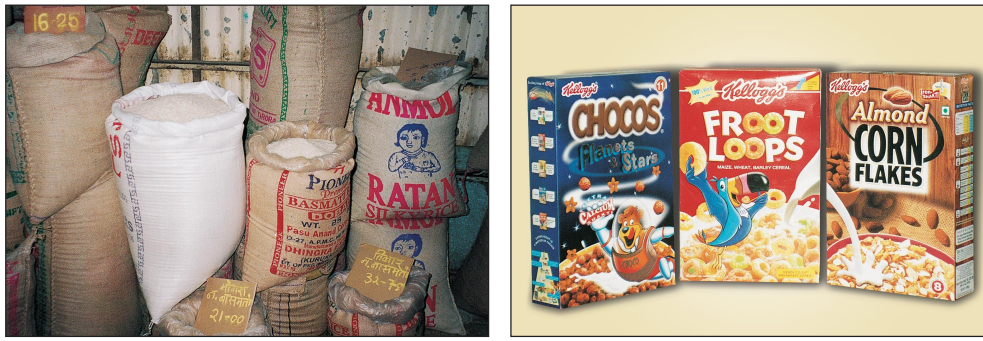
PACKAGING OF CEREALS AND CEREAL PRODUCTS

India produces a variety of food grains like paddy, wheat, maize, barley millets like, jowar, bajra, ragi. The country is self sufficient in grain production and is the second largest rice producer in the world with a 20% share.



Packages for Cereals and Cereal Products

Table 1 gives the details of food grains produced in India.

TABLE 1

Food Grains Production in India

(in million tonnes)

Crop	1997-98	1998-99	1999-2000	2000-01	2001-02
Rice	82.5	86.1	89.7	84.9	91.0
Wheat	66.4	71.3	76.4	68.7	73.1
Coarse Cereals	30.4	31.3	30.3	31.6	31.9
Pulses	13.0	14.9	13.4	10.7	13.2
Foodgrains	192.3	203.6	209.8	195.9	209.2
Kharif	101.6	102.9	105.5	103.4	108.5
Rabi	90.7	100.7	104.3	92.5	100.7

[Source: Economic Survey of India, 2001-02]

Grain processing is the biggest component of the food sector, sharing over 40% of the total value. The primary processing sector shares 96% of the total value while the secondary and tertiary sector shares 4% of the total value addition.

The grain processing industry covers a range of food products. These include the basic primary food, such as wheat and rice products, sugar, oil, pulses and the processes for converting them into edible form and processed food like biscuits, bakery products, breakfast food, etc. Growth in

the industry until a few years ago was mainly in traditional sectors like rice, flour and oil milling. However, swelling consumerism has seen the introduction of a range of new products like breakfast cereals, texturised protein food, etc.

Product Range

Cereal products and pulses can be broadly classified into the following groups:

- Whole cereals/pulses where only the husk of the grain is removed, e.g. rice, wheat, gram, lentils, etc.
- Split pulses like tur dal, gram dal, etc.
- Milled grain products are made by removing the bran and usually the germ of the seed and then crushing the kernel into various sized pieces. These include wheat flour, maida, semolina (rawa), besan etc.
- Processed cereals and pulses like weaning food, breakfast cereals, etc.
- Ready mixes like cake mix, idli mix, vada mix etc.

Spoilage Factors

The factors influencing the quality of cereals and pulses are:

- **Physical:** Physical losses are caused by spillages, which occur due to use of faulty packaging materials.
- **Physiological:** Examples of physiological losses include respiration and heating in grains, temperature, humidity and oxygen.
- **Biological:** Losses due to micro-organisms, insects, rodents, etc.

The grains and pulses are low moisture commodities due to which they are less susceptible to spoilage and have greater shelf-life. The spoilage mainly occurs due to moisture absorption during storage leading to fungal growth at high temperature and humidity. Before bulk packaging and storage, the whole grains are fumigated to reduce microbial load and increase storage period.

The following factors are to be taken into consideration while developing packaging materials for cereal and cereal products:

- Protection against environmental conditions like humidity, temperature, etc
- The packaging material should be able to withstand mechanical hazards during transportation and facilitate stacking several tiers high so as to optimize the use of available space
- To protect the contents from spillage
- To protect the contents from insect infestation
- To protect from external odour
- Easy to handle
- Economical and easily available

Whole Grains and Split Pulses

These are sold mainly in bulk quantities. The requirements for bulk packaging are therefore,

most important for these commodities. The packaging materials used for bulk packing of cereals and pulses are as follows:

- Jute Bags
- Woven sacks made out of high density polyethylene or polypropylene
- Multiwall paper Sacks. The multiwall paper sacks are not commonly used in India owing to its high cost and lack of proper availability.

Jute Bags

Traditionally, jute has been the packaging material used for bulk packaging of food grains and pulses. With the increasing growth of these commodities, there has been a quest to look at

Jute Bag for Branded Basmati Rice

Jute Bag for Unbranded Products

alternate packaging materials due to the stagnant jute production. Plastic woven sacks have the potential to fulfill this need in a cost-effective manner. These are made either from HDPE or PP.

Disadvantages of jute bags include:

- **Availability:** Food grade jute bags are not easily available.
- **Mineral Oil Contamination:** Mineral oil is used as a lubricant in processing of jute fibres. Mineral oil adds hydrocarbon odour to the fabric and some free radicals are also found in mineral oil which affects normal metabolism of human bodies. Alternatively, lubricants based on vegetable oil have been developed by Indian Jute Industries Research Association (IJIRA) for manufacture of odourless and hydrocarbon free jute fabric for food contact application. However, bags made out of odour free fabric are expensive.
    - Poor resistance to UV radiation.
    - Susceptibility of the material to insect infestation and rotting.
    - Poor resistance to corrosive chemicals.
- **Insect Breeding:** It is a regular practice in the grain trade to reuse bags. The structure of jute fabric being porous, the insects like stored grains and pests find it easier to lay their eggs on its fibres. The eggs of stored grain pests are microscopic in nature and one can know about the presence of infestation only when it gets developed into the larva stage. Such bags can therefore serve as a potential source of infestation.

Many a times the used bags are contaminated with food items or with chemicals, and in such cases they serve as a potential source of contamination.

- **Cost: Jute sacks are 5-6 times heavier than the sack made out of plastic material like HDPE or Polypropylene for a similar weight pack.** The jute goods are transported all the way from east India to other parts of the country, which are thousands of miles away. Owing to these factors, the cost of jute bags is much higher than the plastic sacks.

The nature of jute packaging is such that, lot of food packed therein gets exposed to deteriorating factors and germs. Air borne germs and the ones present in the storage godowns may seek way through the pores of the fabric and may contaminate the food. Such food, when consumed may cause illness like food poisoning.

High Density Polyethylene (HDPE)/Polypropylene (PP) Woven Sacks

HDPE and PP woven sacks have replaced jute bags in number of applications. Several plants manufacturing these sacks have come up in different parts of the country making the availability of these products possible at low price.

HDPE/PP Woven Sacks

Advantages of HDPE and PP woven sacks include:

- Elongation at break of HDPE tapes is about 15-20% in comparison to jute bags, which is about 30%. Owing to this property HDPE woven sacks have better resistance to dropping.
- HDPE/PP woven sacks do not impart any odour to the food product packed in them
- HDPE/PP woven sacks are not attacked by insects
- HDPE and PP woven sacks of strength equivalent to that of jute bags can be made using almost 70 times lower weight of the resin and hence are almost 60-65% cheaper than the jute bags.
- HDPE and PP woven sacks are the most hygienic material for packing of cereals and pulses and one need not reuse the same owing to their low cost.
- Fabric allows diffusion of air/gases easily through the gaps between the filament thus facilitates ventilation of grains during earlier stages of harvest and penetration of fumigants.
- Although HDPE/PP undergo degradation under UV light, it is possible to arrest the same by using appropriate UV stabilizers.
- It is possible to laminate HDPE woven sacks with LDPE. The laminated bags protect the product packed in the bag from moisture and also prevent the loss of products like flours due to spillage, which usually occur through plain jute bags, which are commonly used for packing of flour.

Lamination of PP woven sacks with polypropylene is also possible, as the grade of PP suitable for lamination is now available in the market.

Consumer Packs for Whole Food Grains

Although cereals and pulses are primarily packed in bulk packs owing to the development of super markets and due to increase in consumer awareness on the quality of food products, branded commodities are now being sold in the market on a large scale. The packaging material used for consumer packs of whole cereals and pulses are as follows:

Plastic Pouches for 1 kg Branded Rice

a) Packs made of printed LDPE/LLDPE film

b) Packs made of Polypropylene (PP) or Biaxially Oriented Polypropylene (BOPP) film

c) High Molecular High Density Polyethylene film packs

d) Laminates made from BOPP/LDPE, Cast Polypropylene (CPP)/LDPE, Polyester/LDPE are used in few branded commodities. Although laminates are essential for expensive products like Basmati rice where the flavour retention of the product is very important, it may prove to be very expensive for low value products.

The three types of films mentioned above (a, b, and c) offer adequate protection to the consumer packs and they are the most cost effective packaging materials for consumer packs of cereals and pulses. Laminate mentioned in (d) helps in protecting the product from insect attacks, as polyester is a tough material due to which the insects find it difficult to puncture the laminate.

Milled Grain Products

Wheat is one of the most abundantly available cereals in our country. About 40% of it is used for production of whole wheat flour (atta) and about 17% is used by roller flour

Plastic Pouches for Atta

milling industry. Thus, the packaging of milled products has acquired lot of importance owing to the production of atta and roller flour milling of wheat. Mickinsey – Confederation of Indian Industries (CII) report on food sector has projected that branded flour (atta) market will grow to Rs.15,000 crores by the year 2005 as the consumption pattern is shifting from subsistence food to basic food. The requirement of packaging material in this segment of the milled products will, therefore, grow significantly.

Milled products like atta, maida, suji and besan are prone to deteriorate with changes such as rancidity, microbial spoilage and insect attack. The deterioration is rapid when the moisture exceeds 13%. Prevention of Food Adulteration Act specifies maximum moisture content of 14% for wheat flour (atta) and maida and 14.5% for suji. The studies conducted on moisture absorption of milled products have revealed that moisture levels above 12% cause rapid deterioration due to hydrolysis of fat present in these products, hence moisture content of about 10% is recommended at the time of packing to ensure longer shelf-life of these products.

Bulk Packs

Most of the milled products like maida, suji, atta etc. produced in the roller flour mill are packed in used gunny bags for many years. The used gunny bags are highly unhygienic packaging materials as they are contaminated with the product packed in it prior to its use in packing milled products. Since these act as a potential source of contamination and infestation they are now being packed in HDPE or PP woven sacks. These woven sacks are either laminated with LDPE or a HMHDPE liner of suitable thickness is used. HMHDPE liner has lower moisture vapour transmission rate as compared to LDPE and thus gives better protection against moisture. Being a hard material, it also prevents penetration of insects.

Consumer Packs

The recommended packaging materials for consumer packs are as follows:

- **Polyethylene Film**: Low Density Polyethylene (LDPE) is the most commonly used packaging material for milled products owing to its low cost and easy availability. LDPE film has good balanced property such as tensile strength, bursting strength, impact resistance and tear strength. It has good barrier properties to water and water vapour. It can be heat sealed very easily and gives good tough welds. The film can also be printed very easily. However, it has poor barrier to gases.
- **Linear Low Density Polyethylene (LLDPE)**: LLDPE is a superior material than LDPE. Comparative properties of LLDPE and LDPE are given below to highlight the advantages of LLDPE.
    - Improved tensile properties: For products with similar melt flow index, the tensile strength of LLDPE is 50-60% higher.
    - Improved stiffness: Strength of LLDPE is 50% higher than that of LDPE.
    - Puncture Resistance: Puncture resistance of LLDPE film is twice as much as that of LDPE having similar thickness.

Table 2 – gives comparative properties of LDPE and LLDPE films.

TABLE 2

Properties of LDPE and LLDPE Films

Properties		ASTM Test Method	LLDPE Film	LDPE Film
Basic Density (g/cc)		D-792	0.925	0.923
Elmendorf Test Strength (g)	MD	D-1922	280	130
	TD	D-822	400	230
Tensile Strength (Psi)	MD	D-882	3240	2560
	TD			1980
Elongation (%)	MD		640	390
	TD		680	510
Gloss at 45° (%)		D-2457	80	83
Haze (%)		D-1003	6.4	4.0

Owing to better physical characteristics of LLDPE films, LDPE has now been replaced by LLDPE in number of cereal products applications.

Thickness of LLDPE film used for different consumer packs is as follows:

- 1kg Pack-250 gauge
- 2kg Pack-300 gauge
- 5kg Pack-400 gauge

White opaque film gives better aesthetics.

- **High Molecular High Density Polyethylene (HMHDPE):** This material is characterised by its toughness and high mechanical strength. The film prepared out of this material is translucent and it can be modified by addition of pigments. The films have very good strength and are thus used in very low thickness for packing of cereal products. The film being tougher, insect penetration is difficult.

- **Co-extruded Films:** Milled products like wheat flour contain small amount of fat which tend to ooze out through the LDPE or LLDPE film giving a sticky fat to the surface of the pack and also affecting the print of the film. It is therefore advantageous to use co-extruded film whereby a thin layer of HDPE/HMHDPE can be incorporated to prevent fat seepage. Three layer co-extruded film having structure LDPE/HDPE/LLDPE is found useful in overcoming this difficulty. Use of metallocene resins in the above structure was found to produce a film having good weldability and high hot tack. As atta is a powdery product, fly-off of the product is observed during filling the packs. The powder which flys off gets deposited in the seal area thereby affecting the strength of the seal. The metallocene resin helps in producing good seal along contaminated area. The above structure of co-extruded film using metallocene resin is, therefore, a very effective packaging material for milled products like atta.

- **Polypropylene (PP):** Polypropylene finds wide application in packaging of food products, like atta, soji etc. owing to its following properties:
  - Density: Polypropylene has very low density among the commonly used plastics due to which it gives higher yield {meterage of film per kg for material} as compared to LDPE or LLDPE.
  - High stiffness and High Tensile Strength.
  - High Transparency: Polypropylene has very high transparency as compared to LDPE and LLDPE. It is the most suitable material for products, which require visibility.
  - Lower moisture vapour transmission rate
  - Cost: One of the advantages of PP is its low cost as it can be used at lower thickness owing to its high tensile strength. This is a big advantage for low cost, bulky products like atta.
- **Biaxially Oriented Polypropylene Film (BOPP):** Biaxially Oriented Polypropylene film has higher strength than polypropylene film and it is available in a heat sealable grade also. It has excellent barrier to moisture, high transparency and gloss. It can be reverse printed and can be laminated as a two-layer film. Heat sealable BOPP film with thickness ranging from 2µ to 40µ is widely used for packaging of cereals.
- **Laminates**: Laminates made of BOPP/LDPE or Polyester/LDPE are used for packaging of milled cereal products. The advantages of laminates are as follows:
  - Polyester and BOPP based laminates can be reverse printed thus giving good appearance to the pack. As the printed side of the film is sandwiched between two film layers, the odour due to ink solvents appearing into the pouch is prevented thereby protecting the product from tainting.
  - Polyester being a tough material, insects cannot puncture the pouch easily and hence the entry of insects can be controlled.
  - Cereal products are mostly sold through grocery outlets. The grocer sells many other items like soaps and detergents, incense sticks, strong smelling deodorants, vegetable oils. It has been observed that the grocer displays the consumer packs by placing them next to strong smelling items like soaps, incense sticks etc., as a result, the products packed inside the LDPE pack pick up the odour of the material stored in its vicinity. This problem can be overcome by using laminates with polyester/poly structure.
  - As the laminates are expensive, they are mostly used for packing high value products.

It is therefore evident that the types of packaging material to be selected for cereal based products depends on various factors mentioned above and the packaging technologist should combine these factors to suit the requirements of product to be packed and arrive at a cost effective packaging system.

The packaging materials mentioned above are the primary packaging materials for milled products. For deciding on the thickness of the primary packaging materials, the type of secondary packaging material used should also be considered. It is observed that owing to cost considerations mostly woven sacks made out of HDPE or polypropylene are used as secondary packaging material. It should be borne in mind that HDPE/PP woven sacks provide less protection to the bags in handling and transit as compared to the corrugated boxes. The thickness of the bags should, therefore, be suitably designed so that the bags are able to withstand above mentioned hazards.

Processed Cereal and Pulse Products

Owing to the changing food habits of people, cereal products like breakfast cereals, weaning food have acquired lot of importance in the diet of Indian consumers. The packaging of these products are discussed here.

Breakfast Cereals

Breakfast cereals made from both "whole" grains and milled grains, are served hot and cold and may be previously cooked or uncooked. Ready to eat breakfast cereals are classified as

Packages for Breakfast Cereals

Plastic Pouches for Breakfast Cereals

flaked products, puffed products, shredded products and granulated products. They are low moisture products, crispy in nature and fortified with essential nutrients. Hence, the packaging material requirement includes the high moisture barrier properties and retention of nutrients throughout the storage period. Hot breakfast cereals are made from whole grains and must be cooked before eating. Cold breakfast cereals are products like "shredded wheat", corn flakes, granulated cereals and breakfast cereals coated with sugar and are eaten by adding cold milk. These ready-to-eat cereals are processed by addition of flavouring agents, precooking and subsequent aeration and drying to create puffed crisp products. Because the grain is cooked prior to expansion, flour can be mixed to obtain various flavours and texture effects. By extruding and expanding through different dies and with varying toasting and healing temperatures a variety of different products like puffed rice, shredded and flaked wheat, puffed and toasted oats are obtained. Flavours are also added using synthetic sweetner.

The shelf-life of the breakfast cereal depends on the quality of oil contained in them. Breakfast cereals having low oil content such as wheat, barley, rice and maize where the oil content is 1.5 – 2% have comparatively long shelf-life to cereals made from oats where the oil content in the product is about 4 – 11%. Hence, while selecting a suitable packing media for packaging of breakfast cereals, the following factors are taken into account:

- Moisture gain resulting in loss of crispness
- Lipid oxidation resulting in rancidity and off flavour
- Breakage resulting in an aesthetically undesirable product
- Loss of vitamins
- Loss of aroma from flavoured product
- **Loss of Crispness:** The crispness is lost due to moisture absorbed by the product. Hence, the packing material should have good barrier properties to keep away the moisture from penetrating inside.

- **Lipid Oxygen:** In dry breakfast cereals, lipid oxygen is one of the primary means of chemical deterioration. The grains used in breakfast cereals have high ratio of unsaturated and saturated fat, which gives rise to lipid oxidation. To minimize oxidative rancidity, it is necessary that the package excludes light. Excluding oxygen may be of limited assistance in extending the shelf-life. When a case study for storage stability of flaked oat cereal was conducted, it was found that PVC/PVDC copolymer coated with PP-LDPE performed to offer good oxygen barrier. Use of antioxidants in packing materials can increase the shelf-life of a product, but is not permitted in most countries.
- **Mechanical Damage:** The rigidity of the packing material could save the packed product from handling damages including transport.
- **Loss of Vitamins:** This can be a problem when certain cereals are flavoured with fruit. In such cases, loss of flavours would indicate the end of shelf-life of the cereal. Micronutrients present in cereals are not the major factor in determining the shelf-life of cereal.
- **Packaging Materials: Corn flakes are packed in polyester/foil/LDPE laminate packs, which are inserted in a duplex board printed carton. Other packaging material that is used include**
  - 15µ BOPP/200 gauge LDPE laminate
  - 12µ metallised polyester/200 gauge LDPE laminate

The above laminates are less expensive as compared to the carton pack.

Weaning Food

Weaning food are an essential diet of growing infants. They are used to change the diet pattern of infants from liquid food like breast milk and substituted milk proportions to cooked solid food. They can be used as and when desired with minimum of processing and with desirable sensory quality and shelf-life. Infants are usually weaned between 4 and 6 months as baby's feeding behaviour progresses from sucking to biting and chewing. Weaning food are classified as:

- Processed cereal based products, which are subdivided into simple cereal, cereals with an added high protein food, pasta and rusks and biscuits.
- Baby food, which are primarily intended for use during the usual infant weaning period and for progressive adoption of infants and young children to ordinary food. Baby food include a very diverse category of products, comprising complete meals, soups, desserts, puddings, vegetable juices, fruit juices, etc.

Pouch in Carton for Baby Food

There is no clear definition of weaning food but in general they include all staple food that are the first food added to the diet of infants.

Weaning food based on cereals are highly sensitive to changes in moisture, resulting in caking when the relative humidity exceeds 60%. At higher moisture the product turns bitter owing to hydrolytic rancidity. They are mostly available in bag-in-box type packaging where LDPE is used as the sealant layer. The other films used for liner bags are BOPP/Poly or Polyester/Poly. Some baby food are available in lined cartons.

Plastic Bag Vs Jute Bag for "Atta" Packaging – IIT Delhi Study

The study discloses that for producing packaging with Plastic Film Bags for one lakh tons of "Atta", the raw material required is only 680 MT. But for the same quantity of packaging with Jute Bags, requires 1960 MT of material. The results of this analysis are organised in two categories, namely resource utilisation and atmospheric emission.

Energy Consumption

The analysis by steps identifies the production of jute and subsequent manufacture of bags (Phase I and Phase II) as being responsible for the higher consumption of energy (~68.69 thousand Gj per one lakh metric ton of packed "Atta") as compared to plastic film bags (~62.58 Gj per one lakh metric ton of packed "Atta"). Energy consumption related to transportation (Phase III) of "Atta" shows that transportation in jute bags requires significantly higher amount of energy, (~261 Gj per one lakh metric ton of packed "Atta"), as compared to that in plastic film bags.

Life Cycle data for Different Materials used for Packaging One lakh ton of "Atta".

Material Required	**Jute Bags** 1960 (kgs)		**Plastic Film Bags** 680 (kgs)	
	Energy* (´000 GJ)	Water* (´000 Tonnes)	Energy* (´000 GJ)	Water* (´000 Tonnes)
Phase I: Production of Raw material	21.50	1677	38.36	264
Phase II: Production of Bags and Liners	47.19	1506	24.22	296
Total	68.69	3183	62.58	560

Phase III: Distribution	**Jute Bags**		**Plastic Film Bags**	
	Fuel	**Energy**	**Fuel**	**Energy**
	4663	261.29	Taken as Basis	

Phase IV: Waste Management	**Jute**	**Plastic Film Bags**
Recycling Percent	Energy Savings*	Energy Savings (thousand GJ/680 tonne)
100%	Not Applicable	17.20
80%		13.76
Incineration	Energy Recovered	Energy Recovered (thousand GJ/680 tonne)
100%	Not Applicable	35.24
80%		28.12

*Units Energy (GJ), Water (Thousand Tons), Fuel (Tonnes)

Atmospheric Emission

About ten components dominate the category of atmospheric emission for jute bags and plastic film bags: CO, CO_2, SO_x, NO_x, CH_4, HCI, dust, heavy metals, suspended solids and chlorides.

Another major resource utilisation is being demonstrated in terms of consumption of water. The manufacture of jute bags is found to be responsible for the greatest consumption of water overall; ~ 1608 (thousand ton/lakh ton of packed "Atta") in case of jute bag production. This is about 63 times higher than that for plastic film bags for same amount of packed "Atta".

Reuse of jute bags has also been considered as one of the option to reduce waste. It has been found that even for 95% reuse of Jute Bags the energy consumption is double than that consumed in making new Plastic Film Bags. Also the water consumption in case of 95% reuse of Jute Bags is 20 times of that used in new Plastic Film Bags. More importantly attention is also given to two end-of-life cases, i.e. 100% incineration (waste to energy, energy recovery) and/or 100% recycling (energy usage). According to this phase energy recovery due to incineration is about 15.8 MJ/kg for plastic film bags, while there is no incineration for wasted Jute. It should also be noted that in case of recycling of plastics, the waste enters into a new life and if this waste management technique is considered the life cycle analysis of plastics/jute bags can be termed as "Cradle to Cradle" approach instead of "Cradle to Grave".

[Source: Plastics and Resource Consurvatin Land, Water, Forests & Energy - Plastics for Environment & Sustainable Development]

Conclusion

The demand for cereal products is driven by the ever changing consumer and their lifestyle. Packaging transforms and reinvents itself, evolving to meet the changing demands of modern society. The developing world faces very different challenges, relying on packaging to preserve food and to avoid waste.

Plastics with their unique and diverse combination of properties are the ideal material to meet these growing demands of innovation and performance in a sustainable manner.

Over the years plastics have grown by replacing traditional materials in various applications.

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