Paper 2: Principle of the Food Processing and Preservation

Module 32: Controlled atmosphere Storage and Modified atmosphere Storage Packaging

32.1 Introduction

The fresh, high qualityproducts are the major requirements for the national as well as international food industry during this current era. After harvesting,especially for fresh fruits and vegetables continue their respiration process. To maintain quality, the respiration rate has to be reduced, especially when the products are stored for an extended period or shipped to distant markets. The best way to preserve quality and extend shelf life is by cooling, and another method used to extend shelf life is the modification of the atmosphere surrounding the product. Most products tend to keep longer in atmospheres that are high in carbon dioxide and low in oxygen. Atmosphere modification is usually used as a complement for cooling. Controlled Atmosphere Storage (CAS) and Modified atmospheric packaging (MAP) are two hot topics for food researchers to maintain food quality and freshness.

32.2 Controlled Atmosphere Storage (CAS)

The technique of modification of the atmosphere surrounding perishable products is referred to as CAS. In CAS, the atmosphere is created artificially and the gas composition is continuously monitored and adjusted to maintain the optimum gas concentration. There are different types of controlled atmosphere storage depending mainly on the method or degree of control of the gases. Mainly two type of control atmosphere storage systems like ñStatic controlled atmosphere storageò and ñFlushed controlled atmosphere storageò most commonly used. ñStaticò is where the product generates the atmosphere and ñFlushedò is where the atmosphere is supplied from a flowing gas stream, which purges thestore continuously.

32.2.1Historical development

The first commercial applications of the use of modified gas atmospheres were for CAS offruits and vegetables. Fresh carcass meat was exported from New Zealand and Australia under CAS in the early 1930s. Early developments were generally for storage and transportation of bulk foods. Scientific investigations on the effect of gases on extending the shelf life of foods were conducted in 1930 on fresh meat. It was reported that a doubling of the shelf life of refrigerated pork and lamb when these meats were stored in an atmosphere of 100% CO_2.

32.2.2Beneficial Effects of CAS

Using CAS has a wide range of benefits such as the following:

1.A considerable decrease in respiration rate of fruits and vegetable

2. A reduction in the effect of ethylene on metabolism due to the interaction of O_2 withethylene.

3. An extension in storage life, which can even be doubled, in as much as the overripening is delayed.

4. The preservation of an excellent firmness of meat, due to effect of CO_2 concentrationon the enzymes acting on cellular membranes.

5. A high turgidity is achieved, such that fruits become more juicy and crispy.

6. A smaller loss of acidity, sugars and vitamin C, so that the nutritional and sensoryquality is higher.

7. A limited degradation of chlorophyll, with a consequent higher stability of colour.

32.3 ATMOSPHERE CONDITIONING

The reduction of O_2 level inside the storage rooms can be biologically achieved by means of fruit respiration, or by O_2 burning, or by replacing air by feeding nitrogen. In first case, the reduction in O_2 down to a steady state level takes place within 15-25 days, with a slow and progressive decrease thereof. When a non-biological system is used, O_2 can be reduced to levels of 6-8% within 24 h and the subsequent lowering to the desired levels for storage can take place via respiration. The reduction in O_2 level can be rapid only if the fruits have reached a temperature lower than 5°C. The fastest reduction in O_2 level in the atmosphere is obtained by using nitrogen generators (by now, a widely used system), or by feeding liquid N_2. Lowering O_2 down to steady state controlled atmosphere levels by means of non-biological techniques is disadvantageous froma financial standpoint, due to the high consumption of fuel or of nitrogen. Nitrogen generator selectively separate air to produce an enriched nitrogen system.

The storability of fruits and vegetables is strictly related to their respiration rate, which is an expression of metabolic activity. Aerobic respiration requires O_2, and results in CO_2 and heat release. More than 95% of the energy released is lost as heat. The temperature decrease, in particular if helped by modification of the atmosphere leads to a reduction in respiration rate, and therefore to an increase in storage life in fruits with climacteric respiration. Selection of the most suitable atmosphere depends on cultivars, stage of maturity, environmental and cultivation parameters.

32.4Requirements for Ideal CAS

A. CA STORAGE ROOM

A gas tight room is an obvious prerequisite for achieving a good controlled atmosphere storage system. Thusit is necessary to make room walls gas -tight. In order to ensure that the walls are gas tight to CA storage they are lined with sheets of galvanized steel.

B.Temperature Control

The main way of preserving fruits, vegetables and meat in storage or during long distance transportis by refrigeration, and controlled atmospheres are considered a supplement to increase orenhance the effect of refrigeration. CA storage is only successful when applied at low temperatures. Standard refrigeration units are therefore integral components of CAS system.Temperature control is achieved by having pipes containing a refrigerant inside the storage.Ammonia or chlorofluorocarbons are common refrigerants.

C. Humidity Control

Most fruits, vegetables and meats, which are kept in CA storage, require a high relative humidity, generally the closer to saturation the better, so long as moisture does not condense on thefoods. The amount of heat absorbed by the cooling coils of the refrigeration unit is related to the temperature of the refrigerant they contain and the surface area of the coils. If therefrigerant temperature is low compared to the store air temperature then water will condenseon the evaporator. This removal of moisture from the store air, reduces its relative humidity,which results in the stored food losing moisture by evaporation-transpiration. In order to reducefood desiccation the refrigerant temperature should be kept close to the store air temperature.

D. Gas Control

The atmosphere in a modern CA store is constantly analysed for CO_2 and O_2 levels using an Infrared gas analyser to measure the gas content in the store constantly.There are also ethylene analysers that continuously measure ethylene concentration in the store. In storage rooms where low ethylene is essential, checks can be made that the ventilation and ethylene removal systems are operating correctly.

E. Scrubbers

The composition of the gas mixture inside the storage rooms undergoes continuous change as a function of the metabolic activity of the stored product and scrubbers are necessary toabsorb excess CO_2. Scrubbers are generally classified according to the absorbent material:$Ca(OH)_2$, NaOH, H_2 O, zeolites, activated charcoals. They are alsoclassified according to themode of absorption (i.e. chemical or physical), or to the mode of air passage through theabsorbing agent. Scrubbers using activated charcoal are currently the most popular. Gasremoval with this type of equipment is based on the fixing of CO_2 in a particular way, andreleasing it again on contact with atmospheric air, even at room temperature.

32.5 Adverse Effect

CA storage has also adverse effects, at O_2 levels below 1%, in the absence of CO_2, anaerobic conditions can prevail with the consequent formation of alcohol and physiological changes. Also high CO_2 and low O_2 may cause abnormality in metabolism in fruits and vegetables.

32.6Modified Atmosphere Packaging (MAP)

MAP is the replacement of air (N_2 content 78%, O_2 content 21%, CO_2 content 0.035%, together with water vapour and traces of inert gases) in a pack with a single gas or mixture of gases; the proportion of each component is fixed when the mixture is introduced.

Sometimes, certain additives are incorporated into the polymeric packaging film or within packaging containers to modify the headspace atmosphere and to extend shelf-life. This is referred to as Active Packaging. Modified atmosphere can be created also passively. In passive modification, the respiring product is placed in a polymeric package and sealed hermetically. Only the respiration of the product and the gas permeability of the film influence the change in gaseous composition of the environment surrounding the product. If the productôs respiration characteristics are properly matched to the films permeability values, then a beneficial modified atmosphere can be passively created within a package. The concept of active packaging has been developed torectify the deficiencies in passive packaging. For e.g. when a film is a good barrier to moisture, but not to oxygen, the film can still be used along with an oxygen scavenger to exclude oxygen from the pack. Similarly, carbon dioxide absorbents/emitters, ethanol emitters and ethylene absorbents can be used to control oxygen levels inside the MA pack. The appropriate absorbent materials are placed alongside with the food. By their activity, they modify the headspace of the package and thereby contribute to extend the shelf-life of the contents. In case of active modification, two basic techniques are employed to replace air in MAP i.e. Gas flushing and Compensated Vacuum.

32.7Historical development

Commercial retailing of fresh meat in MAP tray systems was introduced in the early 1970s. European meat processing and packaging developed during the 1980s with centralised production of MAP meat in consumer packs for distribution to retail outlets. In the past few years, there has been a considerable increase in the range of foods packed in modified atmospheres for retailsale including meat, poultry, fish, bacon, bread, cakes, crisps, cheese and salad vegetables.

32.8Gases used in MAP

In MAP, the pack is flushed with a gas or a combination of gases. The common gases used are oxygen, nitrogen and carbon dioxide. Traces of carbon monoxide, nitrous oxide, ozone, argon, ethanol, vapour and sulphur dioxide are also used. Minimum oxygen levels are used to pack food under MA because oxygen reacts with the foodstuff resulting in theoxidative breakdown of food into their constitutive parts. Oxygen also combines easilywith fats and oils causing rancidity. Nitrogen is an inert gas. It has no anti-microbial activity and acts as a cushion, thereby preventing pack collapse. Since it displaces oxygen from the pack, oxidative rancidity is delayed. Carbon dioxide is responsible for the bacteriostatic and fungistatic effect in MA packaged food. It retards the growth of moulds and aerobic bacteria. The inhibitory effect of carbon dioxide to micro-organisms is increased as the temperature is lowered because of increased solubility.

32.9PACKAGING MATERIALS

Several factors influence the design of a suitable modified atmosphere package: commodity, temperature, optimum atmosphere (% O_2, % CO_2), respiration rate, product weight, and atmosphere outside the package. Based on this information, a packaging film as well as the area of the film have to be selected in such a way that the optimum atmosphere is obtained inside the package.Selection of the most appropriate packaging materials is essential to maintain the quality and safety of MAP foods. Flexible and semi-rigid plastics and plastic laminates are the most common materials used for MAP foods. Plastic materials account for approximately one-third of the total materials demand for foodpackaging applications, and their use is forecast to grow. Relative ease of forming, light weight, good clarity, heat sealing and strength are some of the properties of plastics that make them suitable as food packaging materials. Advances in polymer processing have enabled the development of plastics that are better suited to particular food packaging applications. However, no single plastic possesses the properties that make it suited to all food packaging applications.Plastic packaging materials may consist of a monolayer formed from a single plastic, but most, if not all, MAP films are multilayer structures formed from several layers of different plastics. Using coextrusion, lamination or coating technologies, it is possible to combine different types of plastic to form films, sheets or rigid packs. Plastics packaging for MAP applications is most commonly found in the form of flexible films for bags, pouches, pillow packs and top webs or as rigid and semi-rigid structures for base trays, dishes, cups and tubs. Commonly used plastic flexible laminates are produced from polyethylene (PE), polypropylene (PP), polyamide (nylons), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polyvinylidene chloride (PVdC) and ethylene vinyl alcohol (EVOH). It should be noted that certain desired properties can be enhanced by further processing the material. For example, coating a plastic with aluminium (metallisation) can improve the gas and vapour barrier properties and enhance the visual appearance of the material. PP is commonly metallised by passing the film through a mist of vaporised aluminium under vacuum. Similar treatments to improve gas and vapour barrier properties include application of a silicon oxide (SiO_2) coating (also referred to as glass coating) to PET film and a diamond-like-carbon (DLC) coating to PET.

32.9.1 Characteristics of ideal film

The ideal film must possess the following characteristics:

- Ability to change the gas permeability properties in case of rise in temperature.
- Controllable moisture vapour transmission rate (MVTR) in order to prevent supersaturation.
- Good thermal and ozone resistance.
- Commercial suitability and ease of handling and application.
- Non-reactant with produce and nontoxic.

32.10POTENTIAL ADVANTAGES AND DISADVANTAGES OF MAP

32.10.1 Advantages

- Fresh appearance.
- Potential shelf-life increase by 50 ï 400 %.
- Reduced economic losses.
- Product distributed over long distances.
- Increased market area.
- Provides a high quality product.

32.10.2Disadvantages

- Visible added cost.

- Temperature control necessary.
- Different gas formulation needed for each product type.
- Special equipment and training required.

32.11Safety Aspects of MAP on Microbial and Pathogenic Organisms

The microbial load in the packaged food has a significant effect on the quality of final product. A high microbial load and temperatures higher than recommended for particular food can reduce the shelf life of a product by 50-70 %. There are ample evidences that elevated CO_2 extends the lag phase of bacterial growth and can slow the propagation of bacteria. Low O_2 is likely to favour mesophilllic microbes such as *Listeria* and lactic acid bacteria. Elevated CO_2 may favour gram-positive bacteria over gram-negative bacteria, especially *Coryneforms* and lactic acid bacteria. It is studied that 20-30 % CO_2 or even 10 % CO_2 may be sufficient to retard bacterial growth. High levels of CO_2 have generally been found to have an inhibitory effect on *Staphylococcus aureus*, *Salmonella sp*. and *Y. enterocolitica*. The degree of inhibition increases as temperature decreases. MAP stored products at 4°C have a shelf life 2 to 3 times greater than air-packed products. An important factor in determining the microbiological safety of MAP food is whether the food is sold as óready-to-eatô or órawô. The use of MAP for any raw produce that is subsequently cooked is considered less hazardous because cooking will kill all vegetative pathogens. The safety and stability of foods largely depends upon the initial microbial load. Modification of the atmosphere surrounding the food may provide one condition or hurdle that helps restrict the growth of microorganisms.

32.12FUTURE CHALLENGES OF MAP-

MAP undoubtedly enhances the shelf life of products without preservatives. The success of MAP depends on many factors including good initial product quality, the appropriate gas mixture of the product, reliable packaging equipment, and maintenance of controlled temperatures. It is important to realize that storage not only improves the quality but also delays the rate of spoilage. However, as consumers are more aware of the economic advantage of MAP technology, it will slowly emerge as the preservation cum packaging technology of future, propelling the food industry into a new era of food products, distribution and marketing.