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Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 14: Packaging of Food Grains and Their Flours

1. INTRODUCTION:

Cereals are considered to be fruits of cultivated grasses. They are the members of the monocotyledonous family *Gramineae*. The principal cereal crops are wheat, barley, oats, rye, rice, maize, sorghum and the millets. Cereals have been important crops for thousands of years and the successful production, storage and use of cereals has contributed largely to the development of modern civilization. Today cereals and cereal-based products are an important part of the diet in most countries, and each year new products based on cereals are developed and marketed to increasingly urbane consumers.

2. GRAINS

The cereals are harvested, transported and stored in the form of grains. The anatomical structure of all cereal grains is basically similar, differing from one cereal to another in detail only.

The mature grain of the common cereals consists of carbohydrates, proteins, lipids, minerals and water, together with small quantities of vitamins, enzymes and other substances, some of which are important nutrients in the human diet. Carbohydrates are quantitatively the most important constituents, forming 77 to 87% of the total dry matter. The lipids in milled cereals are likely to undergo two types of deterioration: Hydrolysis from endogenous lipases, and oxidation from endogenous lipoxygenases or molecular oxygen. Destruction of the grain and the fragmentation that occurs in milling promote deterioration by bringing the lipid and the enzyme together. The structure and quality of the grains changes due to various processing steps applied. The threats to grain during storage are moisture, temperature, fungi, bacteria, insects and other pests. If the grain moisture content can be controlled, the threats due to temperature-rise, fungi and insects can be largely controlled.

It is not the moisture content that is important for long term storage but rather the water activity (a_w), a safe moisture content for long term storage of grain and oil-seeds usually being accepted as one in equilibrium with 70% relative humidity, i.e. 0.70 a_w. Above 0.75

a_w molds will grow rapidly during storage, with subsequent deterioration. Thus, the loss of product. Moisture sorption isotherms for wheat, barley and maize have been published and all have a typical sigmoid shape. The moisture content equivalent to 0.70 a_w varies quite significantly among the different grains, thus stressing the utility of expressing stability in terms of a_w rather than moisture content.

Storage of grains take many forms, ranging from piles of unprotected grains on the floor, underground pits or containers, and piles of sacked grain, to storage bins of many sizes and shapes. It is essential that the grain has been dried to a moisture content equivalent to 0.70 a_w or less before packaging and storage. Consumer packages for grain commonly consist of heat sealed pouches made from LDPE; these provide a satisfactory moisture barrier and result in the required shelf lives for the grains.

2.1 Wheat

The wheat grain is a live, respiring organism commonly carrying endemic fungi. Respiration is slow at 14% moisture content and 20°C, but increases as moisture content and temperature increase. The process of respiration generates heat, which is difficult to remove since wheat is a poor conductor as well as CO_2 and water vapour, resulting in loss of weight. Except the grain is turned over to allow evaporation of the water, it will sweat and become caked in the storage.

Moisture contents of 16% to 30% can support fungal growth in wheat. Thus, there is the risk of mycotoxin production. Above 30% moisture content, it is susceptible to bacterial infestation, leading to spoilage, excessive heat production and possibly charring. Insect life also becomes more active as the temperature rises and, because of their respiration, live insects in grain also increase the grain temperature. Deterioration during storage is intensified by mechanical damage during harvesting since microorganisms attack damaged grains more readily than intact grains. A drop of 3% in moisture increases the shelf life four times. The major problems at these higher moisture contents include accelerated wheat enzyme activities and microbial spoilage.

2.2 Rice

Rice is consumed in large quantities in many countries. Brown or unmilled rice is more nutritious than milled rice, but storage stability problems and a traditional consumer preference for whole rice have limited the quantities of brown rice packaged and sold for direct consumption. A major limiting factor to less use of brown rice is accumulation of free fatty acids in rice stored under warm and humid conditions. Fatty acids can be released by lipase activity present in the rice bran layer of damaged grains and by high lipase-containing microorganisms adhering to rice.

In a study to evaluate the effects of CO_2 gas flushing on the shelf life of brown rice, greater stability of the rice was obtained at refrigerated (4°C) storage when it was packaged in nylon-EVA copolymer laminate film bag rather than a regular plastic bag. However, no differences were found when stored at 24°C. The gas flushed bags formed a hard, rigid pack similar to a vacuum packaged product and maintained this appearance for at least 3 years. It was suggested that if bulk rice in warehouses could be stored as brown rice instead of as rough rice in laminate or gas flushed bags, savings of at least 20% by weight and 30 to 35% by volume should result.

3. FLOUR

Wheat flour is the ground or milled form of wheat grain in which the bran and germ are partly removed and the remainder is comminuted to a suitable degree of fineness. It has been suggested that for long periods of conservation, flour should be stored in a closed atmosphere. Under these conditions, flour acidity increases due to the accumulation of linoleic and linolenic acids. Flour is stored commercially in bags or in bulk bins. The threats to flour in storage are similar to those of wheat in storage, viz., mold and bacterial attack, insect infestation, oxidative rancidity and eventual deterioration of baking quality.

The expected shelf life of plain white flour packaged in paper bags and stored in cool and dry conditions and protected from infestation is 23 years. The rate of increase in acidity increases with storage temperature and decreasing flour grade by increasing ash residue in the flour. Thus, the shelf life of brown and wholemeal flours is shorter than that of white flour. Freedom from insect infestation during storage can be guaranteed only if the flour is free from insects at the time of packing, and even the storage area is free from insect infestation. The use of multi-walled kraft paper bags, sometimes with an LDPE liner, completely eliminates any infestation hazard.

The optimum moisture content for the storage of flour is related to the intended shelf life, the barrier properties of the packaging material, and the ambient conditions. For use within a few weeks, flour can be packaged at 14% moisture content, but at moisture contents higher than 13%, mustiness due to mold growth may develop over time. At moisture contents lower than 12%, the risk of lipid oxidation and the development of rancidity increases. Australian millers maintain flour moisture contents below 12% for shipment to warm and humid areas, while in the United Kingdom wheat flour is stored at maximum moisture content of 12%.

Reference to a moisture sorption isotherm shows that a moisture content of 12% corresponds to a_w of 0.50. As with wheat and other grains, the moisture content is an unreliable means to measure stability and what is required are moisture sorption isotherms at various temperatures so that the moisture content which corresponds to the maximum a_w for stability at a particular storage temperature can be determined. This will vary depending on the type of grain as well as the variety. But, data on the shelf life of flour at various a_w's and values for critical moisture contents are missing, and it is therefore difficult to specify precisely the type of moisture vapour barrier required in a package.

Notwithstanding the lack of information about critical moisture contents and shelf lives as a function of a_w, bags made from cotton twill or paper have been used successfully for decades for consumer packs of flour. Kraft paper bags with an LDPE liner provides additional protection, thus, a longer shelf life.

4. BREAKFAST CEREALS

Breakfast cereals can be categorised according to (1) the amount of cooking required, (2) the form of the product, and (3) the cereal used as raw material. All cereals contains large amount of starch which in its natural form is insoluble, tasteless and unsuitable for human consumption. It must be cooked or processed to make it digestible and acceptable. In hot cereals the cooking is carried out in the home, while ready-to-eat cereals are cooked during manufacture or processing.

If the cereal is cooked with excess water and moderate heat like in boiling, the starch gelatinizes and becomes susceptible to starch-hydrolysing enzymes in the human digestive system. If the cereal is cooked with a minimum of water or without water but at higher temperatures as in toasting, nonenzymatic browning between protein and reducing sugars may occur and there may be some depolymerisation of the starch.

4.1 Characteristics of Breakfast Cereals

Ready-to-eat cereals probably originated from the Seventh Day Adventist Church, whose members, preferring an entirely vegetarian diet, experimented with the processing of cereals in the mid-nineteenth century. A granulated product called Granula and made by J.C. Jackson in 1863 may have been the first commercially available ready-to-eat breakfast cereal. A similar product called Granola was made by J.H. Kellogg by grinding biscuits made from wheat meal, oatmeal and maize meal.

Ready-to-eat cereals include flaked, shredded and granulated products, generally made from wheat, maize or rice, even though oats and barley are also used. The basic cereal may be supplemented with sugar, honey or malt extract. All types are prepared by processes which tend to cause hydrolysis or dextrinization rather than gelatinization of the starch. Flaked products are made from wheat, corn, oats or rice. After cooking at elevated pressure and the addition of flavourings such as malt, sugar and salt, the cereal is dried to 15 to 20% moisture content and conditioned for 13 days. It is then flaked, toasted, cooled and packaged.

Shredded cereals are made from whole wheat grains which are cooked to gelatinize the starch. After cooling and conditioning, the grain is fed through shredders. The shreds are baked for 20 min at 260°C, dried to 1% moisture, cooled and packaged. Granulated products are made from a yeast dough consisting of wheat flour and salt. The dough is baked as large loaves, then broken up, dried and ground to a standard fineness.

Flaked cereals are sometimes coated with sugar to provide a hard, transparent coating that does not become sticky even under humid conditions. The sugar content of cornflakes increases from 7% to 43% as a result of the coating process.

4.2 Deterioration in Breakfast Cereals

There are five major modes of deterioration to be considered while selecting packaging materials for breakfast cereals. They are (1) Moisture gain resulting in loss of crispness, (2) Lipid oxidation resulting in rancidity and off-flavours, (3) Loss of vitamins, (4) Breakage, resulting in an aesthetically undesirable product and (5) Loss of aroma from flavoured product.

The shelf life of breakfast cereals depends on the content and quality of the oil contained in them. Thus, products made from cereals having a low oil content such as wheat, barley, rice and maize grits (oil content: 1.5 to 2.0%) have a longer shelf life than products made from oats (oil content: 4 to 11%, average 7%). Although whole corn has a high oil content (4.4%), most of the oil is contained in the germ which is removed in making grits.

4.3 Packaging of Breakfast Cereals

Packaging of breakfast cereals has traditionally been in fibreboard boxes with a supercalendered waxed glassine liner. Now the glassine liner has been replaced by various plastic materials, in particular with thin gauge HDPE which is usually folded rather than heat sealed. HDPE coextruded with a thin layer of EVA copolymer is a recent introduction, the EVA copolymer allowing a lower heat seal temperature and offering the consumer an attractive and peelable seal.

When the cereal product is not hygroscopic and holds a satisfactory texture when in equilibrium with the ambient conditions, a liner may not be needed for moisture protection and may even serve to entrap rancid aromas. In such case, either no liner or one which is vapour permeable may be used. As well as providing a barrier to vapour, the liner must also restrain cereal aromas within and at the same time prevent foreign odours entering the packaged product. It should also be reclosable to protect the remaining cereal in the package.

To minimize oxidative rancidity in the cereals it is important that the package eliminate light. Excluding oxygen may be of limited assistance in extending shelf life. For this reason, most processors do not bother to use good oxygen barrier packaging. In a study of the storage stability of flaked oat cereal packaged in materials of different oxygen barrier properties with and without the addition of an iron-based oxygen absorber, the absorber delayed lipid oxidation provided that it was used with a packaging material such as PVC/PVDC copolymer-coated PP-LDPE that was a good oxygen barrier. The use of an anti-oxidant in the package liner has been shown to be successful in extending shelf life but is not generally permitted in most countries.

In shredded cereals, rancid odours accumulates if shredded wheat is stored in an airtight container, due to the higher unsaturated fat content. Therefore, it is usually sold in breather boxes without linings. When so packaged, the product is just as stable as any other prepared cereal, except that moisture absorption takes place much more readily.

The vitamin and mineral fortification of cereals is widely used in many countries. The major cause of vitamin loss in packaged cereals is the temperature of storage. In a study on the effects of processing and storage on micronutrients in breakfast cereals, it was found that micronutrient loss is not a major factor in determining the shelf life of dry cereals. There was no considerable loss of added vitamins during normal shelf lives, with the possible exception of vitamin A and C. Vitamin A survived six months at room temperature with no measurable loss.

The rigidity and compression resistance of the carton together must provide the necessary resistance to product breakage throughout production line operations, storage and distribution. Rigidity also prevents the bulging of the carton. Protecting breakfast cereals from breakage does not appear to be a problem using currently available carton stock and carton designs.

Loss of flavour is a problem with certain cereal products to which fruit flavours have been added before packaging. In these cases, loss of flavour results in the product being considered to be at the end of its shelf life by the consumer. A study evaluating HDPE and glassine as liner found that the permeability coefficients of *d*-limonene (common flavour component in citrus products) in the HDPE liner were three to four times higher than in glassine. It was also found that the solubility of *d*-limonene in the glassine liner was significantly lower than in the HDPE liner for the same vapour pressures. Hence, equilibrium distribution of the limonene vapour between a product such as a fruit-flavoured cereal and the respective liners will result in a lower limonene concentration within the glassine liner, and scalping of the flavour can be expected to be more significant in the HDPE liner.

5. Conclusion

Moisture and temperature are the major factors affecting the shelf life of cereal grains and their flours. So the packaging materials used should have good moisture barrier properties for grains, while in case of flours the packaging material should also prevent light. The primary mode of chemical deterioration in dry breakfast cereals is lipid oxidation and two reasons have been advanced for this. First, a_w of dry cereals is at or below the monolayer which essentially stops all other types of deteriorative reactions. Second, unsaturated fats are required in lipid oxidation and the grains used in breakfast cereals have a high ratio of unsaturated to saturated fats. Thus, the laminated liners with aluminium foil can be used with paper board cartons which prevents light and moisture.

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