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A study on the dehydration of vegetables using novel drying techniques

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Abstract
The drying of foods is vastly vital technique for the food business and offers potential for ingredient development and novel merchandise to customers. In recent years, there are several advances in technology related to the economic drying of food as well as pre-treatments, techniques, instrumentation and quality. Recent analysis has disclosed that novel drying approaches like microwave or ultrasound-assisted drying, high field of force drying, setup drying and refractance window drying is currently taken to enhance the potency and affectivity of drying so energy consumption is reduced while at an equivalent time conserving the standard of the tip product. Novel drying techniques have introduced and are being presently employed in food business as a result of its some benefits such as-shorter drying time, operational safety, and higher quality of merchandise, non- polluting, higher management method, and a lot of economic. However, while analysis has showed these technologies to achieve success, industrial practitioners don't typically recognize what techniques have the best potential in business. The event of foods dried victimization novel techniques introduces totally different challenges: the buyer perception, the approval of the novel technology and also the retention of the physical, sensory and nutritionally quality of foods. The present work highlights recent developments of valuable novel drying techniques to market property within the food business and points towards. The potential of novel technologies for drying and food preservation has gained enlarged industrial interest and has the potential to switch, a minimum of part, the normal entrenched preservation ways, because the business seeks to become a lot of environmentally and economically property. This paper identifies a bunch of technologies that have shown important potential in food engineering analysis and development.

Keywords: Dehydration, food business, merchandise to customers

Introduction

Food drying is a method of preservation by means of removal of water (through heat and mass transfer process) basically free water which is responsible for water activity is responsible for growth and multiplication of microorganisms. Hence drying leads to extension of shelf- life of food commodities such as vegetables lowering down the water content to acceptable limit. The drying time, temperature and water activity influences the quality of the final product. The factors that affects transfer of energy for drying includes air temperature, air velocity and surface area of the food material. The important objectives that drying techniques must fulfil are: 1. preserving the fresh food commodities so that they are available whole year 2. Reducing the weight and volume of the product for easy transportation and storage 3. Preserving the nutritional and quality aspects of food commodities. 4. It should sustainable method in terms of less energy consumption; therefore novel drying techniques are being used in today’s world

The novel drying techniques have introduced and are being currently used in food industry such as microwave drying, ultrasonic drying, infrared drying, osmotic drying , pulsed electric field drying and these techniques are also being used in combination because as these have advantages such as- shorter drying time, operational safety, better quality of products, non-polluting, better control process, more economic. This review paper basically describes the single and combined novel drying techniques that were being used by different researchers for drying of vegetables.

Novel drying techniques are the new drying methods introduced by researchers to solve the problems associated with conventional drying methods like sun drying, hot air drying and oven drying that reduces the quality attributes like textural change, nutrient loss, browning of the dried food product etc. with increased time and energy consumption. In this review paper several novel drying have been described for drying of vegetables such as:

Pulsed electric field (PEF) drying: Pulsed electric field (PEF) is one of the a novel technique which has the ability to permeabilize the cells of the fruit and vegetable tissues without increase of the temperature of the product and also avoids excessive deterioration of the tissue. Pulsed electric fields is basically a non-thermal technology which has several applications in food processing. During PEF treatments, food tissues are exposed to an external electrical field for microseconds, which induces local structural changes and causes the breakdown of cell membranes.

Infrared drying: Infrared drying (IR drying) is one of the promising drying method for food products. The infrared radiation is used to dry food products with high moisture, the energy gets penetrated into the materials to a small depth and then is converted to heat. Application of IR heating is gaining popularity in food processing because of its definite advantages over conventional heating. Faster and efficient heat transfer, lower processing cost, uniform product heating and better organoleptic and nutritional value of processed material are some of the important features of IR drying.

Osmotic dehydration: Osmotic dehydration process is done by immersing of solid food, whole or in pieces, in aqueous hypertonic solution of high osmotic pressure which leads to loss of water through the cell membranes of the product and then it flows along with the inter-cellular space before diffusing into the solution. Osmotic dehydration is affected by severe factors they are raw materials, pre-treatments, nature, temperature, and concentration of osmotic solution, agitation, immersion time, and raw material to osmotic solution ratio.

Electro hydrodynamic (EDH) drying: This method of drying is a new method of drying which is non thermal in nature. In this method electric wind also known as corona wind is generated by gaseous ions under the influence of high voltage electric field. The corona discharge is brought by means of ionization of a fluid like air which is surrounding the conductor that is electrically charged.

Microwave hydro-diffusion gravity method: This method is the combination of microwaves for hydro-diffusion of water from the interior to the exterior of the vegetables and earth's gravity is used to collect and separate it. This technique is performed at atmospheric pressure without the addition of any solvent or water. It is rapid, powerful and green technology.

Ultrasonic assisted vacuum drying: This is most commonly used combined drying technique because ultrasonic assisted drying increases the rate of drying and causes the minimum change in quality aspects and vacuum drying is being used to sensitive food products whereby creating a vacuum to decrease the chamber pressure below the vapour pressure of water making it to boil which results in increased drying rate of the food commodities.

Freeze drying with infra-red drying: freeze drying method is widely used to get high quality of dried vegetables. This is because the solid state of water, transport of moisture during the freeze drying is by sublimation and low temperature basically protects the primary structure and shape of the vegetables and as the result vegetables have low bulk density, high porosity and better rehydration properties. But using freeze drying alone has limitations in producing high value products such as- slow process, low throughput, high energy consumption and need expensive equipment. So it was combined with infrared which in return gave shorter drying time, high energy efficiency and better quality of product.

These all were the novel techniques used by different researchers and have been described in this review paper, other that these described novel techniques, there are also several novel techniques such as superheated steam drying, high electric field drying, heat pump drying, electromagnetic drying, radio-frequency drying, refractance window drying and explosion puffing drying.

All these novel drying methods have one or more than one advantages that make them more suitable for the use. Thus using these novel drying methods can somewhere contributes to the environment by reducing the energy consumption, contributes towards reducing the hunger by make the vegetables either seasonal available all around the year and also towards the economic as these methods are economic by nature

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Objective 1

To study the novel advanced drying techniques used for the utilization of vegetables

1. Pulse electric field: Foods are dried and dehydrated to increase their self-life, storage and lesser processing requirements and enhance transportability. Preservation techniques are mostly based on drying through heat by sunlight causes quality degradation and product contamination. In the case of drying process the basic thing is amount of energy and the nature of items. An ideal drying system has processes of drying of vegetables which has mass transfer processes consisting removal of water by Evaporation. To reduce the energy required and cost of operation which basically measure the drying processes? The time and temperature which can affect the cell permeability and the drying rate is the strength of pulse electric field used. The utilization of pulse electric field as a pre-treatment with temperature during dehydration which increases the mass transfer of product. It has not been studied that the effect of electric field strength, pulse number and temperature on cell disintegration affects the quality of product and drying time. Pulsed electric field helps in dehydration uses less energy intensive as compared to dehydration. Study the effect of pulsed electric field strength, time of treatment in the form of number of pulses and temperature during treatment of vegetables and to change these variables on the basis of energy input, cell disintegration and drying time.

Pulse electric field has been proposed for enhancing or assisting different processing operations, like solid–liquid extraction (e.g., extraction of ingredients, winemaking, sucrose extraction, garbage and by-product revalorization), mechanical extraction (e.g., juice expression, mechanical oil extraction), cutting/slicing (e.g., potato snack production), dehydration (e.g., hot air drying, osmotic dehydration, freeze-drying), freezing, or peeling. Benefits of PEF are often summarized in improve process yield, increase process velocity, improve food quality (e.g., reduce fat uptake, reduce impact on sensory properties, increase health-related compounds), decrease the intensity of other processing variables (e.g., temperature, grinding degree), increase the cost efficiency of the operation (e.g., reduce energy consumption). Moisture removal from food materials is an integral part of food processing. Production of dehydrated foods within the food industry is usually accomplished by thermal dehydration or hot drying. The continuous efforts of the food processing industry for producing dehydrated foods have been centered around enhancing drying rate, reducing energy consumption and minimizing thermal degradation of food constituents. Increased in mass transfer rates which affects drying medium temperature would result in faster drying of food as having high energy cost and thermal degradation might be changed. The increase of the dehydrated foods market demands operating top quality processes due to the warmth sensitivity of valuable components of those products. Ohmic, microwave and traditional thermal heating as pre-treatment methods during dehydration of vegetables are reported to scale back drying times but this involved performing at relatively elevated temperatures which might lead to thermal degradation of nutrients. The particular processes that facilitate mass transfer of foods without adversely affecting quality could be better alternatives to enhancing drying rates and to save lots of energy than adjusting the method parameters of conventional thermal treatments. Osmotic dehydration (OD) may be a process which partially removes water from food materials through soaking in suitable hypertonic solution.

Pulse electric fields (PEFs) have surfaced as non-thermal technology with several implicit operations in food processing. During PEF treatments, food is subordinated to an external electrical field for a many food, which induces original structural changes and ultimately causes the breakdown of cell membranes. Grounded on this process, called electro-permeabilization, PEFs can be exploited for different pretensions, e.g. the inactivation of microorganisms and quality- related enzymes and the enhancement of both bibulous dehumidification processes and birth of intracellular metabolites. In addition, the use of PEF treatments has been lately proposed to induce stress responses in metabolically active shops at the cellular position. These stress responses are allowed to spark a wide range of metabolic pathways that lead to the accumulation of secondary metabolites involved in the response of shops under both biotic and abiotic stress conditions. In a former study, proposed the operation of PEF treatments to increase the quantum of carotenoids in tomato fruit as well as in tomato authorities attained from PEF-treated fruit. The effect of PEF processing on the bio-accessibility of carotenoids in deduced products has been studied. PEF treatments should be applied to tomatoes in a pre-processing treatment to get a functional-product with increased antioxidant potential. The maximum concentration of total and individual carotenoids was found within the derived product obtained from tomatoes subjected to 30 pulses at 2 kV cm−1; The concentration and bio-accessible fraction of carotenoids in that of tomato-based product can be processed for selected PEF conditions in order to enhance its health-related properties of tomatoes. It is necessary to evaluate the basics effect of these particular products on human health. Statistical analysis displays the amount of individual carotenoid found in the micellar fraction of the digested tomato product was influenced ($p < 0.0001$) by the electric field strength applied to whole tomatoes. The quantity of pulses formed to exert a effect on the amount of carotenoids released from the matrix of tomatoes. The maximum increase of the total carotenoid bio-accessibility was derived product obtained from the tomatoes which treated with the 5 pulses at 2-3 kV cm−1(0.38 kJ kg−1).

2. Infrared drying

Infrared drying (IR drying) is considered as a promising drying method for meals products. When infrared radiation is used to dry meals merchandise of excessive moisture, the power is penetrated into the substances to a small depth and then is converted to heat.

Vegetable used: Carrot and garlic

- The effect of IR rays on the great of carrot and garlic were studied and pleasant can be evaluated by means of instrumental and sensory analysis.
- Carrot samples were saved over night at 4'C and garlic samples have been stored at ambient temperature 20'C before processing.
- The carrot had been robotically peeled, washed and sliced into 3mm thick pieces. The sliced samples had been than blanched at 98'C for 3 min. After draining the carrot samples were divided into three batches and dehydrated by way of using infrared into three batches and dehydrated via using infrared method. The garlic samples have been peeled, sliced into 3mm pieces and dehydrated by using microwave infrared.

Drying price is described as the quantity of water eliminated per unit place and time. Infrared drying at once elevated the temperature of the samples except heating the air.

During dehydration the colour of food changes however it was observed that the colour of drilled carrot resembled the sparkling product the most after air drying whereas its rehydration ability was once the lowest infrared dehydrated carrot had the fine rehydration capacity.

Warmness air assisted infrared is drying of potato and carrot is carried out and product extraordinarily terrific is in difference with warm air dried samples the synergistic have an effect on of heat air and is in the route of blended mode hot air assisted ir drying decreased the processing time with the resource of almost forty eight as in distinction to warm air drying on my very private barring bettering the gorgeous of merchandise larger rehydration ratio and lower browning index values are determined for mixed mode dried merchandise photomicrographs of dehydrated carrot and potato set up superiority of product shape for combined mode dried merchandise the ir dried carrot had greater with the beneficial resource of 17 retention of carotenoid than warm air dried sample the processing stipulations such as tempo and temperature of air affected the drying characteristics in the route of blended mode drying accelerated values of exquisite diffusivity of water are located with blended mode drying drying of meals merchandise is one of the most not unusual strategies used to adorn the stability as it decreases the water activity of product in flip reduces microbiological task and minimizes bodily and chemical adjustments at some stage in storage mayor and sereno 2004. warm air drying is the most many instances employed industrial method for drying of ingredients belongings then again low electrical energy effectivity longer drying time and horrible product extraordinarily exceptional are some of the drawbacks of warmth air drying improved cutting-edge drying techniques that have been tried for drying are scenario assisted techniques which embody dielectric heating radio frequency and microwave electromagnetic heating infrared inductive heating ohmic heating and heating in the presence of exterior fields such as pulsed electric powered hassle ultrasound and uv slight even as the software program application of microwave for materials dehydration is hooked up to some extent use of fantastic methods such as infrared and radiofrequency drying has received momentum entirely in the recent preceding.

Application of ir heating is gaining reputation in ingredients processing because of its actual advantages over normal heating quicker and efficient heat switch decrease processing price uniform product heating and higher organoleptic and dietary cost of processed cloth are some of the necessary components of ir drying (Sandhu 1986) infrared drying has been investigated as a potential method for acquiring high superb dried foods stuffs which encompass fruits greens and grains (abe and afzal 1997) (afzal and abe 1998) (hebbar and rastogi 2001 zhu *et al* 2002) (baysal *et al* 2003 celma *et al* 2008) fee curve the drying of carrot slices and potato slabs were persisted until the moisture content reached the favored diploma of 7-8 wb the time required for drying every the vegetables beneath extraordinary modes is in table 1 the reduction in drying time used to be nearly 48 and 17 with combination mode and IR drying respectively as in contrast to hot air drying the top notch reduction in drying time with combination mode ought to be attributed to the synergistic have an impact on of IR and warm air the fast diffusion of moisture to the floor of cloth due to IR heating and simultaneous elimination of moisture from the floor with the aid of compelled convection resulted in a faster drying method the higher drying time in ir mode may also desire to be attributed to natural convective waft of air which is slower than that in contrast to pressured convection in blended mode drying the moisture content material cloth values bought at one of a kind intervals of drying time had been used for the estimation of drying

Osmotic dehydration

For preserving of vegetables there are lots of preserving methods used. The main focus of vegetable processing is to supply safe, nutritious, and acceptable the vegetables throughout the year for this we have to preserve the vegetable by using different preservation method. Nowadays Osmotic dehydration is one of the best novel techniques of food preservation. This process is done by immersing of solid vegetables, whole or in pieces, in aqueous hypertonic solution of high osmotic pressure. Osmotic dehydration is affected by severe factors they are raw materials, pre-treatments, nature, temperature, and concentration of osmotic solution, agitation, immersion time, and raw material to osmotic solution ratio. From the research paper they suggested the sample size of vegetables should be 3 mm to a maximum of 10 mm in rectangle, ring or cube shape in osmotic dehydration process (Akbarian *et al*. 2014). This dehydration technique provides minimum thermal degradation of nutrients due to low temperature water removal process. It has some benefits such as reducing the damage of heat to the flavor of vegetables, color of vegetables, it also inhibiting the browning of enzymes and decreases the energy costs these are the main advantages of osmotic dehydration. Some factors affecting mass transfer during osmotic dehydration these are depending on types of osmotic agent which we used, also depends on concentrations of osmotic agent, processing temperatures, agitation process and pre-treatment methods. Pre-treatment methods are those methods which use before the osmotic dehydration of any vegetables. Osmotic agent tends to easier penetrate the edible coating, low molecular weight of food products than high molecular weight food products (Akbarian *et al*). The increase in the processing temperature provides easier the mass transfer process during osmotic dehydration. In the research paper I also found that the agitation process had a significant effect on the increase in water loss during osmotic dehydration (Akbarian *et al*. 2014).

Osmotic dehydration (OD) is a novel technique in this technique vegetables immerse in a hypertonic aqueous solution which is called osmotic agent, leading to loss of water through the cell membranes of the vegetables and subsequent flow along the inter-cellular space before diffusing into the solution. The removal of water out of the tissue, it is completed by a counter-current diffusion of the osmotic agent from the solution toward the vegetable tissue. The researcher found that these two simultaneous transports bring about depressing effect on the water activity (aw) of the samples (Lee *et al*. 2011) [5]. When some researcher researched on pumpkin slice then they found that the solution temperature and sucrose concentration were the most pronounced factors affecting sucrose gain and water loss of pumpkin slice during osmotic dehydration followed by immersion time. Researcher obtained that osmotic dehydration in which they used sucrose solution it was able to improve the quality of hot air drying of pumpkin slice in term of the color of product, shrinkage, texture, aroma as well as sensory acceptability of the product. (Lee *et al*. 2011) [5].

Electro hydrodynamic (EDH) drying

This research has been done by Changjiang Ding Jun Lu and Zhiqing Song. Carrots are among those vegetables that are consumed raw and in cooked form. They are rich in carotene, vitamins, minerals and fibre. But due high moisture content, improper storage and handling their shelf life is reduced along with nutritional quality so researchers have come up with new novel technique that is electro-hydrodynamic drying. This method of drying was a new method of drying which is non thermal in nature. Researchers have found that this method has higher drying rates, less energy consumption and provides superior quality of product as in physiochemical properties-colour, flavour, nutrient content and shrinkage. They also did the mathematical modelling and stimulation of drying curves by using the root mean square error, reduced mean square of the deviation and modelling efficiency which they have opted as primary criteria for selecting the equation that is suitable to tell the variation in the in the drying curves. They have opted for page model which was theoretically suitable for describing the drying rate curve when carrot slices were at 10kV to 30Kv. In this technique they have used 50Hz of electric field, vertically mounted electrodes along with multiple sharp pointed needles which are projected onto a fixed horizontal grounded metallic plate onto which samples were dried, needles were 20 mm long and 1mm wide. In order to set higher voltage for EDH method, power was connected to voltage regulator along with adjustable voltage range of 0-50 kV for A.C current. The drying temperature selected by researchers was 21 plus minus 2 degree Celsius with drying relative humidity of 30 plus minus 5% and ambient speed was 0m/s. They have found experimentally that drying rate for carrots was greater in the EDH and also found that quality, carotene content was improved. They also found that the drying rate of EDH drying increases with the increase in voltage. Thus this method is suitable for giving better quality products.

Combined Drying Techniques

1. Effects of pulsed electric fields and preliminary vacuum drying on freezing assisted process in potato tissue:

The different drying techniques related to pulsed field treatment and preliminary vacuum drying with freezing is extremely much similar for the potato tissue. The pulse electric field treatment is done at the 220 V/cm using the system to protect the high level of potato dis-integration. The VD was done at pressure of $p = 0.30$ bar. Impacts of PEF and VD on freeze-thawing and freeze-drying processes were tested. During the freezing and thawing increased with increasing of the moisture ratio level. The PEF treatment also taken at the FD and changes the final level of dehydration after prolonged FD for 48h. This introduced that application of different drying and VD combined with FT affects the rehydration and VD combined with FD support the rehydration of dried potato tissue. The obtained rules can be useful for future practical implementations of freezing assisted processes with fine control of deterioration of product quality and reduces the operating costs.

PEF treatment of fruit and vegetable mashes, such as those obtained from apples, grapes, or carrots, increases juice yield and enhances release of valuable compounds such as colours or antioxidants. The use of continuous liquid-solid-separation techniques a quality juices are more often produced at very high yield without the availability of enzymes. Treatment of different vegetables with PEF help in lowering the heat and energy required for sugar production. Different vegetables are full of anthocyanins and bioactive substances that has been reported through the utilization of Pulse electric field. Similar results are found for other plant tissues, like red beet, broccoli, or kale. Lesser the energy used in this technique and having less processing times makes the PEF more viable relate to the normal processes of mechanical grinding and drying, hot-break, and enzyme maceration. Pulse electric field of membrane permeabilization increase with the loss of pressure and have significant tissue softening which result in handling, pumping, and cutting processes. PEF treatment of vegetables with an energy input of 2-3 kJ/kg can improved the cutting causing less in deterioration and softer cut surfaces. PEF is currently wont to replace conventional preheating of potatoes (60°C, 30 min) and improve cut quality for industrial production of french-fried potatoes. The PEF industry for the potato processing is having a capacity of up to 70 t/hr. The reduce in the energy, water requirement and time can increase the release of sugar and help in reduced fat uptake for the major benefits.

PEF can enhance peeling of fruits and vegetables. In contrast with the steam peeling, the lower energy is requirements for peeling significantly. In relate to peeling, no pollution of effluents is reduced even no neutralization required.

2. Vacuum pre-treatment coupled to ultrasound assisted osmotic dehydration as a novel method for garlic slices dehydration

Garlic (Allium sativum L.) is assessed as a semi-perishable spicy herb and is employed worldwide as a seasoning, spice and flavoring remedy. Garlic contains distinctive organosulfur compounds, which give its characteristic flavor and odor and most of its potent biological activity. In recent years, some pretreatments are created to shorten the drying amount and to boost the energy potency of the drying method and quality of the dried product. Diffusion dehydration (OD) has received substantial attention in recent years because it is one in all the only and cheap pre-drying treatments of foodstuffs. It's been according to scale back the energy consumption, improve product quality, and speed up the drying time. A stimulating choice is that the use of ultrasound technology with the OD method due to its lower energy consumption and lower temperature application that would cut back degradation of food quality. Ultrasound technology could be an inexperienced approach of physical, chemical and engineering processes and consequently it's currently recognized as a viable and environmentally-benign different. Previous researches recommend that ultrasound or vacuum treatment is wont to enhance the mass transfer rate of the OD method of foodstuffs. Ultrasound technology could be an inexperienced approach of physical, chemical and engineering processes and consequently it's currently recognized as a viable and environmentally-benign different. The propagation of ultrasound through a liquid medium produces a range of effects like acoustic cavitation, sponge result, acoustic streaming or micro-streaming and microscopic channels, all of that greatly have an effect on the mass transfer. The applying of multifrequency mode ultrasound and vacuum technology throughout OD had a major result on garlic slices. The novel dehydration technique of markedly increased the mass transfer rate throughout OD of garlic slices. The vacuum and ultrasound technology combined result was attributed to the exhaustion of animate thing air and therefore the increase within the mass transfer space, formation of the microscopic pores and therefore the cell rupture. In addition, the ultrasound treatment improved the rehydration method, leading to higher rehydration rate and water retention. LF-NMR results quantified the wet migration within the cavum, living substance and animate thing area, and therefore the plasma membrane of garlic cells. Treated garlic slices had higher quality properties (allicin content, ΔE and firmness) compared with NOD, VOD and UOD treated samples. It is complete from the results that VUOD is effectively used as a completely unique dehydration technique contributory to the improved quality of the garlic finish product.

3. Microwave assisted dehydration of broccoli by-products and simultaneous extraction of bioactive compounds

The broccoli head typically utilized by frozen-food business (Brassica oleracea power unit. Parthenon), accounts just for fifty fifth of the business product. The remaining forty fifth square measure broccoli by-products comprising elements of stalks, inflorescences, and leaves. The creation of this high proportion of by-products is crosswise to different vegetable industries, manufacturing a high economic and environmental impact. Even so, such by-products represent a supply of organic process and bioactive compounds. Within the case of broccoli by-products, they're edible elements sharing a similar composition of the commercially obtainable broccoli heads. Microwave power-assisted drying uses microwave energy to heat the water gift within the material while not the requirement to heat the environment of the sample, providing energy saving. The aim of this system has been to five succeed the reduction of wet of the product by water vaporization, promoting at the same time a blanching result. Exploitation a similar principle, however avoiding water vaporization, the microwave hydro diffusion and gravity (MHG) technique permits to dry and to gather the inner water of the samples by gravity diffusion. This water, from cells distention and rupture, contains intracellular water soluble compounds that diffuse outside the fabric, dropping by earth gravity out of the microwave reactor, and falling through a perforated Pyrex disc. Microwave hydro diffusion and gravity (MHG) of broccoli by-products permits the coincident dehydration of the various perishable elements, together with inflorescences, leaves and stalks in a very short amount of your time, and therefore the extraction of a little fraction as associate solution made in phenoplast compounds, fructose, glucose, mannitol, cellulose polysaccharides, free amino acids, and glucosinolates.

4. Sustainable dehydration of onion slices by means of novel technique, microwave hydro-diffusion gravity method

Onions are among the category of semi-perishable food commodity and the deterioration of onions during storage may cause high amount of post -harvest losses. That's why we need to dehydrate them to increase their shelf life, so a novel method of drying was found out which is microwave hydro- diffusion gravity. Muhammad Kashif Iqbal Khan, Muhammad Ansar, Akmal Nazir and Abid Aslam Maan did drying in two steps- 1. Pre-treatment of onion slices by microwave hydro gravity diffusion method, 2. Drying of the pre-treated slice by means freeze drier or hot air oven and found that that at 400 W for 14 minutes, 80% of the moisture was removed from onions, so this is the best combination. This novel technique prevents the burning and maintains the nutritional quality. And there was not much colour change or colour difference between the fresh and MHG treated onions. But a significant colour difference was there among dried samples. They found that the drying results showed reduced energy consumption because of the pre-treatment with MHG method and minimum energy requirement for this method is 0.54 mega when they were dried with hot air oven but also found that drying done by this novel technique is divided into three phases: - 1. The heating phase which consists of initial 3 or 4 minutes needed to heat the water present in the onion slices. 2. The evaporation phase, in this the water evaporates from the onion cells because of the heating happened in first step. 3. The browning or the burning phase whereby most of the water gets evaporated and may result in burning of the onion slices. The total time required for drying was found by the researchers to be dependent upon the power, so at the low power of 120W 120 minutes of drying time was recorded beyond this burning started. And with the increase in power of 480W the drying time was reduced to 14 minutes. So to avoid the decrement in the nutritional quality, they recommended use to the shorter processing time. This novel technique this is very effective in maintaining the quality of the product, energy saving and drying time.

5. Dehydration of green beans using ultrasound assisted vacuum drying as a novel technique

According to Zeynep Hazal Tekin, Mehmet Başlar, Salih Karasu and Mahmut Kilicli, This novel technique can be used for drying not only green beans but for any vegetable. Drying by means of ultrasound under vacuum leads to increase in the rate of dehydration, drying under vacuum leads to surface removal of water by lowering down the boiling point of water. Also, they found that this technique is found to improve the quality of the vegetables along with energy saving and reduces the processing time with the increase of mass transfer and effective diffusivity rates as compared to traditional methods. Ultrasonic waves have the ability that can affect internal and external resistance of mass transfer and because of compression and release happening in a continuous matter leads to the formation of sponge like micro channels. Because of these compression and release processes there is easy removal of free and bound water. For studying the drying rate of green beans they used three different methods in order to compare which one is better. The three different methods were oven drying, vacuum oven drying and ultrasonic drying under vacuum with the temperature rates of 55, 65, 75 degrees Celsius. And for vacuum and oven drying vacuum drier and air circulation oven drier is used. As a result they found out that for USV the energy consumption is high but because of shorter drying time and increased drying rate, it is more economical because cost of storage and personnel can be decreased also USV drying method reduces the dehydration time to approximately 1 hour because of higher drying rate as compared to other methods like vacuum drying under same conditions. Researchers have found that lower colour change and higher phenolic content was determined in the samples that have been dried at 65 degree Celsius, so they concluded that this novel technique can be applied for drying of other vegetables.

6. A novel dehydration technique for carrot slices by using the ultrasound and vacuum drying methods

Carrots (*Daucus carota*)is one of those vegetables which is grown and consumed throughout the world because of its higher carotene content and they also contains higher amount of water so for keeping for long period of time they need to be dehydrated to avoid nutritional loss and quality loss over time due to physical, chemical and microbiological changes. Drying is a process which includes heat and mass transfer with phase change, chemical and physical changes. So Zhi-Gang Chen, Xiao-Yu Guo, and Tao Wu came up with novel dehydration method which is a combination of ultrasound and vacuum dehydration in order to reduce the drying time and to improve the quality of carrot slices. They dried the carrot slices by using the ultrasonic vacuum drying (USV) and vacuum drying at the temperature of 65 degree Celsius and 75 degree Celsius. They found that drying rate was influenced by the method of drying and temperature of drying and USV drying method has shown 41-53% reduction in drying time as compared to vacuum drying method. They also concluded that the drying time of USV method and vacuum method at the temperature of 75 degree Celsius was found to be 140 minutes and 340 minutes along with this they also found that nutritional value, rehydration potential, colour of the sample and texture was better in case of USV drying method as compared to vacuum drying method as the vitamin c retention in vacuum and USV drying method was found to be 35.5% and 48.4% at 65 degree Celsius and 41.6% and 62.5% at 75 degree Celsius along with beta carotene was found to be retained in good amount when the carrots were dried with vacuum drying and USV and it was retained at the percentage of 75.1% and 89.2% and they also noted that there was less energy consumption in case of USV drying method .

7. Drying of Shiitake mushroom by combining freeze drying (FD) and mild infrared radiation (MIRD) Hong-cai Wang, Min Zhang, Benu Adhikari.

The shiitake (*Lentinula edodes)* is an edible mushroom which is native to East Asia, researchers have found that this kind of mushroom has average initial moisture of 84 plus minus 1.7% by means of hot air oven at the temperature of 105 degree Celsius, so it required drying for long shelf life. According to researchers freeze drying method is widely used to get high quality of dried vegetables. This is because the solid state of water, transport of moisture during the freeze drying is by sublimation and low temperature basically protects the primary structure and shape of the vegetables and as the result vegetables have low bulk density, high porosity and better rehydration properties. But using freeze drying alone has limitations in producing high value products such as- slow process, low throughput, and high energy consumption and need expensive equipment. So it was combined with infrared which in return gave shorter drying time, high energy efficiency and better quality of product, so researchers have this combined drying method for drying of shiitake mushroom. Researchers had used mild – infrared drying (MIRD) before or after the freeze-drying to get the above given advantages. They have firstly frozen the mushrooms at the temperature of -35 plus minus 2 degree Celsius for 5 hours in ultra- low temperature freezer, then they shifted these frozen sample to FD chamber or cold trap at the temperature of -40 degree Celsius and then maintained the final temperature as 50 degree Celsius within the FD chamber until they get 12% of moisture content. They did MIRD after freeze-drying at 60 degree Celsius until the moisture content was less than 12%. They also did MIRD step as pre-drying step before freeze-drying by maintaining the temperature of 60 degree Celsius and then the samples were frozen at -35 degree Celsius to get the moisture content below 12%. As a result they found out that doing the freeze-drying for 4 hours followed by mild-infrared drying had saved 48% of time as compared to freeze- drying alone along with maintaining the quality of mushroom. They also found that rehydration ratio, the colour, microstructures and apparent density of FD-MIRD shiitake mushroom was not notably different as compared to those dried with FD alone but MIRD helps to produce more porous microstructures in dried shiitake mushroom. Not only this they have observed that combination of FD with MIRD had a significant effect on aroma retention and also caused increase of sulphur compounds like trisulphide and dimethyl and also leads to better quality of mushrooms.

Objective 2

To study the effects of different drying techniques on functional and sensory parameters of vegetables

Pulsed electric field (PEF)

Technique permeabilizes cells present in vegetable tissues without an important increase of the product temperature and avoiding an excessive deterioration of the tissue. Pulsed electric field improve process yield, increase process velocity and improve food quality decrease the intensity of other processing variables and increase the cost efficiency of the operation. PEF treatments, food tissues are subjected to an external electrical field for a few seconds, which induces local structural changes and eventually causes the breakdown of cell membranes called electro permeabilization. The basic application of PEF treatments is to increase the level of carotenoids in fruit as well as in tomato juices obtained from PEF-treated. The effect of PEF processing on the bio-accessibility of carotenoids in fruit, vegetables and derived products has been scarcely. Pulse electric field treatment may be applied to the tomatoes as a pre-processing treatment to get the derived product with increased antioxidant level.

Infrared drying (IR drying)

The power is penetrated into the substances to a small depth and then is converted to heat. Warmness air assisted infrared drying of potato and carrot is carried out and product extraordinarily terrific is in difference with warm air dried samples the synergistic have an effect on of heat air. IR heating and simultaneous elimination of moisture from the floor with the aid of compelled convection resulted in a faster drying method the higher drying time in ir mode may also desire to be attributed to natural convective waft of air which is slower than that in contrast to pressured convection in blended mode. Its actual advantages over normal heating quicker and efficient heat switch decrease processing price uniform product heating and higher organoleptic and dietary cost of processed cloth are some of the necessary components of ir drying. Infrared drying has been investigated as a potential method for acquiring high superb dried foods stuffs which encompass green vegetables. However, a awfully high infrared power, intensity, drying temperature and a awfully low infrared distance ought to be avoided because the vegetable product are hot. The consequences of infrared parameters on vegetable quality were unpredictable. The energy consumption underneath infrared emission was conjointly variable. Once the reduction of drying time was extended, the energy consumption belittled. Once the reduction was inadequate, the energy consumption exaggerated. The applying of infrared emission will have an effect on the vegetable quality. Generally, the infrared emission will decrease the water activity, scale back the entire color modification and improve the nutrient retention.

Electro hydrodynamic (EDH) drying

This method of drying was a new method of drying which is non thermal in nature. This method has higher drying rates, less energy consumption and provides superior quality of product as in physiochemical properties- colour, flavour, nutrient content and shrinkage. They are rich in carotene, vitamins, minerals and fibre. HD drying embody fast rates of evaporation and heat-releasing interaction of the electrical field with a nonconductor material. Multi-point and plate conductor systems square measure economical in fast drying of agricultural materials. Compared to hot air (convective) drying systems, EHD drying systems provide lower food production prices beside superior quality in terms of physiochemical properties like color, shrinkage, flavor, and nutrient content. Compared to convective and freeze, EHD drying systems, given their easier style and lesser energy consumption, show nice potential for bulk and industrial drying applications. But due high moisture content, improper storage and handling their shelf life is reduced along with nutritional quality so researchers have come up with new novel technique that is electro-hydro dynamic drying.

Ultrasound assisted vacuum drying

Drying by means of ultrasound under vacuum leads to increase in the rate of dehydration, drying under vacuum leads to surface removal of water by lowering down the boiling point of water. this technique is found to improve the quality of the vegetables along with energy saving and reduces the processing time with the increase of mass transfer and effective diffusivity rates as compared to traditional methods. Ultrasonic waves have the ability that can affect internal and external resistance of mass transfer and because of compression and release happening in a continuous matter leads to the formation of sponge like micro channels. Because of these compression and release processes there is easy removal of free and bound water. USV drying method reduces the dehydration time to approximately 1 hour because of higher drying rate as compared to other methods like vacuum drying under same conditions. When ultrasound technology was applied before drying, a rise in drying dynamics was invariably discovered, though some totally different results were additionally conferred.

For ultrasound assisted drying, the ultrasound power invariably gave a positive result on the drying method, however, the magnitude of ultrasound improvement was for the most part obsessed on the method variables, like air rate, air temperature, microwave power and vacuum pressure, etc. the applying of ultrasound technology can somehow have an effect on the food quality, together with the physical and chemical ones. Generally, the ultrasound application will decrease the water activity, improve the merchandise color and scale back the nutrient loss.

Freeze drying (FD) and mild infrared radiation (MIRD)

Freeze drying method is widely used to get high quality of dried vegetables. This is because the solid state of water, transport of moisture during the freeze drying is by sublimation and low temperature basically protects the primary structure and shape of the vegetables and as the result vegetables have low bulk density, high porosity and better rehydration properties. Vacuum evaporation of biological materials is one in all the most effective ways of water removal, with final merchandise of highest quality. The solid state of water throughout evaporation protects the primary structure and also the form of the merchandise with smallest volume reduction. Additionally, the lower temperatures within the method permit peak nutrient and bioactive compound retention. Evaporation is wide accustomed dehydrate the plant-based foods as well as fruits, vegetables, spices, and even some nontraditional foods. Despite the long time interval and being a fashionable drying technique, it's most well-liked for the high final quality. Though some losses in vitamins and different valuable biocompounds are often found once evaporation, this sort of dehydration technique is that the best to preserve organicprocess qualities compared to different dehydration ways, particularly once operated under vacuum. Additionally, quality parameters like rehydration and body of freeze-dried vegetables are favorable for producing style of food. It was combined with infrared which in return gave shorter drying time, high energy efficiency and better quality of product, so researchers have this combined drying method for drying of shiitake mushroom. Infrared drying (MIRD) before or after the freeze-drying to get the above given advantages. Combination of FD with MIRD had a significant effect on aroma retention and also caused increase of Sulphur compounds like tri-sulphide and dimethyl and also leads to better quality of mushrooms. They have firstly frozen the mushrooms at the temperature of -35 plus minus 2 degree Celsius for 5 hours in ultra- low temperature freezer, then they shifted these frozen samples to FD chamber. Rehydration ratio, the colour, microstructures and apparent density of FD-MIRD shiitake mushroom was not notably different as compared to those dried with FD alone but MIRD helps to produce more porous microstructures in dried shiitake mushroom.

Objective 3

To study the effects of various drying techniques on quality parameters of food

There are several changes are happening in quality parameters of drying. The extended changes depend upon the care taken in preparing the fabric before dehydration and on the method used. The major quality parameters affects the dried food products which include colour, visual appeal, shape of product, flavour, microbial load, retention of nutrients, porosity-bulk density, texture, rehydration properties, water activity, moisture content, rid from pests, insects and other contaminants, preservatives, and off-odours. The state of the merchandise, like glassy, crystalline or rubbery, is additionally important. Drying remains the foremost popular method for preservation of agricultural products (e.g., fruits, vegetables, herbs, and spices), ensuring microbial safety of various biological materials. This particular method has several disadvantages and limitations as well. Drying differs from evaporating therein the previous takes the food to only about total dryness or the equivalence of 97 or 98% solids. The oldest method of drying food is the food under a hot sun with moisture retentions.

Some products which are prepared from drying include different types of powdered milk powder, instant coffee, fish dried potato flakes, shellfish, jerky, and dried fruits.

Dehydration is the removal of water from a product by not affecting its flavour. the aim of dehydrating (drying) is typically to enhance the time period of the merchandise, and thus dehydration may be a unit operation of great importance to the food industry. During dehydration moisture content is reduced, the water activity of the merchandise is additionally reduced. Once the water activity has dropped to about 0.6, the merchandise is typically considered to be shelf stable. Products could even be dried for other reasons; as an example, to manage texture properties like crispness (biscuits), to standardize composition, and to reduce weight for transport. the foremost important reason, however, is control of water activity. Drying is dear, since the energy required to urge obviate water is high. during this chapter we'll discuss the results of evaporation and drying on quality of foods.

Drying causes physical and biochemical changes within the fruit tissue. The loss of water is amid shrinkage of the bulk tissue and changes in microstructure, including cell collapse, cell shrinkage, cell membrane detachment (plasmolysis) or cell membrane breakage (lysis). These changes strongly influence the moisture transport properties of the tissue and also induce variations within the final product quality. the merchandise texture is influenced as an example by the bulk density, porosity, cell size, cell shape and cell wall thickness of the dried product. The hydration and rehydration capacity of the dried product mainly depends on the level of shrinkage and porosity in the food product. Biochemical changes within the sort of nutrient and colour degradation also are observed.

In order to style a drying process that delivers superior quality products, knowledge of the fruit microstructure and its evolution during drying is vital. The aforementioned studies mostly specific within the relations between the last word microstructure and quality attributes of the completely dehydrated products. the microstructure changes during drying and these changes should be controlled or levelled up to urge the final product quality. Related to the past, some norms inspect the changes in porosity and texture, also regarding to the pore and cell size distribution of food products. A 3D imaging was always used to quantify the rapture and shrinkage and the basic changes in apple cells diameter, roundness and area particularly during drying. This study relied on a destructive technique supported light microscopy and can only concentrate on a limited number of cells. during this context, there's an outsized potential of X-ray micro-computed tomography (CT) to be used to inspect changes of the 3D microstructure during drying and its impact on the macrostructural changes. This non-destructive technique is emerging within the sector of food science. The successfully utilized and formation to research the microstructure characteristics are, amongst others is really very different from apple fruit cultivars, dried apple, frozen apple, fried potato, dried banana and kiwi. The appliance X-ray micro-CT to identify microstructural changes during a dynamic process was recently done, during which they investigated the changes of porosity, cell and pore size distribution, also as cellular water distribution of apple tissue during a convective drying process. However, the impact of the drying methods on the evolution of food microstructure isn't known to our greatest knowledge, albeit it's a crucial aspect in determining the food quality. Such knowledge also can be used as a basis for improving mechanistic models that enable scrutinizing morphological changes of cellular food structures during drying, for instance, the turgor loss, cell shrinkage, membrane breakage and cell membrane wrinkling.

Physical Property

Dehydration changes food products in several ways, affecting the organoleptic qualities of the merchandise. Dehydration requires high temperatures for which may cause the chemical reactions which really like caramelization, nonenzymatic browning and denaturation of proteins within the food product. Drying also affects the physical parameters of the merchandise, as removal of water causes shrinkage. Physical properties like as color, texture, density, porosity, and rehydration capacity are affected by the drying method. A tough and woody texture, slow and incomplete rehydration, and loss of the standard fresh food juiciness are the foremost common defects encountered during drying. The physicochemical changes for these changes is much complex, and its understanding requires useful standard lab measurements.

Color may be a major quality parameter in dehydrated foods. During drying, color may change due to chemical or biochemical reactions.

Enzymatic oxidation, Maillard reactions, caramelization, and ascorbic acid browning are the basic chemical reactions that can occur during drying and storage of food material. Discoloration and browning due to air drying can give the various result regarding various chemical reactions including pigment destruction. Due to the various natures of fruits and vegetables, there are many factors which will affect the magnitude of fabric shrinkage during drying. Cellular structure and mechanical properties of food material and drying conditions are the basic and important factors that highly affect the level of shrinkage. The most important physical changes that foodstuffs undergo during drying is that the reduction of their volume called as shrinkage. Shrinkage is caused by structural collapse due to the loss of water. Changes in shape and size, loss of rehydration capacity, surface cracking, and hardening of food materials are among the foremost important physical phenomena related to shrinkage.

Porosity and bulk density are very important related to physical properties in foods. These two properties play an important role in the formation of rehydration materials and therefore handling and packaging aspects. The extent of shrinkage of fruit result in the changes in porosity during drying. The bulk shrinkage and the porosity changes were associated with moisture content of dried foods. Porosity in fruits and vegetables increases during drying, counting on the initial moisture content, composition, and size, also because the sort of drying method employed. Fruits and vegetables are mostly composed of a solid matrix with a big amount of liquid water within the cell at different level.

The structural rigidity of the internal tissue prevents shrinkage of the product when kept to drying process. Fruits and vegetables are hygroscopic in nature and contain 80% to 90% water. This vast amount of water is found in several cellular environments like the intracellular environment, intercellular environment, and therefore the cell membrane environment. The proportion of water that present inside the cell (intracellular spaces) is mentioned as intracellular water, and water that's present in intercellular spaces is mentioned as intercellular water or capillary water.

Case hardening occurs when there is rapid drying which comes to an end of compounds such as sugars to form a hard, brittle and impermeable case the food piece. The phenomenon can cause decrease to the rate of dehydration. Case hardening may occur in high-sugar products which are as tropical fruits and many temperate fruit products. Dehydration procedures are made to lower the formation of case hardening.

Physical changes, such as structure, case hardening, collapse, pore formation, cracking, rehydration, caking and stickiness can affect the quality of final dried products. Air drying useful to destroy the cell structure and takes the more time for dehydration. Due to the solid state of water freeze drying protects primary structure and the shape of the product keeping the cells almost solid, with high porosity end products.

Chemical Property

Browning, lipid oxidation, colour loss and alter of flavour in foods can occur during drying and storage. Browning reactions are often classified as enzymatic and non-enzymatic. Enzymatic browning of foods is undesirable because it develops undesirable colour and off flavour. the appliance of warmth, sulphur dioxide or sulphites and acids can help control this problem. the main disadvantage of using these treatments for food products is their adverse destructive effect on B-complex vitamin or thiamine. Enzymatic browning can be inhibits in fruit by dipping in osmatic solution. This treatment also can reduce the moisture content with osmotic pre-concentration. There are three major sorts of non-enzymatic reaction:

- Maillard reaction,
- Caramelization
- Ascorbic acid oxidation.

Factors which will influence non-enzymatic browning are water activity, temperature, pH and therefore the chemical composition of foods. Browning actually occurs at the mid-point of drying period. this might flow from to migration of soluble constituents towards the middle. Browning is additionally more severe near the top of the drying period when the moisture level of the sample is low and fewer evaporative cooling is happening. Rapid drying through 15–20% moisture range can minimize the time for Maillard browning. In carbohydrate foods, browning are often controlled by removing or avoiding amines and conversely, in protein foods, by eliminating the reducing sugars. Sulphur treatment can prevent the initial condensation reaction by forming nonreactive hydroxy-sulphonate sugar derivatives. In caramelization, heating of sugars produces hydroxy methyl furfural, which polymerizes easily. This reaction could also be slowed by sulphite, which reacts with sugars to decrease the concentration of the aldehydic form. Discoloration of vitamin C containing vegetables can occur thanks to formation of de-hydro-ascorbic acid and di-keto-gluconic acids from vitamin C during the ultimate stages of drying. Sulphur-dioxide treatment can also prevent the browning to reactivity of Bi-sulphite towards carbonyl groups which present within the breakdown of products. Fatty foods are susceptible to develop rancidity at very low moisture content. Lipid oxidation is liable for rancidity whereas conversion of off-flavours, and the loss of fat-soluble vitamins and pigments different foods, mostly in dehydrated foods. Factors that influence the oxidation rate include moisture content, sort of substrate (fatty acid), extent of reaction, oxygen content, temperature, presence of metals or natural antioxidants, enzyme activity, UV light, protein content and free aminoalkanoic acid content. Moisture content plays an enormous part within the rate of oxidation whereas air-dried foods are less vulnerable to lipid oxidation than freeze-dried products thanks to lower porosity.

Nutritional quality of food are often suffering from handling, processing, and packaging. Apart from the physical and chemical changes, drying can cause loss of nutritional value and nutrients. the main losses of vitamins and other substances happen due to solubility in water, enzymatic oxidation, oxygen and warmth sensitivity, and metal ion catalysis during processing. additionally, sugar–amine interactions (Maillard reaction) can occur during drying and storage, causing loss of nutrients. of these losses in food are often reduced by: pre-treatments, proper selection of drying methods, new and innovative drying methods, and optimization of drying conditions.

Change In Proteins

The biological value of protein depends on the tactic of drying. Low temperature treatments of protein can enhance the digestibility of protein. Milk proteins are partially denatured during drum drying, and these leads to a discount in solubility of the powdered milk, aggregation and loss of clotting ability. The storage temperatures and the moisture contents above 4-5%, the biological value of milk protein is decreased by Maillard reactions between lysine and lactose. Lysine is very much heat sensible and losses in milk by the application of spray and drum drying.

Rancidity is an important problem in dried foods. The oxidation of fat is bigger at higher temperature than at coldness of dehydration. Protection of fat with antioxidant is an efficient control.

Change In Lipids

Lipid oxidation is responsible for rancidity which causes the development of off flavours. The loss of fat- soluble vitamins and pigments, especially in dehydrated foods. Factors that affect oxidation rate include moisture content, sort of substrate (fatty acid), extent of reaction, oxygen content, temperature, presence of metals, presence of natural antioxidants, enzyme activity, ultraviolet light, protein content, free aminoalkanoic acid content, other chemical reactions. Moisture plays a crucial part within the rate of oxidation. The elimination of oxygen from foods can reduce oxidation, but the oxygen concentration must be very low to possess an impact. The effect of oxygen on lipid oxidation is additionally closely associated with the merchandise porosity. Freeze -dried foods are more vulnerable to oxygen due to their high porosity. Air-dried foods tend to possess less area thanks to shrinkage and thus aren't as suffering from oxygen. Minimizing the oxygen level during processing and storage, and addition of antioxidants also as sequestering agents, has been recommended within the literature to stop lipid oxidation.

Change In Carbohydrate

Fruits are basically rich sources of carbohydrates and low sources of proteins and fats. The principal of deterioration in fruit and vegetables is due to carbohydrates. Discoloration could also be thanks to enzymatic browning, or to caramelization sorts of reactions. the reaction of organic acids and reducing sugars causes discolorations called as browning. The addition of sulphur-dioxide to tissues may be a means of controlling browning. Carbohydrate deterioration is most vital in fruit and vegetable tissues being dried. Slow sun drying is really help in extensive spoilage whereas the tissues are protected with sulphates, or suitable agents.

Changes In Vitamins

Vitamins have different solubility in water, and, as drying proceeds, some (e.g., riboflavin) become supersaturated and precipitate from solution. Losses are therefore small. Others, (e.g., ascorbic acid) are soluble until the moisture content of the food falls to very low levels and react with solutes at higher rates as drying proceeds. Vitamin C is also sensitive to heat and oxidation. Short drying times, low temperatures, and low moisture and oxygen levels during storage are necessary to avoid large losses. Thiamin is also heat sensitive, but other water-soluble vitamins are more stable to heat and oxidation, and losses during drying rarely exceed 5-10% (excluding blanching losses).

Oil-soluble nutrients (e.g., essential fatty acids and vitamins A, D, E, and K) are mostly contained within the dry matter of the food and they are therefore concentrated during drying. However, water is a solvent for heavy-metal catalysts that promote oxidation of unsaturated nutrients. As water is removed, the catalysts become more reactive, and the rate of oxidation accelerates. Fat-soluble vitamins are lost by interaction with the peroxides produced by fat oxidation. Losses during storage are reduced by low oxygen concentrations and storage temperatures and by exclusion of light.

Microbiological Property

Dried food products are considered to be safe with reference to microbial hazard. there's a critical water activity (aw) below which no microorganisms can grow. The drying process causes the water activity and moisture content of the foods in reduced manner, hence the growth of microorganisms in the foods is essential to be prevented. As the low-aw foods should not be considered sterile as they will be contaminated by fungi and other contaminants during the drying process. In particularly dry products some pathogens are like yeast and mold can grow during storage, preservation and transportation. They will be causing health problems when there is enough pathogen or spore cells remain active. The pathogenic bacteria could not grow below water activity of 0.85–0.86, instead yeasts and moulds are more tolerant to a reduced water activity of 0.80. there's no growth occurs below aw of about 0.62. Reducing the water activity inhibits microbial growth but doesn't end in a sterile product. the warmth of the drying process does reduce total microbial count, but the survival of food spoilage organisms may produce to problems within the rehydrated product. the sort of microflora present in dried products depends on the characteristics of the products, like pH, composition, pre-treatments, and kinds of endogenous and contaminated microflora and method of drying. Brining (addition of salts) together with drying decreases the microbial load. The dried products should be stored under appropriate conditions to guard them from infection by dust, insects and rodents. Dehydrated foods are preserved because their water activity is at A level where no microbiological activity can occur and where deteriorative chemical and biochemical reaction rates are reduced to a minimum. The reduced water activity below the 0.6 to 0.7 prevents the microbiological spoilage. Most oxidation reactions and enzyme reactions are going to be inhibited as water activity decreases. However, auto oxidation of lipids could happen at very low tide activity values 0.2. The increased rate of non-enzymatic browning reactions (Maillard reaction) is formed at intermediate water activity values of range 0.4 to 0.65. These reactions end in the loss of nutritive value, formation of brown pigments, also because the formation of off-flavours, especially when the products are stored at high temperatures. the expansion of microorganisms in foods is essentially prevented/delayed by drying. However, since dry foods have hygroscopicity and therefore the moisture content isn't constant, the ratio within the air within the storage is vital. When the ratio and moisture content balance is disturbed, an appropriate moisture environment is made especially for mold growth. After drying, there could also be enough pathogens and spore cells to cause the disease, even they will remain viable for months and this will cause health problems.

Conclusion

Drying is the oldest method of preservation by means of removal of water (through heat and mass transfer process) basically free water which is responsible for water activity is responsible for growth and multiplication of microorganisms. Hence drying leads to extension of shelf- life of food commodities such as vegetables lowering down the water content to acceptable limit. The important objectives that drying techniques must fulfil are: preserving the fresh food commodities so that they are available whole year, reducing the weight and volume of the product for easy transportation and storage, preserving the nutritional and quality aspects of food commodities, it should sustainable method in terms of less energy consumption, therefore novel drying techniques are being used in today's world. The event of food dried victimization novel techniques introduces totally different challenges: the buyer perception, the approval of the novel technology and also the retention of the physical, sensory and nutritionary quality of foods. The present work highlights recent developments of valuable novel drying techniques to market property within the food business and points towards. The potential of novel technologies for drying and food preservation has gained enlarged industrial interest and has the potential to switch, a minimum of part, the normal entrenched preservation ways, because the business seeks to become a lot of environmentally and economically property The novel drying techniques have introduced and are being currently used in food industry such as microwave drying, ultrasonic drying, infrared drying, osmotic drying , pulsed electric field drying, superheated steam drying, high electric field drying, heat pump drying, electromagnetic drying, radio-frequency drying, refractance window drying and explosion puffing drying, these techniques are also being used in combination because as these have advantages such as-shorter drying time, operational safety, better quality of products, non- polluting, better control process, more economic. Novel drying techniques are the new drying methods introduced by researchers to solve the problems associated with conventional drying methods like sun drying, hot air drying and oven drying that reduces the quality attributes like textural change, nutrient loss, browning of the dried food product etc. with increased time and energy consumption.

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