Chapter **5**

PACKAGING ASPECTS OF WHEAT, RICE, MILLED PRODUCTS AND SUGAR

A R Indiramma

Food Packaging Technology Department
Central Food Technological Research Institute
Mysore 570 020 (INDIA)

Chapter 5

PACKAGING ASPECTS OF WHEAT, RICE, MILLED PRODUCTS AND SUGAR

Food grains are the rich source of life sustaining nutrients. Cereals/flours are good carbohydrate sources. In addition, they provide protein, fat, vitamins, minerals, etc. They are the dietary staples providing the required calories for more than 95% of India's population. Among them, rice is the predominant cereal grain followed by wheat, maize, millet and sorghum. Cereals are annual crops but the consumption is throughout the year. Losses due to insect and rodent attack, microbial spoilage and pilferage may occur during storage. Hence, proper and safe storage methods need to be provided till they are consumed. Satisfactory storage can be achieved with proper and suitable packaging materials. Cereals in general are characterized by good storage stability, moderate density and low cost. Despite their good storage stability, they are affected by high humidity, physiological factors such as respiration and consequent heat build-up in grains, biological factors like insects, pests, rodents and microorganisms and to some extent by oxygen. Flours are more sensitive to humidity and are more prone to biological deteriorations than whole grains. All these factors cause qualitative and quantitative changes. As such, proper packaging and storage methods are essential for good storage stability.

Sugar is another important commodity, which is stored in bulk and sold loose at retail stores throughout the year. The type of spoilage and hence the packaging requirement varies according to the type of sugar. White cane sugar which is more popular in India is crystallized enough not to absorb water under normal storage conditions. But at high relative humidities it picks up moisture rapidly. To protect it from pilferage and spillage and insects like ant, proper packaging and storage methods are required.

Nature and Deteriorative Characteristics of Cereals/ Flours and Sugar

In order to design functional and economical package for any food product, knowledge of its deteriorative characteristics on storage and the causes of deterioration are essential. Cereal grains/flours during storage are affected by the following factors mutually working with each other in causing deterioration.

1. Physical factors like temperature and humidity.
2. Chemical factors like moisture and oxygen.
3. Physiological factors like respiration and heating.
4. Biological factors like insects and pests, microorganisms, rodents and birds.

Moisture is the most important factor among the ones related to rate of deterioration. The data relating moisture content with relative humidity (Table 5.1) forms the basis for package design.

An equilibrium relative humidity of more than 70% can lead to mould growth in grains and flours. In whole grains, heating due to increased respiration rate may result in insect and/or fungal activity. Higher the temperature, lower will be the equilibrium moisture content. Hence, for better storage stability of grains, the moisture should be about 11 – 12 % and 10-11% for flours at the time of packaging. If the moisture content is very close to or above the critical level, diurnal changes in temperature can cause mould growth due to moisture condensation on the surface. Insects and mites also depend on grain moisture for their life. The optimum level of moisture for most of the insects was found to be between 11 and 16% in grains; 14% is the lowest moisture level, which permits fungal invasion in most of the cereals. Apart from controlling moisture, lowering of temperature and restricting oxygen supply also inhibit insect growth. Apart form these, varietal differences, the degree of maturity, methods of handling and transportation,

Table 5.1. Moisture and relative humidity data for grains & flours

RH	EMC at 27° C, %					Remarks	
%	Rice	Wheat	Atta	Semolina	Maida	Grains	Flour
1 1	6.4	4.5	5.	6.4	6.3	Brittle	Very Dry
22	8.4	6.6	7.4	9.7	9.5	Slightly Brittle	Free flowing
32	9.8	7.5	8.4	10.0	10.2	Good	Free flowing
44	11.6	8.9	9.5	11.4	11.1	Good	Free flowing
56	12.9	9.9	10.6	12.4	12.5	Good	Free flowing
64	13.9	11.1	12.1	13.8	13.4	Good	Tendency for caking
70	14.8	12.0	13.0	14.4	14.0	Good	Tendency for caking
75	15.5	13.0	13.6	15.1	15.0	Musty	Soft and soggy
86	18.5	15.6	18.3	16.9	16.8	Mould	Mould
92	23.0	22.3	24.2	18.8	18.9	Mould	Mould
CMC	14.8	12	13-14	13.5-14.5	13-14	Good	Tendency for caking
CRH			70				

RH = Relative humidity *CMC = Critical moisture content*
EMC = Equilibrium moisture content *CRH = Critical realtive humidity*

and the number of broken/cracked kernels also effect the storage stability.

Sugar crystals are stable over a broad band of relative humidity. Its moisture content generally lies between 0.02 and 0.04%. But once it is exposed to 86% RH and above, it suddenly picks up moisture and turns watery. Hence, sugar is effected by moisture above 85% RH only. Above this, it picks up moisture and when RH comes below due to changes in either temperature or variations in atmosphere, it dries out and crystals agglomerate themselves together. It is also susceptible to attack by insects like ant.

Packaging Requirements of Grains/Flours and Sugar

To retard the above deterioration in the products, a functional package:

1. Should have the ability to protect the contents from spoilage and spillage,
2. Should offer protection against environmental conditions, (should be a good barrier to moisture),
3. Should prevent insect infestation and insect damage (should have good insect resistant property),
4. Should offer protection against microorganisms, (should be oxygen barrier to prevent their growth),
5. Should possess necessary strength properties to withstand mechanical hazards during transportation and storage,
6. Should assist in selling by attractive graphics,
7. Should be economical, easily available and disposable, and
8. Should conform to the food laws.

Current trends in Packaging and Storage of Whole Grains/Flours and Sugar

In order to preserve the quality and wholesomeness of cereal grains, many storage methods are being employed. Cereals are mostly stored loose in bulk, in a variety of containers or in sacks stacked in warehouses.

The method of choice of storage depends on factors like:

1. Type and value of produce.
2. Duration of storage.
3. Climate.
4. Transport system.

The advantages and disadvantages of bulk storage over sack storage are as follows:

Bulk	Sacks
Inflexible storage	Flexibility of storage
Mechanizable	Partly mechanizable
Rapid handling	Slow handling
Little spillage	Considerable spillage
High capital cost	Low capital cost
Low operating cost	High operating cost
Low rodent loss potential	High rodent loss potential
Little protection against reinfestation	Reinfestation occurs

5. Cost and availability of labour and sacks.
6. Incidence of rodents and certain types of insects and infestation.

Bulk Storage of Grains

Traditionally, grains are bulk stored in Bukhari type, Kothar type or Morai type rural food structures constructed on elevated platforms which are supported on timber posts or brick/stone masonary pillars. They are constructed using bamboo/bamboo split, timber, reeds, red gram stems plastered with mud. Underground rural food grain structures are also constructed and they are made water proof using bitumen. Modern methods of grain storage are an elaboration of traditional method but are constructed using modern materials. The bulk bins are constructed with concrete, steel or glass lined steel. A system to transport grains/flours and by-products to the bins and a system of feeders and conveyers to move flour and mill feed to packaging bins, bulk rail road cars and bulk trucks and to transfer them from one bin to another are in practice. Air-tight bulk storage silos keep the grain free from insects, rodents and other pests. Here insects are killed by oxygen depletion and not by carbon dioxide accumulation. Metal silos up to 200 tons capacity are commonly used. Flexible bag silos of butyl rubber or PVC supported in metal mesh cases are available. But they need to be protected by rodents. Sometimes, to overcome the changes in pressure during storage resulting from high production of carbon dioxide, a pressure release valve is fitted at the top of the silo. The silos are well sealed to provide a hermetically sealed structure and are also suitable for gas fumigation. The shelf life of the grain stored in silos depends largely on moisture content of the grain and the storage atmosphere.

Bag Storage of Grain /Flours / Sugar in Warehouses

This is the most common method used world wide for grain and sugar storage. Grains and sugar are packed in jute / paper / rice straw / burlap / HDPE or PP woven bags and stored in a variety of types of buildings constructed with stone, local brick, corrugated iron, mud and wattle with or without plastered walls and cement or stone floor and corrugated iron or thatched roof. Such types of godowns are planned for the storage of 100 to 500 tons of grains.

Fig. 5.1. Storage of grains in jute sacks

Jute /Hessian Sacks

These are traditional bulk packages, for grains/flours and sugar which offer good handling properties. The flours and sugar require A- twill bags, which have a weave clearance of 1-2% only to prevent spillage. B-twill or D. W. bags having a weave clearance of 6-10% can be used for most of the cereals. But as such they cannot protect the products from moisture ingress. So stacked jute bags are covered with tarpaulin sheets. Their protective functions can be improved by inclusion of webs of paper, plastic and foil. These prevent sifting of the contents and provide water vapour barrier property.

Plastic Woven Sacks

Flat or circular woven plastic sacks of PP or HDPE with suitable PE layer can be sued for cereals/flours and sugar. They offer good protection at high humidities economically. Up to 100 kg product can be packed in them. The relative merits and demerits of jute and HDPE / PP woven sacks are given in Table 5.2.

Multiwall Paper Sacks

For storage of flours and sugar below 86% RH, paper bags made of 3 – 7 plies of kraft, union kraft or extensible kraft are generally used to hold upto 50 kg capacity.

Fig. 5.2. Plastic woven sacks being stacked

Table 5.2. Relative merits & demerits of jute sacks & HDPE/PP woven sacks

Jute sacks	HDPE / PP woven sacks
Good stack stability:	Poor stacking and destacking (unstable stacks with perpetual chances of stack collapse). This has been solved by antislip woven sacks.
Good breathability, poor moisture protection	Good breathability in unlined woven sacks, good moisture protection in lined woven sacks.
Higher incidence of bag damage indicating poor end-use performance.	Better endurance and recyclable.
Amenable for use of hooks and better reclosure.	Poor recovery of holes caused by hooks which increases grain seepage. This has been overcome in antislip woven (PP/HDPE) bags.
Poor mechanical strength.	Good mechanical strength and lends for re-use.
Natural and have no problem with standards for safety. But should conform to standards IS 2566, 3984, 12650, 15138.	Synthetic; need to be checked for safety and should conform to IS 14887.
Contamination of food grains by jute batching oils present in the jute bags may occur.	No such contamination can occur. Hygeinic & aesthetic.
Spillage may occur during transportation.	Least spillage during transportation.
Costiler than plastic woven sacks	Cheaper than jute sacks.

Laminating them further with PE/PP and/ or aluminum foil lining would further increase their utility.

The advantage of bag storage over bulk storage of grains is that bags may be piled under any convenient shelter and can be transported and handled without special equipment. The main disadvantage is that bag's storage space and bagging become expensive particularly where manday charges are high. Under-water storage of grains in 60 kg unit packs packed in double plastic bags with nylon inner bag and nylon/ Al. foil/ PE outer bag was found to retain original freshness of the product even after prolonged storage. The seeds protected under water found to have better germination capacity than those stored by conventional methods. Carbon dioxide packaging is more effective than air. Low temperature storage in straw or gunny bags also yields better results.

Unit Packages

Retail packaging is the key to successful marketing of modern food products. It goes beyond eye appeal, convenience in size, shape and ease of opening. The product is to be protected against infestation, contamination, entry of oxygen and moisture.

The main function of the unit packages for cereal flours and sugar is containment of a measured quantity. So the consumer knows how much he or she is buying and the merchant knows how much to charge quickly and easily for the transaction. As the bulk density of these products is high, packaging material needs to have good impact strength and good tensile strength for working on FFS machines and good puncture resistance as some grains have sharp edges. Textile / jute / burlap bags are used for this purpose for above 10 kg unit packs. But as they are highly vulnerable to vermin infestation, plastic woven sacks are being used for the purpose. Up to 10 kg unit packs, both LDPE and LLDPE meet the requirements and blends of the two, with LLDPE being used for additional strength, are the most commonly used packaging materials.

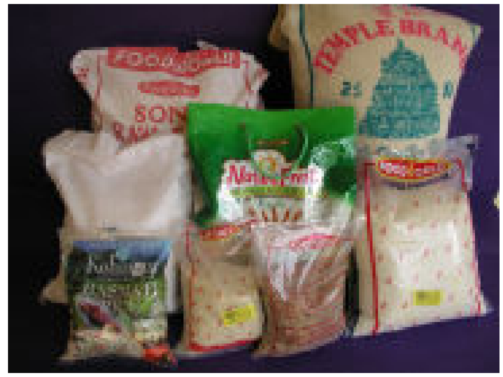

Fig. 5.3. Rice packs in units of 1 to 25 kg

To protect special variety products like Basmati rice, brown rice and flours from flavour loss and from development of

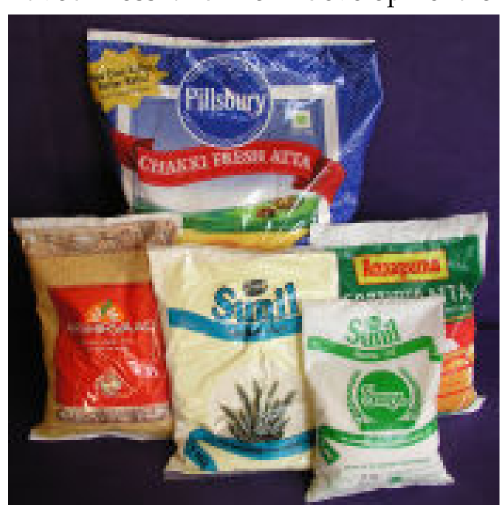

Fig. 5.4. Attractive unit packages for milled products

oxidative rancidity, flavour barrier packaging material is needed. Hence, reverse printed polyester laminated to LDPE for longer shelf-life and coextruded LDPE/ LLDPE are used. PET/LDPE laminate, apart from protecting flavour loss and rancidity, retards insect infestation, prevents pick up of foreign odours and offers excellent printing surface. Antioxidants like BHT have a better effect when rice is packed in an oxygen barrier film . Vacuum / CO_2 flush packaging also extends shelf life of brown rice. Brown rice, which has 3–6 months shelf life in LDPE bags, will have about one year shelf life when vacuum packed in nylon based laminates. Vacuum or CO_2 flush packaging can control pests and insects without fumigation or usage of chemicals apart from offering

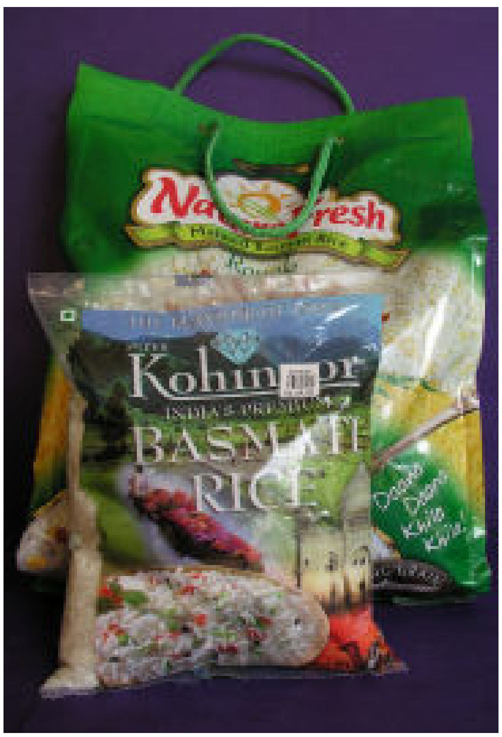

Fig.5.5. Retail packs of basmati rice in PET/ LDPE laminates of 1 and 5 kg units.

protection from oxidative rancidity for any foodgrain. Vacuum packed bag in boxes are good for transportation also. Shelf-life of over 2 years can be expected for vacuum packed rice when stored at 17-30°C and 65-85% RH. But these oxygen barrier materials are expensive. Hence, to protect the products from off-flavours developed due to rancidity, perforated bags are being used to allow rancid odour to escape.

Insect Infestation in Grains and Flours

Insect infestation is a major problem in grains and flours. They are the prime targets of many predators like insects, pests, rodents, mites and undesirable microorganisms. Besides destroying a significant portion of food, they qualitatively affect the remaining part through excretion of toxic chemicals and contamination with excreta and insect fragments. Standards specify maximum limits for these parameters. Though insect penetration can be controlled by using different packaging materials, initial insect contamination should be destroyed at the time of packing. Insect resistance of packaging materials for some common insects is presented in Table 5.3. Vacuum or CO_2 packaging can prevent the development of pests inside the bag. But the high barrier films required for them are expensive. Hence periodic treatment with permitted pesticides only can prevent reinfestation or cross infestation. The grains are to be fumigated or irradiated or treated with microwave. Permeabilities of different films and laminates to fumigants are given in Table 5.4. When used in the recommended dosages, shelf-life of grains will be extended to more than 6 months as against one month for the untreated product. These methods have been found to be most effective in controlling pests in grains / flours.

Table 5.3. Insect resistance of some films and laminates

Films	Time of penetration in months for different insects			
	Sitophilus oryzae	Rhizopertha dominica	Stegobium panicium	Tribolium castaneum
LDPE 50 µm	< 1	< 1	> 3	< 3
LDPE 100 µm	< 2	< 2	> 3	> 3
HDPE 25 µm	< ¼	< 2	> 3	> 3
HDPE 50 µm	2	2	> 3	> 3
HDPE 75 µm	> 3	> 3	> 3	> 3
Polypropylene 50 µm	> 3	> 3	> 3	> 3
Polypropylene 75 µm	> 3	> 3	> 3	> 3
75 µm MXXT Cellophane	< ¼	< 1	> 3	> 3
75 µm MXXDT Cello/LDPE 37 µm	< 1	< 2	> 3	> 3
PET 12 µm/LDPE 75 µm	> 3	> 3	> 3	> 3
MET.PET 12 µm/LDPE 37 µm	> 3	> 3	> 3	> 3
PET 12 µm/Al.Foil 0.02 mm/ LDPE 37 µm	> 3	> 3	> 3	> 3
75 µm Cello /Al.Foil 0.2 mm/ LDPE 37 µm	> 3	> 3	> 3	> 3

Test Conditions: Temperature: 25—28°C, RH: 70-75%. *Source: Narasimhan et al., 1986*

Fig. 5.6. Bags being prepared for fumigation.

Recent Trends

Retail packaging being the present trend, the stress is on use of more decoration, transparency, simplification of package construction and production of packages by automatic means. Since preservation in smaller packages is more difficult, use of increased quantities of films and laminates for improved protection and increased shelf life will become popular. This will be expensive as more storage space and more packaging materials are required. Hence, a unit package must be carefully designed and automatically packed for cost reduction.

Table 5.4. Permeability of packaging films to different fumigants

	Methyl bromide 32 mg/L			Ethylene dibromide 32 mg/L			Methyl formate 32 mg/L			Ethyl Formate 44 mg/L			Phosphine 1.5 mg/L		
Films	MC	P%	PR	MC	P%	PR	MC	P%	PR	MC	P%	PR	MC	P%	PR
HDPE 25 µm	14.7	31.0	42.0	11.2	35.0	63.0	20.7	47.0	113.0	12.4	40.5	72.9	0.24	16.0	1.3
HDPE 50 µm	14.5	30.0	41.0	9.3	28.5	51.0	6.5	20.5	50.1	5.8	24.0	43.2	0.0	0.0	0.0
HDPE 75 µm	12.9	23.3	29.0	8.1	18.8	34.0	6.0	15.0	36.4	7.0	21.2	36.4	0.0	0.0	0.0
Polyethylene 50 µm	14.5	30.0	41.0	9.2	28.5	31.0	7.4	17.0	41.0	8.7	29.1	52.4	0.05	3.2	0.26
Polyethylene 75 µm	11.6	18.0	25.0	9.2	28.5	31.0	3.0	7.2	71.3	7.0	24.0	43.2	0.0	0.0	0.0
MXXT Cello 75 µm	12.7	22.3	31.0	9.0	27.9	49.0	20.7	47.1	113.9	2.9	26.5	47.8	0.25	16.6	1.3
MXXDT Cello 75 µm/ LDPE 37 µm	8.7	6.4	9.0	8.0	29.9	46.0	25.7	25.4	61.5	13.9	44.3	79.6	0.14	8.8	0.72
PET 12 µm/LDPE 75 µm	11.4	17.5	24.0	4.2	30.0	23.0	18.6	42.4	102.5	14.5	46.8	84.3	0.5	3.2	0.26
Met. PET 12 µm/LDPE 37 µm	12.2	20.8	28.0	0.0	0.0	0.0	13.2	30.1	72.9	7.9	26.5	47.8	0.0	0.0	0.0
PET 12 µm/Al Foil 0.02 mm/LDPE 37 µm	10.4	13.2	18.0	7.3	20.7	40.0	17.8	40.5	78.0	8.3	27.8	50.1	0.0	0.0	0.0
Paper 15 µm/Al.Foil 0.02 mm/LDPE 37 µm	12.4	26.1	29.0	5.9	18.8	32.0	5.7	13.2	31.9	5.4	19.0	34.1	0.0	0.0	0.0
Paper 15 µm/Al.Foil 0.02 mm/LDPE 37 µm	5.0	15.3	27.0	5.5	16.2	28.0	2.0	4.7	11.3	2.5	10.1	18.2	0.0	0.0	0.0
Glassine 40 gsm	8.7	6.6	9.0	6.4	20.0	23.0	22.0	50.0	120.7	8.3	27.8	50.1	0.05	3.2	0.26

Test Conditions: Temperature: 25—28°C, RH: 70-75%.
MC= Mean Concentration, mg/L; P= Transmission rate, % through the films.
PA = Transmission rate, mg/h.m²
Source: Narasimhan et al., 1986

Conclusion

The critical moisture for cereals and flours being less than14%, care should be taken that the moisture content of the products is well below the critical moisture level at the time of packaging when sold at places where RH is above 70%. If a proper method like fumigation/irradiation to kill the insects is followed, insect infestation can be controlled. Sugar needs protection above 86% RH. For bulk storage of grain, metal silos which offer good air tight storage condition, is the most modern and scientific method for longer shelf-life compared to other methods. Low temperature storage is more effective for long-term storage for grains. Bag storage in warehouses is very common for grains and sugar. Jute / HDPE / PP woven sacks are being emphasized. Government of India through Gazette notification has allowed food grains to be packed in non-jute bags upto 40% and sugar upto 50%. Woven plastic sacks will register highest growth rate, if they are allowed to compete with jute sacks without restriction owing to their advantages. Unit packages for sugar and flours are becoming popular. Pigmented 75 μm LDPE, LLDPE, PET/PE films are good for the purpose.

It can be concluded that packaging for cereals/flours and sugar is vital and necessary for storage, handling, display and preservation of these products in the present economy. However, since these are essential commodities, packaging must accomplish all its functions at the lowest possible cost. As such, minimizing losses using economical packaging is the need of the hour.

BIBLIOGRAPHY

Arya SS, Mohan MS and Nath H (1971). Studies on packaging and storage of atta (wheat flour) under tropical conditions. J Food Sci Technol, 8(3): 134-139.

Balasubrahmanyam N (1995). Packaging of cereal and pulse based products. In: Profile on Food Packaging, CFTRI, Mysore.

Balasubramanyam N and Murali Krishna V (1994). Sorption characteristics and packaging of milled wheat products. Indian Miller, 17(3): 33-39.

BIS (1971). IS 607. Code of practice for construction of bagged foodgrain storage structure. Bureau of Indian Standards, New Delhi.

BIS (1983). IS 603. Code of practice for construction of underground rural foodgrain storage structure. Bureau of Indian Standards, New Delhi.

BIS (1984). IS 2566. B.Twill jute bags for packing foodgrains. Bureau of Indian Standards, New Delhi.

BIS (1986). IS 600. Code of practice for construction of Bukhari type rural food grain storage structure. Bureau of Indian Standards, New Delhi.

BIS (1986). IS 601. Code of practice for construction of kothar type rural food-grain storage structure. Bureau of Indian Standards, New Delhi.

BIS (1986). IS 602. Code of practice for construction of Morai type rural food-grain storage structure. Bureau of Indian Standards, New Delhi.

BIS (1997). IS 12650. Jute bags for packing 50 kg foodgrains. Bureau of Indian Standards, New Delhi.

BIS (2000). IS 14887. HDPE/PP woven - sacks for packing 50 kg/25 kg food-grains. Bureau of Indian Standards, New Delhi.

BIS (2002). IS 3984. B.W. Flour bags -Specification. Bureau of Indian Standards, New Delhi.

BIS (2003). IS 15318. Jute bags for packing 50 kg sugar. Bureau of Indian Standards, New Delhi.

Greddes WF (1952). Factors influencing keeping quality of grains in storage. Brewers Dig, 27(7): 897.

Grob K, Lanfranchi M, Egli J and Artho A (1991). Determination of food contamination by mineral oil from jute sack using coupled LC-GC. J AOAC, 74(3): 506-512.

Grough MC and Bateman GA (1997). Moisture humidity equilibria of tropical stored produce. I. Cereals. Tropical Stored Products Information , 33: 25-40.

Grough MC and Calverely DJB (1976). The influence of tropical climates on flexible liners for welded metal silos. Tropical Stored Products Information, 32:13-23.

Ito H, Shibabe S and Iizuka H (1971). Effect of storage studies of microorga-nisms on γ-irradiated rice. Cereal Chem, 48(2): 140-149.

Jenkins WA and Harrington JP (1991). Dry foods. In: Packaging Foods with Plastics. Technomic Publishing Company, Lancaster, Pennsylvania.

Kenneford SO and Dowd T (1981). Guidelines on the use of flexible silos for grain storage in the tropics. Tropical Stored Products Information, 42: 11-20.

Kumar KR and Anand Swamy B (1977). Packaging studies of atta and soji in unit packages. Indian Miller, 7(5): 7-15.

Locatellie DP and Daolio E (1993). Effectiveness of carbon dioxide under reduced pressure against some insects infesting packaged rice. J Stored Products Res, 29 (1): 81-87.

Mahadevaiah B, Kumar KR and Balasubramanyam N (1977). Packaging studies on pulses and cereal flours in flexible films. Indian Food Packer, 31(4): 25-31.

Mitsuda H, Kawai F and Yamomota A (1972). Under-water and underground storage of cereal grains. Food Technol, 26(3): 50-52, 54-56.

Narasimhan KS, Muttu M, Kumar KR and Majumdar SK (1986). Functional efficiency of newer packging materials with reference to insect free packaging. In: Proceedings of the Symposium on Recent Developments in Food Packaging. AFST(I), Mysore, 12-17.

New JH and Rees DP, (1988). Laboratory studies on vacuum and inert gas packing for the control of stored product insects in foodstuffs, J Sci Food and Agri, 43(3): 235-244.

Rajiv Dhar (2003). Plastics as safe and hygienic medium for packaging food and food products. In: Plastics for Environment and Sustainable Development, ICPE, Mumbai, and CIPET, Chennai.

Ramdas P (1978). Storage and handling of wheat products. Indian Miller 9(3): 7-17.

Singh Y, Sharma SS and Thapar VK (1979). Suitability of packing materials for storing wheat flours. Bull Grain Technol. 17(2): 119-124.

Sudha Rao V and Gholap AS (2000). Disinfestation of Basmati rice by one use of γ-radiation. Int J Food Sci Technol, 35(5): 533-540.

Yanai S, Ishitani T and Kojo T (1979). Influence of gaseous environment on the hermetic storage of milled rice. J Japanese Soc Food Sci Technol, 26(3):145-150.