Recent Advances in Apricot Dehydration

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Abstract— Fruits like apricot have high water activity and they are highly heat sensitive and easily degradable. About 50% of the apricot fruit produced in a year getting wasted due to the short harvest season and the sensitivity to storage even at refrigerated conditions. For that drying methods are used and dehydration must not only be efficient and economic but also yield high-quality products based on flavour, nutrients, colour, rehydration, uniformity, appearance, and texture. We are using the fruits in our daily life to gain essential nutrients. Preservation of these fruits will reduce the wastage. The storage stability of the apricot primarily depends on the moisture content present in the fruit. When the moisture content is reduced, apricot can be stored for long period. For reducing the moisture content, drying or dehydration process is carried out on apricot. This review paper discusses the technologies for dehydration of fruits like apricot from open sun drying to recent hybrid drying including other methods.

KEYWORDS: Apricot, Drying, Dehydration, Moisture content, Preservation, Technologies.

1 INTRODUCTION

Apricot mostly contain a rich source of vitamins, especially beta-carotene, water which is responsible for giving apricots their natural yellow-orange colour. Turkey is the biggest apricot producer in the world. According to the FAO statistical database about 20% of the total production in the world. Also, the world's total annual production of dried apricot is about 77% from Turkey. Apricots contain several health-developing components. They are grown for our health benefits. Water is one of the most important components of foods. Moisture is the amount of water content present in vegetables and this moisture is the reason for growth of microbes in it, so by reducing the moisture content in apricot the shelf life is increased and their nutritive value is not disturbed. There are several methods for increasing the shelf life of fruits such as drying, pasteurisation, blanching, changing atmosphere, freezing, infrared and fermentation. Due to the short harvest season and the sensitivity to storage even at refrigerated conditions, most fresh apricots are preserved in some form. The most preferred method for increasing shelf life among these processes is drying. Drying is nothing but a process in which heat is applied to remove moisture content from vegetables and fruits. Dehydrated fruits have more shelf life than untreated vegetables. In 1800s Masson and Chollet the French inventors used Air at 105°F for Dehydration of fruits. From 1800s drying process evolved slowly by making some changes with respect to the sources and methodology. The oldest one is the open sun drying and the latest technique is microwave hybrid drying. Many other techniques like osmotic dehydration, solar drying, dielectric drying electro hydrodynamic drying, fluidized bed drying, freeze drying, vacuum drying, have large scope for production of quality dried products and powders. By these processes the vegetable get better flavour, rehydration, and acceptability. [1]

2 DRYING

Drying is well known food preservation process, which improves the consumption period of biological materials like fruits and vegetables .Drying aims at decrease of moisture content up to the desired level. Air drying and open sun drying is the most useful technique for drying of fruits and vegetables, this process also has a bad impact on product quality such as colour, rehydration capacity, texture, and other properties due to long drying time and less efficiency of heat transfer. Microwave drying is a new technology, which is a rapid and efficient drying alternative to hot air drying. Microwave drying has some major drawbacks when it applies alone. Therefore combined method can be successfully applied to avoid these effects. One of the most common techniques is microwave combined (hybrid) drying.Vegetables are dried until they are brittle. At Brittle stage a partial amount of moisture remains in the fruits and microorganisms stop growing. For the Drying process, the fruits are first washed in cold water to remove soil and chemical residue. Drying slows down the action of enzymes but does not inactivate them. By removing moisture, the fruit become smaller and lighter in weight. Fruits like apricot, kiwi, raisin (dry grapes) undergo Drying process. Storage over long periods must be done properly. For example the dried fruits must be maintained at a stable temperature But these dried apricot lose very little of their nutritional value.

2011 figures published by the UN's Food and Agriculture Organization estimate that total production of apricot in India is a mere 10,000 tons per annum, ranking it 38th in world. And Turkey grew 716,415 tons the same year. Jammu and Kashmir's Ladakh region grows most of India's apricots. Other regions like Kargil; Lahaul and Spiti of Himachal Pradesh; as well as Kumaon and the Garhwal Hills in Uttar Pradesh has annual growth of apricot. Dried apricots are available as desiccated apricots also. The quality of dried fruit varies remarkably in India. The country's apricot market causes low sales, supply, and demand in [2].

3 PRE TREATMENT PROCESS

Initially the pre-treatment process starts with the cleaning of the fresh apricot. The impurities like dust and dirt are removed in this stage. For this process brine water is used and ensures that no impurities are present. The outer layer is peeled off for apricot. As the part of pre-treatment process blanching or dipping is done. Blanching is the process in which the apricots are soaked into the boiling water or into the steam. Dipping is a process in which the apricot are soaked into the solution. The most effective pre-treatment for apricots is sulphuring and also the potential of osmotic dehydration as a pre-treatment has been used which does not only water removal but also in many cases it's a taste improvement. The advantage of osmotic dehydration using date solution was the enrichment of apricot with sugars (sucrose, fructose, glucose) and also with other soluble vitamins. This pre-treatment process has various abilities like preserving more nutritional content, prevents discoloration etc.

4 RECENT TECHNOLOGIES FOR PRETREATMENT PROCESS

In addition to osmotic dehydration there are some new novel nonthermal technologies are used to improve the properties like inactivating microorganisms at near-ambient temperatures and reducing thermal degradation of apricot samples, therefore consequently preserving the sensory and nutritional quality of food products.

4.1 ULTRASOUND TECHNOLOGY

Ultrasound pre-treatment of fruit apricot before drying has shown promise in greatly reducing the overall drying time and enhancing the retention of quality aspects of dried fruits. Because ultrasound wave with frequency 25 kHz and the intensity at 4,870 or 100 kW=m^3 at 30°C which can produce minute vapour filled bubbles that cause a sponge effect on apricot. The oscillatory motion of an ultrasound wave causes acoustic streaming and thus enhancing mass transfer in the sample and it takes 282.8 min to remove 95% of the initial water content in the fruit in Fig-1. In addition to all these properties the higher surface tension force caused by this mechanism maintains the moisture inside the capillaries of apricot material creating microscopic channels which may promote moisture removal in [3].

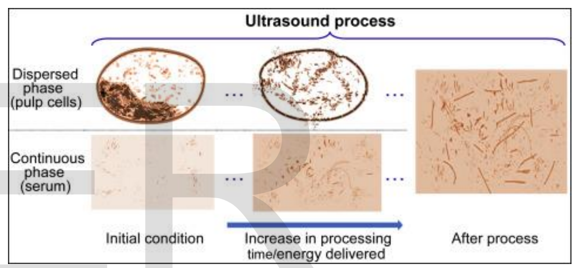

Fig – 1: Ultrasound Technology [4]

4.2 NANO TECHNOLOGY

As the size of apricot gets reduced to nanoscale range, there is an immense increase in the surface to volume ratio of material which increases reactivity and changes mechanical, electrical, and optical properties in apricot fruit. Apricot have some properties like high dielectric constant and loss factor, which is helpful to improve dielectric drying rates. There is a suitable method based on vacuum impregnation to inject calcium into fruits like apricot and further applied it to develop material rich in vitamins, minerals, and dietary fibre.[2]

5 HIGH QUALITY METHODS FOR APRICOT DRYING

5.1 OPEN SUN DRYING

Open sun drying is the simplest and most common traditional method to preserve products in which fruits like Apricot directly exposed to solar radiation. This results in partly absorbed and partly reflected. Fresh apricots of 700g were divided into two pieces by removing the pit and then pre-treated with sulphated SO_2 which have initial moisture content of 4g.Open air sun drying is performed under July and August. A wire mesh tray is used on which the apricot is placed and on the first day of drying it becomes 511.32g at a temperature of 33-41℃ .Then on the second day of drying sample become 214.54g at a temperature of 32-42℃ and on third day 146.4g at 34-42℃. It continued drying when the moisture content of sample reached 15-17% on dry basis. The main defect is the inability to control the drying operation properly, weather uncertainties, large area requirement, insect infestation, mixing with dust and other foreign material and so on .[5]

5.2 AIR DRYING

Sun drying has some limitations like it produce a product with in a rich orange colour, translucent appearance and a desirable gummy texture however it has many disadvantages. In recent years air drying has been applied to overcome these limitations, the optimization of drying of apricots are determined by sulphating and drying. Fresh apricots are removed from the storage room at 4℃, before drying they are washed and cut into two halves by remove the pit with initial moisture content of 28%.Before adding sulphite, apricot was dipped into sodium bisulphite solution to achieve 800-1000 ppm sulphite in fresh tissue. Sulphite apricot halves were placed on the tray dryer and a temperature of 50-80℃ air is supplied .Drying time is reduced by 50% when it dried at 80℃ compared to 50℃ and finally apricot got dried with 20% of moisture content. The quality of dried apricot was determined by browning development and hardness determination. Browning is determined by dried apricot in 250ml Erlenmeyer flask containing 100 ml ethanol solution. The flask is covered with parafilm to remain at room temperature for 24 hour with occasional shaking, then the solution was filtered using filter paper. Then hardness is determined by treating each five dried apricot halves were punched five times in different places with cylindrical flat ended punch. Sulphite is the major factor in controlling dry apricots quality. [6]

5.3 FREEZE DRYING

Freeze drying is also called lyophilisation. It is a process in which material is freeze and then high pressure vacuum is applied to convert the water in the form of ice. The water passes directly from solid state to vapour state without passing through the liquid state. This conversion of phase change is known as sublimation of water which can take place at pressures and temperature below triple points. Apricot were cut in to two halves and frozen at -30°C for 24 hr and freeze dried using a freeze dryer. A pressure of 0.05 mbar is applied and sublimation was carried out at 20°C. Each apricot samples were weighed every 30 minutes. During freeze drying a thermocouple pt100 was used to measure the temperature in the centre of the sample apricot. Dried apricot were cooled and then packed in polyethylene bags. [7]

5.4 DIELECTRIC DRYING

Dielectric heating, a term which covers both Radio Frequency (RF) and microwave systems. It has been used for industrial drying for many years because it has a number of advantages over other drying process. In this process most of the foods are dielectric material which stores electric energy and converts it into heat. A dielectric material consists of and a large number of microscopic electric dipole which can be polarised by action of electric field. The principle for this process is that energy is absorbed by a wet vegetable. Apricot were cut into two halves and stored in a refrigerator at 4℃. After this apricot were put into cylinder and the vibrator operating at 230rpm then opened the valve at 0.6Mpa. Dielectric properties were measured at 915MHz using a coaxial probe. The apricot were heated in a micro oven (60W) and heated for 40s [8].In case of microwave dielectric heating the applicator can no longer be a simple capacitor and the electric field in the material will be in electromagnetic form. This energy is absorbed by the water present in the material apricot by rise in temperature and some water is evaporated, by which the moisture content is reduced and the apricot got dried. [8]

5.5 FLUIDIZED BED DRYING

Fluidized Bed Drying widely used in food processing industries. There will be a direct contact between product particles and gas is passed in Fluidized Bed system. The product particles are suspended in the heated air throughout the time required for drying. Fresh apricots were cut into two halves. After cutting, apricot were kept in refrigerator at 4℃ for more than 24 hour before drying. The Fluidized Bed Dryer obtained the drying air through the heat pump dehumidifier system, which were applied at 30℃, 40℃, 50℃ and is controlled by using flow control valve. This system runs for 2 hour to achieve steady state condition of drying before apricot was introduced. Here any type of inert gas or air is used which is passed at high pressure, through a perforated bottom of the containing product to be dried. The average relative humidity throughout the drying period was 15% and the vegetable was introduced through the inlet velocity of hot air at constant value of 2.2m/s. This velocity was selected because it was between fluidisation and terminal velocity of selected fruit which is apricot. These are lifted from the bottom and suspended in the stream of air. This movement in product by fluidized particles and the hot gas surrounding results in equal drying of sample surfaces. In fluidized bed dryer, uniform conditions of temperature, composition and particle size distribution is achieved through the bed because of complete mixing between the solid and gas is obtained. There will be a good contact in warm drying air and wet particles is found and separated in fluidized bed dryer. The dried apricot were collected in a sealable container from the dryer at 30 min intervals through the sample outlet [9].

5.6 ELECTRO HYDRODYNAMIC DRYING

Electro hydrodynamic drying is non-thermal technology. It is particularly used to dehydrate heat sensitive food products like apricot. It is a promising technology to dry apricot and convert without using additional heat. Electro hydrodynamic drying is a method of inducing electric wind (Corona wind).In order to produce corona discharge electrostatic field of a high voltage power supply is used, this air flow generate a high voltage difference between an emitter electrodes and the required current was measured using a digital multi meter. Due to high voltage and curvature of emitter, the surrounded air is ionized by gaseous ion under the influence of a high voltage electric field by which corona discharge is produced. The cathode of the power supply was connected to a stainless steel ring. To improve the electric discharge the needle points of electrode placed around the ring. A circular aluminium plate is attached to the ground at a distance from the electrode to obtain a powerful electrostatic field between the plate and electrode. This is the electrodynamics setup for drying. Before drying the apricot those were stored in the refrigerator at 4°C and after 4 hours stabilization at room temperature (24°C) apricot were cut into two halves and removed the pits. This apricot slice with initial moisture content of 60% was exposed to a voltage of 10kv and oven dried at 55°C and then apricot got dried to obtain final moisture content of 11% after 780 minutes of drying Fig-2. The air flow enhances moisture removal from wet product apricot by increasing convective mass transfer rates. This results the convective heat transfer and moisture removal from apricot. [10]

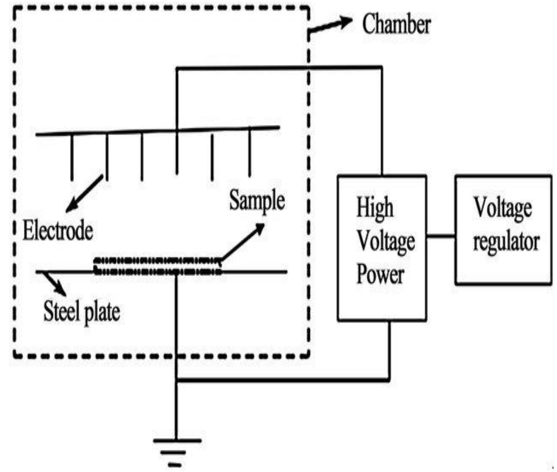

Fig – 2: Electrohydrodynamic drying setup [11]

5.7 OSMOTIC DEHYDRATION

Osmotic Dehydration has received greater attention in recent years as an effective method for preservation of apricots. It is less energy intensive than air drying because it can be conducted at low temperature. A combined process of osmotic dehydration, which followed by air dehydration has been developed to obtain dry apricot ingredients, having a natural colour, without sulphur dioxide, which could be suitable for different applications. In Osmotic Dehydration the solutes used are generally sugar syrup with apricot. This is multicomponent diffusion process. In this process the water flow with minerals, vitamin etc. It is also treated with brine to reduce their moisture content.

It gives three types of simultaneous counter current flow

- Water diffusion into solution
- Solute diffusion into food
- Leaching out of product

Osmotic Dehydration is the process of water removal by immersion of water containing cellular solid in which water does not go through a phase change. The setup for this consists of novel agitation system, immersion device, a bag filter and vacuum evaporator pump. Fresh apricot were cut into two halves and refrigerated at 5°C. In osmotic dehydration there are various osmotic agents like glucose, fructose, sucrose, maltodextric and sorbitol is used. The ratio of fruit to solution is at 1/25 to avoid significant dilution of the medium by water removal. Apricot were immersed in a glass jar with osmotic solution which has initial concentration from 40% to 70% (w/w).Then the glass jar is placed in a water bath by maintain the temperature varied from 25°C to 45°C of the syrup. Apricot withdrawn at every two hours and then rinsed then blotted with tissue paper to remove excess solution from the surface of apricot and then returned to the osmotic solution to continue the drying process for 24hr then the final moisture content of apricot is determined as 7% .Osmotic dehydration facilitate processing of fruits like apricot with retention of initial characteristics such as colour, aroma and nutritional compounds.

Food preservation is the process of treating and handling food to stop or slow down the spoilage caused by microorganism. Preservation usually involves preventing the growth of fungus, bacterium and other microorganism and also retarding the oxidation of fat which cause rancidity. In the process of osmotic dehydration natural ageing and discoloration that can occur as the enzymatic browning reaction in apples are inhibited. Osmotic dehydration is one of the best and suitable process to increase the shelf life. This process is preferred over others due to their vitamin and minerals, colour, flavour and taste retention properties value as it is not much varied after dehydration of apricot .[12]

5.8 INFRARED DRYING (IR)

Infrared drying is a method which has high energy efficiency. Transmit electromagnetic radiation in the range between medium to short wave and infrared wavelength between 2 and 3.5 µm is used as drying equipment. Fresh apricots were cut into two halves to remove its pits and these samples were placed in infrared drier in a way that inside of apricot is opened to its ambience. In infrared drier temperature of 80°C is supplied and apricot were dried at this temperature. Apricot sample moisture level is observed by balance mounted on the drier and there is a loss in the initial mass of sample as a per of 20%, 30%, 40%, 50% and 60% is taken out from infrared drier. Then the surface of the material apricot gets dried by the penetration of infrared radiation in moisture, porous material. The transmission of radiation depends on the moisture content present in it. Infrared drying become more popular in recent years because of its advantages such as low drying time, the quality of the final product more over it is cheaper in price compare to other methods.[13]

5.9 MICROWAVE DRYING (MW)

Microwave drier is more effective than infrared drier in terms of less losses of vitamins, rate of drying and preservation of original colour of apricot and also the speed of drying and the preservation of colour in the microwave drier were found to be better than those in the infrared drier. Fresh apricot is cut into two halves and after removing pits the sample were placed in microwave drier. Microwave was regulated at a wavelength of 12.2cm corresponding to a frequency of 2.450±0.05Hz and forcing the moisture to be out. . In microwave drier temperature of 80°C is supplied and apricot were dried at this temperature. Apricot sample moisture level is observed by balance mounted on the drier and there is a loss in the initial mass of sample as a per of 20%, 30%, 40%, 50% and 60% is taken out from microwave drier. The selected air temperature is depended upon the product characteristics. There are some advantages like fast volumetric heating, short drying time and at the same time the major disadvantage is that product texture may be affected badly. [13]

6 RECENT COMBINED DRYING TECHNOLOGY

6.1 INFRARED FREEZE DRYING (IRFD)

Infrared freeze drying is a new processing method for high quality dried apricot at reduced cost. Fresh apricot is washed and cut into two halves and then the sample were treated with infrared (IR) heating at each of the three different intensities 3000, 4000, and 5000 Wm^{-2} to reduce the weight level up to 30%, 40%, and 50% .The pre-dehydrated apricot sample were then further freeze-dried to achieve a final moisture content of about 5%.The samples were also pre-dehydrated with hot-air drying at a temperature of 62.8°C followed by freeze-drying and dried with regular freeze-drying without pre-dehydration. By using infrared for pre-dehydration of apricot sample it reduces 40% weight level and it also leads to a reduction in required freeze time by 42%. This indicating a great energy saving potential for infrared freeze drying method, since the energy efficiency of freeze-drying is very low. Infrared freeze drying could be a desirable method for producing high quality and nutritional rich dried apricot. [14]

6.2 INFRARED FLUIDISED BED DRIER (IRFBD)

Infrared fluid bed drying include high heat and mass transfer coefficients, short process time, and high quality and low energy consumption. Fresh apricot were cut into two halves and kept at refrigerator at a temperature of 4°C. The apricot drying were conducted by using a infrared fluidized bed dryer. The bed which contained apricot that uniformly spread over a perforated plate which is placed inside the dryer. Initial moisture content of apricot is 70%. The pressure drop over a bed of apricot fruit was maintained for different air flow velocities. Fan speed is gradually increases using an inverter and air velocity is maintained at ±0.1m/s and pressure drop at ±0.1pa. The drying is performed at three different temperature 40, 55, 70 °C while applying infrared power of 500, 1000 and 1500W with air velocity of 0.93, 1.76, 2.6 m/s. Then the apricot got dried and collected from the bottom of the bed. [15]

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6.3 MICROWAVE-HOT AIR DRYING (MWHD)

The most commonly used technique for apricot drying is sun drying and hot air drying, these methods are slow therefore drying needs more time and products expose uncontrolled weather and unhygienic conditions. These situation adversely affect the product quality and safety. A hybrid (microwave-hot air) domestic oven was to dry apricot halves .Apricot were stored at 4°C and halved into two and arranged a single layer on the drying tray. Microwave and hot air are utilized at the same time in the oven, microwave power can be adjusted to 120,150 and 180W and the conventional heating system supply hot air from 50°C, 60°C, 70°C. The oven contains a fan for circulating air and polyamide platforms which the tray holding with apricots. Microwave is emitted from top of the oven and the holes are opened from bottom for connecting the platforms to digital balance. The time required for drying of apricot from initial moisture content of 77% to the final moisture content of 22% changed from 409 to 1560 min. Drying time of apricot is decreased with increase in microwave power from 120-180W. At 120 and 150W microwave power with increase in drying temperature from 50-70°C caused a reduction in drying time by 54.4 and 57.8% and the reduction in drying time is 47.5% at 180W.

In the final stage of drying, apricot absorbs less microwave energy due to its low die electric property. The moisture content of apricot was high at initial stage of drying operation. High moisture content causes high absorption of microwave energy and higher moisture diffusion. The highest drying rate occurs at 180W microwave power and 70°C air temperature. This hybrid drying technique are has some advantage over microwave and hot air applied alone Fig-3. There are some disadvantage like elimination of overheating and long drying time, energy consumption, drying expenditure and improvement of product quality. [16]

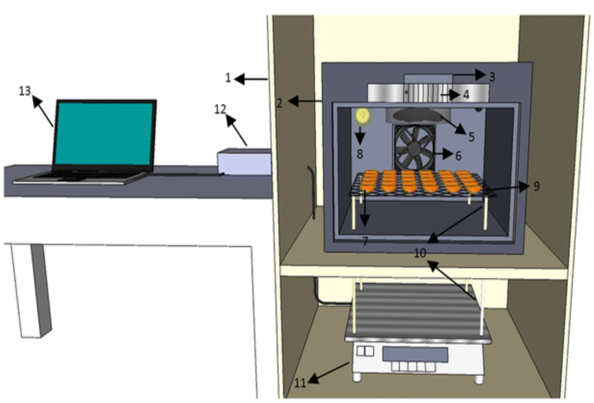

Fig - 3: Microwave apricot drying setup [16]

6.4 MICROWAVE VACCUM DRYING (MWVD)

Microwave vacuum drying consists of microwave oven equipped with a vacuum desiccator inside. Fresh apricot washed and cut in two halves and it placed at the bottom of the glass desiccator, which was laid inside the microwave oven. The vacuum pump maintained the vacuity of dissector. The vapour from the apricot was collected in a condenser and collected in a buffering bottle. To avoid the water spilling of vacuum pump from the buffering bottle, silica gel is filled with drying column. Microwave power was set at 250W and pressure is maintained at 20±2 bar with one minute heating on followed by 2 minute heating off and the microwave heating time is up to 30 minute. After drying apricot were taken out of the desiccator. Microwave-vacuum drying could be used as a highly efficient dehydration method for apricot drying. With 30 min of microwave heating under current vacuum conditions, the moisture level of the apricot slices was reduced from around 85% to approximately 10%.[13]

6.5 MICROWAVE FREEZE DRYING (MWFD)

A major problem with freeze drying is the long drying time needed, which leads to the increase in energy consumption and capital costs. In order to increase the freeze drying rate, the combination of microwave and freeze drying instead of the traditional radiant heating has already been proven to give better heat and mass transfer rates. Recently, it shows that microwave freeze drying is one of the best techniques drying to enhance overall quality and drying rate. Fresh apricot were washed and cut in two halves then stored in refrigerator at 4°C for 24 hour. There are two drying cavities like freeze drier and microwave drier. When the apricot were dried in the freeze drier they were dried at 100pa by a vacuum pump and the temperature about -40°C to -45°C.The microwave frequency was 2450Hz and the power was regulated from 0 to 2000W.The pre frozen sample were transferred to the drying chamber. Before moving the frozen apricot into the drying chamber, the cold trap was set at a temperature of -40°C.The vacuum pump is turned on at 100pa.The drying continued until the moisture content become 6%. [16]

7 POST TREATMENT AND STORAGE OF DRIED APRICOT

After the completion of the dehydration process the apricot will be in the brittle condition. Check the moisture of dehydrated apricot when removed completely. If some pieces has more moisture than the other, It is collected and processed again. Dried apricot samples were packed in polyethylene (PE) packages. Apricot should be stored at -0.5°C to 0°C at a humidity of 90 to 95%.The temperature plays an important role in the storage of dried apricot, the lower the storage temperature (<-2°C) the lower the quality losses. They must be stored in a cool and dry place. The storage temperature is one of the important factor which decides the span of the apricot. If it is stored in a cool place it can last for longer duration. The packing must be sealed properly that the air doesn't enter into the package [1]. Sealed bags can be stored no more than 1 month at room temperature, but up to 6 months in the refrigerator.

8 CONCLUSION

This review has shown some recent developments in high quality drying of foods, especially fruits like apricot based on flavour, nutrients, colour rehydration, uniformity, appearance, and texture. On the other hand drying efficiency and product quality can also be improved by varying mode of heat input, it shows the development of drying technology from open sun drying to MW-, IR-, assisted drying have been applied to shorten drying time and improve final quality of dried products. Many different combinations of drying methods were used to avoid disadvantages of single drying method such as long drying time, high power consumption, or low product quality. Among these technologies more novel and multi-age-combined high-quality and high-efficiency drying technologies have been developed, such as MW-enhanced combined drying methods (MWHD),(MWFD),(MWVD) and IR-combined drying methods (IRFD), (IRFBD).During the process, chemical, physical and biological activities, which deteriorate the foods, are lowered considerably; hence extend the shelf life of dried products. It also provides certain benefits i.e. minimizing thermal damage to the nutrients, inhibiting enzymatic browning and reducing costs. It provides a nutritious and wholesome product which is available round the year [2].From these microwave hybrid drying (MWHD) and infrared hybrid drying (IRHD) is preferred over others due to their vitamin and minerals, colour, flavour and taste retention properties value as not much varied after dehydration of apricot.

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