Paper No.: 02

Paper Title: The Principles of the Food Processing & Preservation

Module No. : 18

Module Title: Principles Underlying the Preparation of Intermediate Moisture Foods

18.0 Introduction

A recent development in the food industry is the 'emphasis on intermediate moisture foods which have the facility of being stored and marketed in a substantially non-refrigerated condition. These foods were designed to avoid the need to be packaged in a hermetically sealed container and commercially sterilized or maintained in a frozen or refrigerated state throughout the period of distribution and storage by the consumer.

The intermediate-moisture foods are based on the principle of reducing the availability of the water in the food for microbial growth. The availability of water for spore germination and microbial growth is closely related to its relative vapor pressure, commonly designated as water activity. It was found that the use of a wide variety of water-soluble solutes, or osmotic agents, has the effect of depressing the water activity of the foods to levels at which most bacteria will not grow.

The importance of considering the combined action of decreased water activity with other preservation factors as a way to develop new improved foodstuffs has been studied. Leistner (1994) introduced the hurdle concept, or hurdle effect, to illustrate the fact that in most foods, a combination of preservation parameters (hurdles) accounts for their final microbial stability and safety. Since then, these concepts have been improved to the point that depending on the acting hurdles of high relevance to a particular product, shelf-stability can be accomplished by a careful handling of complementary hurdles. For instance, the pH of intermediate moisture foods (IMF) should be as low as palatability permits, and whenever possible, below pH 5.0. Undoubtedly, this imposes a limitation not only on colonizing microflora, but also on foodstuffs, since pH cannot be reduced in many products without flavour impairment. Even at low pH values and low a_w, certain yeast and mould species that can tolerate high solute concentrations might pose a risk to the stability of IMF.

Fruits are a good example of foodstuffs that accept pH reduction without affecting the flavour significantly. Important developments on IMF based on fruits and vegetables are reported elsewhere. Technological problems have prevented IMF from further developments. Also, consumer health concerns associated with the high levels of humectants and preservatives used, have contributed to this situation. This last issue has become more important in recent years due to greater public awareness of food safety concerns. Additionally, consumers are searching for fresh-like characteristics in products. The food industry has responded to these demands with the so-called minimally processed fruits and vegetables, which have become a widespread industry. Consequently, safety considerations are being addressed seriously by food microbiologists.

The principle used by Leistner for shelf-stable high moisture meats (a_w >0.90), where only mild heat treatment is used and the product still exhibits a long shelf life without refrigeration, can be applied to other foodstuffs. Fruits would be a good choice. For industrialized countries, production of shelf-stable products (SSP) is more attractive than IMF because the required a_w for SSP is not as low and less humectants and/or less drying of the product is necessary. If fresh-like fruit is the goal, dehydration should not be used in processing. Reduction of a_w by addition of humectants should be employed at a minimum level to maintain the product in a high moisture state. To compensate for the high moisture left in the product (in terms of stability), a controlled blanching can be applied without affecting the sensory and nutritional properties; pH reductions can be made that will not impair flavour; and preservatives can be added to alleviate the risk of spoilage by microflora. In conjunction with the above mentioned factors, a slight thermal treatment, pH reduction, slight aw reduction and the addition of antimicrobials (sorbic or benzoic acid, sulphite), all placed in context with the hurdle principle applied to fruits, make up an interesting alternative to IMF preservation of fruits, as well as to commercial minimally processed fruits.

Over the last decade, use of IMF principle has led to important developments of innovative technologies for obtaining shelf-stable "high moisture fruit products" (HMFP) storable for 3-8 months without refrigeration. These new technologies are based on a combination of inhibiting factors to combat the deleterious effects of microorganisms in fruits, including additional factors to diminish major quality loss in reactions rates. Slight reduction of water activity (a_w 0.94-0.98), control of pH (pH 3.0-4.1), mild heat treatment, addition of preservatives (concentrations £ 1,500 ppm), and anti-browning additives were the factors selected to formulate the preservation procedure. These techniques were preceded by the pioneer work of Leistner (1994) on the combined effects of several factors applied to meat products - named "hurdle" technology. Microbiological preservation with these combined techniques, by gently applying individual stress factors to control microbial growth, avoid the severity of techniques based on the employment of only one conservation factor.

18.1 Preliminary operations

Preliminary operations involve washing, selecting, peeling, slicing, and general blanching of fresh fruits. Fresh produce must be processed between 4 and 48 hours after harvest to prevent the growth of spoilage microorganisms.

18.1.1 Washing: This operation involves eliminating dirt from the material before it passes through the processing line. Fruits are washed with potable water by immersion, spraying or brushing to eliminate the soil. Sodium hypochlorite is usually added to the water at a rate of 10% (v/v). The effectiveness of chlorine is enhanced by using a low pH, high temperature, pure water, and the correct contact time.

18.1.2 Fruit selection: The cleaned product is selected for processing by separating the damaged fruits from those free of defects and disease. The fruit must be of a uniform size, form, colour, and maturity.

18.1.3 Peeling: This operation consists of removing the skin from the fruit (usually by hand) using a sharp knife. There are several peeling methods available, but on an industrial scale, peeling is normally accomplished mechanically (e.g., rotating carborundum drums) and chemically, or with high-pressure steam peelers.

18.1.4 Slicing: This operation involves cutting the fruit into several uniform pieces, which is more convenient than handling the entire fruit. This is accomplished manually with a sharp knife or with special cutting machines that produce clean, neat slices.

18.1.5 Blanching: This is a critical control operation in the processing of intermediate and high moisture fruit products (HMFP). It is an early step for processing of several fruits. Destruction of contaminating organisms is not the treatment's main objective, but it occurs nevertheless because the temperature used is lethal to yeast, most moulds, and aerobic natural flora. Many microorganisms can survive heat treatment but are sensitive to other hurdles like pH and water activity (a_w). A 60 to 99% reduction in the microbial load of IMF/HMFP for papaya, pineapple, strawberry, and mango has been reported. For mangoes, the microbial counts decreased from 14.3

× 10^3 cfu/g in the fresh fruit to 1.3 × 10^3 cfu/g after blanching. The blanching temperatures were between 85 and 100°C for very short periods, usually 3 to 5 minutes.

18.2 Desired a_w and syrup formulation

The desired a_w is determined by equilibrium of the components in the food system. This includes the addition of water, sugar (sucrose, glucose, or fructose), and chemicals such as citric acid, sodium bisulphite, and potassium sorbate, etc. The levels of sodium bisulphite and potassium sorbate in the system can be used at 150 and 1000 ppm, respectively. Once the system is in equilibrium, the a_w can be measured using an automatic water activity meter to an accuracy of + or - 0.005.

18.2.1 Calculations required

To determine the desired a_w in syrup (a_w equilibrium), the Ross equation is used:

$$a_{w\ equilibrium} = (a°w)fruit \cdot (a°w)\ sugar \quad (1)$$

where, $a°_{w\ fruit}$ is the water activity of the fruit and $a°_{w\ sugar}$ is the water activity of sugar, both calculated at the total molality of the system. The product of the molality of sucrose in the fruit water and solution must equal the desired water activity in equilibrium. The $a°_W$ values of the sugar are obtained using the Norrish equation:

$$a°_{w\ sucrose} = X_1 \exp(-kX^2{}_2) \quad (2)$$

where k is a constant for sugars, X_1 and X_2 are the molar fractions of water and sugar, respectively.

Phosphoric or citric acids are generally used to reduce the syrupôs pH so that the final pH of the fruit-syrup system is in equilibrium in the desired range (3.0 to 4.1). Monitoring of a_w and pH in the fruit and syrup until constant values for these parameters are reached can determine the time to equilibrate the system. This may be from three to five days at constant room temperature depending on the size of fruit pieces.

18.2.2 Water content vs. a_w relationship

Figures.1 and 2 represent typical curves that can be applied to most food systems for equilibrium water content (g water/g solid) versus water activity (% ERH). The graphs indicate the range in which foods can be adjusted. In general, dehydrated foods have less than 0.60 a_w; meanwhile, intermediate moisture foods (IMF) have water activity ranging between 0.62 and 0.92. Figure.1 shows that the water activity does not decrease much below 0.99 until the moisture content is reduced to 1 g H_20 per g of solid. A decrease in water activity or water content can be accomplished by drying, and by the addition of humectants, which reduces water activity through the effects of Raoultôs law, or by the addition of dried ingredients such as starch, gums, or fibres, which interact with water through several mechanisms.

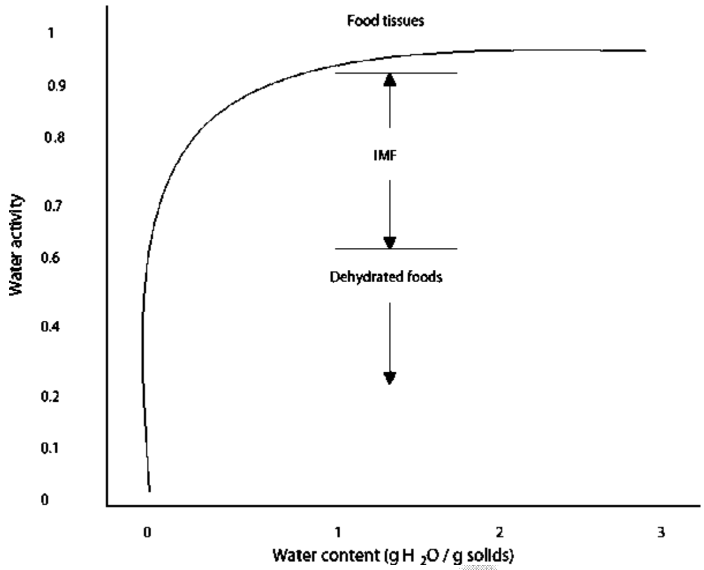

Figure.1: Typical equilibrium of water content vs. water activity in foods.

18.2.3 Preparation of syrup or brine solution

To prepare the syrup or brine, a sufficient amount of sugar or salt is dissolved in water in order to reach the desired a_w. Concentrations of sulphur dioxide and potassium sorbate are prepared, reaching a final concentration of 100-150 ppm and 1000-1500 ppm, respectively. In the case of fruit products, citric or phosphoric acid are used to lower the pH of the syrup so that the final pH at equilibrium is in the range 3.0-4.1.

High moisture food products (HMFP) are very different from IMF products and need to be dehydrated. HMFP have a lower sugar concentration, 24-28% w/w compared to 20-40% w/w, and a higher moisture content, 55-75% w/w compared to 20-40% w/w, which makes them similar to canned food products. HMFP can be consumed directly after processing or bulk stored for processing out of season.

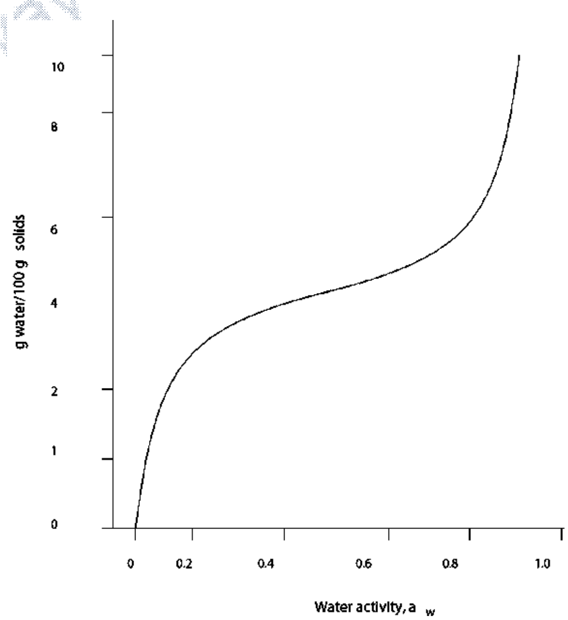

Figure.2: Equilibrium of water activity vs. moisture content, typical in foods.

Lower region of isotherm.

Several process flow-diagrams are given below for the preparation of IMF (Figures.3 & 4). For each, the amount of sugar, salt, chemical preservatives (benzoates, sorbates, vanillin, etc.), browning agents (ascorbic acid, etc.), texturizers (calcium salts, etc.), etc., must be determined according to the weight of fruit used and the final levels required after equilibration of the product.

The intermediate moisture fruit products stabilized by combined methods (Figure.4) were prepared from mango (*Mangifera indica L.*) var. ñBocadoò and papaya (*Carica papaya L.*) var. ñCriollaò, grown in Venezuela. Mango and papaya fruits were cut into slices and chunks, subjected to steam blanching for 4 minutes, cooled in water, and stabilized in sucrose syrups (42.25% w/w for mango and 33% w/w for papaya), with a fruit syrup ratio1:2 to attain equilibrium with a_w at 0.0.97 and 0.98, respectively. A final pH of 3.0 for mango and 3.5 for papaya was accomplished by adding citric acid. Sufficient sodium sulphite and potassium sorbate were also added to achieve equilibrium at 150 and 1000 ppm, respectively. The fruit products were equilibrated in 20 L plastic containers before packing into 500 g glass jars. The fruit products were stored for at least 30 days at 35°C, exhibiting good acceptability, microbial stability, and fresh-like appearance.

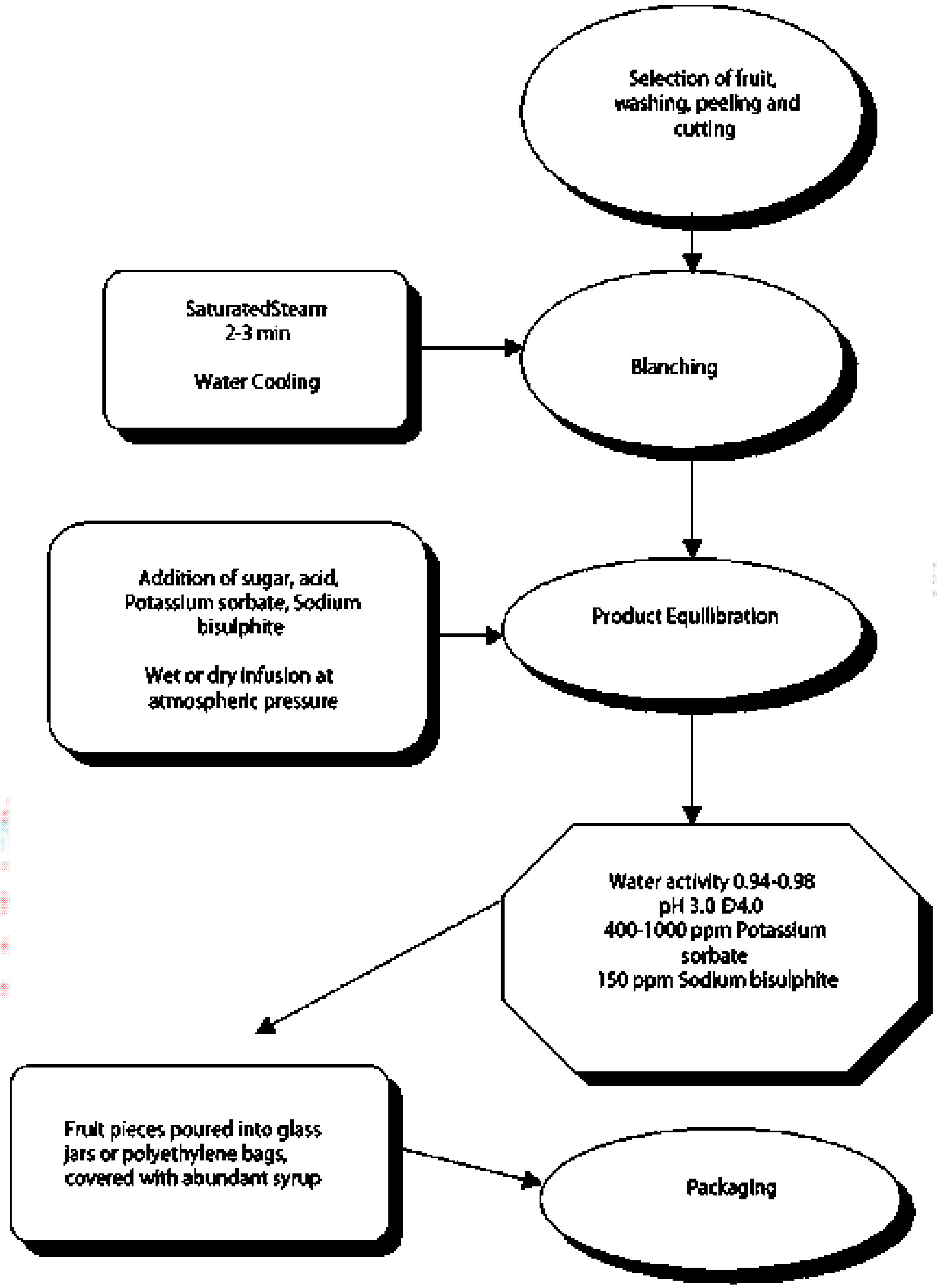

Figure.3: Preparation of shelf-stable IMF/HMFP

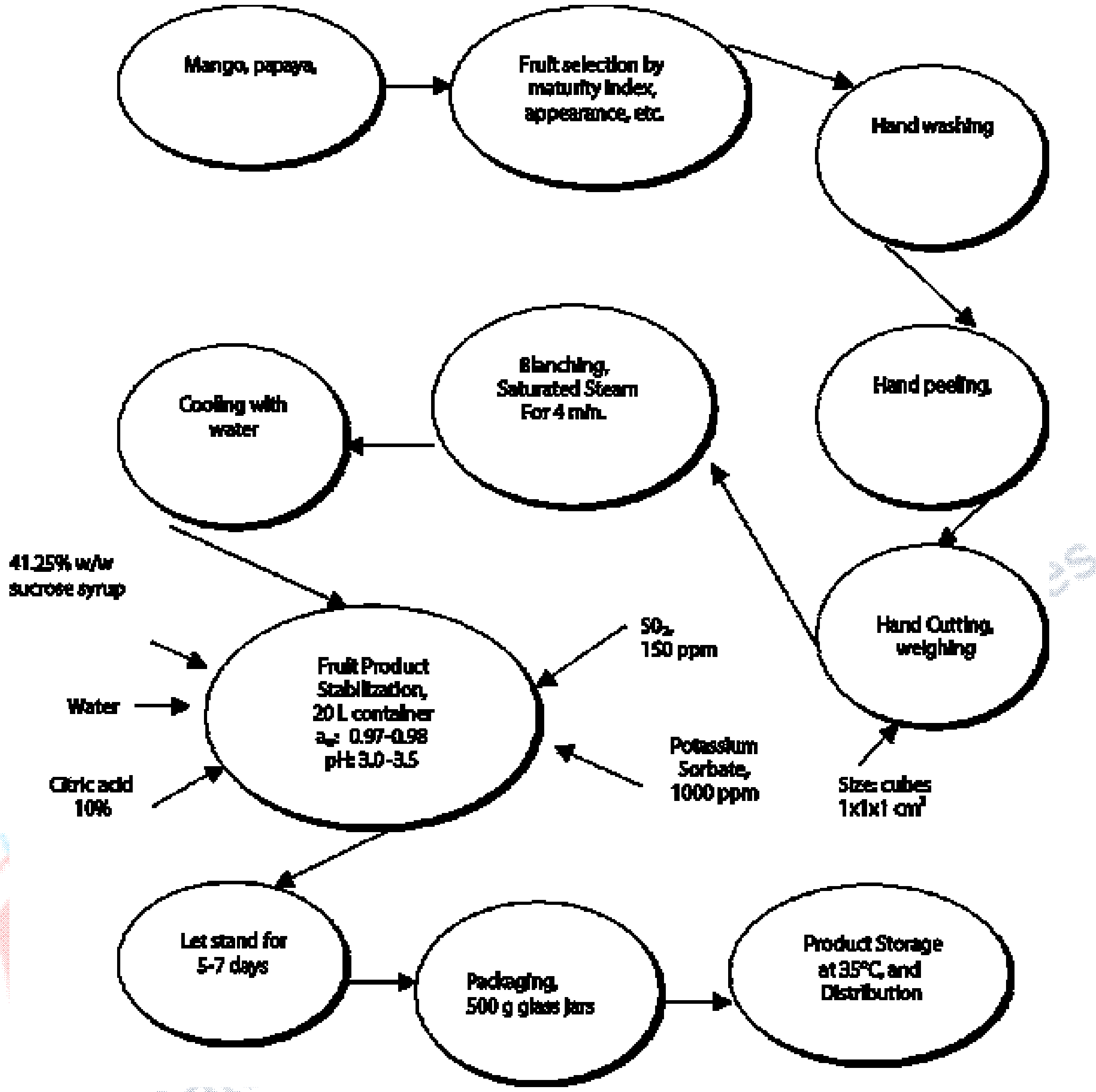

Figure.4: Schematic diagram for the preparation of shelf stable mango and papaya fruits by combined methods

18.3 Packaging methods for intermediate moisture processed products

The purpose of food packaging is to maintain quality and to obtain shelf life extension of products by reducing mechanical damage and retarding microbial spoilage. Three types of packaging methods exist for intermediate moisture processed products, ie., unit packaging, transport packaging, and loading packaging. Other packaging methods are vacuum and modified atmospheres.

18.4 Packaging with small units: This type of packaging method uses (1) closed plastic bags, (2) rigid or semi-rigid plastic trays zipped in upper part with polymeric plastic film, (3) covered trays for distribution of products to institutions (e.g., hotels, restaurants, and food shops) and small business consumer markets, (4) perforated or unperforated PE or PVC bags, (5) shallow trays, (6) cartons, and (7) thermo-formed plastic tubs or expanded PS containers covered/sealed with polymeric film. Two of the main requirements for this type of packaging are its permeability characteristics to any gases present and to water vapour. Other important considerations include: appearance (brightness and transparency), texture, resistance to water permeability, resistance to impact and deformation, thermo-seal capacity, ease in forming/fabricating/filling, and utilization of production equipment.

18.5 Transport the package: Packaging for transport of products is dominated by sealed cartons made from corrugated paper. These types of packages provide good resistance to mechanical damage of IMF, and facilitate manual handling of IMF during transportation to markets. The cartons should be made of paper, > 0.2 mm thick, obtained from vegetable cellulose bonded either in three layers with the middle one corrugated or in five layers with the second and fourth layers corrugated. Both systems can provide a strong and rigid material.

18.6 Loading packaging units: This type of packaging implies the use of palletization of packages to reduce the cost of handling. In this way, the mechanical work of loading and unloading by carriers can be facilitated, permitting better utilization of storage space and reducing mechanical damage during transportation.

18.7 Vacuum and modified atmosphere packaging: Vacuum packaging of fresh commodities involves eliminating (at least some) the air in the package using a suction machine. This method reduces the level of both oxygen and nitrogen in the package, prolonging the shelf life of IMF for extended periods. The basic principle behind modified atmosphere packaging (MAP) is that a modified atmosphere can be created passively by correctly using permeable packaging materials, or actively, by using a special gas mixture combined with such materials. The purpose of both is to create an optimal gas balance inside the package, where the respiration activity of a product is as low as possible; on the other hand, the oxygen concentration and carbon dioxide levels are not detrimental to the product. In general, the aim is to have a gas composition of 2-5% CO_2, 2-5% O2, and the rest nitrogen. A problem that arises when using MAP is the restricted availability of permeable material in the market, as only a few materials are permeable enough to match the respiration of fruits and vegetables. Most films do not result in optimal O_2 and CO_2 atmospheres, especially when the product has high respiration. However, one solution is to make microholes of defined sizes and defined quantity in the material to avoid anaerobiosis. Other solutions are to combine ethylene vinyl acetate with orientated polypropylene and low-density polyethylene, or to combine ceramic material with polyethylene. Both composite materials have significantly higher gas permeability than polyethylene or orientated polypropylene. They are used a lot in the packaging of salads, although gas permeability should be higher.

18.8 Repackaging considerations: Minimally processed fruit products can be repackaged from bulk containers into small packages such as glass or plastic jars, and high-density polyethylene bags for retail markets and consumer distribution. The stabilized fruit products can be processed in the form of slices, chunks, whole fruit, marmalades, or nectars.

18.9 Syrup reconstitution and utilization: Syrup reconstitution is needed for repackaging of IMF, which requires the addition of sugar, and additives to adjust the water activity, pH, and control of browning reaction. The syrup covers the fruit inside the package and protects against microbial contamination. It should have a pH between 3.0 and 4.1. The tank holding the fruit and syrup prior to repackaging should be maintained at constant room temperature for 3 to 5 days during equilibration.

18.10 Optimal utilization of the final product: The final IMF product can be eaten as received or used in bulk for off-season processing, in confectionery, bakery goods, and dairy products, or for preserves, jams, and jellies. Fruit pieces can be utilized for salads, barbecue sauces, pizzas, fruit drink formulations, etc.

18.11 Quality control

18.11.1 Recommended microbiological tests: Several microbiological tests should be implemented in the processing area according to the Good Manufacturing Practice (GMP). Microbiological tests also apply to working personnel who manipulate and prepare the IMF products.

18.11.2 Total aerobic counts (TAC): TAC is performed in petri dishes with standard plate count agar (SPCA). These are plated with a spread from the hair, fingerprints, shoe soles, work tables, utensils, and skin of workers with the aid of a wet cue tip, which has been impregnated with a sterile peptone solution (1% v/v). The impregnated cue tip is passed through the desired area being controlled, then spread onto the agar surface in the petri dish. The plates are incubated at 35-37°C ± 2°C for 18 to 24 hours.

18.11.3 Mould and Yeast counts (MYC): To count mould and yeast cells, plates with potato-dextrose agar are plated with the same infected areas described above and incubated for 5-7 days at 25-30°C ± 2°C. Microbial tests, such as those described above, are also performed on raw fruit to count initial populations, and on the finished product to determine the number of surviving organisms after a combined treatment application.

Knowledge of the combined effect of the preservation factors used for IMF & high moisture fruit products (HMFP) on the growth and survival of certain key microorganisms that may pose risks to the quality and safety of IMF / HMFP is of great interest in the design of the technology. The major microorganisms of concern in IMF / HMFP are primarily moulds and yeasts, due to the high carbohydrate content present in the moisture associated with these products.

18.12 Nutritional changes

Very small changes in the nutritional characteristics of IMF are experienced during processing and storage, due to the mild heat treatment applied (compared to thermally processed fruit products). Blanching does not affect the nutritional properties, but it does inactivate the enzymes and provide some reduction of indigenous flora.

18.12.1 Changes in sensory attributes and acceptability: Changes in flavour, texture, odour, and colour have not been reported in high moisture minimally processed fruit products (HMPFP), such as papaya, peach, pineapple, and mango. There are reported changes in the texture of certain IMF products such as meat and meat products.

18.13 Conclusion

The Intermediate Moisture Foods (IMF) are semi-moist foods that have some of their water bound by sucrose, glycerol, sorbitol, salt or certain organic acids for a short period of time, thus, preventing the growth of many microorganisms. In 1980s, the committee for IMF of Franceǿs National Center for Coordination of Research on Food and Nutrition proposed the definition for intermediate moisture foods: ñfood products of soft texture, subjected to one or more technological treatments, consumable without further preparation and with a shelf stability of several months, assured without thermal sterilization, nor freezing or refrigeration, but by an adequate adjustment of their formulation: composition, pH, additives and mainly aw (activity of water) which must be approximately between 0.65 and 0.90 measured at 250 C. Generally, they contain moderate levels of moisture of the order of 20 to 50 per cent. The IM foods have an acceptable eating quality and reasonable storage stability under ambient conditions.