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A study on the dehydration of fruits using novel drying techniques

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Abstract
Fruits and vegetables are important sources of essential nutrients such as vitamins, minerals, and fiber. Since. The moisture content of fruits and vegetables is higher than Eighty percent, they are classified as highly perishable commodities. Keeping the product fresh is the best way to maintain its nutritional value. Drying, on the other hand, is an appropriate change for post-harvest management especially in countries with a good distribution of low temperature and hand-pulling equipment. Drying is a very important process in the food industry and provides opportunities for the development of novel ingredients and products for consumers. Drying of fruits and vegetables has been principally accomplished by convective drying Some important physical properties of the products are changed by this drying technique such as loss of colour change of texture, chemical changes affecting flavour and nutrients and shrinkage Some dried fruits and vegetables are rehydrated prior to further processing and for that purpose, these fruits require a minimum quality for adequate rehydration which is not always possible with conventional convective drying. There are a number of studies that have addressed the problems associated with conventional convective drying. The high temperature of the drying process is an important cause of the loss of quality. Lowering the process temperature has great potential for improving the quality of dried products however in such conditions, the operating time and the associated cost become unacceptable.
In recent years, there have been many technological advances associated with the drying up of the food industry, including advanced pre-treatments, techniques, equipment and quality. In this study, we have studied novel drying methods such as microwave-assisted drying- or ultrasound, high power drying, heat pump drying and refractory drying windows that can now be adopted to improve the efficiency of drying and to reduce energy consumption while simultaneously saving the final product quality. Thus we have concluded that these technologies are successful, marketers often do not know what strategies they have great power in the industry. The current work highlights the recent development of novel drying methods that are important to promote sustainability in the food industry and to move forward.

Keywords: Dehydration, drying, techniques, physical, technological

Introduction
Fruits play an important role in the human diet and nutrition. They are an important source of essential nutrients, vitamins, and minerals without providing crude fiber and bulk. They give color, flavor and variety to other boring foods. Due to the high moisture content (above 80%) it is very rotten. India is the second-largest producer of food, and it is estimated that the production will reach 308.65 million tonnes in 2020-2021 which corresponds to a rise of 3.74 percent compared to the previous year. Estimated losses of 40-50%; occur in many developing countries in tropical and subtropical areas due to inadequate refrigerators and freezing zones. The main goal of food processing is to turn those perishable goods into stable products that can be stored for a long time thereby reducing losses and being available in times of scarcity and off-season and in areas far from the production area. Processing can transform food into new or usable forms and make it much easier to process. Several process technologies have been used on an industrial scale to preserve fruits and vegetables, which are the main ones other than cans, cold, and dehydration.
Drying is one of the oldest and most important ways to preserve food. It is intended to reduce food moisture and is widely used in foods such as fruits, vegetables, spices and other high-fat products (80%), as well as in what is considered 'highly corrosive'. Dried foods offer many benefits including: extended product shelf life, reduced packaging, storage, management and transportation costs, and increases the chances of being out-of-season and offers a wider range of products to consumers.

More than 85% of industrial dryers are a convective form of hot air or flammable gasses as a means of heat transfer. As it is a complex process that involves heat as well as mass transfer, the drying process consumes a lot of energy and accounts for about 12-20% of the energy used in the manufacturing industry. With conventional drying methods that rely on efficient and flexible heat transfer methods, the final product can suffer due to poor quality, and the potential for product contamination can be increased. For this reason, in recent years, there has been a remarkable increase in technological advances in food diets in relation to pre-treatment drying, strategies, equipment, and quality. These activities address the growing need for improved drying methods to maintain the final product quality in improved energy consumption. Newly emerged novel drying techniques will help prevent postharvest losses by delaying spoilage and increasing the shelf life Novel drying methods come from a research perspective that may have a positive impact on the food industry both in terms of product quality and energy efficiency. These novel techniques use different body scenarios to improve the drying techniques already sold, such as in the case of ultrasound or microwave drying, or use more recent ones. events identified as in the case of hot steam drying or drying of the display window. Although a significant amount of scientific research has been done in the field of novel drying, there has been very little commercialization. The exploitation of these systems due to the high cost and energy efficiency is not well understood. In addition, a small amount of work aimed at demonstrating that this technology is useful for commercial exploitation. With this in mind, the purpose of this current work is to highlight some of the latest and most significant developments in the food industry, with great emphasis on the recent development of important drying methods. In the midst of this. dehydration is particularly acute in developing countries with poorly developed low temperatures and hot springs.

The sharp rise in energy costs has encouraged a dramatic increase in global interest in the last decade. The development of techniques and the development of novel drying methods have led to the discovery of a wide range of dehydrated products. especially fast-acting ingredients, derived from fruits and vegetables with properties that have not been anticipated for some years past and fast food growth has exacerbated the need for such ingredients. Due to changing lifestyles especially in developed countries, there is now a great need for a variety of dried products that emphasize high quality and freshness without the hassle. This requires further basic research on drying conditions and equipment and its effect on food qualities. Developments related to dehydration in general were reviewed earlier by several authors regarding the theory and methods involved and its practical application.

Drying is an important function of the unit in food processing and storage. It is used to improve the stability of food products by reducing water activity. Reducing the water activity of In the last period, the product reduces microbial activity and curtails physicochemical mutations. Energy efficiency units are very active in the food consumption industry. Convection is the most common way to transfer heat to dry objects. Active drying transfers heat from hot air into the product with convection, and evaporation of the water is returned to the air again by convection. A lot of obstacles are associated with the corresponding drought of agricultural products, such as a long dry season, unequal product quality, low efficiency, and high power consumption. High power use of the display suspension is associated with air temperature and indirect temperature of the product with hot air. The accompanying dry limit has encouraged the development of many drying technologies, such as cool bed drying, microwave drying, osmotic drying, infrared drying (IR), and various

Dehydration involves the use of heat to evaporate water and other ways to remove water vapor after its separation from vegetable tissues. It is therefore a function of integrated / simultaneous heating and mass transfer to provide energy. Air current is the most common method.

Heat transfer to dry tissue and convection are more involved. The two most important features of water transfer are the water transfer surface of the dryer and the removal of water vapor from the surface.

Acquiring dehydrated products of high quality at a reasonable cost. dehydration should occur immediately. Four key factors affecting the rate and total drying time: product properties, especially particle size and geometry, and its geometric arrangement with respect to heat transfer, physical properties of medium drying / environment and features of drying machines.

Moisture content of the fruits play a major role in their shelf life. High moisture content easily paves the path for microbial attack, which easily deteriorates the fruits early. Moisture content of the fruits can be reduced by adopting novel drying techniques. There are many drying techniques used to reduce the moisture content of the fruits. Some of the drying techniques are Sun drying, Vacuum drying, Microwave drying, Freeze drying, and Ultrasound drying. Among these different types of drying, sun drying is the cheapest and easily available source of drying. Sun drying can be adopted by farmers to reduce the moisture content of the fruits before storage or transportation. Sun drying is simply drying the fruits in the open sun or drying in a solar dryer. Solar dryers are made more efficient by attaching photovoltaic and electric cells making the solar dryer hybrid to increase the efficiency of drying. Sun drying can be very effectively used for small-scale drying and it is a convenient and good drying technique that can be easily adopted by farmers. Sun drying is greatly influenced by the climatic conditions of the location. If the moisture of the fruits is reduced during the period of harvesting, the shelf life of the fruits can be greatly increased. Sun-drying being the cheapest and most reliable method of drying it also has many disadvantages like the drying period in open sun drying methods is high and they are completely climate-dependent and it can be greatly affected by animals.

Chapter 2: Literature Review

The aim of this report is to present the Novel Drying techniques for fruits be constructed for "Capstone II" of course code FOT 453 that is RESEARCH PROJECT. Any student must confer to the rules and guidelines that have been laid out in the following sections while writing their final report. It must also be kept in mind that the soft copy of the report that any student prepares will also have to be submitted on University Management System(UMS).

Objective 1

- To study the novel advanced drying techniques used for the utilization of Fruits.

Microwave Drying

Microwave drying is also considered a fourth generation drying technology. Microwave drying is divided into three drying phases

1. **Heating Up Phase:** It is the of conversion of microwave energy into thermal energy within moist products and increase in temperature of the product with time can be observed, and when the vapour pressure of the moisture inside the product increases than that of the vapour pressure of the surrounding environment the product start losing moisture but at relatively slower rates
2. **Rapid Drying Phase:** It is the phase in which a stable temperature profile is established and the thermal energy generated from the microwave energy is used for the vaporization of moisture, however in the porous food material the rates of evaporation of moisture at different locations is dependent on the extent of local conversion of microwave energy into thermal energy
3. **Reduced Drying Rate Phase:** It is the period in which the local moisture is reduced to a point when the energy required for vaporization of moisture is less than the thermal energy generated and local temperature rises above the boiling temperature the of water. Product temperature still rises resulting in over drying or charring

Dipole rotation and ionic conduction are two primary mechanisms involved in microwave-material interaction. Electric fields accelerate ions in ionic conduction, forcing them to flow in the opposite direction of their own polarity. The movement of the ions causes collisions with the material's molecules. Heat is produced as a result of the disorganised kinetic energy created. The rotational energy level of polar molecules corresponds to the energy level of microwaves. As a result, microwave energy interacts with matter through the dielectric rotation of molecules. Instead of being transported from the surface to the inner section as is the case with traditional hot air drying, the friction between the fast revolving molecules generates heat throughout the material.

Principles of Microwave Drying

Microwaves have wavelengths ranging from 1mm to 1m and cover the electromagnetic range from 0.3 to 300 GHz (between radio waves and infrared radiations). In most European countries, microwaves can be used at a frequency of 2.45 GHz, which corresponds to a vacuum wavelength of 12.2 cm. The frequency of 915 MHz is authorised for industrial uses and under special authorisation. Microwaves have the following characteristics:

- Microwaves are reflected when they pass through conductors.
- Microwaves can polarise (alter dipole orientation within) the materials molecules that absorb them.
- Microwaves can also permeate glass and polymers without causing considerable energy loss.

Pectin Honey Coating

Because the concept of green food is so popular these days, there was a pressing need to adopt green drying procedures that did not involve the use of any chemicals. As a result, the dehydration capabilities of edible pectin and honey coatings are used to explain a sustainable drying technique in this work. This method involves coating the surface of fruit with a thin layer of edible coating that acts as a barrier to moisture, oxygen, carbon dioxide, smells, lipids, and other solutes. Because of its unique colloidal characteristics, pectin is of particular interest as a possible coating component among polysaccharides. Several substances, such as antioxidants, antimicrobials, tastes, and probiotics, can be included into polymeric formulations and taken with food to improve the food's safety, nutritional, and sensory properties. A natural component, honey, was incorporated in pectin water formulations based on the foregoing considerations and with the goal of obtaining a dehydrating and functional edible coating. As a result, the goal is to use a pectin-honey (PH) based coating as a new, environmentally friendly way for dehydrating selected types of cut fruits while simultaneously protecting their safety and quality by utilising honey's antibacterial activity. Gabriella Santagata1 and colleagues' The dehydration process was carried out at a low temperature to preserve the nutritional and sensory components of dried fruit that had not been treated with sugar or chemical additions, resulting in a high-quality end product.

Electro Hydrothermal Drying

Alex Martynenk, Kamran Iranshahi, and Daniel I. Onwude Electro hydrodynamic drying (EHD) is a promising method for preserving the nutritional value and sensory appeal of dried fruits and vegetables. We need to rethink the current EHD dryer designs in order to scale up this technology successfully. By improving EHD process settings, there is also a huge opportunity to improve the nutritional content and sensory quality of dried items. The existing obstacles in scaling up the technology, enhancing nutrient retention, and boosting the sensory appeal of dried items are highlighted in this paper. Quantifying the remaining nutritional and sensory aspects of EH has received special attention.

Osmotic Dehydration

Osmotic dehydration, because of its nutrition and flavour retention, is one of the best drying techniques. When used in conjunction with other drying procedures, the product's shelf life will be extended.

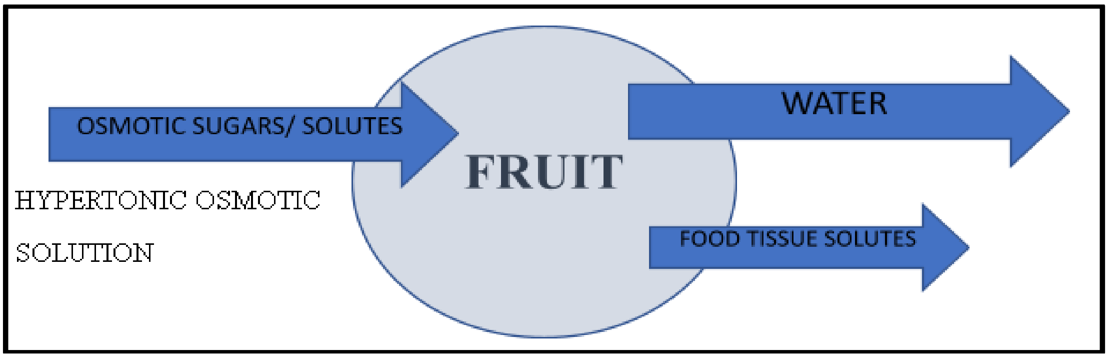
Osmotic dehydration is a counter-current mass transfer mechanism in which the solute flows into the food while moisture is eluted from the food's interior to the hypertonic solution. The solutes, such as organic acids, minerals, perfumes, and colourants, migrate into the hypertonic solution from the food items due to the semi-permeability of the cell membrane. This transfer is insignificant in terms of volume but critical in terms of product mix. (Ahmad *et al*., 2016, p. 30).

Osmotic dehydration is a technique for removing water from items like fruits and vegetables by immersing them in high-osmotic-pressure aqueous solutions. The following is the basic mechanism of osmotic dehydration:

Foods are submerged in a sugar or saline solution. Between the food product and the solvent, three forms of mass transfer occur after immersion.

The first is the outward flow of water from the food tissues to the osmotic solution; the second is the transfer of solute particles from the osmotic solution to the food tissue; and the third is the transfer of the food tissue's own solutes (sugars, organic acids, minerals, vitamins) into the osmotic solution, which is quantitatively negligible compared to the first two types of transfer but crucial in terms of product composition.

The flux of water removal is much greater than the flux of solutes infusion, which explains why "osmotic dehydration" is formed by combining the terms "dehydration" and "osmosis." Fruit cell walls operate as a semipermeable membrane that allows water and low molecular solutes to pass through during osmotic dehydration. As a result of the membrane's limited permeability, solute impregnation occurs closer to the fruit's surface rather than the core. Capillary flow and diffusion, on the other hand, remove water molecules from the fruit matrix. (Shi & Le Maguer, 2002).



Osmoactive Agents

Special regulations Fernandes & Rodrigues (2008) apply to osmoactive chemicals used in food. They must be edible, with a pleasant taste and flavour, nontoxic, food inert, and, if possible, highly osmoactive. Most trials evaluating the applicability of various osmoactive chemicals focused on the final product's quality. Water loss rate and ultimate water content in the material are used to determine their technical applicability. In most cases, saturated solutions or solutions with similar concentrations are compared. Water loss and the amount of the chemical penetrating the osmosed material are the two parameters used to rank different osmoactive compounds, according to studies. Lowering the material's water activity was also utilised as a criterion for osmoactive chemical acceptability.

Fruits are typically dehydrated with sugar solutions, while vegetables are dehydrated with glycerol, starch syrup, and sodium chloride. The most commonly utilised ingredient is sucrose. Glucose and fructose both dehydrate the fruits and vegetables in the same way. According to some studies, fructose raises the dry matter content by 50% when compared to sucrose. With fructose as a hypertonic solution, the end product's water activity was likewise reduced. Glucose produced more water loss and solids accumulation in apple, banana, and kiwifruit than sucrose. Starch syrup allows for a similar final water content in dried material as sucrose, but with a far smaller inflow of osmoactive substance into tissue. The syrup's dextrose equivalent had a significant impact on the ratio of water loss to solids increase. Osmotic dehydration of fruits and vegetables was also done with corn syrup solids, cane sugar syrup, palm sugar syrup, and hydrolysed lactose syrup.

1. **Calcium chloride is a mineral composed of calcium and chlorine:** Increases the stiffness of apple chunks and keeps the texture while storing them. Because of the combined impact of ascorbic acid or sulfur dioxide, it prevents browning.
2. **Ethanol:** During the de-hydro cooling process, the viscosity and freezing point of the osmotic solution are reduced.
3. **Fructose:** Because fructose has a higher rate of solute penetration than sucrose, sucrose is favoured.
4. **Invert sugar:** Because it has twice as many molecules per unit volume when totally inverted, it is more effective than sucrose at the same concentration. There is only a small change in the rate of osmotic dehydration.
5. **Lactose:** Has a substantially lower sweetness level than sucrose.
6. **Maltodextrin:** Can be employed in a mixed system or at greater total solids concentrations.
7. **Sucrose/sugar:** Due to oxidative browning, dry sugar is not acceptable. Difficulty in getting rid of the sugar syrup that has formed. Its sweetness makes it unsuitable for vegetable processing.
8. **Invert sugar and salt mixture, sucrose and salt mixture, ethanol and salt mixture:** Due to the combination of characteristics of both solutes, it is more effective than sucrose alone.
9. **Calcium chloride is a mineral composed of calcium and chlorine:** Increases the stiffness of apple chunks and keeps the texture while storing them. Because of the combined impact of ascorbic acid or sulfur dioxide, it prevents browning.
10. **Ethanol:** During the de-hydro cooling process, the viscosity and freezing point of the osmotic solution are reduced.

Sun Drying

Sun drying is one the oldest and cheapest means of drying the fruits. There are five different types of sun drying methods followed across centuries. The first is Open Sun Drying (OSD), where the fruit is dried in the open sun. Black Cloth Shade (BCS), is the method where the fruits are placed in an area which is covered with black cloth. White Cloth Shade (WCS) is the method in which the fruits are kept under a white cloth. Next is the Conventional Solar Dryer (CSD), which gave a revolution in solar drying technique. The latest method is Improved Solar Drying (ISD), which is a hybrid passive mode solar dryer.

In Open sun drying the fruits are left open under the sun to dry, it takes the longest time to dry. In Black Cloth Shade drying, the black cloth absorbs greater heat due to radiation and keeps the surrounding heat which can further improve the drying efficiency. In White Cloth Shade drying increases the drying time, since white does not absorb heat the surrounding is kept cooler which acts as a barrier to dry. White Cloth Shade takes longer to dry than any other methods. In Conventional Solar Dryer, drying takes place at a quicker rate as it has solar panels attached to it. Solar panels absorb the solar energy and give energy which helps to dry the fruits.

The mean drying air temperatures for the OSD, BCS, WCS, CSD and ISD methods were 26.8, 26.7, 24.5, 32.6 and 40.3 deg C; respectively. Results showed that the five solar drying methods were capable of retaining the sensory quality and nutritional composition of dried fruits.

Other drying methods like vacuum drying, Microwave oven drying and freeze drying helps to reduce the moisture content and make a better-quality product than drying under sun but they are done under controlled conditions (Chua and Chou, 2003) [2]. Since the other drying techniques need high investment and regular power supply, they are not preferred in the rural areas of Africa. So, the people of Africa adopted an open sun drying method, white cloth shade drying method, Black Cloth Shade drying method and Conventional Solar drying method in order to dry the fruits produced in their locality. They preferred sun drying techniques because solar energy is a freely and abundantly available source of renewable energy but solar drying (Chua and Chou, 2003; Hii *et al*., 2012; Orphanides *et al*., 2016; Kumar *et al*., 2016) [2, 3, 1, 9]. has disadvantages like contamination due to dust and rain, scavenging by birds and animals, excessive or inadequate drying of fruit. These disadvantages affect the nutritional composition and sensory quality attributes of the solar dried fruit. Considering these disadvantages, a newly improved solar dryer was proposed as an alternative for traditional sun drying methods. This Improved solar dryer helps to decrease their nutritional loss and improve their sensory quality attributes. Improved Solar Dryers would help the farmers to reduce the post-harvest losses of fruits compared to the traditional sun drying methods.

Infrared Drying

The use of IR heating is gaining popularity in food processing because of its specific benefits over normal temperature. Rapid and rapid heat transfer decreased the cost of processing, heating the same product, and the better organoleptic and nutritional value of other materials. These are the important features of IR suspension. Infrared drying has been studied as a possible alternative for obtaining high quality fixed foods such as fruits, vegetables, and grains

The product's quality was compared to dried hot air samples. The effect of hot air interaction with IR during integrated mode (hot IR suspension) reduced processing time by approximately 48% compared to hot air drying alone, without improving product quality. High rehydration rates and low brown index values are recognized as dry mixed component mode products. Processing conditions such as velocity as well as air temperature affect the drying characteristics during the drying of the combined mode. The highest values of effective water distribution are seen in the combination of integrated modes.

IR suspension has several advantages over conventional drying systems. These benefits include short process life, energy efficiency, uniform or product temperature, high-quality end products, high process control parameters, high heat transfer coefficient, space-saving, and eco-friendly. IR temperature was identified as a promising way to get a high-quality food product, including fruits, vegetables, cereals, and more high-value products.

The Foundations of IR Heating

Wavelength Distribution and Heating Mechanism IR radiation covers the electromagnetic component spectrum, which falls within the region of visible light as well as microwaves.

When lightning strikes on the surface of food, it causes changes in electronics, rotation, and vibration in atomic regions and molecules. Changes are made electronically and here. The rotation angle corresponds to a distance of 0.2–0.7 m (ultraviolet and visible radiation) and over 1000 m (microwaves), respectively. IR radiation causes a change in the vibration state of the molecule. After the entry of food building materials, IR radiation vibrates existing molecules at a frequency of 60,000–150,000 MHz, which leads to friction between cells and rapid internal heat. In IR the rays do not need any means of diffusion. The Icon is transferred from the heating element to the surface of the product without heating the surrounding air. Fruits are healthy on a very short shelf due to high humidity (MC) (above 82%), and it is important to use a variety of conservation techniques to increase shelf life. Another way to reduce the drying time is to provide heat with IR radiation. This heating process is especially suitable for drying thin layers of material with a large area exposed to radiation. IR drying is based on the location of water to absorb IR radiation. IR rays The technology varies in length from 0.75 to 100 m, divided into IR wavelengths (0.75-2 m), intermediate IR waves (2-4 m), and longwave waves (4-100 m). Using IR heating to dry food has recently become of special interest due to the level of radiator construction. Efficiency is the ability to produce the desired result or desired product. IR heating performance is between 80% and 90%. The radiation emitted is within the minimum range as well. Drying fruits, vegetables, pasta, and fish flakes was also done in the IR dryer tunnel. Many advantages of infrared heating include uniform temperature, short processing time, high heat transfer rate, and power use, and improved product. In addition, IR drying was detected and applied to various food analyses to measure water content in food products. Benefits of Infrared Radiation The resulting heat includes high heat transfer coefficients, short process times, and low energy costs. Comparing IR suspension with the revealing suspension of the apple has shown that the time to process the process can be increased by 50% when heating is done with IR energy. Total power consumption is defined as the sum of This includes energy used in air heating, fan driving power, conveyor driving power, and the applied power of infrared heaters (Abe and Afzal, 1997; Afzal and Abe, 1998; Hebbar and Rastogi, 2001; Zhu *et al*., 2002; Baysal *et al*., 2003; Celma *et al*., 2008).

Satisfaction of the market with industry demand creates a need for the design and development of effective drying techniques to reduce energy consumption and maintain product quality. Moreover, the use of smart suspension has increased, resulting in the need for more energy-saving ways to reduce the amount of energy required. Thus, there is an urgent need to design dryers with proper energy management and high efficiency. A few factors distinguish the power management drying process from others: evaporation rate, ambient heat loss, thermal efficiency, and electricity, gas, or steam power consumption.

Convection, conduction, and radiation are the main sources of heat transfer. Several methods are used in the drying industry, such as sun drying, hot air, microwave, vacuum, and infrared radiation. Sun-drying is the most common method used for the drying of fruits and vegetables when products are distributed under direct sunlight.

It will dry the hot air easily by injecting hot air into the room and evaporating the moisture content of the object through conduction and convection. In a dry vacuum, the pressure is reduced and thus the boiling point of the water becomes lower, i.e., below 100 ° C. Alternatively, the equipment can be burned using very high-frequency electric waves in microwave dryers.

By exposing objects to infrared radiation, heat-generated energy can access food items. Infrared radiation has gained popularity because of its high thermal efficiency and rapid reaction time and drying rate compared to normal heat. Infrared radiation has been widely used in recent years in contrast to thermal processing systems in the food industry such as pasteurization, drying, and frying.

Infrared Dryer

Infrared drying has become very popular in recent years because of its benefits, such as its low drying time, the optimal quality of the final dried product, and large energy savings, in addition to its cheap price, compared to the microwave and vacuum suspension methods. If infrared (IR) radiation is used to dry or heat something, it is absorbed by solids in its upper layer. Even so, radiation penetrates to some depth in wet, hollow objects; their transmission capacity is determined by humidity content.

The efficiency of infrared dryers is directly related to the absorption factors of content, which determines the economic feasibility of drought. Infrared dehydration is a form of dehydration. This means that energy saving with an IR dryer is more than just a flexible dryer and more methods. Considering the distance between the heat source and the material, the airflow speed and temperature, and material sheet speed (if IR is a continuous dryer), can have a significant impact on energy efficiency. (Cassano *et al*., 2006; Salehi *et al*., 2016a).

Objective 2

- **To study the effect of drying techniques on functional and sensory parameters of fruits**

Deterioration of food structure due to moisture removal from food products causes significant changes in sewing This causes a decrease and a change in the porosity of the dried fruit products. Characteristic features such as stiffness, cracking, stiffness, chewing, stiffness, cohesiveness and firmness can be determined by the analysis of the texture profile. Apple slices dried in two compounds, microwave vacuum (MWVD) and freeze-drying (FD) methods, were analyzed for texture. They reported that the brightness of the FD + MWVD samples was higher than the MWVD + FD samples and the hardness of the FD + MWVD samples was lower than the MWVD + FD samples. Frozen apples showed a softer texture compared to drying air in their study with the effect of pulsed vacuum and ultrasound osmo-pretreatments on glass temperature changes, texture, microstructure and calcium infiltration dried apples (Fuji varieties). Learn about the drying kinetics of nopal (Opuntia ficus-indica) using three different

methods and their effect on their mechanical properties reveal that flexible drying has more complexity than samples treated only by osmotic drying. On the other hand, samples treated with osmotic suspension became elastic. This is an indication that osmotic treatment of fruit before drying can be a possible way to preserve the mechanical properties of the fruit. It is a well-established fact that people's perceptions of the taste of many dried fruit products can be influenced by their color. Color testing can be done using destructive or non-destructive methods. Damage is performed by examining the color spectrum extracted spectrophotometric ally or by using fluid-based chromatography. Alternatively, the non-destructive method can be applied using the CIELAB color scheme (L * a * b *). It seems to be helpful in describing the deterioration of visible color once

provide useful information on quality control of various fruits and vegetables during drying such as kiwi fruit, bananas and apples.

Similarly Concerning the nutritional content, EHD drying preserves vitamins, carotenes, and antioxidants significantly better than convective air drying. From the sensory perspective, EHD drying enhances the color of dried products, as well as their general appearance. With respect to scalability, placing the fruit on a grounded mesh electrode dries the fruit much faster and more uniformly than the grounded plate electrode. Future research should be directed toward simultaneous measurements of multiple food nutrients and sensory properties during EHD drying with a grounded mesh collector. Quantifying the impact of the food loading density on drying kinetics and energy consumption of the EHD drying process should also be a future research goal. Research comparing EHD drying with commercially available drying methods such as freeze-drying, microwave drying, and infrared drying should also be carried out.

Decreased volume in biological material has been found to be a function of moisture content. noted that shrinkage occurred with respect to the amount of moisture extracted from fruit in their fruit studies during sun drying and the distribution, reduction and partial drying of litchi fruit Respectively. Heat and water loss cause stress on the structure of food cells and this leads to changes in mood and decrease in size. When moisture is removed within a solid food product network during drying, pressure imbalances are produced between the inner and outer parts of the food product, creating reduced stress leading to material loss, structural changes and sometimes product disintegration. Decreases in food products during drying can be modeled using strong or basic relationships. In empirical production, shrinkage, volume, location or thickness are the function of the moisture content or the relative humidity in most models. Empirical models are suitable for objects with very low porosity or objects with the development of the same porosity during set-up. In contrast, basic models are based on greater balance, density and porosity. Three different types of wrinkles have been reported during drying: one-size, isotropic or three-dimensional and anisotropic or arbitrary. Recently line and quadratic models developed by modeling infrared radiation combined with ring pineapple ringing in terms of shrinking. They concluded that the quadratic model was better than the line model to predict the shrinkage kinetics of all four types namely external radius, internal radius, density and volume of pineapple rings and also applies to other types of fin microwave drying when microwave energy combines with the material heat energy is generated within the product because of molecular excitation and the next crucial step is to remove the water vapour immediately. To remove water air is passed over the surface of the material hence the combined process is called “microwave convective drying”. Temperature of the air passing over the surface can be varied to reduce the drying time. Photomicrographs of watery carrots and potatoes show the height of the product structure of the composite products made from dried products. IR dried carrot was high (with 17%) carotenoid retention as a sample of dried hot air.

Number of studies show the advantage of using microwave assisted technology for drying of fruits. Drying of banana slices with microwave drying gave the good quality of products, the quality of raisins dried by the microwave drying were superior when compared to hot air dried samples on the basis of colour damage, darkness, crystallized sugar, stickiness and uniformity

It is principally in the falling rate period that microwave drying proved most beneficial. As the material absorbs the microwave energy, a temperature gradient occurs where the center temperature is greater, forcing the moisture out.

The drying curves of kiwi fruits showed that the drying of kiwi by microwave method was much faster than hot air drying to be more precise the drying time of kiwi fruit was reduced to 89% of the hot the sir drying similarly it was found that microwave drying reduced the drying time of bananas by 64.3%

However, microwave drying alone has some major drawbacks which include uneven heating, textural damage, limited product penetration of MW radiation into the product

Nervous testing is a method of accurately measuring people's responses to food with minimal side effects developed by an authorized sensor to check food quality. Many sensory attributes can be associated with the physical and chemical characteristics of a food product. reported that low drying temperatures produced dried banana products that were more widely accepted in their research on the effect of drying on the quality of dried bananas. Sensitive analysis of star fruit showed that star fruit preceded by osmotic dehydration was more widely accepted by consumers in terms of appearance, texture, and taste than air dried fruit and starfruit pre-blended with a mixture of sucrose and $CaCl_2$. Air-dried star fruit has very low effects on appearance, texture, and taste. Acceptance was also higher when air drying was performed at 60 ° C rather than 70 ° C. Sensory ratios associated with metal strength, chewing, sticking, firmness, gum and viscosity. High fat diets may be easier due to fat oxidation. Oxygen at less than 1% is effective in delaying decay, hardening and other degradation processes in dry food production. Intact of processing conditions in the flavor compounds of custard apple has shown that burning the pulp at 55 and 85℃, often produces a growing flavor.

spectrum, compounds are above 85℃. At 55℃, significant increases in the levels of α-pinene, β-pinene, linalool, germacrene and spathulenol were observed; high concentrations of cineole, limonene, α-cubebene and α-copaene, caryophyllene, α-farnecene and δcadenene were formed, while these substances were not entirely present in the new pulp. Significant increases in the levels of α-pinene, β-pinene, 1, 8-cineole, limonene, aromadendrene, α-farnecene, γcadenene, δ-cadinene and spathulenol were obtained by pulp burning at 85℃. Sprinkle dried samples, showing a note of extra flavor with the use of whole milk powder compared to skim milk powder. This is an indication that the drying of the fruit at low temperatures can have a beneficial effect on the fruit in terms of taste.

Pulsed Electric Field (PEF) chamber and exposed to various electric field strengths. The samples were immediately weighed and placed in the osmotic dehydration solution. The OD treatment periods were 0, 10, 20, 30, 60, and 120 minutes, based on previous results. Final determinations for fresh, treated, and reposed samples included mass, volume, brix, water activity, and moisture. In comparison to samples that were not pre-treated, the use of pulsed electric fields as a pre-treatment of osmotic dehydration in kiwifruit increased water mass transfer and reduced final sugar content. In osmotic therapy, the water phenomenological coefficient rises in proportion to the electric fields used in the pre-treatment. Because the administration of an electric field prior to osmotic therapy removes electrolytes, reduces Ca^{2+} pump activity, and leaves aquaporin's as the principal protein channel for water transmembrane transport alone, the normal functionality of the cell homeostasis system is harmed. However, because the sucrose transmembrane transport is carried out by the Na^+ pump, the sucrose phenomenological coefficient decreases with the applied electric field in osmotic therapy. As a result, any drop in the overall quantity of electrolytes reduces the sucrose content.

For osmotic dehydration of banana slices, it is recommended that the pH of the sucrose solution be controlled. Controlling the pH of a sucrose solution has also been demonstrated to impact the rate of osmotic dehydration in apples and carrots. To prevent the browning of fruit pieces during the osmotic process, ascorbic acid is added to the sugar solution. Lactose can be used to partially replace sucrose. Osmoactive drug mixtures are also employed. A 1:1 ratio of sucrose and starch syrup. In dry matter, dehydrated apples in a solution comprising 42 percent fructose, 52 percent sucrose, 3% maltose, 3% polysaccharides, and 0.5 percent sodium chloride. Sucrose and fructose in various quantities are combined in this solution. Water loss was similar across all solutions studied, although osmoactive drug penetration varied. Pasteurization worked best with peaches that had been dried in glucose and fructose solutions. Apple slices dried quickly after being soaked in a solution of sucrose and glucose. Guava's water activity was reduced to 0.77 by combining crystalline sucrose and glucose, whereas sucrose alone had a water activity of 0.80. Osmotic dehydration of peas and papaya was achieved using a sucrose and citrate mixture.

The effect of ultrasounds followed by vacuum drying was studied on parameters like drying kinetics, quality assessment which included retention of vitamin c and beta-carotene, color of the dried carrot slices, microstructure of dried carrot slices and rehydration properties and following results were obtained.

The drying curves (time vs MR) of the carrot slices with USV and vacuum drying techniques were plotted and it was observed that the drying time required for complete dehydration of the sample was shortest when USV drying technique was applied at 75 ℃which is 2.4 times faster than vacuum drying techniques alone. Energy consumption is another important consideration while choosing the drying technique and energy consumed is directly proportional to the time consumed and as discussed earlier that USV at 75 ℃ takes the shortest time thus it is the most energy efficient technique. Moving to quality assessment the

pectin-honey (PH) based coating as an innovative eco sustainable method for dehydrating selected kinds of cut fruits and contemporary preserving their safety and quality by exploiting the antimicrobial activity of honey. The dehydration process was carried out at low temperature; in this way, the nutritional and sensorial properties of dried fruit, not treated with sugar and/or chemical additives, could be maintained by providing a final high quality food. The effects of PH coating on fruit water content (dehydration process), total polyphenols and vitamin C amount, antioxidant activity, volatile molecules profile, microbiological quality and fruit surface adhesion were investigated. Results of the above investigations are as follows:

In the fruit dehydration process. It was observed that the presence of coating induced a higher dehydration percentage in all tested samples. Generally, the coated samples showed a greater water loss than the untreated sample. Moreover, the polyphenol concentration, antioxidant activity and vitamin C content were particularly heightened in coated samples, pointing out the pectin-honey coating protection. The analysis of volatile compounds highlighted a general improvement of volatile compounds and sensorial flavors in all coated fruit samples, except for terpenoids. The innovative dehydration process allowed us to obtain 18 coated fruits with an improved microbipolar. Drying has become very popular in food and non-food drying in recent years because of its benefits such as low drying time, acceptable quality of dry end product and energy saving power. IR rays are usually absorbed by solid solids in their surface in contrast to microwaves that penetrate deep into the material causing the volume of heat.

The efficiency of IR drying power is directly related to the absorption factors that determine the economic and technological potential of drought. Several researchers have studied the drying kinetics and quality features of various food products using IR radiation and complete reviews can be found in the literature. It was investigated for rehydration; various drying methods such as HAD, intermediate IR drying (IID) and vacuum microwave spouted-bed drying (VMSD) are used. Set-up time and product quality not found acceptable in HAD and VMSD as compared for those on IID. Recently, the effects of four drying methods, namely. HAD, hot air-assisted radiofrequency drying, IR drying and hot air drying assisted by microwave color, microstructure, density, rehydration capacity and texture after fruit rehydration. The results showed that the drying time required for stemmed servants using IR drying was only 50% (180 min) of the required hot air drying (360 min).

A combination of IR and microwave radiation was developed to study the drying properties of solid rice. It has been suggested that microwave radiation should be used in the first stage of suspension, when the sample has high humidity.

This is because microwaves are capable of heating the entire volume of the sample and the IR radiation can easily accelerate the evaporation of moisture further. The same combination of IR and vacuum microwave dryer is made to dry raspberries. Microwave power and vacuum pressure have been found to have an important effect on the quality parameters of raspberry products, such as color, dehydration, anthocyanin storage, and antioxidant activity. An increase in microwave capacity was found to increase the moisture separation.

Objective 3

- **To study the effect of various drying techniques on quality parameters of food**

The quality of dried fruits depends on the drying method used and the drying conditions (such as temperature, pressure, and drying times). From a consumer point of view, good quality was defined as high nutritional value, rapid dehydration, low bulk density, minimal wrinkles, and attractive color.

Many biochemical reactions can be caused by an increase in food temperature Maillard reaction, vitamin depletion, fat oxidation, thermal depletion unstable proteins (leading to fluctuations in melting or germination capacity grains, for example), enzyme reactions (which may be stimulated or inhibited), and so on. Some of these biochemical reactions produce the right components, for example, due to their sensory properties (flavor enhancement); others may be more or less undesirable for reasons of nutritious or potentially toxic foods (vitamin loss, mutations by color, taste or smell, formation of toxic compounds). All reactions are connected to simultaneous emergence of product composition, temperature and water content (or chemical energy, or water function), these factors vary from one individual to another point to another, from the center to the top of the products.

Vitamin C (ascorbic acid) is an essential nutrient, and is often regarded as an indicator of the quality of the process components. Ascorbic acid can be oxidized into dehydroascorbic acid under aerobic conditions, followed by hydrolysis and additional oxidation. This deterioration is influenced by water performance and temperature. Generally, vitamin C storage after drying is low, even if the content is very high (in g /kg of product) can be reported with dry products, due to evaporation of water and the result of torture. As a general rule, long drying time (low temperatures, high relative humidity, thick products), reduces the retention of ascorbic acid.

Drying provides high retention of vitamin C, as a result of low temperatures, reduced flow of reactants, and reduced O2 component pressure. Vitamin C retention is also enhanced by all the drying processes under inert air, which reduces the presence of O2.

Color is one of the most important attributes in the quality of dried food, because it is part of their physical appearance and, therefore, most of the time one of the first methods that consumers consider when choosing a new product. The color may change during drying due to chemical and biochemical reactions. Prices of such reactions are highly dependent on drying and processing methods. The color of the fruit, vegetables, aromatic plants and spices is due

The presence of pigment (carotenoids, chlorophyll, anthocyanin, betalains) is at risk of damage due to enzymatic or non-enzymatic reactions, resulting in drying and persistence at the end time.

Chlorophyll green pigment-soluble pigments have a tendency to degrade food systems that are often misunderstood. Chlorophyll can become unpleasant brown compounds such as pheophorbide or pheophytin. Pheophorbide can be digested into colorless compounds in active metabolic tissues. Pheophytin formation is caused by heat and He ions. The first step to Deterioration of chlorophyll in digested foods is a disorder of the tissues, leading to chemical, enzymatic, and perhaps even genetic mutations products of chlorophyll catabolism.

The sensory qualities of taste, fragrance, colour, and acceptability were used to assess the organoleptic quality of fresh and dried fruits. The desirable organoleptic characteristics of dried fruit products differed considerably between solar drying processes. Both mangoes and pineapples had identical ratings. For mangoes and pineapples, the average rank of acceptable organoleptic qualities varied from 4 (somewhat disliked) to 9. (like extremely). The dried pineapple slices scored higher on organoleptic qualities than the fresh slices, with the items dried using the CSD and ISD procedures receiving the highest acceptance scores. Mango goods dried using the CSD and ISD procedures had higher average scores for flavour, fragrance, and colour than those dried using the OSD, WCS, and BCS methods. Despite the fact that the component organoleptic characteristics were good, the overall acceptability of the fresh mango slices was lower than that of the solar dried slices. The organoleptic qualities were highest in the mango and pineapple products dried using the ISD technique, implying that the fruit products dried using the ISD drier had better acceptance.

The amount of moisture dehydrated from both the mangoes and pineapples samples, as well as the concentration of the dry matter content, carbs, and total sugars, increased considerably (p 0.05) in the dried products, regardless of the drying technique. The rise in dry matter content, carbs, and total sugars concentrations was more evident in fruits dried using enhanced solar drying (CSD and ISD) methods than in fruits dried using classic solar drying methods. The fruits dried using the OSD, WCS, and BCS procedures, on the other hand, lost considerably more total acidity and phenols (p 0.05) than the CSD and ISD methods. Furthermore, there was no significant ($p > 0.05$) difference in the concentration of the proximate component of mango and pineapple samples dried using the OSD, WCS, and BCS techniques.

All of the proximate composition parameters for mangoes and pineapples dried using the ISD method were significantly (p 0.05) higher than those for mangoes and pineapples dried using the CSD method, implying that the ISD has an improved and superior capacity for retaining proximate content in dried fruit (mango and pineapple) products. The dried mango and pineapple samples were dried using all five solar drying processes. The mineral benefits from the OSD, WCS, and BCS techniques were not significantly different. Fruit samples dried using the CSD and ISD dryers had higher mineral content than those dried using the OSD, WCS, and BCS techniques. The relative increase in mineral content was significantly higher (p 0.05) in the fruits dried using the ISD method than the CSD method, indicating that the proposed ISD dryer has a greater capacity for retaining mineral composition during the drying process, resulting in a significant (p 0.05) increase in macro- and micro mineral content. Except for the ISD, all of the solar drying procedures resulted in substantial (p 0.05) declines in the vitamin content of the dried mango and pineapple products. The losses were lower in fruits dried using enhanced solar drying methods (CSD and ISD) than in fruits prepared using classic solar drying methods. Between the OSD, WCS, and BCS techniques, there was no significant difference in vitamin content drop ($p > 0.05$). However, vitamin loss was lower in fruits dried using the ISD technique than in fruits dried using the CSD method, suggesting that the ISD drier is better at keeping volatile vitamins.

The effects of ultrasonic assisted osmotic dehydration followed by traditional drying on a variety of fruits. The fruits were chopped into various little forms such as cubes, cylinders, and triangles, and their initial moisture content and total solids were determined. The samples were immersed in an osmotic solution made from food-grade sugar and distilled water with a Brix range of 25 to 70. By immersing the samples in an ultrasonic bath for 10 to 45 minutes, ultrasonic waves were passed through them. The ultrasonic waves had a frequency of 25 kHz and a power density of 4000 W/m2. The dehydrated samples were drained and transported to a forced circulating air-drying oven after pre-treatment. Air-drying was done at 60°C. The use of ultrasound-assisted osmotic dehydration resulted in more water loss and sugar gain. The impact of ultrasound-assisted osmotic dehydration on the kidneys was shown to be significant. It was concluded that the effect of the ultrasound assisted osmotic dehydration on the effective water diffusivity depended on the degree of breakdown of cells in the fruit tissue.

Investigated the effect of osmotic dehydration on apricot freeze drying. 10 mm chunks of fresh apricots were cut. To inhibit enzymatic browning reactions, samples were blanched with steam at 100°C for 3 minutes. Date solution and sucrose solution at 30 and 50 percent (w/w) concentrations were employed as osmotic solutions. Osmotic dehydration was performed at 25°C for 2 hours with a 50 tour/minute rotation. Finally, the sample was freeze dried by freezing it at -30°C for 24 hours and then drying it. The freeze-drying kinetics of apricots were shown to be modified by the solution type and concentration of the osmotic pre-treatment. At a low concentration (30 percent w/w), date solution outperformed sucrose solution, while at a high concentration (50 percent w/w), date solution outperformed sucrose solution. The quickest drying time and best freeze-drying kinetics were obtained by osmotic dehydration in date solution (30 percent w/w). The quality of apricots was determined using vitamin C and total sugars parameters. Vitamin C loss was limited to 21%, with 14% occurring during osmotic dehydration and 7% occurring during freeze drying. Because the procedure was placed at a moderate temperature, freeze drying caused less damage to vitamin C. Osmotic dehydration increased the sugar content of apricot samples by 57 percent. Because of the high concentration of soluble in apricots, freeze drying increased total sugars by 8%.

Conclusion

The power of Novel technologies for drying and storing food has gained increasing interest in industry and has the potential to change, at least in part, sustainable conservation measures, as the industry seeks to be more environmentally and economically viable. This paper identifies a technical team that has demonstrated significant potential in food research and development. Most importantly, this paper introduces new technologies that allow for the development of food products while maintaining food quality. Such knowledge is needed by the food industry to make informed decisions about the most suitable drying technology in certain fields. However, microwave drying and vacuum drying are some of the drying methods that have gained popularity in recent years and provide greater consistency between energy consumption and product quality. A sudden controlled decay in the vacuum seems to be one of the most exciting novels to launch on an industrial scale. Hybrid drying (a combination of different drying methods) contributes to the dehydration process by reducing drying time, increasing energy efficiency or improving product quality. Between conventional milling technology and micronization, cryogenic milling appears to be advanced in color, flexibility and flavor retention, minimum particle size distribution, and energy consumption. Controlling some of key (external) processing parameters such as temperature, pressure, wind speed, electric field strength, etc., allow for high power efficiency, and the quality of the best products in the drying processes. Osmotic dehydration can successfully reduce the weight of a substance by half, but it still needs a post drying treatment for the best results. It is expected that the osmo-air drying technique has good potential for fruits as it saves energy and improves quality. This approach could be utilised on a small scale to help create self-employed people and small businesses. Exhibitions and the media could help to popularize the consumption of such nutritious and valuable items. Much research has been done on osmotic dehydration over the last three decades, and it has been discovered that it is one of the finest methods for preservation because it does not destroy many nutritional characteristics, colour, flavour, or texture. On the other hand, this method is too cost-effective, and because no preservatives were used, it has no negative effects on the human body.

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