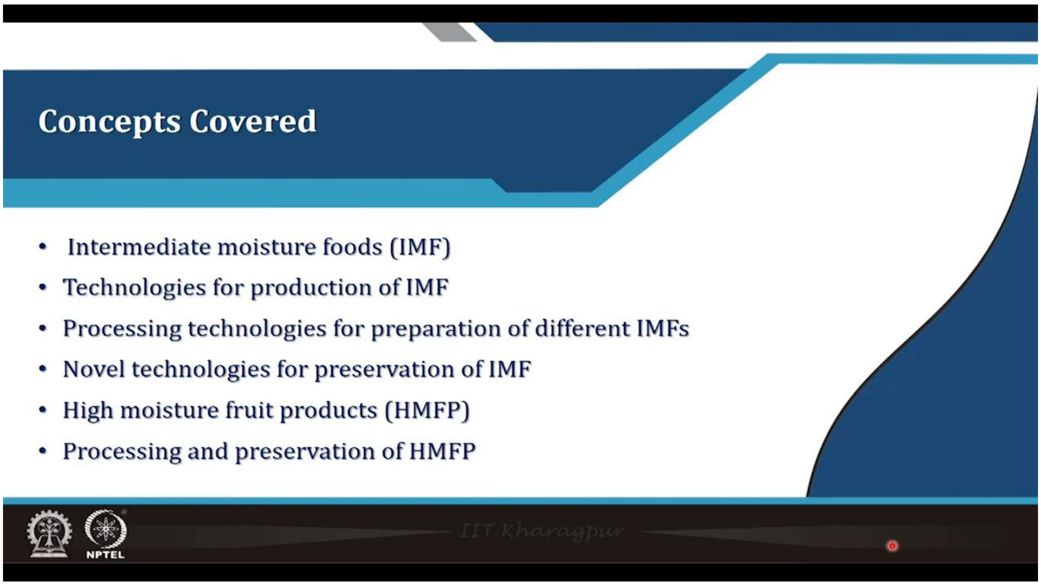
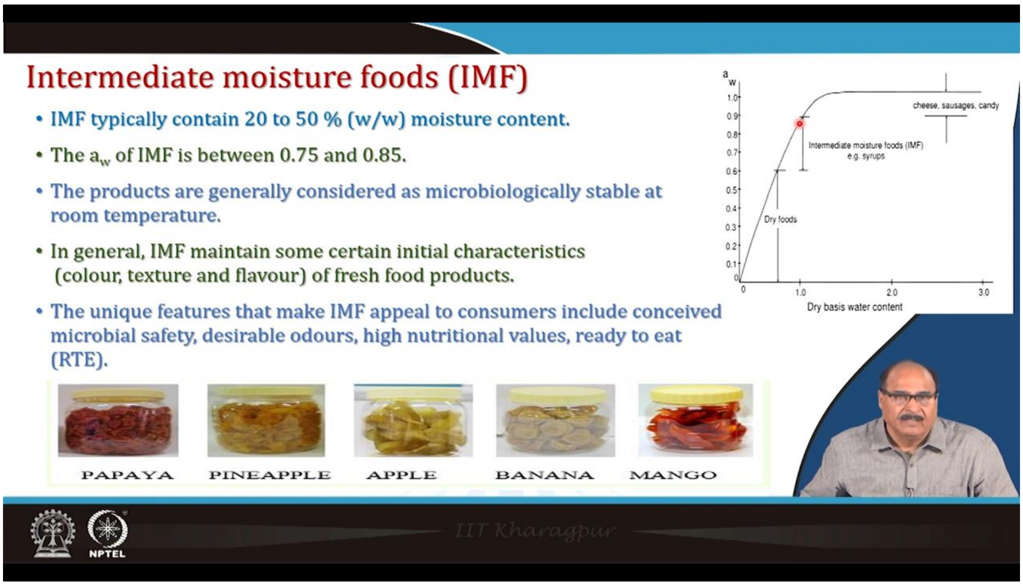
Post Harvest Operations and Processing Fruits, Vegetables, Spices and Plantation Crop Products

Professor H. N. Mishra
Agricultural and Food Engineering Department
Indian Institute of Technology, Kharagpur

Lecture – 23
Intermediate and High Moisture Fruit Products

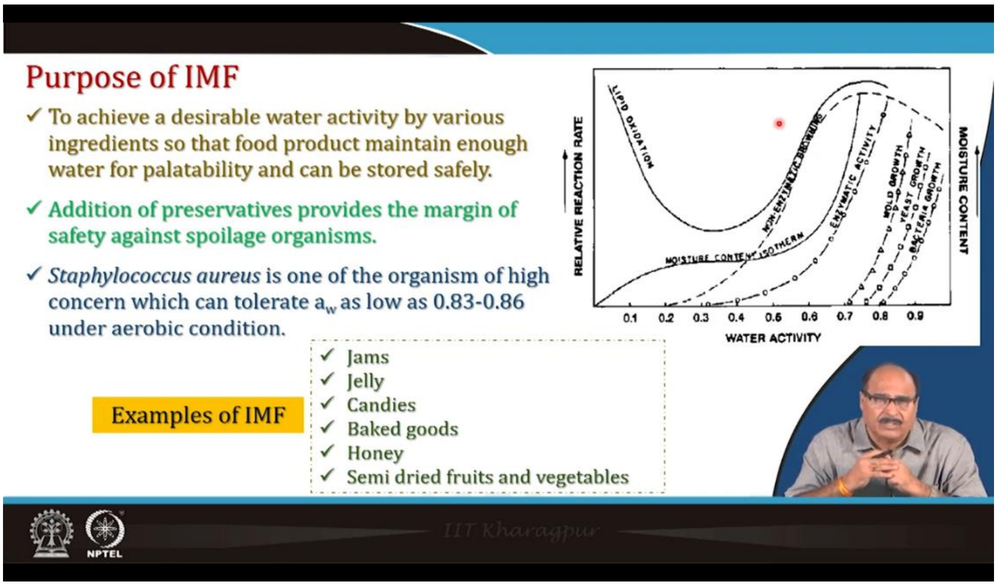


The topic covers intermediate moisture foods, different technologies for production of intermediate moisture foods (IMF), technologies for preparation of different IMF, novel technologies for preservation of IMF, high moisture fruit products (HMFP), and processing and preservation of HMFPs.



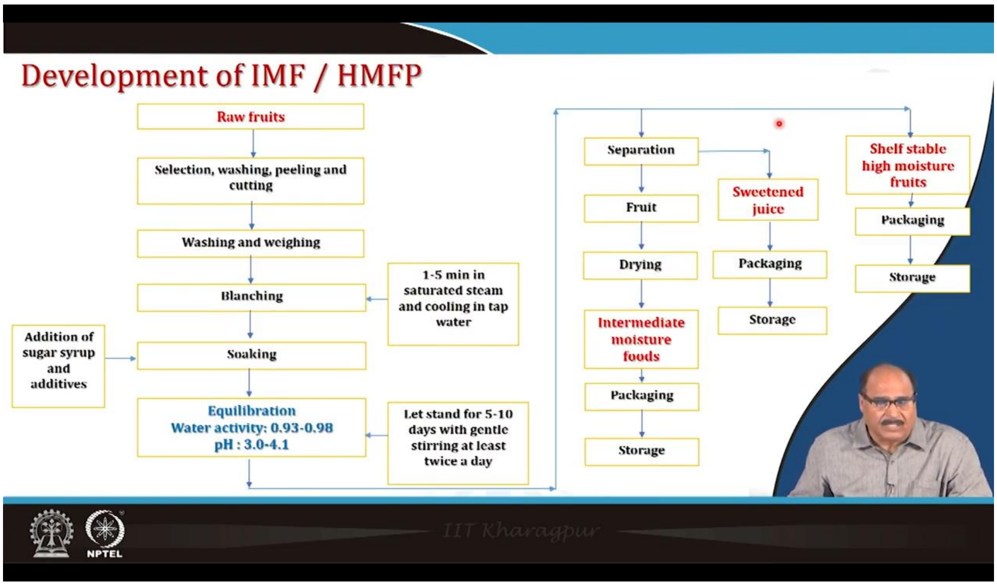
Intermediate moisture foods

IMF typically contain 20 to 50 % (w/w) moisture content. The a_w of IMF is between 0.75 and 0.85. The products are generally considered as microbiologically stable at room temperature. In general, IMF maintain some certain initial characteristics (colour, texture and flavour) of fresh food products. The unique features that make IMF appeal to consumers include conceived microbial safety, desirable odours, high nutritional values, ready to eat (RTE). As shown in figure, the water activity in the range of 0.7-0.85 is considered as intermediate moisture content. These are the some of the products made from papaya, pineapple, apple, banana, which are available in the market with intermediate moisture food.



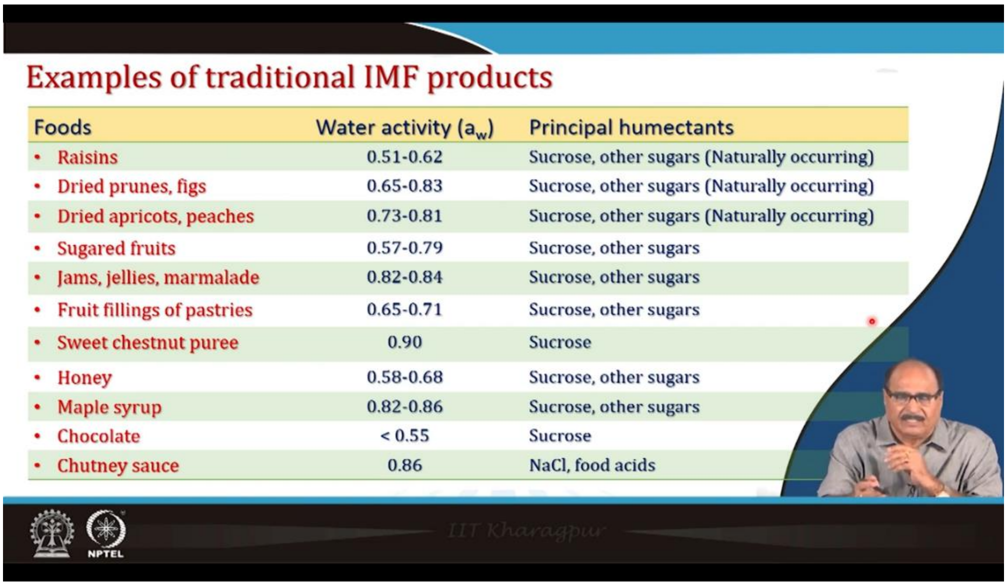
Purpose of IMF

To achieve a desirable water activity by various ingredients so that food product maintain enough water for palatability and can be stored safely. Addition of preservatives provides the margin of safety against spoilage organisms. *Staphylococcus aureus* is one of the organism of high concern which can tolerate aw as low as 0.83-0.86 under aerobic condition. Common examples of intermediate moisture foods include jams, jelly, candies, baked goods, honey, and semi dried fruits and vegetables.



Development of IMF/HFMP

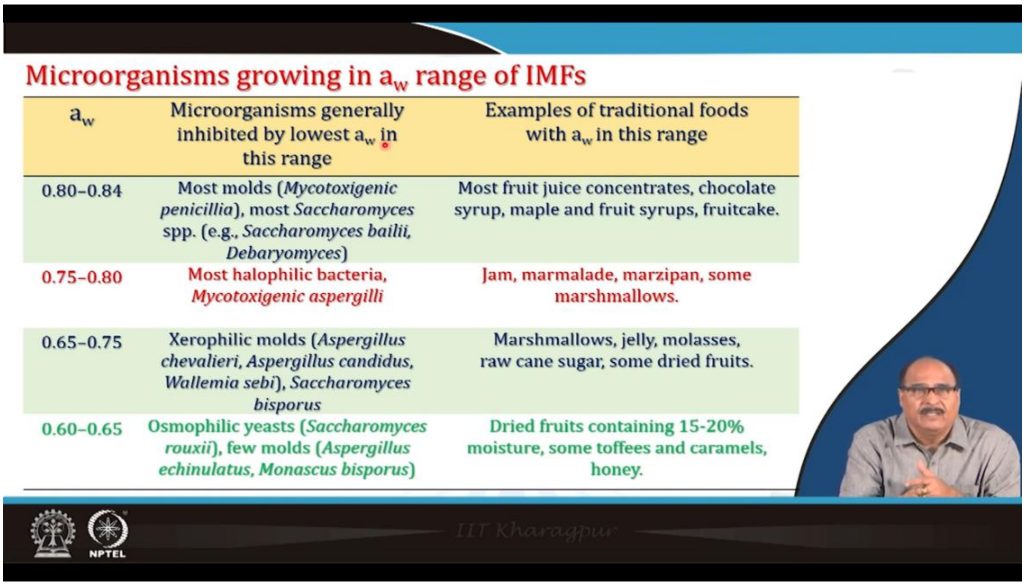
The raw materials are taken and common treatments are carried out such as selection, washing, cutting, peeling, blanching, soaking (addition of sugar syrup and additives), equilibration for 5-10 days with gentle stirring at least twice a day and getting the water activity in normal form that may be up to 0.93-0.98 and pH is 3 to 4.1, followed by separation, where sweetened juice will be collected, packaged, and stored. After drying, the IMFs will be packed and stored.



Foods	Water activity (a_w)	Principal humectants
• Raisins	0.51-0.62	Sucrose, other sugars (Naturally occurring)
• Dried prunes, figs	0.65-0.83	Sucrose, other sugars (Naturally occurring)
• Dried apricots, peaches	0.73-0.81	Sucrose, other sugars (Naturally occurring)
• Sugared fruits	0.57-0.79	Sucrose, other sugars
• Jams, jellies, marmalade	0.82-0.84	Sucrose, other sugars
• Fruit fillings of pastries	0.65-0.71	Sucrose, other sugars
• Sweet chestnut puree	0.90	Sucrose
• Honey	0.58-0.68	Sucrose, other sugars
• Maple syrup	0.82-0.86	Sucrose, other sugars
• Chocolate	< 0.55	Sucrose
• Chutney sauce	0.86	NaCl, food acids

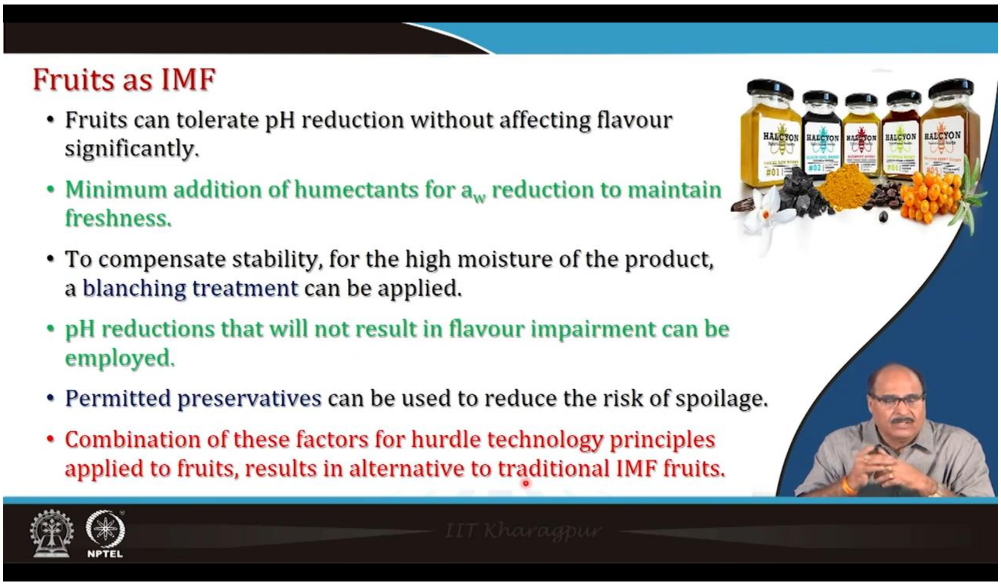
Examples of traditional IMF products

The table shows some examples of traditional intermediate moisture food products, particularly, from fruits and vegetable origin, their water activity ranges, and the principal humectants applied. For example, the water activity of sugared fruits ranged from 0.57-0.79 and sucrose is the principal humectant. Honey is also considered an intermediate moisture food. Its water activity varied between 0.58-0.68. Here sucrose or other sugars may be present. The water activity of chutney sauce is 0.86. Here, sodium chloride or some food acids are used.



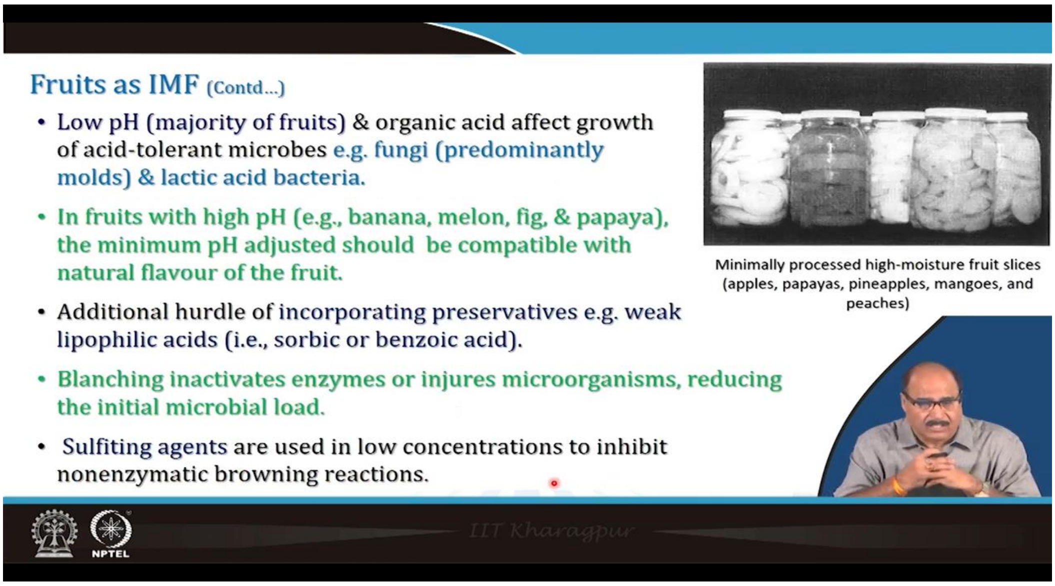
Microogranisms growing in a_w range of IMFs

Most molds (*Mycotoxigenic penicillia*), most *Saccharomyces* spp. (e.g., *Saccharomyces bailii*, *Debaryomyces*) are generally inhibited at a_w of 0.80-0.84, for example, most fruit juice concentrates, chocolate syrup, maple and fruit syrups, fruitcake. Most halophilic bacteria, *Mycotoxigenic aspergilli* are inhibited at a_w of 0.75-0.80, for example, jam, marmalade, marzipan, some marshmallows. Osmophilic yeasts (*Saccharomyces rouxii*), few molds (*Aspergillus echinulatus*, *Monascus bisporus*) are inhibited at a_w of 0.60-0.65, for example, dried fruits containing 15-20% moisture, some toffees and caramels, honey.

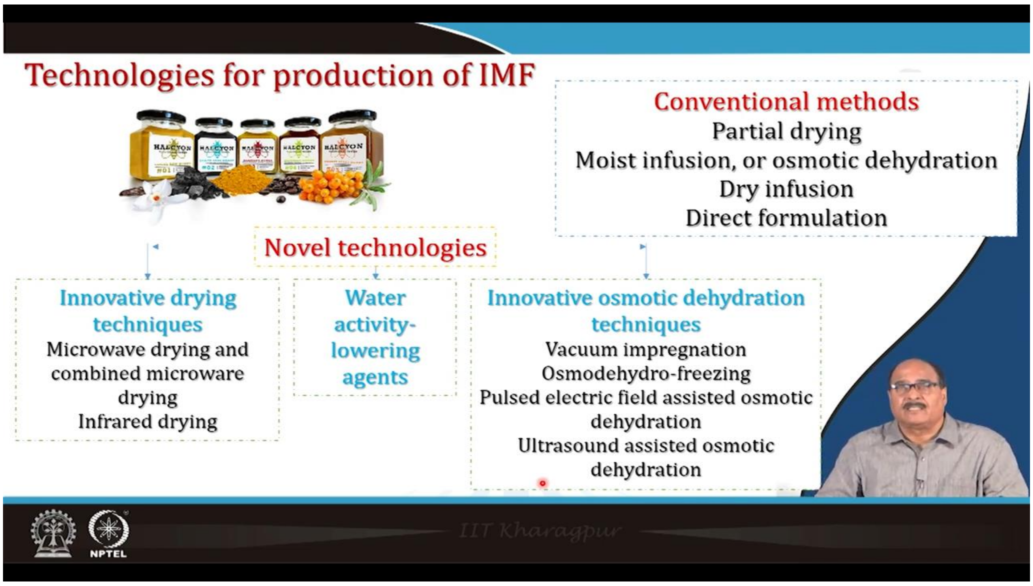


Fruits as IMF

Fruits can tolerate pH reduction without affecting flavour significantly. Minimum addition of humectants for a_w reduction to maintain freshness. To compensate stability, for the high moisture of the product, a blanching treatment can be applied. pH reductions that will not result in flavour impairment can be employed. Permitted preservatives can be used to reduce the risk of spoilage. Combination of these factors for hurdle technology principles applied to fruits, results in alternative to traditional IMF fruits.

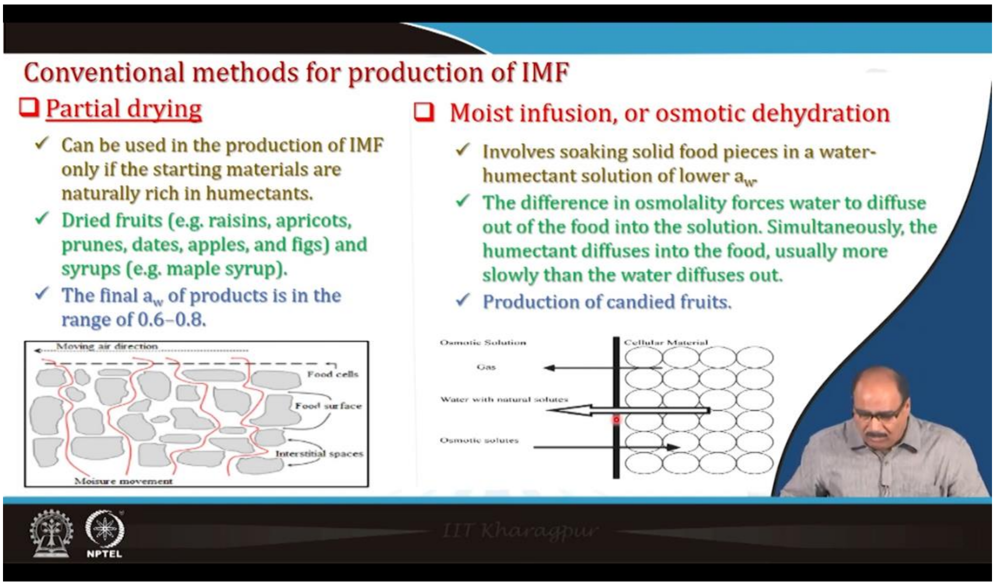


Low pH (majority of fruits) & organic acid affect growth of acid-tolerant microbes e.g. fungi (predominantly molds) & lactic acid bacteria. In fruits with high pH (e.g., banana, melon, fig, & papaya), the minimum pH adjusted should be compatible with natural flavour of the fruit. Additional hurdle of incorporating preservatives e.g. weak lipophilic acids (i.e., sorbic or benzoic acid). Blanching inactivates enzymes or injures microorganisms, reducing the initial microbial load. Sulfiting agents are used in low concentrations to inhibit nonenzymatic browning reactions.



Technologies for production of IMF

The conventional methods are partial drying, moist infusion or osmotic dehydration, dry infusion or direct formulation, and the novel drying techniques including microwave drying, microwave convective air drying, combination of drying or infrared drying or even water activity lowering agents can be used or innovative osmotic dehydration technique like vacuum impregnation, osmodehydro freezing, pulsed electric field assisted osmotic dehydration or ultrasound assisted osmotic dehydration can be used for production of intermediate moisture food.



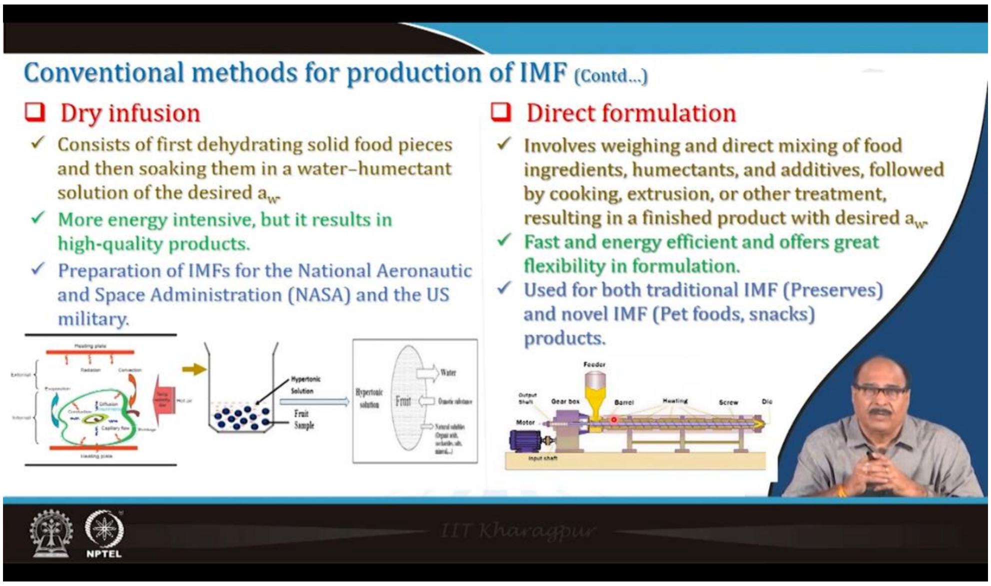
Conventional methods for production of IMF

Partial drying

It can be used in the production of IMF only if the starting materials are naturally rich in humectants e.g. dried fruits (e.g. raisins, apricots, prunes, dates, apples, and figs) and syrups (e.g. maple syrup). The final aw of products is in the range of 0.6–0.8.

Moist infusion, or osmotic dehydration

It involves soaking solid food pieces in a water humectant solution of lower water activity. The difference in osmolality forces water to diffuse out of the food into the solution. Simultaneously, the humectant diffuses into the food, usually more slowly than the water diffuses out. This process is used for production of candied fruits.

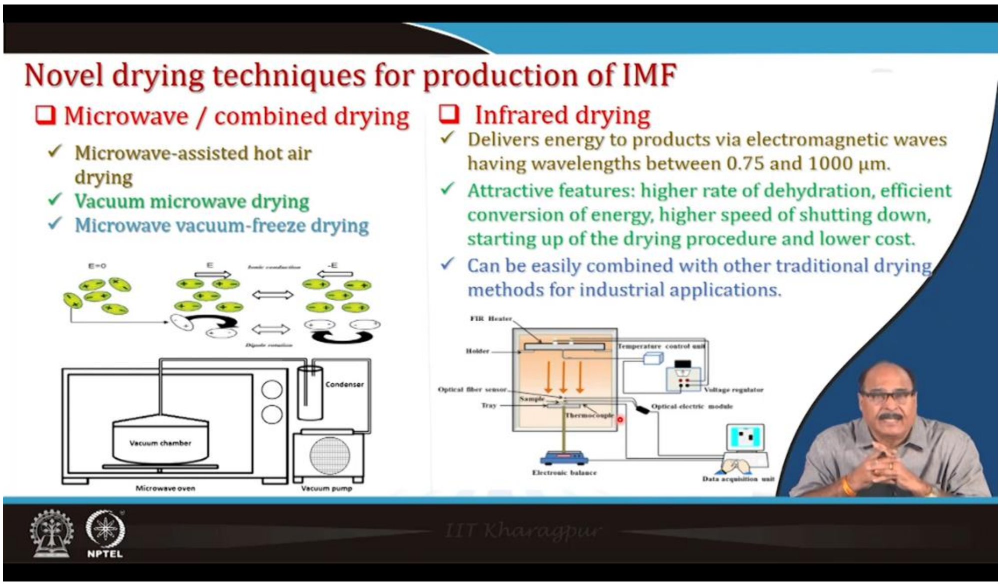


Dry infusion

Dry infusion consists of first dehydrating solid food pieces and then soaking them in a water humectants solution of the desired water activity. It is more energy intensive, but it results in high quality products. And it is used for preparation of IMFs for the NASA and US military.

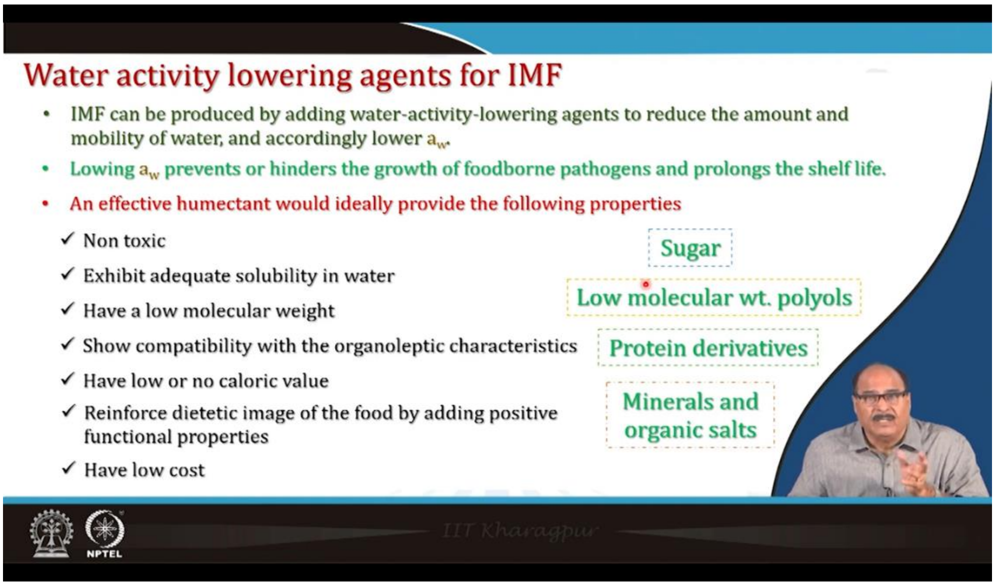
Direct formulation

It involves weighing and direct mixing of the food ingredients, humectants and additives, followed by cooking, extrusion or other treatment resulting in the finished product of desired water activity. It is fast and energy efficient and offers great flexibility in formulation. It is used for both the traditional IMF like preserves candies etc as well as novel IMF like pet foods, snack products.



Novel drying techniques for production of IMF

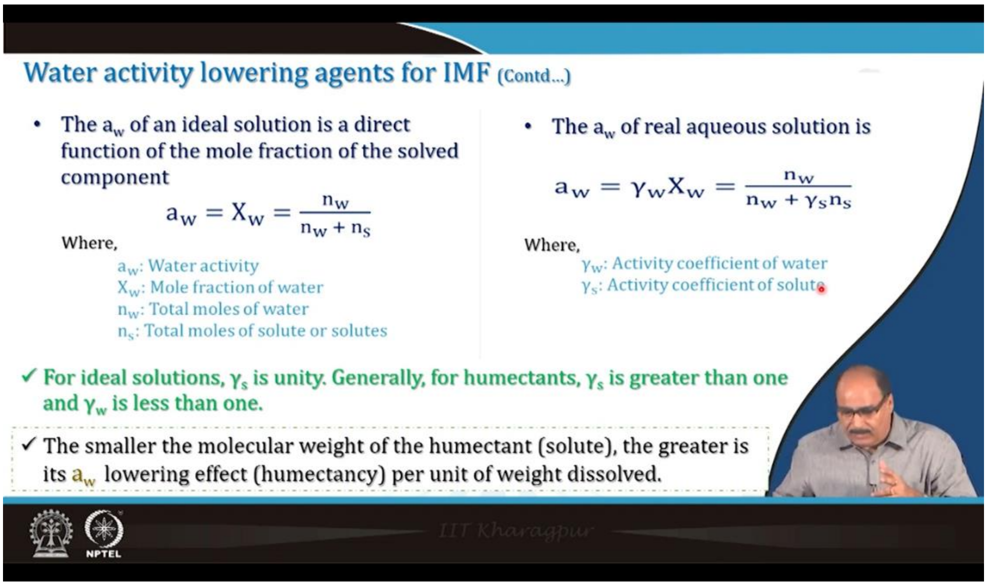
The novel techniques for the production of IMF include the microwave or combined microwave drying like microwave assisted hot air drying, vacuum microwave drying and microwave vacuum-freeze drying. Infrared drying delivers energy to the products by electromagnetic waves having wavelengths between 0.75 and 1000 µm. So, it can easily be combined with other traditional drying methods for industrial applications.



Water activity lowering agents for intermediate moisture foods

The IMF can be produced by adding water activity lowering agents to reduce the amount of and mobility of the water and accordingly to lower the water activity. So, lowering water effectivity prevents or hinders the growth of foodborne pathogens and prolongs the shelf life.

An effective humectant would ideally provide the following properties such as it is non-toxic, exhibit adequate solubility in water, have a low molecular weight, show compatibility with the organoleptic characteristics, have low or no calorific value, reinforce dietetic image of the food by adding positive functional properties and finally it should have low cost. So, some of the common water activity lowering agents which are used in IMF include sugar, low molecular weight polyols, protein derivatives, and minerals and organic acids.



The a_w of an ideal solution is a direct function of the mole fraction of the solved component

$$a_w = X_w = \frac{n_w}{n_w + n_s}$$

Where,

a_w= Water activity

X_w= Mole fraction of water

n_w= Total moles of water

n_s= Total moles of solute

The a_w of real aqueous solution is

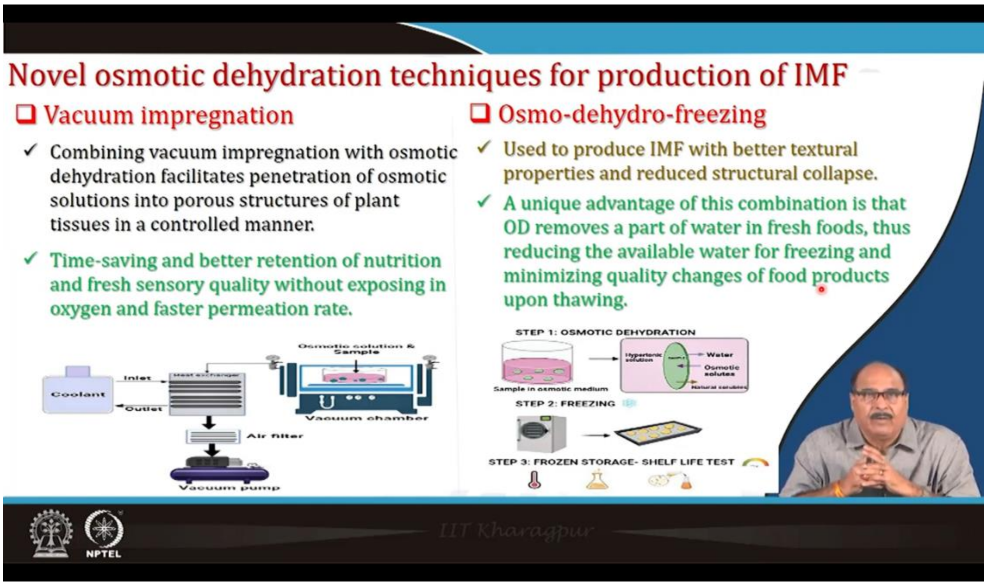
$$a_w = \gamma_w X_w = \frac{n_w}{n_w + \gamma_s n_s}$$

Where,

γ_w= Activity coefficient of water

γ_s= Activity coefficient of solute

For ideal solutions, γ_s is unity. Generally, for humectants, γ_s is greater than one and γ_w is less than one. The smaller the molecular weight of the humectant (solute), the greater is its a_w lowering effect (humectancy) per unit of weight dissolved.

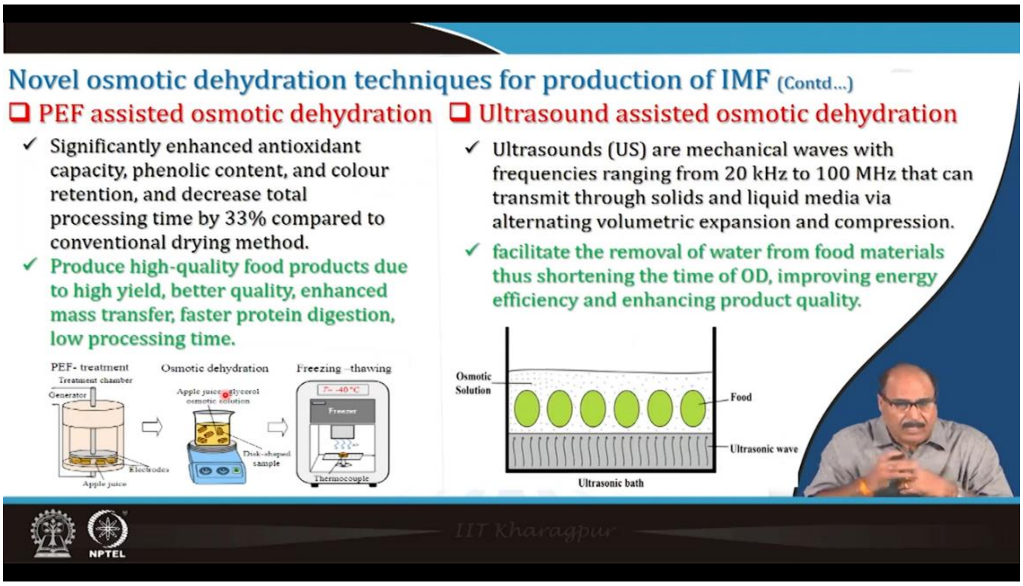


Vacuum impregnation

Combining vacuum impregnation with osmotic dehydration facilitates penetration of osmotic solutions into porous structures of plant tissues in a controlled manner.

Osmo-dehydro-freezing

This technique is used to produce IMF with better textural properties and reduced structural collapse. A unique advantage of this combination is that OD removes a part of water in fresh foods, thus reducing the available water for freezing and minimizing quality changes of food products upon thawing.

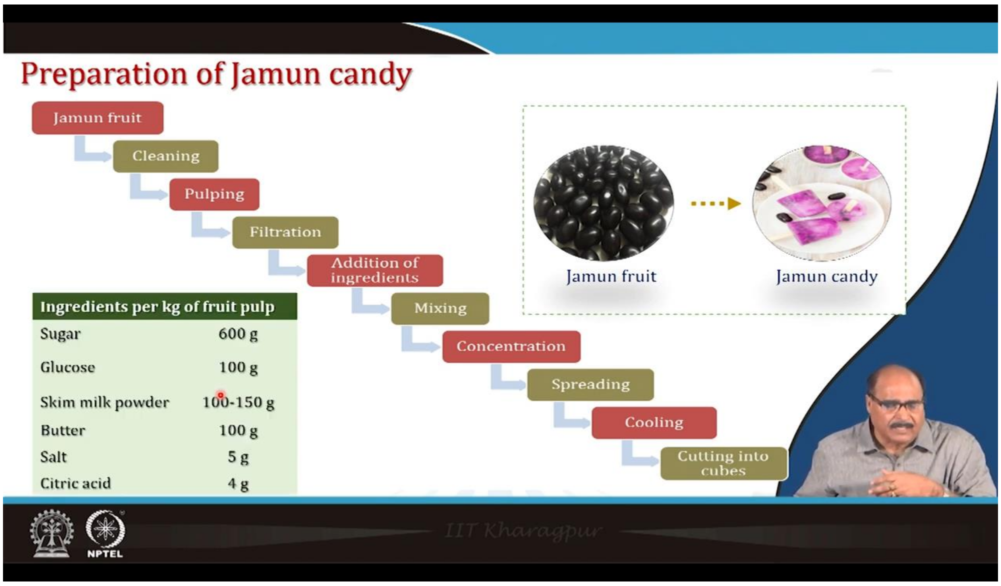


PEF assisted osmotic dehydration

PEF assisted osmotic dehydration significantly enhanced antioxidant capacity, phenolic content and colour retention of the, and there is a decrease in total processing time by 33 percent compared to the conventional drying method. It produces high-quality food products due to high yield, better quality, enhanced mass transfer, faster protein digestion, low processing time.

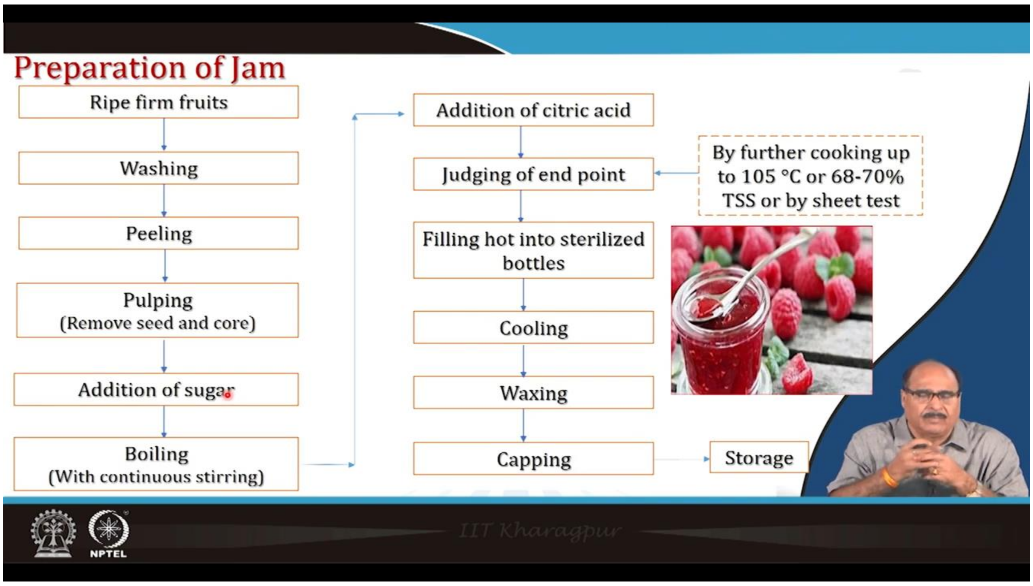
Ultrasound assisted osmotic dehydration

Ultrasounds (US) are mechanical waves with frequencies ranging from 20 kHz to 100 MHz that can transmit through solids and liquid media via alternating volumetric expansion and compression. It facilitates the removal of water from food materials thus shortening the time of OD, improving energy efficiency and enhancing product quality.



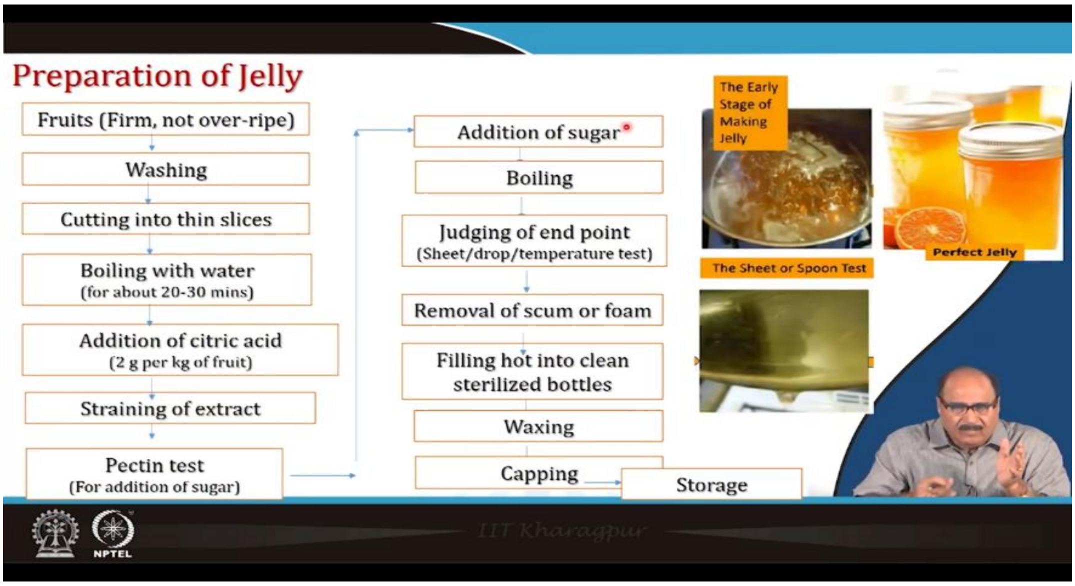
Preparation of jamun candy

This is a flow diagram for preparation of jamun candy, which includes cleaning, pulping, filtration, addition of ingredients, mixing, concentration, spreading, cooling and cutting into different cubes. The ingredient per kg of the fruit pulp is recommended as shown in the table.



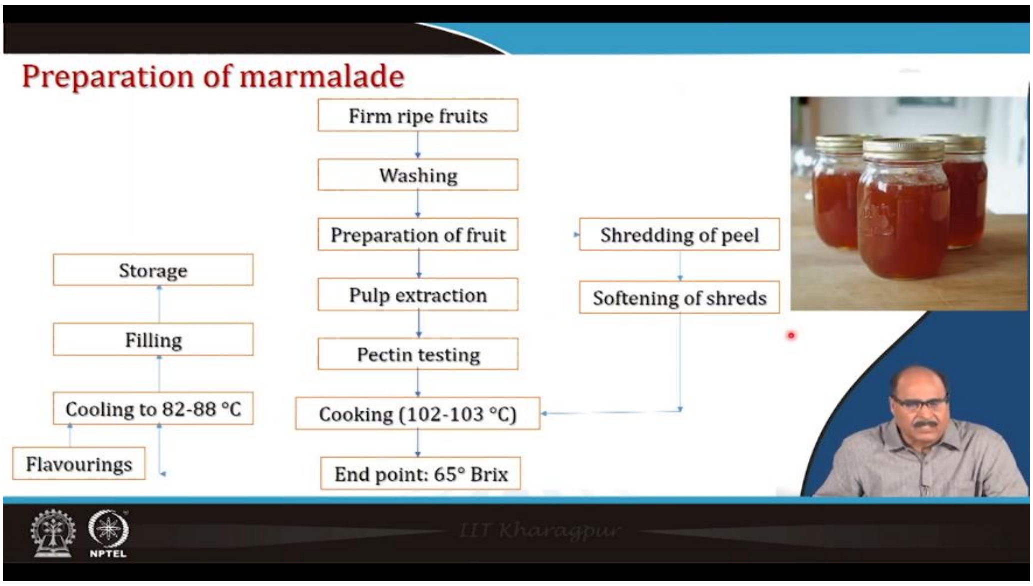
Preparation of jam

It includes a series of process such as washing, peeling, pulping (remove the seed and core), addition of sugar, boiling (with continuous stirring), addition of citric acid, judging of end point (by further cooking up to 105 °C or TSS of 68 to 70%), filling hot into the sterilized bottles, cooling, waxing and then capping.



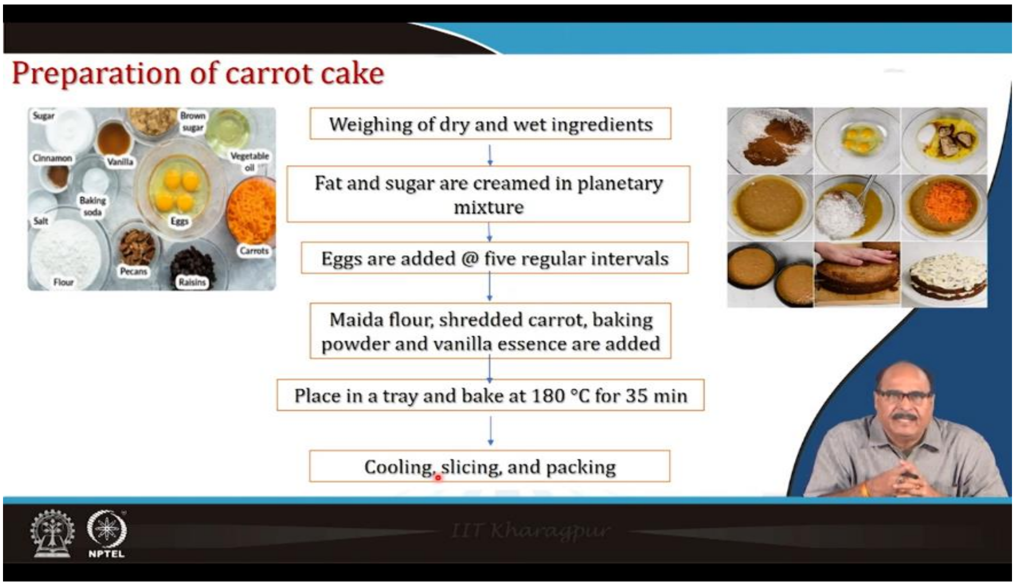
Preparation of jelly

The preparation of jelly involves selection of firm fruit, followed by washing, cutting into thin slices, boiling with water for about 20-30 min, addition of citric acid (2 g per kg of fruit), straining of extract, testing of pectin (for addition of sugar), addition of sugar, boiling, judging the end point using sheet/drop/temperature test, removal of scum or foam, filling hot into clean sterilized bottles, waxing, capping, and storage.



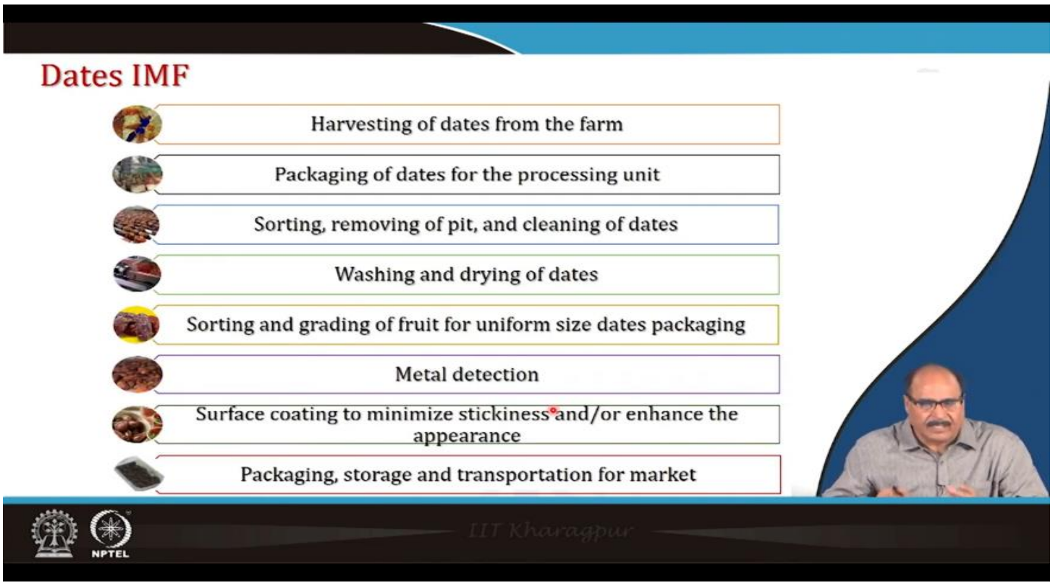
Prepartion of marmalade

The process flow chart of marmalade is same as that of jam, but the only difference is the addition of shredded peels followed by softening of shreds after the pulp extraction, pectin testing, and at the time of cooking. The rest of the process is similar to jam and jelly.



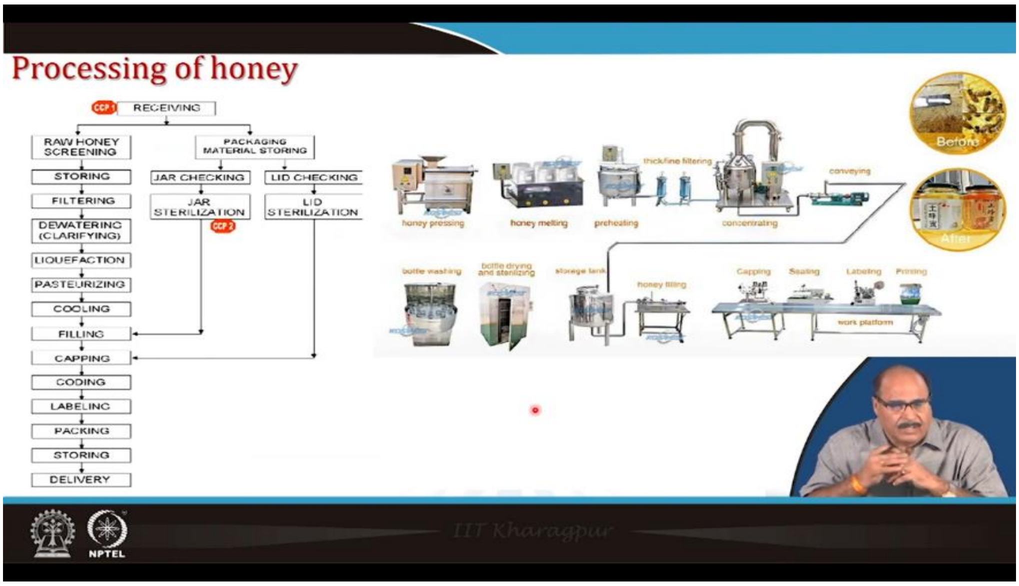
Preparation of carrot cake

The process includes weighing of dry and wet ingredients, fat and sugar are creamed in plenty mixtures. Then eggs are added at the rate of five regular intervals to ensure proper mixing of the eggs and also proper whipping of the air. Then maida flour, shredded carrot, baking powder, vanilla essence are added. These are placed in a tray and bake at 180 °C for 35 minutes followed by cooling, slicing and packing.



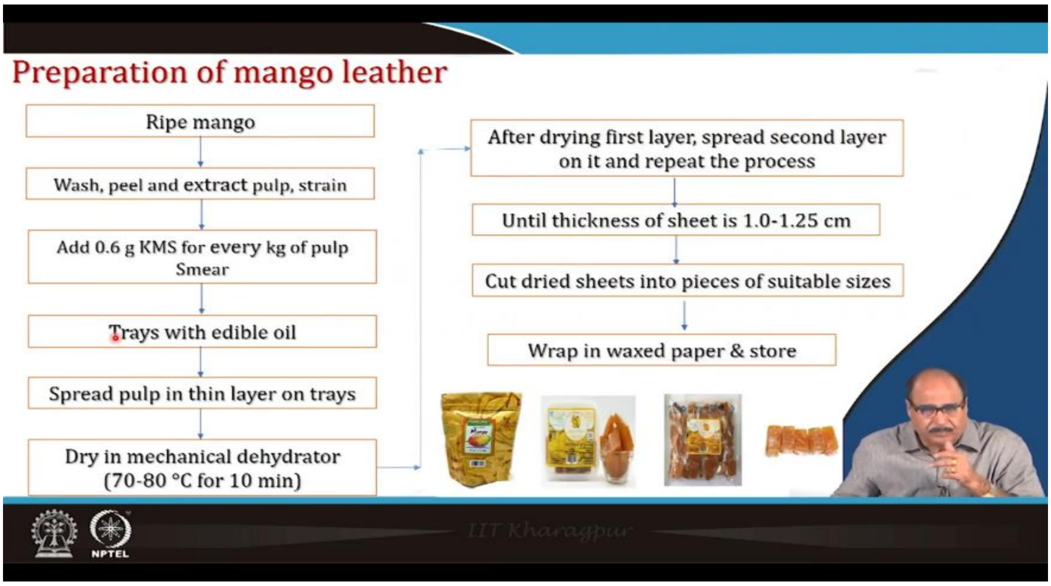
Dates as IMF

This includes harvesting of the dates from the farm, packaging of dates for the processing unit, sorting, removing of pit and cleaning up the dates, washing and drying, sorting and grading of fruit for uniform size date packing, metal detection, then surface coating to minimize stickiness and that enhances the appearance, packaging, storage and transportation for the markets.



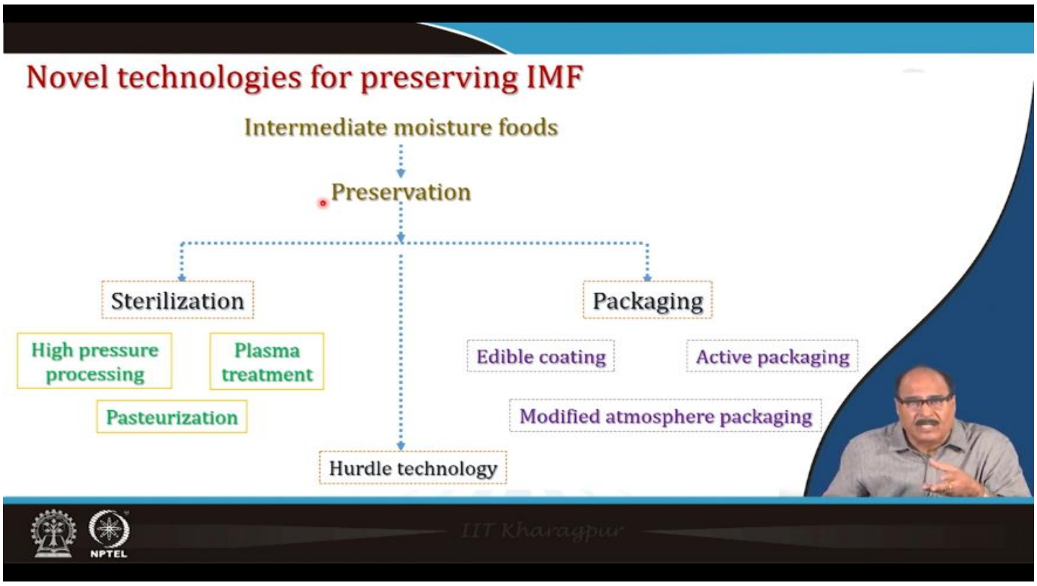
Processing of honey

This slide shows a continuous production and processing of honey. This involves screening of raw honey, storing, filtering, dewatering, liquefaction, pasteurizing, cooling, filling, capping, labeling, packing, storing and finally delivering.



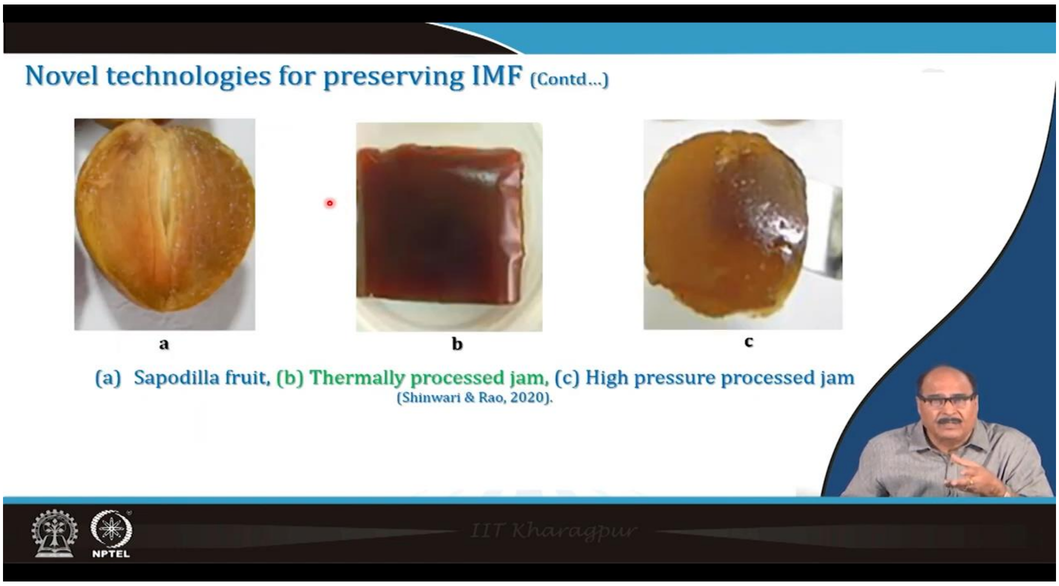
Preparation of mango leather

Ripe mango is taken, washed, peeled, pulp is extracted, and stained it. Then 0.6 g of KMS for every kg of pulp is added, and smeared the trays with edible oil, spread pulp in thin layer on the trays. Dry in mechanical dehydrator may be able to 70 to 280 °C for 10 minutes and then add a layer after layer of this mango leather. After drying the first layer, spread the second layer on it and then repeat this process until thickness of the sheet is maybe 1 to 1.25 centimeter. Then cut dried sheets into pieces of suitable sizes, wrap in waxed paper and store.

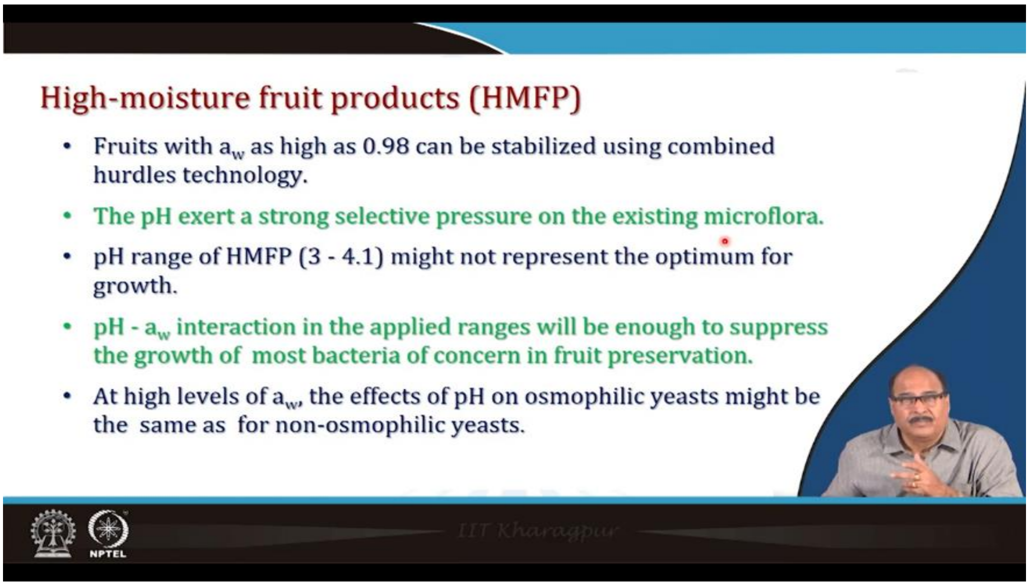


Novel technologies for preserving IMF

Novel technologies for the preservation of intermediate moisture foods include sterilization or packaging or hurdle technology concept. Sterilization can be done using high-pressure processing, plasma treatment or pasteurization, packaging, like edible coating, active packaging, modified atmosphere packaging can be done.

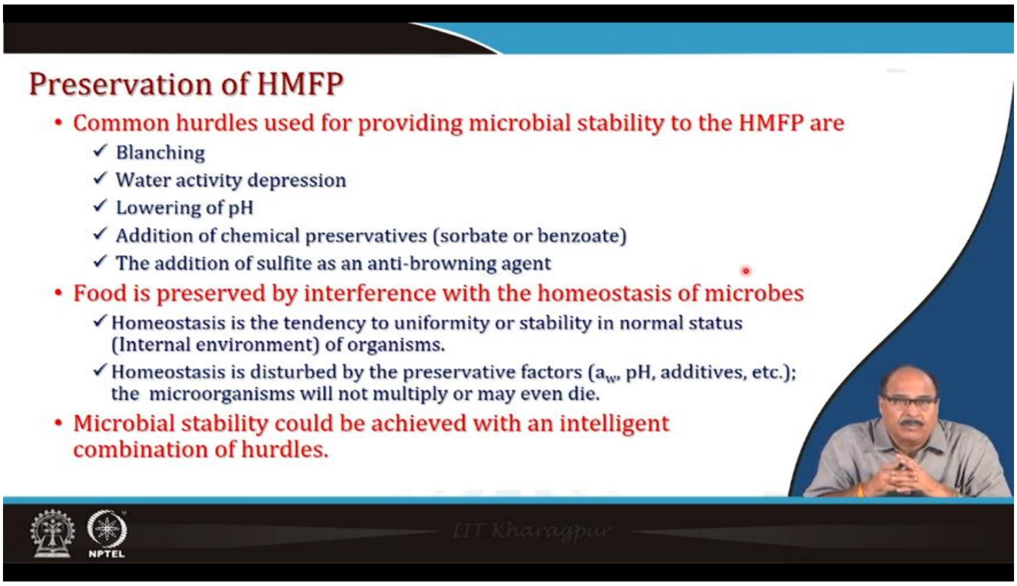


The figures represent the variation in color attributes of the thermally and high pressure processed jam. The high pressure process jam showed better retention of bioactive compounds components as well as stability as compared to thermally processed jam.



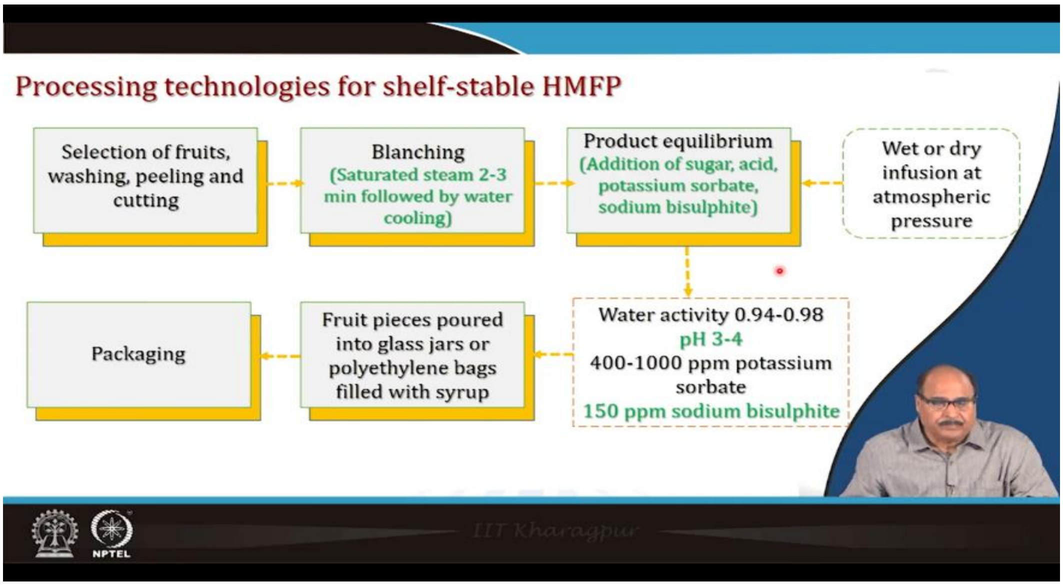
High-moisture fruit products (HFMP)

Fruits with aw as high as 0.98 can be stabilized using combined hurdles technology. The pH exert a strong selective pressure on the existing microflora. pH range of HMFP (3 - 4.1) might not represent the optimum for growth. pH - a_w interaction in the applied ranges will be enough to suppress the growth of most bacteria of concern in fruit preservation. At high levels of aw, the effects of pH on osmophilic yeasts might be the same as for non-osmophilic yeasts.



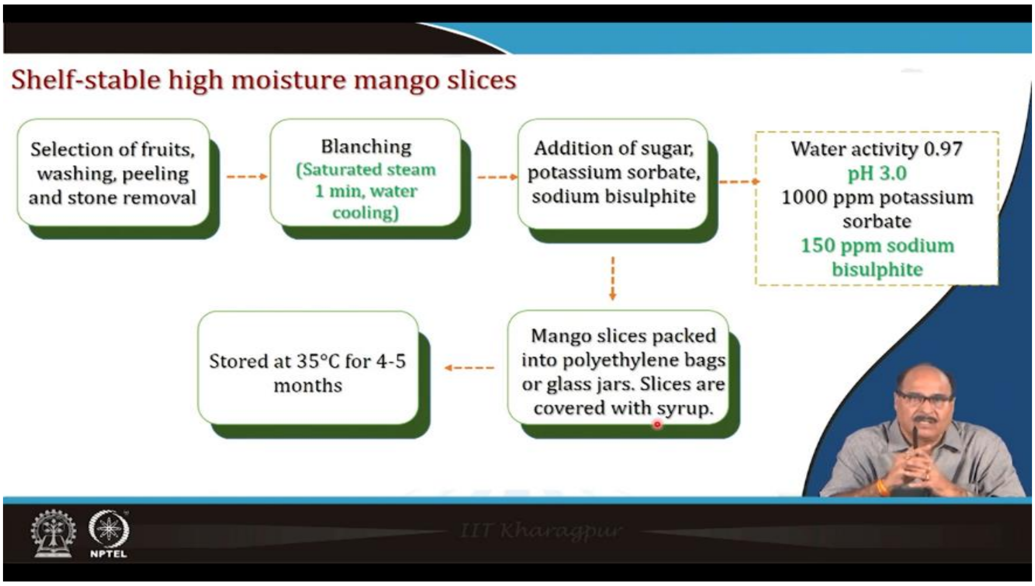
Preservation of HFMP

Common hurdles used for providing microbial stability to the HMFP are blanching, water activity depression, lowering of pH, addition of chemical preservatives may be sorbates or benzoates, and the addition of sulfite as an anti-browning agent. Food is preserved by interference with the homeostasis of microbes. Homeostasis is the tendency to uniformity or stability in normal status (Internal environment) of organisms. Homeostasis is disturbed by the preservative factors (aw, pH, additives, etc.); the microorganisms will not multiply or may even die. Microbial stability could be achieved with an intelligent combination of hurdles.



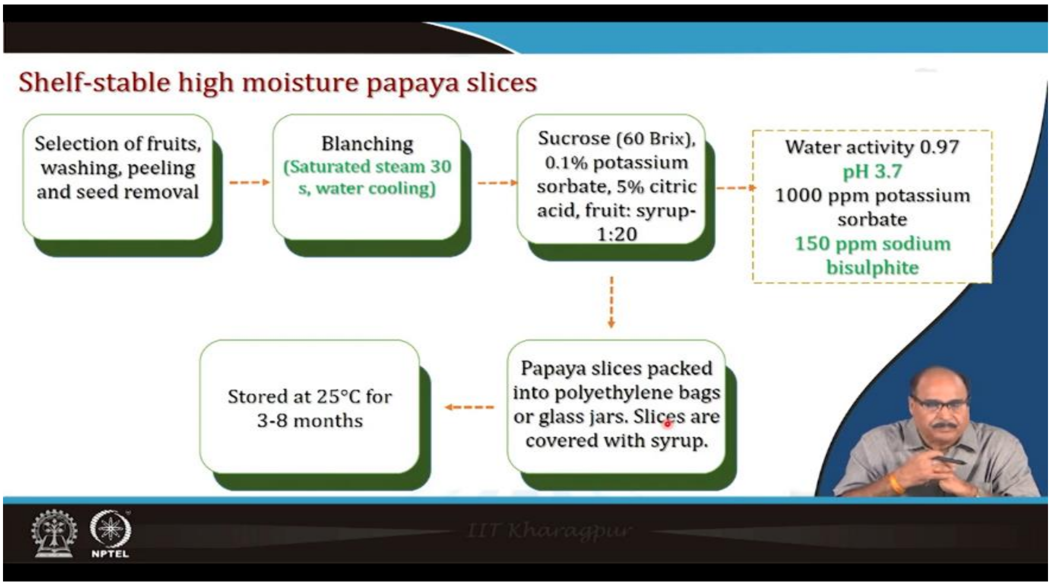
Processing technologies for shelf-stable HFMP

The process technology involves selection of the fruit, washing, peeling and cutting then blanching using saturated steam for 2-3 min followed by water cooling, product equilibrium (addition of sugar, acid, potassium sorbate, sodium bisulphite), application of wet or dry infusion at atmospheric pressure at this point. Then finally, the water activity is in the range of 0.94 to 0.98, pH 3 to 4, meta potassium sorbate of 400 to 1000 ppm, sodium bisulfite of 150 ppm. The fruit pieces are poured into glass jars or polyethylene bags filled with syrup and finally packaging.



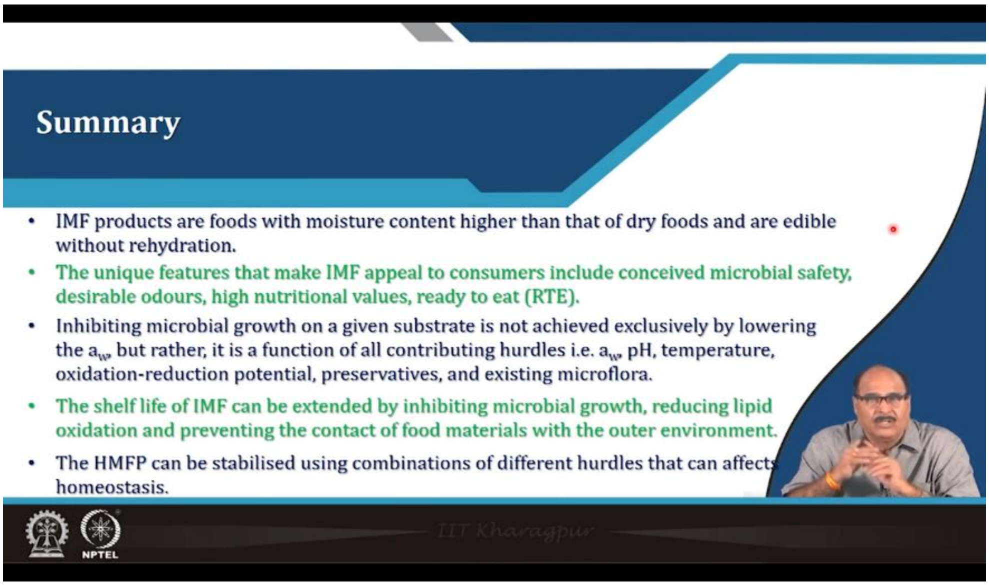
Shelf-stable high moisture mango slices

The process involves selection of fruits, washing, peeling, stone removal, blanched against super saturated steam for 1 minute and then cooling the blanching water, addition of sugar, potassium sorbate and sodium bisulfite, thus water activity is maintained 2.97, pH is 3.0, 1000 ppm potassium sorbate and 150 ppm sodium bisulphite, packing of mango slices into polyethylene bags or glass jars and slices are covered with syrup, and finally stored at 35 °C for 4-5 months.

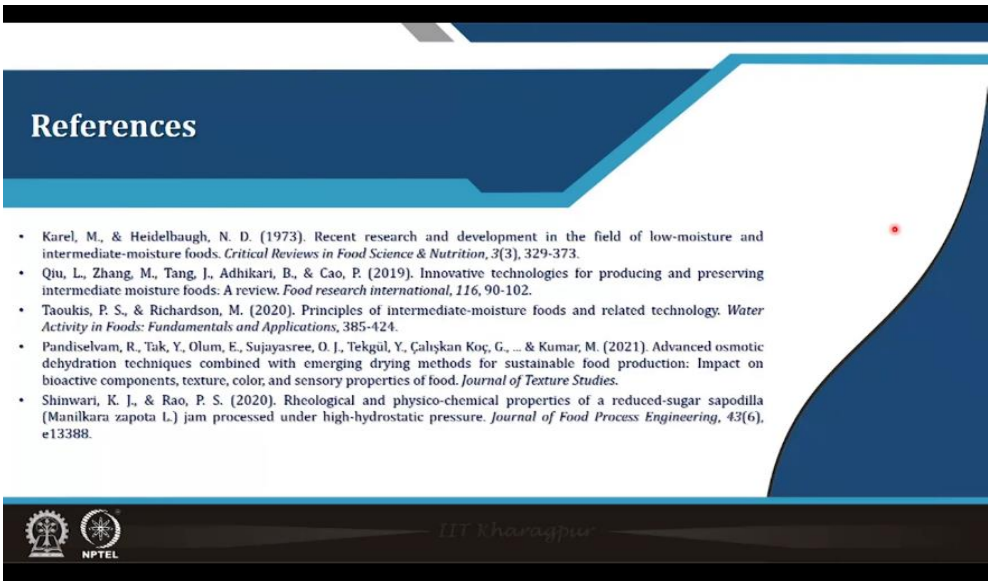


Shelf-stable high moisture papaya slices

The process involves selection of fruits, washing, peeling, seeds removal, blanched against super saturated steam for 1 minute and then cooling the blanching water, then sucrose is added to get the 60 Brixs TSS, 0.1% potassium sorbate, 5% citric acid and the ratio of fruit to syrup is 1:20. Water activity is 0.97, pH is 3.7 and 1000 ppm potassium sorbate and 150 ppm sodium bisulphide and then like in earlier case, here also the slices are packed into polythene bags or glass jars and are covered with syrup, in this jar clear is taken and stored for 25 °C for 3 to 8 months.



In summary, IMF products are foods with moisture content higher than that of dry foods and are edible without rehydration. The unique features that make IMF appeal to consumers include conceived microbial safety, desirable odours, high nutritional values, ready to eat (RTE). Inhibiting microbial growth on a given substrate is not achieved exclusively by lowering the a_w, but rather, it is a function of all contributing hurdles i.e. aw, pH, temperature, oxidation-reduction potential, preservatives, and existing microflora. The shelf life of IMF can be extended by inhibiting microbial growth, reducing lipid oxidation and preventing the contact of food materials with the outer environment. The HMFP can be stabilised using combinations of different hurdles that can affects homeostasis.



These are the reference for further study. Thank you.