product reaches the ultimate consumer in safe condition and to satisfy legal requirements for their sale, the packaging material should maintain chemical quality, purity, colour, flavour and other required attributes. Therefore, the material should be a barrier to water vapour, oxygen and odour and also should be grease resistant and fulfill the following requirements.

- Should be a barrier to volatile and taint proof towards prints, inks, solvent used for inks, adhesive, etc.
- Should be opaque or pigmented to screen the UV light.
- Should have good impact resistance to prevent loss or contamination due to breakage or leakage of the package.
- Should possess good stiffness, tensile strength, tear resistance and heat seal strength to work well on automatic Form-Fill-Seal machines (for flexible films).
- Should be non-toxic and be compatible with the product.
- Should be tamper proof and have airtight sealing.
- Should be economical, easily available, printable and disposable.

Till recently, oils and fats were being packed only in rigid containers. Metal containers are the most common forms of packages for oils and fats. Oils are bulk packed in tin containers and galvanized iron drums and sold loose in retail. For this, the consumer has to carry his own container to collect oil from 50 ml to 1 litre capacity. In spite of Edible Oils Package (Regulation) Order 1998 that "edible oils should be sold in packed form only and any body selling them in loose would be liable for action", only about 10% of the oil consumed is sold in unit packs due to delay in adoption of the rules by various States. The following forms are commonly used.

1. Rigid Containers: Metal/Glass/ Plastic

Square/cylindrical metal containers of 15 kg capacity are used as institutional packs and 2 to 5 kg square containers for vanaspati and cylindrical containers for oils are in use as family packs. Metal containers act as perfect barrier to moisture

Fig. 9.2. Rigid HDPE containers for oils/fats

and oxygen, shield the effects of harmful UV radiation and offer a shelf life of one year. The escalating cost of conventional metal containers and the possible adulteration during retail sale have led to the use of alternate economical packaging material. Tin free steel cans coated with epoxy phenolic lacquer are found to offer required shelf life to oil and vanaspati. Although glass bottles for oils and jars for ghee are being used, heavy weight and fragility restrict their use. Now plastics are widely replacing expensive metal containers due to light weight, low cost, optimum barrier properties, strength and availability in different shapes and sizes. PVC and PET bottles have replaced tin containers to some extent. Even though PVC became popular for its low cost and excellent grease resistance property, its usage is very much reduced in recent years due to the possibility of migration of residual vinylchloride (VC) monomer whose prescribed limit in food is very low. However, with an established facility at CFTRI, now it is possible to determine the extent of VC monomer migration into oils and fats. PVC remains the most popular packaging material in France. The popularity of PET bottles is increasing due to better clarity, barrier properties and impact strength although they are costlier. The effective UV stabilizers in PET containers are able to absorb UV light and thus protect the oil resulting in extension of shelf life. These bottles offer the required shelf life to oils as per the relevant standards. Orientation of PET and PVC helps in down-gauging with increased strength and attraction thus justifying the additional investment on the orientation process. PP/LDPE screw caps with foil/PVC/expanded polyethylene liners are used for these plastic bottles. Since mid 1960s, HDPE containers are being used for vanaspati and oil packing. About 45% of vanaspati produced is packed in HDPE containers. It is being packed in 1 kg, 2 kg and 5 kg unit packs. Opaque/pigmented HDPE jerry cans of 1 kg, 2 kg, 5 kg and 15 kg are used for oil packing. Although HDPE is inferior to PET and PVC in its oxygen barrier properties, the higher wall thickness of the containers allows its use. Smaller containers are not in use for edible oils because of the increased cost of packaging. The cost of rigid plastic containers for consumer package varies from Rs 4-10 per litre depending on the type of plastic. Composite containers of 1 kg with paper/foil/PE body and metal lids for packing oil are also in the market. The approximate cost of different packages and shelf life offered by them under normal storage condition are given in Table 9.1.

Table 9.1. Rigid packages for edible oils and fats, their costs and shelf life offered

Sl. No.	Size (kg)	Packaging material	Approximate Cost(Rs)	Weight (g)	Approximate shelf life
1	15	Tinplate can new	42	900	About 1 year
2	15	HDPE jerry can	33	500	> 180 days
3	5	HDPE jar	14	185	> 180 days
4	2	Tinplate can	8		About 1 year
5	2	HDPE jar	8	90	180 days
6	2	PVC Bottle	6		180 days
7	1	PET Bottle	3	33	180 days
8	1	PVC Bottle	4		180 days
9	1	HDPE Container	5.60		180 days
10	0.5	PET bottle	2	18	180 days

Fig. 9.3. PET containers for edible oils

2. Semi-rigid Packages

In view of the logistic and cost advantages, plastics in semi-rigid and flexible forms have become more popular. Lined folding carton is made from suitable laminates like Met. PET/PE, Al. foil laminate which gives required protection to the product and the outer duplex board carton is meant for extra protection to the primary pouch, graphic design and display. Studies have indicated that the shelf life of double filtered groundnut oil and refined sunflower oil packed in foil based carton was better than that in PET bottles. Nylon based bag-in-box with built-in tap system is also available for oil packaging in view of convenience of easy opening and reclosing system and cost effectiveness. Also, while dispensing oil, volume of headspace air does not increase as in case of bottles and jars and thus helps in controlling oxidation. The minimum unit pack size commonly available is one litre and its cost is beyond the purchasing power of the common man in the country. Tetra Pak cartons of varying capacity from 200 ml to 1 litre are also being used for packaging of oils.

Fig. 9.4. Semi-rigid containers for edible oil

3. Flexible Pouches

The minimum unit pack size in rigid/ semi-rigid containers is 500 ml, a quantity that is too large to purchase by the common man in the country. Hence even today, edible oil is being sold loose. The high packaging cost of rigid/semi-rigid packs, and lack of assurance on quality and quantity in buying loose oil have led to the introduction of flexible pouches as retail packs. Flexible packaging materials have the following advantages:

- Optimum balance between cost and benefits,
- Lower storage and handling costs,
- Amenable to high speed FFS machines.

Unit packages in different forms like pillow pouch, flat pouch, three sides sealed pouch, 4 sides sealed pouch, stand up pouch are available. Selection of packaging materials depends upon several factors such as nature and type of oil, storage conditions, expected shelf life, properties of packaging materials, cost, etc. However, the selection and usage of suitable flexible material was not an easy task. CFTRI carried out enormous amount of work to arrive at an economical and functional flexible pouch for oil. Packaging and storage studies on different oils and fats in different flexible pouches right from mono films to foil based laminates have been carried out. From the studies, the following conclusions were arrived at.

Mono films: The keeping quality of oils were tested in LDPE, HDPE and PP pouches. They were not at all suitable for various reasons. The grease resistance of LDPE is only seven days at 38°C. Even 75-125 μm thick LDPE pouch was sticky within 15 days of packing. It is also prone to environmental stress cracking. HDPE has the drawbacks like cracking and higher heat sealing temperature. PP has very poor impact strength. Inspite of careful filling and sealing without contaminating the sealing area, leakages were observed in many pouches during storage under accelerated storage condition. All polyolefins thus failed to offer desired physical protection. Because of their poor flavour barrier properties, the freshness of refined oils and the characteristic flavour of unrefined oils were lost within very few days of storage. As they are very poor oxygen barriers also, a maximum shelf life of only 15-20 days and 30-40 days were observed under accelerated and normal storage conditions respectively. Hence, mono films fail to offer the necessary physical or chemical protection for oils. Only 100 μm HMHDPE pouch, when tested for hydrogenated oil (vanaspati), was found to satisfy BIS requirement.

Two layer films: The keeping quality of different oils were tested in two layer co-extruded films like HDPE/LDPE, HDPE/ Ionomer, PP/Ionomer and PET/Ionomer laminate, etc. Even though co-extruded HDPE/LLDPE film improved with respect

Fig. 9.5. Oils/fats in flexible plastic pouches

to its grease resistance, environmental stress cracking, etc, over LDPE and sealability and cracking resistance over HDPE, leaker rates were still high and it emerged as the cheapest material for packing vanaspati. The good grease resistance, ability to give good heat seal even with contamination, low temperature sealing and high hot tack renders ionomer the best sealant layer for oils and fats. Leaker rates were reduced substantially with the usage of ionomer. EAA also was found comparable to ionomer in these respects. Ionomer or EAA as the sealant contact layer offered the desired physical protection from chemical deterioration. Because of poor flavour and oxygen barrier property, combinations like HDPE/Ionomer could not offer desired protection from chemical detrioration. This necessitated the use of an oxygen barrier layer. The shelf life of oil was substantially improved when packed in PA/Ionomer and PET/Ionomer. But oxygen permeability of PA is affected by the external RH. So PA/Ionomer is not suitable for storage in high humid places as PA will be totally ineffective as an oxygen barrier.

Three layer structures: The shelf life of oil was studied in 3 layer co-extruded structures like pigmented 90-100 μm HDPE/LDPE/EAA, LLDPE/HDPE/EAA and composite structures like LLDPE/HDPE/LDPE/HDPE/EAA, laminates like PET/AL foil/LDPE, PET/HDPE-LDPE and metPET/HDPE-LDPE structures. The coextruded structures like HDPE/LDPE/EAA, LLDPE/HDPE/EAA, LLDPE/HDPE/LDPE/HDPE/EAA could offer desired physical protection by passing tests like stack load, drop and vibration as per BIS specification. But the peroxide value of oil went high for those oils with high degree of unsaturation. They offered the required shelf life for palm oil, but most of the pigmented materials failed to pass the colour migration test. Oils need a pigmented pouch as the effect of light on oxidation is well known. Laminates like PET/HDPE-LDPE and met PET/HDPE-LDPE offer good protection as indicated by a shelf life of 60-70 days and 120-180 days under accelerated and normal storage conditions, respectively; foil based laminate pouches offer more than 180 days storage life under both the storage conditions. But PET and foil based laminates are available as preformed pouches and are to be filled without contaminating the sealing area as they do not contain EAA or Ionomer.

Five layer co-extruded structures : The most economical and functional structure that can work well on FFS machines is polyamide (PA) based co-extruded structure. Different strucutres like 90-100 μm LLDPE or PP or HDPE/BA/PA/BA/EAA were tested for different oils. LLDPE/BA/PA/BA/EAA yielded better results in terms of offering physical protection, by withstanding drop, stack load and vibration better than the ones with HDPE or PP as the outer layer. Therefore, for small pouch of oil (200 or 500 ml), cheapest and functional package will be a five layer 90-100 micron green or yellow pigmented LLDPE/BA/PA/BA/EAA.

This meets all the requirements of BIS for packed refined oils. However, under accelerated storage conditions, the initial moisture content of 0.04-0.06% reaches the critical level of 0.1% within a few days causing cloudiness in oil. Therefore, nylon based co-extruded material is restricted to use in normal storage conditions. From the above results, the following conclusions can be drawn. In general, no mono-film can offer physical protection or required shelf life of 90 days for oil which is liquid at room temperature. Even in co-extruded films, LDPE or HDPE cannot be chosen as sealant layers due to poor grease resistance/sealing when contaminated at the sealing area and poor impact respectively. Therefore, only EAA copolymer or ionomer can be used as sealant layer which can offer high degree of seal integrity demanded in packaging oil. Pouches comprising LLDPE/HDPE/EAA or ionomer can be used for shorter storage life or for oils more saturated.

To provide adequate protection against rancidity, good oxygen barrier combinations based on PA or PET films are to be used. The usage of nylon as the core layer in co-extruded films not only functions as an oxygen barrier, but also prevents colour migration into oil when pigmented materials are used. Therefore, 5 layer co-extruded material with nylon as core layer and EAA as the sealant layer is the cost effective material which can be used for unit package of all sizes but thier usage is restricted to

Table 9.2. Yields and costs of unit packaging materials

Flexible packaging material	Thickness, μm	Yield, m^2/kg	Approx. cost, Rs/kg
HDPE	25	41.2	70
HM-HDPE	25	40.5	70
CPP	25	44.0	65
BOPP	25	46.0	100
LDPE/HDPE	25/25	21.0	70
HMHDPE/LDPE/LLDPE	110	11.0	82
LLDPE/HDPE/LDPE/LDPE/LDPE	95	11.3	90
LLDPE/BA/PB/BA/LDPE	95	10.7	170
LLDPE/BA/PA/BA/EAA	95	10.7	200
PET/LDPE	12/37	19.6	200
PET/HDPE-LDPE	12/37	18.6	150
MET.PET/LDPE	12/37	19.6	225
MET.PET/HDPE-LDPE	12/100	9.5	200
PAPER/Al FOIL/LDPE	40/9/37	10.2	180
PET/Al FOIL/LDPE	12/9/37	13.3	260

Table 9.3. Requirements for flexible packaging materials for packaging oils/fats as per IS 12724-1989 specification

Tests	Requirements
Migration	The global migration value with n-heptane at 38°C/ 0.5h should be less than 10mg/dm^2 and 60 ppm. There should not be colour migration from coloured plastics into oil/n-heptane.
WVTR (g/m^2/24 h at 90% RH & 38°C)	
50 µm pouch	0.5
125 µm pouch	1.2
250 µm pouch	2.0
OTR (cc/m^2/24 h/ atm. under 65% RH & 27°C)	
50 µm pouch	60
125 µm pouch	150
250 µm pouch	250
Stack load	The pouches when subjected to a uniformly distributed stack load of 20 N per 100 g pouch, 30 N for 200 g pouch, 40 N for 500 g pouch and 50 N for 1,000 g pouch for 72 h under ambient conditions shall not show any leakage at the seams or bursting of the pouch.
Drop impact	None of the five pouches in a set should fail the dropping at ambient conditions — one drop on each flat surface and one drop on each longer side from 1.2 m height.
Vibration	There shall not be leakage from more than one pouch of the lot subjected to vibration under ambient conditions for 30 min at 1 G.
Critical MC (%) and FFA	0.1 and 0.25 for refined oil
(% oleic acid)	0.25 and 0.25 for vanaspati
Shelf life	30 days and 90 days under accelerated and normal storage conditions, respectively.

normal storage conditions. Preformed pouches made from PET/HDPE-LDPE and reverse printed PET/ HDPE-LDPE laminates are also being used. Even though these are slightly costlier, they offer better shelf life to oil by retarding oxidation of oil by absorbing UV rays. These films also offer very good printing surface.

PET/HDPE-LDPE standup pouches and pouches with screw cap spout comprising PET/HDPE-LDPE are becoming very popular due to good appearance, display capacity and convenience. The oil need not be transferred to a container immediately. For longer storage life and for storing under accelerated conditions, high moisture barrier materials (WVTR < 2 $g/m^2/d$ at 38°C and 90% RH) like met. PET/HDPE-LDPE or foil laminates have to be used. Vanaspati being chemically stable, can be packed in HM-HDPE or HDPE/LDPE films of 80-100 μm. Some flexible packaging materials used or being considered to pack oils and fats with their approximate costs are given in Table 9.2.

However, all the plastic packaging materials should be tested for their safety in food contact application by conducting global migration/colour migration/monomer migration tests as per respective BIS specifications. The product should be of best quality at the time of packing as no package can improve the sub-standard quality of a product. At the time of packing, the maximum moisture content of oil and vanaspati should be 0.04% and 0.10%, respectively and FFA of 0.07% to 0.12%, respectively and peroxide value of <2 for oils.

Standards/Regulations: Oil is a commodity consumed by every person. It may become health hazardous unless protected properly. Therefore, different standards like PFA, Agmark and BIS are formulated which give specifications on the quality parameters of oil at the time of sale, the shelf life of oil in different plastic packaging materials and specifications on safety and performance of packaging materials. The main specifications laid down by BIS for flexible pouches for refined oils and vanaspati are presented in Table 9.3. However, the shelf life required for oil in PET/PVC bottles are 60 and 180 days under normal and accelerated storage conditions, respectively. The vinyl chloride (VC) monomer content in PVC should be < 1 ppm and VC migration into oil < 10 ppb.

BIS Specifications for oil/fat in plastic packaging materials are given in Table 9.4.

Table 9.4. BIS Specifications for plastic packaging materials for packing edible oils/fats

IS No. - Year	Specification
12724-1989	Flexible packaging materials for packaging of refined edible oil.
12883-1989	Polyvinyl chloride (PVC) bottle for edible oils.
12887-1989	Polyethylene terephthalate (PET) bottles for packaging of edible oils.
11352-1985	Specification for flexible packs for packaging vanaspati.
10840-1994	Blow moulded HDPE container for packaging of vanaspati.

Future Trends

Considerable progress has been made in the country in the field of oils and fat packaging. Multi-layer films with variety of film structures which have made significant entry in food packaging can be explored in view of their tailor made barrier and functional properties. Metallised BOPP as one of the structures in the multilayer film is being considered. Although costlier, Met.PET/HD-LD laminate pouches can be considered for better shelf life of oils. Apart from multilayer films, multilayer bottles can have good future for oils due to their good barrier properties. Stretch blown PET and PVC bottles with good barrier and strength properties and cost-effectiveness are finding more application. Opaque, pigmented HDPE containers offer good protection to oil from light. Bag-in-box with tap and laminate pouches with screw cap spout has great potential in oil packaging in view of their cost effectiveness and convenience over conventional packages. Tetrabrik packs, in view of their barrier properties, can offer longer storage life.

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