FREEZING DRYING OF CARROT SLICES OF DIFFERENT THICKNESS

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Master Thesis

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I certify that in my opinion the thesis submitted by Ahmed JANAANI "FREEZING DRYING OF CARROT SLICES OF DIFFERENT THICKNESS" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

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This thesis is accepted by the examining committee with a unanimous vote in the Department of Energy Systems Engineering as a Master thesis. January,2020

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The degree of Master thesis by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

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"I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well."

Ahmed JANAANI

ABSTRACT

M. Sc. Thesis

FREEZING DRYING OF CARROT SLICES OF DIFFERENT THICKNESS
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In this study the carrots are dried by the method of freeze drying. Cut the carrots into circular slices, these circular slices were divided into two halves. The first section had a diameter of 5 mm and the other section was 7 mm. These slices were dried using a device SCANVAC COOLSAFE the weights of the carrot slices differed and for each weight and diameter we dried for two hours and using different temperatures. When evaluating, the amount of carrot slices for freeze-dried samples was observed that the dried samples were 5 times more than the amount of carrots. Weighing freeze-dried carrot slices during a total of 14 drying hours loss data were recorded. It was applied on 10 different mathematical models using the MATLAB program. The error analysis of the models at the result v was made using the estimated standard error (RMSE), chi-square (x^2) and regression coefficients (R^2) in the models used. According to the results, it was determined that the Page model was closer to the experimental results compared to the other models. Statistical error values found for samples; R^2, x^2, RMSE values respectively It was found to be 0.018565707 for 5 mm and 0.019532936 for 7 mm.

ÖZET

Yüksek Lisans Tezi

FARKLI KALINLIKLARDAKİ HAVUÇ DİLİMLERİNİN DONDURARAK KURUTULMASI

Ahmed JANAANI

Karabük Üniversitesi
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Bu çalışmada havuçlar dondurularak kurutma yöntemi ile kurutulur. Havuçları, Dairesel bir şekilde ikiye bölerek kare şeklinde kesilir. İlk bölüm 5mm çapında diğeri ise 7mm'dir. Bu dilimler bir SCANVAC COOLSAFE cihazı kullanılarak 2 saat kurutuldu. Havuç dilimlerinin ağırlıkları, her biri farklı ağırlık ve Çapa göre ikiye ayrılır. Toplam 14 saat kurutma liyofilize havuç dilimlerinin ağırlığı kayıp verilerden kaydedildi. MATLAB yazılımı kullanılarak 10 farklı matematiksel modele uygulanmıştır. Sonuç v'deki modellerin hata analizidir. Kullanılan modellerde tahmini standart hata (RMSE)kare iki(x^2) ve regresyon kat sayıları(R^2) kullanılarak yapılmıştır. Elde edilen sonuçlara göre sayfa modelinin deneysel sonuçlara diğer modellere göre daha yakın olduğu belirlenmiştir. Örnekler için istatiksel hata değerleri bulunabilir. Sırayla (R^2, x^2) ve RMSE değerleri 5mm için 0,018565707 ve 7mm'dir için 0,019532936 olarak bulundu.

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SAYMBOLS AND ABBREVITIONS INDEX

$MR_{deneysel}$: Humidity rate determined by experimental data,

$MR_{deneysel,ort}$: Average of experimental moisture content values,

$MR_{tahmini}$: Estimated humidity,

$MR_{tahmini,ort}$: Average of estimated moisture content values,

N : Number of experimental data,

Z : It is the coefficient number in the model used.

PART 1

INTRODUCTION

There are many methods that are used for the purpose of drying, and one of these methods is The freeze drying process is a process that takes place as follows: First, the food that we want to freeze with drying is processed by reducing its internal humidity and this means that it becomes less prone to spoilage. In this stage, the snow is converted into steam by evaporation during an almost vacuum-free environment. Finally, after all these processes the moisture in foods will be very little. The entire dewatering process takes place at a lower temperature environment than that of a traditional dryer. The advantages are given by freezing the dye preserving most of the food's properties to a great extent. The Time are gives foods a long shelf life. Better quality recoverability, after water absorption and added value. In this study we will be using carrots. Food Vacuum freeze dryers are always used in meat, vegetables and spices, as well as in aquatic products, instant foods, and finally in specialty products. the market demand is increasing rapidly because the quality of the Freeze-drying products are compatible at the present time with the green environment and are comfortable and healthy, and they are now destinations that harm all society at the present time. As we mentioned above, this process reduces the internal humidity of meat, vegetables and fruits, all of which makes them maintain the correct system of products, that was done. By reducing the surrounding pressure, this leads to allowing the frozen water in the material to sublimate directly from the solid phase to the gaseous phase, which leads to achieving the purpose of the process. Also, there is no need to keep freeze-drying products in the cooling, which can keep a long time at the normal temperature, which means the same with fresh materials after soaking, so it is very popular with both moderate and high customers.

There are also many of food drying techniques and storage methods. One of the oldest known methods of preservation of foodstuffs is drying. Drying can be defined

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as the process of removing the water in a product consisting mainly of water and dry matter by various methods. The methods applied for drying vegetables and fruits are based on the principle of evaporating the water contained in the product to be dried by applying heat and mass transfer simultaneously. In technical drying, external intervention is made to the drying process and the moisture contained in the material is removed by different methods. For this reason, drying is defined as bringing the moisture of the product to be dried to the desired dryness values. The whole unit of units (heating, dehumidification, dehumidification, etc.) that enables the product to reach drying values in a certain period is called "drying system". The drying process is widely applied in many branches of industry (such as food, paper, cement, timber and chemical industry) Drying applied to foodstuffs has many purposes, and perhaps the most obvious of these is to prevent product spoilage during long-term storage. In end of the drying process, product can be stored for a long time without spoiling, by reducing the humidity of the product to a sufficient level to limit microbial growth or other reactions. In addition, by reducing the moisture content of the product, quality features such as aroma and nutritional value are preserved. in the same time, by reducing the product volume at the end of the drying process, it increases efficiency in transport and storage of foodstuff.

Carrots can be dried using a dryer. It helps maintain the bright orange color and flavor of the carrots, reduce their size, and store them in a small space. We will cut the carrots into 7 mm slices and 5 slices, the size of 100 gm, using a device SCANVAC COOLSAFE, at a temperature of -40, for a period of up to 14 hours. Today, carrots are one of the vegetables used for human nutrition because it contains a high percentage of fiber and vitamins, and carrots are one of the important sources of beta-carotenoids that prevent cancer, vitamin A and potassium, and it contains cholesterol-lowering pectin, vitamin B, vitamin C, folic acid, thiamine and magnesium. Dried carrots are also used in dried soups and in powdered form in sauces and pastries. The purpose of drying carrots is to be stored safely over a long period. However, the volume and weight will be greatly reduced, and the costs of packaging, storage and transportation will be reduced. There are many traditional drying processes and each of them has benefits and disadvantages, in our research we chose the ideal method, which is freeze drying, because of its many benefits we

mentioned above and the product used was carrots and that is because of the importance it has.

PART 2

LITERATURE REVIEW

As is known, food is difficult to obtain in all seasons. Plenty of foods so preserving these foods for a long time is essential to offer. Long-term preservation of food to be used as needed The method that allows processing is the method of cold-drying. Foods of all kinds of fruits, vegetables, meat and milk. As in this study, we used carrots that serve several methods of drying foods. Here are some studies on drying methods.

Yayuan Xua, Cabbage is one of the most attractive raw materials for dried vegetables, as it has a high traceability. In this study it indicates how the drying methods affect the chemical and physical properties, in this paper the split cabbage was subjected to freeze drying (FD) and hot air drying (HAD) as well as by microwave drying (MVD) and by vacuum drying (VD) and MVD in addition to Combined with HAD (MVD + HAD) and VD (MVD + VD)). After performing these methods of drying, measurements were made in terms of antioxidant activity, nutritional components, microstructure, texture, etc. After that, the results of HAD had a worse effect, because it was found that the rate of loss of nutrients was greater than 45%. There were two common approaches to higher retention of nutritional formulations, better antioxidant activity, and lower energy consumption than individual HAD. Also, however, the MVD + HAD products had a higher hydrolysis capacity and a more uniform honeycomb porous structure as they had lower hardness compared to HAD. This research was fundamental to choosing more quality drying methods to obtain excellent quality [1].

Yong Wang, the spray drying process is widely used for the purpose of manufacturing dairy and food powders in the industrial scale. Where active peptides gain bioavailable, for example, products with hydrolysis of various food proteins,

due to the biological functions as in their immunological, antioxidant and antimicrobial properties, many bioactive peptides / hydrolysis from various food sources are shown in this article, with attention to their treatment And also the properties of the final powder. He also proposes a strategy for coating the food peptide by spray drying. Bearing in mind that determining appropriate drying treatments and / or formulation helps to overcome the limitations associated with current treatment of dietary peptides. This study was conducted in Japan at the Powder Technology Association, And it led to good results in terms of spray drying and was in the year 2019 [2].

Tingting Guo, in this research, a new path has been taken in the qualitative analysis of different slices of lemon by using a large-capacity electron Volta mmetric pulse. By using several methods of pre-processing the date, the principal component analysis (PCA) was also used, as well as by separate wavelet transfer (DWT). Including the use of linear discrimination analysis (LDA) it was intended to compare stress and its effect. Through the results of the linear discrimination analysis (LDA), it indicated the choice of DWT and its adoption as a method for extracting the characteristics. Then they used an Extreme Learning Machine (ELM) that was intended to analyze lemons and their different aromas qualitatively in order to compare the results with a common classification model: Random Forest (RF) and Support Vector Machine (SVM). Then they use the models and compare them depending on accuracy of the training set [3].

Duygu Keser, Carrots are an important human food. In this study, the effect of various microwave powers on each of the antioxidant properties, phenol, and odor was shown in this study on dried carrots with various samples and MW powder. They dried fresh and varied carrots (Daucus carota 'Nantes') by applying seven different power levels of 150, 200, 250, 300, 350, 400 and 450 watts (0.50, 0.67, 0.83, 1.00, 1.17 and 1.33). And 1.50 W / g, and they are respectively). The aromatic compounds were extracted from the carrot samples by disinfection, Whereas, the carrot samples extracted the aromatic compounds by disinfection and traps, as they were determined by gas mass spectrometry (GC MS). Regarding fresh carrot samples, the terpenes were relied on as the predominant aroma group, where a large

decrease in the amount of these compounds was observed due to the total dependence on the applied MW energy level. Terpinolene and (E) -bisabolene, elemicin and myristicin were also recognized as the dominant terpenes. With regard to fresh dried eyes, alcohol, furans, aldehydes, pyrazines and acids were used as a main component, depending on the applied MW energy levels. Hexanal, 3-methyl-butanal, acetic acid, and hexanoic acid were the most dominant ones in the dried carrot samples. In order to assess the phenolic compounds, the method was approved using liquid chromatographic separation in addition to tandem mass spectrometry (LC MS / MS). Which was the result of the analysis, it was found that there are seven phenolic compounds in a group, the most common was the share of two of them (3-caffeoylquinic acid and a derivative of di-caffeic acid). The total phenolic content of carrots and their dried fresh samples were determined at an energy level below 150 and 200 W (0.50 and 0.67 W / g). How much was found when the smell and the phenolic compounds were known, it was found that they were better preserved in carrots and their dried fresh samples by means of low energy levels of MW (150 and 200 watts) [4].

Wiesław Kurza, In this study, the accidental freezing of aluminum vaccines was used for transportation and storage. Knowing that the freezing of these aluminum vaccines harms them in the aid that is sensitive to freezing, this is done by separating the network between the antigen aluminum material and the auxiliary, meaning this leads to the formation of aluminum clumps that lead to loss of effectiveness. Then, AlhydrogelTM ([AlO (OH)] xnH2O, aluminum hydroxide, hydrated for absorption) were examined which were stored under certain conditions, and then subjected to freezing temperature to solidify. The aim of this study was to determine the destruction areas of frozen solid Alhydrogel by several methods selected from energy dispersive x-ray spectroscopy, electron microscopy, Raman spectroscopy, as well as infrared spectroscopy for the purpose of Fourier transform, and electron microscopy was used for the purpose of transmission because It works in diffraction mode. Zeta potential readings, albumin absorption strength measurements, thermogravimetric analysis, and mass loss estimate after drying. There are significant structural (physical) and chemical differences between the non-frozen and frozen spoilage vaccine material. These advanced results were of importance in order to understand

the type and nature of damage that aluminum-based vaccines may be damaged by freezing. [5].

Yanhong Liu, In this study, a high-performance liquid chromatography method - tandem mass spectrometry (LC / MS / MS) method was relied on, developed and then validated for the purpose of determining the bound lipid doxorubicin and the metabolite doxorubicinol in the plasma of mice. A treatment of approximately one hundrem ml of plasma samples was taken with Triton X-100 for rapid liposomal separation. Then the extraction process of the samples with one methanol: the first stage was the precipitation of the acetone protein with an additional 50 liters of zinc sulfate at 70% (w / v), as in the second stage the analysis process was by LC / MS / MS with the help of the introduction of a spray ionization. Turbochargers have positive action. The device also allowed multi-reaction monitoring (MRM). Then use the related compound daunorubicin as an internal standard. The approved concentration ranges were found to be from 20 to 8000 ng / ml for doxorubicin and from 0.05 to 20.0 ng / ml for doxorubicinol. The development of the most effective LC-MS / MS method for determining the traceable amount of doxorubicinol is followed by the minimal intervention of doxorubicin. Then the automatic relay reduction process from 285 to 10.5% by increasing the valve wash times when the pentafluorophenylpropyl HPLC column used does not have any significance in the relay. The readings from this study showed validation of GLP accuracy was somewhat good (85-110%) and accuracy (CV less than 14%) through titration ranges for each of them. This method was used to understand the pharmacokinetic profiles of doxorubicinol and doxorubicin in rats after ingestion. Single dose of Stealth®-49 liposomal doxorubicin HCl. It was found that the average AUC value for doxorubicinol is only 0.011% for doxorubicin [6].

Songwen Tana, In this study, pepsin was spray-dried in order to achieve the release and encapsulation of the original whey protein isolates that were hydrolysed by gel (WPI, HWPI, GWPI). The particles are amorphous for pepsin in this drying process. The survival rate for pepsin is 84.3-89.4% and this percentage when drying the spray and begins to decline gradually with an increase in the inlet temperature from 110 to 190 ° C and the dried proteins have wrinkled surfaces, which are associated with the

numbers of Bakelite during the drying process. In the FTIR spectra, free amino acids for HWPI were shown and upon formation the structural change in protein for GWPI was observed, looking the other side of WPI. Then the samples were spray-dried by using pepsin encapsulated in micro-capsules for release studies. Then the release process was done and controlled within 4 hours by changing the percentage of pepsin or release matrices. The results of the release of pepsin showed a relatively zero arrangement with the highest square R value of 0.989 by multiple design of a matrix containing 50% GWPI and 50% WPI and the design Similar to sandwich [7].

Songwen Tan, In this study, the method used was the spray drying method, in which the acidified casein was treated and the resulting gel was somewhat similar to shampoo foam at a certain pH where it was 1, after which the tablets were placed for the purpose of releasing applications that control it. Then it was found that the casein gel, which is ergonomically designed, has a higher moisture content and lower Tg / dehydration temperature compared to the other type of casein (gel casein), in light of the results of the analyzes of DSC and FTIR. It was discovered that casein is sensitive to thermal exposure (DSC), knowing that there is no significant change in casein during the FTIR process. During the spray drying process, it was observed that the size of casein gel particles increased with the decrease in temperature during the process. The use of high temperatures on the particles in the spray drying process, these particles are subject to wrinkling surfaces, for example, raisins. To make microcapsulation of ascorbic acid (Vitamin C), in the spray drying process the dried powders work to reduce the relative moisture content with a temperature higher than Tg / dehydration. This is done by increasing the inlet temperature (100-190 °C), the retention of ascorbic acid is observed (80-60%) with an increase in yield (0-70%). The gel casein disk results were more flexible upon DMA, and the hardness was 0.8 N / mm. According to the controlled release, then the casein gel was to exhibit a slow-character release of ascorbic acid for 24 hours and at a pH of 2 or 12 hours at a pH of 7.4. The results were slight at high pressure pressure (320 MPa) [8].

Mahadi Hasan, In this study, the experiment of artificial drying with heat convection was applied to corn and soybeans at temperatures (30, 40 and 50 degrees Celsius), as corn and beans are of great importance today, especially in the biofuels and food

industry because of their vital and nutritional advantages. This was done by means of a central composite design (CCD). The effective diffusion coefficient, Deff, has been adopted considering that it is thermodynamic properties and in two different ways by integrating ozone into the air for drying and also without combining both beans and corn. It was also found that CCD and Deff differed in values and during ozone drying (DOP) a numerical model was made in order to spread moisture during the process. It was also noted that the activation energy decreased from 43.90 to 35.20 kJ mol-1 for corn and 38.23 to 34.29 kJ 1 for soybeans when the drying air was ozone added. Enthalpy and entropy were the same. Thus, ozone drying can be useful in technological stages to improve the energy in steps that are after harvest [9].

Samuel Getahuna, In this study, energy recovery and safe disposal of fecal sludge (FS) is done through drying processes. Knowing that there is little data for this process for FS. The purpose of this study is to know the characteristics of drying FS, as it was done by relying on samples belonging to ventilated improved pit toilets. With another attached to dry toilets was a urine diversion (UDDT) with an anaerobic reactor (ABR) for wastewater and its systems, which was decentralized. As the solids content and moisture content were depended, and in order to measure the calorific value to characterize the drying method of the FS content, the water activity, volatile solids, differential thermal analysis (TGA - DTA), and thermocouple measurement were used. Different humidity on drying (100 °C) was very similar to samples belonging to sanitation facilities. As shown in the process of the results of the drying process, with respect to the experimental temperature, the FS depends on two to three times the latent heat for the purpose of evaporating the water necessary for drying. The source of the sludge was less important compared to the drying temperature when the solids content that was volatile and of the dried samples was known was the drying temperature. The thermodynamic thermogravimetric analysis showed a large percentage of thermal decomposition (2-11%). This ratio of dry mass stiffness was close to 200 °C and it was below 200 °C, and it did not show a significant difference. The calorific values of the samples were average VIP, UDDT, and ABR at 100 °C, 14.78, 15.70, and 17.26 MJ / kg were for dry solids, respectively. The drying temperature, which is not less than 200 ° C, does not affect the value of FS fuel to the sanitation facilities [10].

Jiabao Ni, In this study, the purpose of this study was to improve the Goji Berry drying speed during an electrodynamic (EHD) drying process as well as to find a better treatment method. As the microscopic advantages of Goji Berry drying, there were various treatment methods, below the EHD drying process and by using a closed jacket. As the rate of drying after pre-treatment in the readings was significantly higher than that of the other type of goji berries with no pretreatment, the EHD drying system showed that there are various effects on the drying properties of the goji berry resulting from the variety of processing methods. Then the different treatment methods and their effect on the effective moisture diffusion coefficient were recorded in descending order: KOH> NaOH> Na2CO3> Ultrasound> sucrose ester. The hydration rate is greatly influenced by pretreatment, and the specific structure and energy consumption of goji berries are dehydrated by EHD. Also, the infrared spectroscopy was assigned an index sequence analysis during drying. The difference between five treatment methods was also examined and analyzed [11].

Wenchao Liu, The instant soups have a high percentage of starch. In this study, the focus was on treating the low starch during the freeze-drying process and its degradation, which leads to a reduction in the viscosity of the soup. It is important to monitor the starch and to know the regression that will occur during the drying process in this study and its processes. In this study I use creamy mushroom soup because it is a soup with high starch content. The first time the freeze-drying process was observed and an understanding of the soup quality and drying properties. Knowing that the quality of the soup is preserved during the drying process, however, the viscosity is greatly reduced. The starch was regressed, that the drying quality and its advantages (for both rehydration behavior and whiteness, and shrinkage rate) of the product that was dried, there were three stages of hybrid drying. Microwave drying (0.8 W / g, 1 hour) + freeze drying (50 °C, 4 hours) + microwave drying (0.8 W / g, until end of drying) It has been successfully improved to preserve the properties of the auxiliary soups as well as to prevent a decrease in its viscosity [12].

GeisaAlbini, the principle of this experiment is to dry the barley by means of a fixed bed dryer. The first two methods were to reverse the airflow every 10 minutes and

the second was to introduce a conventional airflow, while preventing reflection, the moisture distribution along the fixed layer was measured and the effect of the initial moisture content and temperature on the drying data. The air temperature during the drying process was (40 °C and 50 °C), with the air velocity constant (4.0 m / s), with initial moisture contents in three patterns (25%, 20% and 13.5% were moist content). During fixed bed height, the rates for drying were variable. This was expected. With regard to the higher initial moisture content of the grains, the heterogeneity of the process was found to be higher than that of the grains with lower initial moisture content. At 50 °C, the use of reversible airflow in the drying process was shown to have better process uniformity, and the share of conventional drying was to improve energy performance. The results indicate the shortest time required to provide 12% moisture content at 50 °C [13].

Thanh Khuong Nguyena, In this study, the purpose of this study was to follow up on the improvement of the moisture properties of cellular food products, for example potatoes, as well as for two food models that are non-cellular and made of maltodextrin (DE19 and DE36), where the drying process with different temperatures, 25 °C and 55 °C, was used. By magnetic resonance, it showed that the inside of the potato was a proposal that changed the sub-uniform moisture distribution, and that the non-cellular was more consistent. As expected, temperature had an effect on pore formation and drying kinetics. On the other hand, the temperature did not affect the development of the dry layer of the potato, but rather its effect on the improvement of the dry layer of other non-cellular food patterns. Knowing that the two non-cellular types in this experiment show the different temperatures of the glass transition for them, with the same improvement of the dry layer, the validity of the theory which states that the glass transition is the mechanism for the purpose of forming the dry layer is revealed. It also studied the possibility of applying Fick's law by fitting the data for an experimental moisture study file on quadratic polynomials. In the aqueous sectors of materials that have different temperatures for the vitrification during the intermediate stages of drying, and when the dry layer on surfaces is neglected for calculations, the Fick Law has provided good data to help the sectors [14].

Wolf and Gibert, In this paper, the influence of factors on the drying process they have have freeze dried the milk in the glass bottle. In this study, they determined the factors limiting the freeze drying process. By applying their own models to the measurement data, they have determined three transfer parameters in their models. These are the diffusion of water vapor in the dried layer, the mass transfer coefficient in the product and the resistance faced by the heat transfer from the heated shelf to ice. They determined that this resistance is a complete control parameter and therefore controls drying kinetics, as the contact resistance between the glass bottle and the rack is a major barrier to heat transfer [15].

Mellor, the effect of pressure on freeze drying time on heat and mass transfer He examined. Low pressure means that mass transfer increases the driving force, but heat transfer Due to the relation of coefficients with pressure, the heat flow on the dried surface noted that it reduced. The cyclist pressured to overcome this problem developed freeze drying process. In this process, short to increase heat flow increased the pressure for a while and then briefly to increase the steam flow reduced it [16].

Nail, the effect of pressure in the drying cell on drying. In her study, Nail freeze dried the medicine in liquid form. Pine 20 he placed the frozen medicine in the vials in a metal tray on the warming rack inside the drying cell. Nail has determined that in some cases it may be a factor limiting the transfer rate to the culture and stated that there is a resistance to heat transfer from the heat source to the sublimation surface. He found that this resistance to heat transfer was from the air gap between the tray and the bottle and the tray and the heater shelf, and was more pronounced in the low pressure environment. This is explained by the decrease in the thermal conductivity of the gas in the pressure range in which the heat flow of free molecules occurs. Drying rates were measured at 1.3, 0.25 and 0.04 Torr pressures. The results confirmed Nail's theory by showing that the drying rate decreased with decreasing pressure [17].

Pikal, Examined the resistance created by the dried surface layer during the freeze-drying process. In the study, they determined that the dried surface layer resistance

decreased with decreasing pressure. They determined the resistance of the dried layer directly according to the data of the sublimation rate. Therefore, Pikal et al. Determined that low pressure increases the sublimation rate. They carried out the experiments with a specially designed simple container and heat, not by transmission, but by radiation. They also developed a model by measuring the sublimation rates experimentally. They determined the dry product resistance normalized to the steam flow from the data by estimation. They later used dry product resistance as important data to estimate drying rates numerically [18].

Pikal, Examined the heat and mass transfer in the freeze-drying process. A few bottles containing frozen product are placed on the heater shelf and drying 21 They measured their rates and estimated the heat flux. According to the study, as the pressure in the drying cell decreases, the sublimation rate decreases. In addition, the resistance associated with different types of partially sealed bottles was analyzed. Mass transfer coefficients were determined by simple measurements combined with dry product resistances determined in the aforementioned study. They evaluated heat transfer by conduction and radiation. They used effective heat transfer coefficients based on measured temperature differences in the equations [19].

Zamzow and Marshall, developed the first mathematical model of freeze drying. They investigated the states of radiation and conduction boundary conditions, assuming an unrealistic steady state for their model. The non-real steady state assumption allows the calculation of heat conduction towards the product under steady state conditions within a certain time frame. The validity of this model depends on how much the actual temperature profiles in the product overlap for a certain period of time with the default steady-state conditions. Since the traditional freeze-drying process is very slow, the temperature profile in the product is almost at the same level, which confirms the steady-state assumption [20].

Hill and Sunderland, used the fake steady state model. However, free molecules evaluated momentum equations from continuation and transition flow regimes. They considered the flow rate constant across the dried layer due to the pseudo-constant state assumption. Because of the theoretical prediction data and features of the model

available, they compared it with the data published for beef. Accept minor differences between predictions and experimental data as experimental errors [21].

Liapis, has developed a model that includes both sublimation of ice and desorption of water in the dried region. Unlike previously described models, this model used a transient analysis that allows both sublimation and desorption to occur simultaneously. This model is called the sorption-sublimation model. [22].

Dyer and Sunderland, considered the transfer of moisture in the sorption-sublimation model between the steam flow in the dried region and the material being dried. This aspect of the drying process has been ignored in previous freeze drying models and therefore caused errors in the predicted data [23].

Copson, modeled the microwave freeze drying process with the assumption of the common non-real steady state that has been used in the modeling of classic freeze drying. However, Ma and Peltre (1973) have determined that this assumption does not apply to the faster microwave freeze drying situation. In the Copson study, they assumed that the dried layer had hydrodynamic flow. The calculations of the vapor flux were based on the pressure difference between the mobile sublimation interface and the outer surface of the dried layer. Significant differences existed between predicted data and experimental data. These differences revealed that there was a false steady-state assumption and unknown transport properties [24].

Ma and Peltre, provided a temporary dimensional freeze drying analysis with microwave heating. It was the first temporary analysis of microwave-heated freeze-drying. They wrote the temporary mass and energy equations for the dried and frozen regions. They analyzed the heat in the frozen region by conduction and in the dried region by transmission and convection [25].

Jennings, measured the sublimation rates of ice. Measurement results, the results of the results of Nikal and Pikal studies, found that the sublimation rate increases as the pressure decreases [26].

Litvin, Dried carrot slices by combining them with freeze drying, short-term microwave application, and air or vacuum drying. Sliced the carrots in the experiments, 7 to 10 mm thick, for 1 minute 23 Steamed, cooled under running water, frozen at -18 ° C and stored at -18 ° C until further processing. Partially freeze-dried samples were microwaved for 50 seconds and then vacuum and air dried to 5% humidity. The color, dimensions and moisture recovery rate of the partially frozen, microwave-applied and air-dried product are the same as freeze-dried product with the final moisture value and the same quality parameters. It has been determined that the final drying done in the vacuum oven has some beneficial effects on the color. Combining freeze drying with air drying following microwave application, a significant gain was achieved in freeze drying time. It takes a total of 7.25 - 7.50 hours, with a 3.5 - 3.75 hour partial freeze drying followed by a short microwave application and 3.75 hours air drying, while the total time in 9.5 ° C takes only 30 hours [27].

Khalloufi, Experimentally freeze dried strawberries, blueberries and mushrooms. In the study, the products were dried by freeze drying for 72 hours and the relative humidity was increased with saturated salt solutions from 11% to 87%. The weight changes and water activity of the fruits during the drying process were examined and it was stated that the GAB model was better for experimental data [28].

Shishehgarha, Experimentally examined the drying kinetics, color and volume changes, freeze drying at different shelf temperatures (30, 40, 50, 60 and 70 ° C) of sliced 5 mm, 10 mm and whole strawberries. As a result of freeze drying, the drying time of strawberries was 5 hours for 5 mm, 10.7 hours for 10 mm and 50 hours for whole strawberries. They found that strawberries at temperatures lower than 50 ° C had good quality, and that at temperatures higher than 50 ° C, the structure of strawberries collapsed [29].

Araki, In the freeze-drying process, they experimentally examined 15 mm thick sliced and crushed apples in the temperature range of -10 to 70 ° C heater surface temperature and 20 to 30 Pa pressure. They found that the rate of crushed apples to dry was 2.5 higher than sliced apples [30].

Carapelle, They experimentally examined the freeze-drying of frozen wet papers. They examined the various physical parameters (pressure, heater power v, b.) And established the freeze drying system required for the study. They determined optimal parameters to reduce the time and cost of freeze drying in the study and developed a simple example to assist research in this field [31].

Sadıkoğlu and Özdemir, emphasizing the principle of freeze drying process, the important points to be considered in freeze drying by emphasizing the importance of freezing process in drying, stated that microwave drying, which is a method that increases the drying speed, faster compared to the classical freeze drying method [32].

Krokida, Dried apple, banana, carrot and potato in 5 different methods and examined the effect of drying on color. Fresh apples, bananas, carrots and potatoes were cut 20 mm in diameter and 10 mm in thickness. In air drying, the drying temperature is $70 \pm 0.2 \,^{\circ} C$, the relative humidity of the air is 7% and the pressure is 1 ± 0.03 bar. In vacuum drying, the temperature is $70 \pm 0.2 \,^{\circ} C$ and the pressure is 33 ± 0.03 mbar. Microwave drying was carried out at atmospheric pressure and 810 W power. In freeze drying, the samples were cut at 20 mm diameter and 8 mm thickness. Samples frozen at $- 35 \,^{\circ} C$ for 48 hours and 24 in a laboratory freeze-drying chamber dried for hours. Significant browning occurred on air, microwave and vacuum dried products. There was no browning in the color of the samples in freeze-drying [33].

Marques and Freire modeled the drying kinetics of pineapple, guava and mango in freeze drying with "Chen and Douglas", "Van Meel" and "Page" models. They found that the best explaining model for experimental results is Page model [34].

Sadıkoğlu and Liapis worked on parameter estimation and model separation to determine the functional form of the mechanism that can be used to describe the removal of bound water during primary drying. They compared the experimental data of the first drying phase with theoretical models and showed that the removal of bound water did not significantly affect the total mass flow during the first drying phase [35].

Sadıkoğlu and Liapis showed in their experimental study that an increase of 2 ° C in the melting temperature of skim milk can reduce the drying time in the first drying stage by 8.28% [36].

Duran. Compared the water and fat content of fresh, frozen and lyophilized chicken and beef meat. As a result of comparison, they found that the water and fat ratios of chicken and beef were lower in lyophilization [37].

Kwok. Dried saskatoon berry fruit by freeze drying (DK), vacuum microwave drying (VMK), air drying (AK) and the CD method, which is a combination of AK and VMK. Compared with other drying methods, fresh frozen fruits, the other methods significantly decreased the total phenol and anthocyanin content and also decreased antioxidant activity. Those dried with DK showed the highest anthocyanin and antioxidant activity levels, followed by VMK. CD drying resulted as the average of VMK and AK [38].

Sham. Reported that calcium pretreatment, vacuum level and apple variety; by air and effects on the structure of vacuum microwave dried apple crackers They examined. Golden Delicious, Red Delicious and Fuji apples were weighed to a sample amount of 1 kg, washed, sliced in 4 mm thickness, and steamed for 2 minutes. The apple slices were dried at 70°C until the moisture content was 5% compared to the dry base, approximately 3.5 hours, in a belt dryer with air flow rate 1.1 m3 / min. Freeze-drying was dried under 100 μmHg vacuum, room temperature 20°C, condenser temperature -55°C for 10.5 hours. High vacuum application in vacuum microwave drying has decreased the density and increased the brittleness. In addition, Fuji type apples have been reported to have higher calcium content and brittleness than Red and Golden Delicious apples.[39]

Rahman. Studied the pore characteristics of tuna dried by air, vacuum and freeze. Air drying was done at 70°C, 1 m / s air velocity and 3.4% relative humidity, and vacuum drying at 70°C and pressures less than 2 kPa in a vacuum oven. In freeze-drying, the fish are frozen for at least 24 hours at - 40°C. The condenser surface temperature is –65°C, the plate temperature of the room is - 20°C and the vacuum is

108 Pa. The volume weight of the meat part of fresh tuna fish was measured as 1098 kg / m3, and the volume weights of tuna dried by air, vacuum and freeze were 960, 709 and 317 kg / m3, respectively. The porosity of the freeze dried sample was higher than the air and vacuum dried samples [40].

Freeze drying and sun drying of saffron flowers were compared. HPLC (High performance liquid chromatography) at TÜBİTAK ATAL to determine the amount of safranal and crocin, which is the active ingredient, of 4 freeze-dried saffron samples, each of which is 1000 mg, and a total of 4 sun-dried saffron samples with 1000 mg each.) were analyzed. When the analysis results were evaluated, it was seen that the safranal amount of freeze-dried samples was 5 times more than the safranal amount of the samples dried in the sun. It was determined that the amount of crocin in the freeze-dried samples was approximately 40% higher than the crocin amount of the samples dried in the sun [59].

PART 3

THEORETICAL BACKGROUND

Various methods are used in the preservation of food. The most used of these methods are cooling and drying applications.

3.1. FOOD STORAGE TECHNIQUES WITH COOLING

Although refrigeration is an essential storage medium nowadays. Storing food at a low temperature is the simplest and safest way to store many types of food as the food you plan to cool requires the least amount of preparation or the food is already ready for cooling. Refrigerators maintain the quality and safety of food because cold slows bacterial growth and reduces spoilage. Depending on the type of food, it can last between a few days and a few weeks in the refrigerator before the texture and taste deteriorates. Refrigeration is the process of removing heat to reduce the temperature of a substance or an environment below its surrounding volume temperature and to maintain it at that temperature [82-84]. With the cold preservation process, food can last between 5 and 50 times longer. The process of freezing food is defined as a preservation technique based on lowering the water contained in the food to a temperature where it can form ice crystals. Microbiological development is stopped in frozen foods. By reducing the temperature of the food to a temperature between -18°C and -30°C, possible damage to the product at room temperature is prevented or minimized in this way. These temperature levels prevent microbiological spoilage and extend the shelf life of the product. In general, the freezing process consists of four stages:

1. The first ice crystals in the product begin to form and the freezing temperature remains constant until a significant portion of the water in the product freezes.
2. Freezing of the remaining water as a result of the drop in product temperature.

3. In the last stage, after the free water freezes completely, the product temperature decreases without a phase change.
4. Cooling the product called pre-cooling from the initial temperature to freezing point.

The main purpose of the freezing process is to protect the natural structure of foods as much as possible. Significant changes occur in the structure of the food by lowering the temperature in connection with the water content of the food. When the freezing temperature of the product and the freezing temperature is less than 5 ° C, the crystal structure formed in the product becomes small. If the freezing process is slow in this process, the size of the crystal formed in the product increases. This situation especially destroys the cell wall of fruits and vegetables and the product cannot preserve its fresh quality since its structure changes when the product is thawed again. At the same time, during the prolonged freezing process, the water in the cells of the fruit and vegetable spreads out of the cell depending on the concentration and this leads to the dehydration of the cell. Therefore, the rapid freezing process ensures that the product surface remains smooth and does not disrupt the cell structure [41]. The freezing methods used in the food industry are given below.

3.1.1. Cold Weather Freezing Freezing

With cold air, freezing in still (natural convection) air and two main types of freezing in accelerated air (forced convection) There are applications.

3.1.1.1. Still Weather Freezing

As the name suggests, the cold air used in the freezing process is still. The merit of such a freezer is a fully insulated cold 30 chamber. The evaporator of refrigeration equipment can be found on the ceiling, wall or in the middle of the room in the form of a bundle of tubes extending from top to bottom, or in the form of vertical racks. The products to be frozen are stacked between these shelves [42].

This type of freezer is simple and inexpensive in terms of the equipment used. There is no mechanism providing air movement in still air freezing rooms. Air is subject to only natural convection. However, since it is impossible to see this as an air movement, it is accepted that the air is still. Even in some still air freezers, a limited air movement is provided with the help of a fan. However, due to this low air speed, such an arrangement should not be confused with the "freezing in air flow" method. Because in freezing in the air flow, a high freezing speed can be achieved by circulating the air at a high speed with a forced circulation.

In the still air freezing method, the temperature of the cold room is between -15°C and - 30°C. Since the thermal conductivity of the still or very slow moving air is very low, it takes a long time for the foodstuff to freeze. The freezing time can vary from a few hours to several weeks, depending on various factors such as the size of the frozen material, the shape of the packaging, the space between the frozen units and the like. This method was mainly applied for fish freezing and is still widely used for the same purpose [42].

3.1.1.2. Accelerated Air Freezing

The general principle of this type of freezer is that air moves rapidly between the frozen food and the evaporator. The air, which is moved with the help of powerful fans, cools while passing over the cooling spirals (evaporator) and then passes over the frozen product at a speed of 10 - 15 m / s. Since the heat transfer coefficient increases depending on the air speed, the foodstuff is rapidly frozen. Air temperature in air circulation freezing varies between -30°C and -45°C. Food freezing process with air flow can be designed as tunnel or belt. Accordingly, tunnel freezers can be belt or wagon. The speed of the belt or wagons in the tunnel is adjusted according to the freezing time. On the other hand, the movements of the frozen product and the cold air 31 inside the tunnel may be parallel or countercurrent. In reverse flow tunnels, the product to be frozen is given from one side of the tunnel and cold air from the other side. Accordingly, the coldest air encounters the frozen product at the exit of the tunnel with a very low temperature. Then it continues on its way to the tunnel entrance. In this system, the moisture content of the air that cools the product

increases. In this case, when it comes back to the evaporator, snow occurs on the evaporator surface. Due to this disadvantage, which occurs especially in long tunnels, the air movement in the tunnels is arranged diagonally to the product movement. So the air is given from the sides of the tunnel. In this application, the distribution of cold air in the tunnel is homogeneous. Cold air is mostly blown up from the bottom of the belt. With this blowing, the material on the belt gains a slight vibration depending on the air speed and particle size, thus increasing the freezing speed. However, this limited vibration is far from causing the frozen particles to freeze to stick together and thus turn into a mass. However, today, many products are desired to be frozen in individual pieces without becoming a block. For this reason, a new system called fluid bed freezer has been developed based on the very high velocity air emitted from the belt freezers under the belt to keep the particles on the belt floating in the air. In fluid bed freezers, each of the particles rising in the air and falling back, making a boiling-like motion, freezes rapidly by making full contact with the cold air from all surfaces. Fluid bed freezers are actually a belt freezer. However, there are many different fluid bed freezers. Figure 3.1 shows a fluid bed freezer [43].
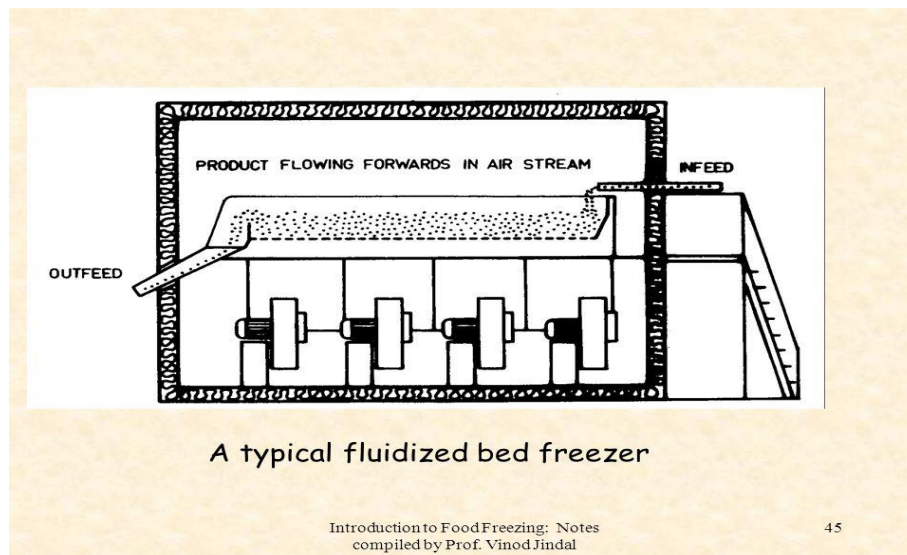

A typical fluidized bed freezer

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Figure 3.1. Fluid bed freezer [62].

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3.1.2. Indirect Contact Freezing

The working principle of this method is to freeze the packaged products placed between two internally cooled plates as a result of contact with the plate. Since there is a plate between the frozen product and the refrigerant that performs the cooling, this method is called freezing by the indirect contact method. Freezing of some foods in the freezer compartment of the refrigerators at home can be seen as a plate freezing method acting from one side. The only condition for freezing foods by indirect contact method is that the product to be frozen is in a rectangular prism shaped package. The freezing rate of a packaged mass without surface contact decreases in this system. Because it is very important in terms of freezing time that the package touches the plate with a smooth surface. Accordingly, when the packages of the same shape and the same thickness are placed side by side on the plate and the other plate is seated from the top, a fast freezing can be achieved in two directions. The plates consist of four corners, hollow aluminum shelves, and there are cooling channels, namely refrigerant evaporator units. The most common plate freezers are the "birdseye multi-plate" (Birdseye multi-plate) freezer type. In these, in a well-insulated cabinet, many plates in the form of shelves are located one above the other. One end of each plate is a rubber tubeand the other end is connected to the refrigerant main return line with a rubber pipe.

Thus, up and down movement of the plates with rubber pipe connections is realized. As a matter of fact, the bottom two plates are opened with a hydraulic arrangement. The packaged foodstuff is lined up here in a single row. Then, upwards, between the other plates are frozen in the same way. Finally, the rack array is compressed slowly with a low pressure (0.05 - 0.1 bar) in a hydraulic arrangement.

This compression is of great importance as the effectiveness of plate freezers depends on the degree of contact between the plate and the food. For the same reason, the packages are filled a little more so that there is no gap in the packages and the content is settled and the heat conduction accelerates as a result of compression [42].

This is the reason why products such as meat and fish that form a whole mass in the packaging freeze more quickly than vegetable and fruit in particulate form with spaces between them. However, the packaging should not burst in the compression of the plates. To ensure this, wooden barriers are placed on both sides between the plates. Since the thickness of these is slightly less than the thickness of the packaging, compression only takes place up to the thickness of the wooden parts [44]. Wood particles compression is limited.

After the plates are frozen, the cabin doors are closed and the cooler is operated at the desired temperature. The product is left here until its temperature reaches -18 ° C. The freezing time varies according to the type and thickness of the packaging material, the type of the frozen product, the temperature and the thickness of the whole packaged food, especially depending on the contact between the packaging and the plate. With this method, packaged masses of 5 cm thickness freeze in 90 - 120 minutes.

There are also continuous working plate freezers. One of these layouts contains a series of pairs of "shelf-plates". When the pair of shelves is uncovered in front of the freezer, the packaged products transported by the tape are automatically filled here. As this stacked rack enters the freezer and moves upward, a new placement on the idle rack begins. Each shelf (or it can be called a station) makes 34 cycles in the freezer and freezing is completed, and each station that has been frozen is emptied sequentially. Figure 3.2 shows a continuous plate freezer.
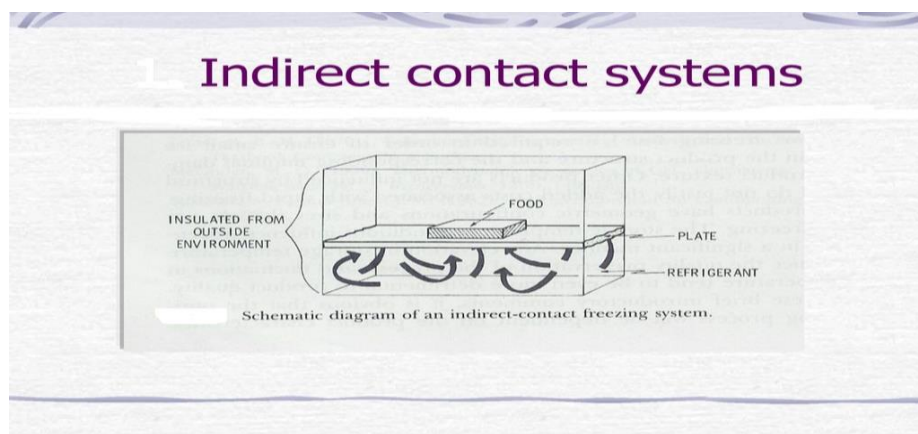

Figure 3.2. Indirect Contact Freezing Product entry and frozen product [62].

In another plate freezing system operating with continuous loading, ice cream is completed by sliding the packages between two plates, one fixed and the other moving, on the fixed plate with the help of a moving plate. Although the indirect contact method is suitable only for smooth-surfaced packaged products, it is also widely applied in the rapid freezing of liquid foods. However, the principle of the devices used for this purpose is different. The plates used for this purpose are cylindrical and the outer part is insulated. There is very little space between the axial shaft (Mutator) of these devices called tubular scraper coolers and the inner surface of the cooling cylinder. There are scrapers on the shaft that literally scrape the inner surface of the cylinder. The liquid or semi-liquid product supplied to the cooler forms a very thin film in the space between the inner surface of the cylinder and the shaft. Meanwhile, while the freezing occurs, the scrapers on the shaft scrape the surface of the cylinder with the rotation of the shaft and clean it. In this way, the freezing surface 35 is cleared from the ice layer that prevents heat conduction, while the rapid stirring of the frozen product during this time accelerates the freezing. Freezing only takes a few seconds.

The product, which is given to the freezer in liquid or puree form, is in the form of a liquid-snow mixture while leaving it. In fact, further freezing is neither correct nor possible in such a system. Otherwise, the cooler becomes blocked and remains in a block state. After this mass in the form of a mixture of liquids is packaged, it is stored by freezing in cold air freezers to the desired degree as the second stage [42].

3.1.3. Dip Freezing

It is the fast freezing process by immersing the products in a non-water based refrigerant. The first immersion freezing process used R-12 and other halocarbons as refrigerants, which increased the atmospheric emissions of these substances. Today, liquid nitrogen has completely replaced these types of refrigerants. The terrible boiling property of liquid nitrogen causes turbulence, thus allowing the separation of products and obtaining a very large surface heat transfer coefficient.

With this method, it is ensured that minimum moisture loss, good odor storage, prevention of excessive freezing, and liquid nitrogen consumption is minimized by the emergence of liquid nitrogen in gas form at approximately room temperature [45].

3.1.4. Cryogenic Liquids Freezing

Immersing the products directly in liquid nitrogen can damage the products. By spraying liquid nitrogen on the products, the risk of damage to the products is reduced. Therefore, designs of freezers working with the principle of spraying liquid nitrogen to products passing through conveyor belts after 1960 have been made [46].

Liquid nitrogen and liquid carbon dioxide are the most commonly used cryogenic liquids in freezing foods. With strawberries and some berries, some delicate foods such as sliced tomatoes and mushrooms can be obtained with a very fast freezing. Cryogenic freezing method has also been developed mainly for this type and its application is still limited to these products [42].

Spiral spray cryogenic freezers and spray cryogenic freezing tunnel freezers work with this method. While small liquid nitrogen droplets evaporate on the products, it rapidly cools and freezes the product. Small liquid nitrogen droplets used in this type of freezer have a high evaporation surface heat transfer coefficient. The reason for this is that the liquid-solid contact takes place very well. Generally, there are three parts in cryogenic freezing tunnel freezers. Pre-cooling is applied to the products entering in the first part by moving the nitrogen gas formed by evaporation in the tunnel with the help of fans. In the second part, the freezing process is performed by spraying liquid nitrogen to the products on the belt. In the last part, the temperature of the product is balanced and taken out from the end of the tunnel [47].

3.1.5. Cryomechanical Freezing

In cryomechanical freezing systems, the product is pre-cooled in cryogenic immersed freezers before mechanical freezers such as spiral and fluidized beds. Fluid bed

mechanical freezers seem to be the most suitable for freezing grape fruits. When a cryogenic immersion freezer is used, a shell is formed on the outside of the product within a few seconds with the help of liquid nitrogen.

The shell formed in the product coming out of the cryogenic freezer is thick enough to withstand the environment of the mechanical freezer, which is warmer compared to this freezer. This layer prevents the product from being damaged due to the movement that occurs during the freezing of the product in the mechanical freezer, and allows the products to keep their shape [48].

3.2. FOOD DRYING TECHNIQUES AND STORAGE METHODS

One of the oldest known methods of preservation of foodstuffs is drying [49]. Drying can be defined as the process of removing the water in a product consisting mainly of water and dry matter by various methods. The methods applied for drying vegetables and fruits are based on the principle of evaporating the water contained in the product to be dried by applying heat and mass transfer simultaneously [50]. In technical drying, external intervention is made to the drying process and the moisture contained in the material is removed by different methods. For this reason, drying is defined as bringing the moisture of the product to be dried to the desired dryness values. The whole unit of units (heating, dehumidification, dehumidification, etc.) that enables the product to reach drying values in a certain period is called "drying system". The drying process is widely applied in many branches of industry (such as food, paper, cement, timber and chemical industry) [51].

Drying applied to foodstuffs has many purposes, and perhaps the most obvious of these is to prevent product spoilage during long-term storage. At the end of the drying process, the product can be stored for a long time without spoiling, by reducing the humidity of the product to a sufficient level to limit microbial growth or other reactions. In addition, by reducing the moisture content of the product, quality features such as aroma and nutritional value are preserved. At the same time, by reducing the product volume at the end of the drying process, it increases efficiency

in transport and storage of foodstuffs [52]. There are many methods used in drying foods. These methods are divided into two groups.

These are respectively;

1. Natural drying (sun drying),
2. Artificial drying.

3.2.1. Natural Drying (Sun Drying)

It is the drying of the product under the sun without any technical intervention. It is the method used for a long time. The most important thing is temperature. Because the moisture contained in the product is thrown into the air with the effect of heat without the product being deformed. The product is laid on the soil or concrete floor, canvas, nylon and cloth and dried.
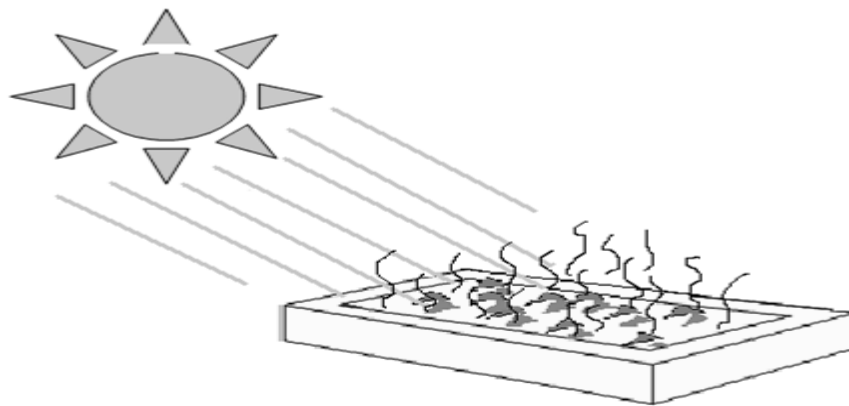
Figure 3.3. Natural drying (sun drying) [62].

3.2.2. Artificial Drying

Artificial drying methods have been developed to shorten the drying time, increase the quality, and protect the product from the sun's radiation effects. The greatest advantage over natural drying is that it provides a controlled drying environment, resulting in a better product than natural drying in terms of appearance [53]. Some artificial drying techniques are listed below.

3.2.2.1. Ultraviolet Radiation Drying

Electromagnetic radiation is used in ultraviolet drying. Monomer structured coatings and dyestuffs are processed by drying under UV radiation. 39 The biggest problem in the application of ultraviolet drying is the high investment cost [54].

Examples of conduction drying include drying cylinders or balls, flat surfaces, open pots, and immersion heaters. The material to be dried must be in contact with the heating surface. In these systems, the amount of moisture prevents overheating. Conveyance drying systems are generally used for drying paper products. In conduction drying; High drying speed, constant heat and mass transfer conditions cannot be provided, the system cannot be controlled as desired, its operation is generally expensive, undesirable working conditions occur around the machine [55].

3.2.2.3. Infrared Radiation Drying

Drying is provided by thermal radiation, infrared lamps, steam heated sources, gas heated incandescent reflectors and electrically heated surfaces. Infrared is effective only on the surface of the material and near the surface. It is therefore suitable for drying thin layers. Infrared heating is used to dry materials such as paper, textiles 40. If the material to be dried is flammable, the product should not be kept close to the heat source [54,55].

3.2.2.4. Vacuum Drying

In these dryers, drying takes place under vacuum at low temperatures. This method is applied in drying heat sensitive products or in products whose moisture content needs to be reduced to low levels [56].

3.2.2.5. Mix Bed Drying

By using a vibrating rack or conveyor, a homogeneous drying is obtained as a result of the material vibrating continuously and at certain intervals. The same result is

obtained by fluidizing some of the bed on the perforated rack or conveyor. It is suitable for drying grain [54].

3.2.2.6. Fluid Bed Drying

The working principle of this type of dryers is based on delivering the hot drying air to the solid particles to be dried at a certain speed from the bottom. This speed is chosen so that solid particles are suspended in the air. The function of the heated air is to create the anti-gravity effect required for both drying and fluidization. This type of dryer can be designed to dry the product in bulk. Temperature can be up to 100 ° C in fluid bed dryers. Some types also have vibration units to move the material to be dried. Drying air is passed through the granular materials in the fluidized bed. Air velocity should be adjusted very carefully. Since the contact between the powder or granular dryers material and the fluidizing gas is very good, heat transfer between the drying air and the particles also takes place effectively. With this mechanism, it is possible to dry the materials without the risk of large temperature differences.

The most important advantage of this system, which allows automatic loading and unloading, is that the drying process is completed in a short time. This type of dryer is suitable for drying coal, limestone, phosphate, plastic and medicine tablets [42,54,55]. Figure 3.5 shows the structure of the fluidized bed dryer.
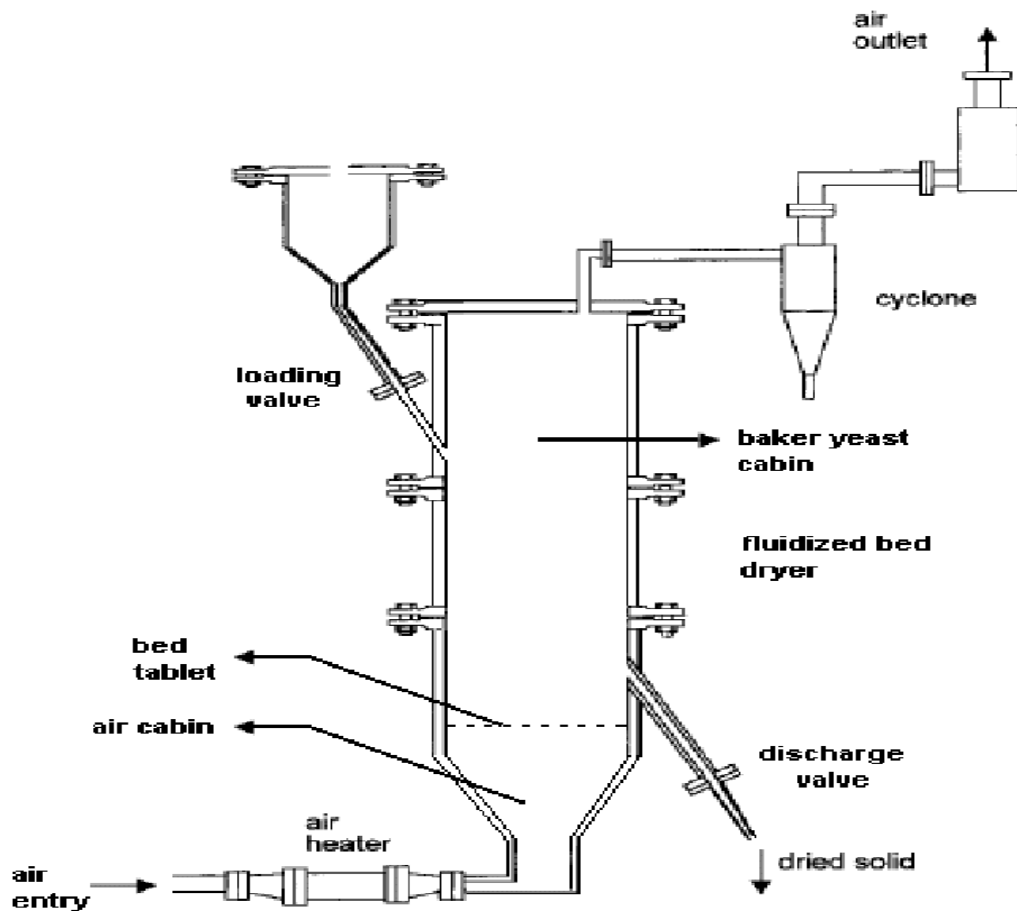
Figure 3.4. Fluid bed dryer.

3.2.2.7. Drying in Hot Steam Environment

In the process of drying in the superheated steam environment, the solvent (water or organic liquid) evaporated during the drying process with air or another gas must be dispersed into the static gas film to reach the bulk gas stream. The gas film, its resistance to mass transfer and the amount of drying vary depending on the rate of release of the solvent vapor.

The thermal efficiency of this method is high, and the solvent is easy to recover into the system. In addition, excessive drying and oxidation caused by air and other chemical reactions are not observed [55].

3.2.2.8. Flash Drying

Evenly divided solid particles in flash drying systems can be quickly and properly dried by spreading into the hot gas stream [55]. There are application examples in pigment, synthetic, resin, food products, paper production [54].

3.2.2.9. Tunnel Dryer

If the amount of product to be dried is large and the general properties of the product are identical with the degree of dryness, it is more appropriate to use continuous type dryers. The substance to be dried is placed in trays on the wagons and passed through the long tunnel. This process is arranged either in the form of continuous wagons or as one wagon leaves the tunnel while another loaded wagon enters the tunnel. In various types of tunnel dryers, the directions of movement of air and product relative to each other are different. If the wagons and hot air move in the same direction, this type of tunnel is called a "parallel flow tunnel". In this type of tunnel dryers, the drying air first encounters the new product. While the drying air cools and increases its humidity in the process, it comes into contact with the further dried product. This situation causes the dried product to absorb moisture again, even if a little. The diagram of a parallel flow tunnel dryer is given in Figure 3.5.
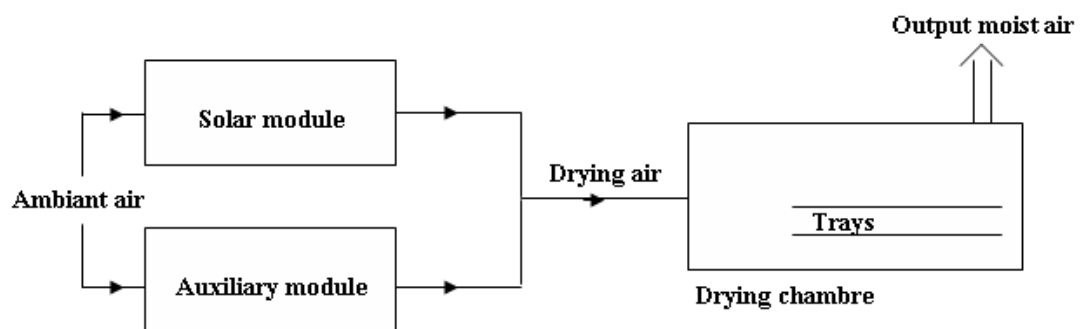

Figure 3.5. Tunnel dryer.

If the drying air and the movement of the wagons are in opposite directions, this type of tunnel is called "opposite flow tunnel". In this type of tunnels, hot and dry air first comes into contact with the most dried product. In these types, hot and dry air first

comes into contact with the driest product, then with the product with high humidity, while the humidity increases gradually by cooling. Figure 3.6 shows the diagram of the counter flow tunnel dryer.
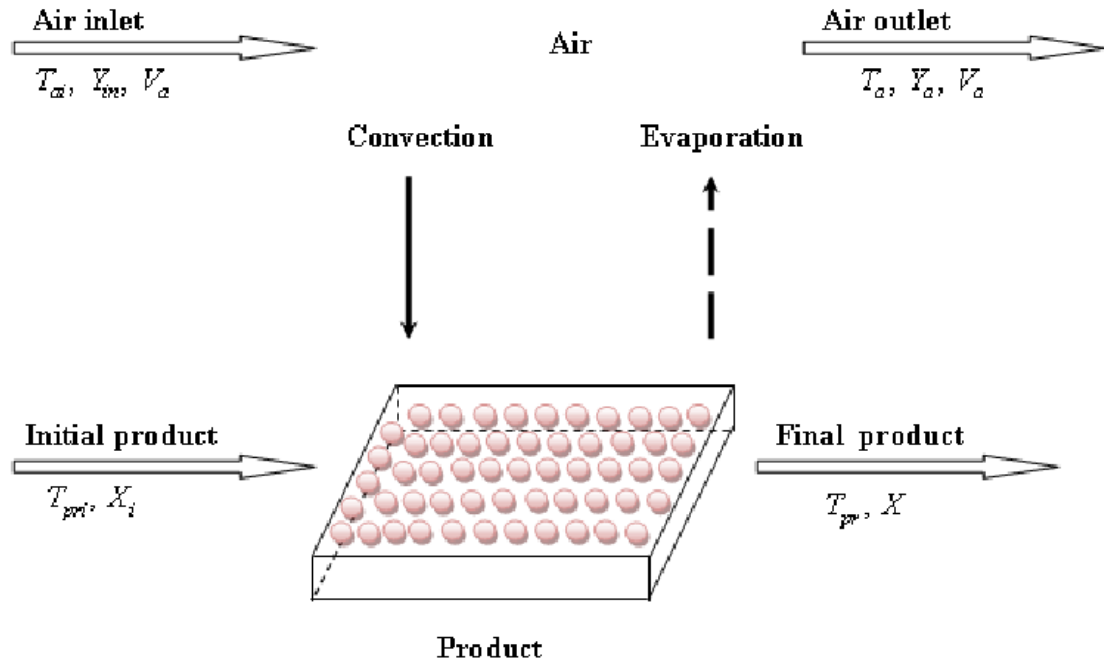
Figure 3.6. Counter flow tunnel dryer [62].

The most common systems for drying fruit and vegetables are parallel or counter flow tunnels. The drying characteristics of the counter flow tunnel and the parallel flow tunnel are different. In parallel flow tunnels, the initial drying rate is very high. Since the surface of the product dries very quickly, there is very little shrinkage or wrinkling in the product. However, voids and cracks occur in granular products. Since the drying air is relatively cold and very humid at the end of the drying tunnel, the final stage of drying takes place very slowly. In counter flow tunnels, as the material dries, it encounters more favorable drying conditions. The first stage of drying takes place with colder and more humid drying air and since the difference in moisture distribution is not much in the dried product, there is a complete and unimpeded wrinkling. The counter flow tunnel is particularly suitable for soft fruits such as plums. Otherwise, the sap water flows out in the first stage of drying. Besides, it is used in cross flow tunnels [57].

3.2.2.10. Spray Dryers

Spray dryers are used in the production of milk powder, coffee, soap and detergent. Because the dried material has the same structure as the droplet or particle structure and the drying time is very short. Liquid materials can be dried in large quantities when dried in spray 44 dryers. Spray dryers can be in the form of two fluid nozzles, high pressure nozzles, or rotating discs.

While the air temperature varies between 93 - 760 ° C, special construction materials are used for high temperatures. The higher the air temperature, the higher the thermal efficiency, so higher temperatures are preferred. Even temperature sensitive products can be dried thanks to the low drying time. The rotating type spray dryer is given in Figure 3.7 [55].
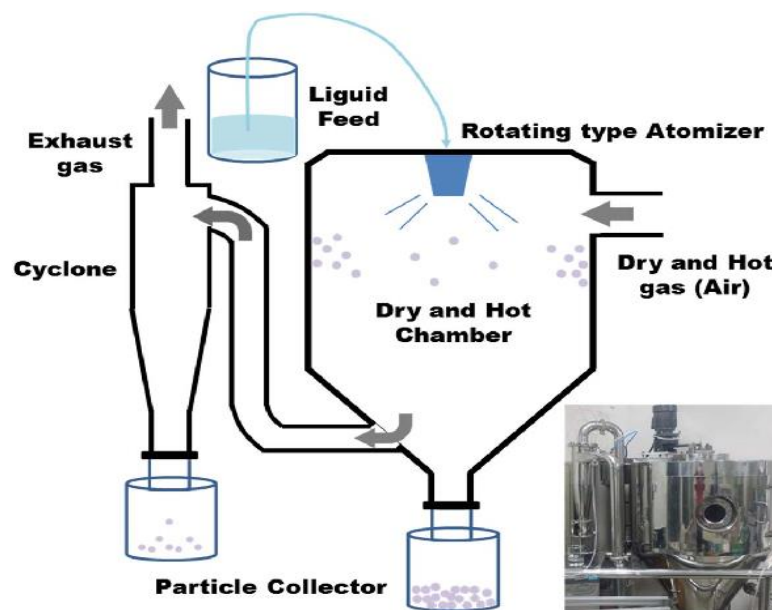
Figure 3.7. Rotating spray dryer.

3.2.2.11. Rotary Dryers

The products to be dried in rotary dryers must be in granular or crystalline form and must be dry enough to be transported by one of the transportation methods generally applied before drying. In addition, the product should have little to no adherence to

cause buildup on the dryer walls. All rotary dryers have a cylindrical body, whose axes are set at a small angle with the horizontal and placed on wheels that will rotate themselves around their axes.

The product to be dried is fed to the dryer from the higher end of the dryer, moves slowly towards the lower end 45 of the dryer with the help of the rotating movement of the dryer and is discharged from there. The progress of the product to be dried in the dryer, its mixing and better contact with the drying air are provided by the shelves and fins in the dryer [57]. The scheme of the rotary dryer is shown in Figure 3.8
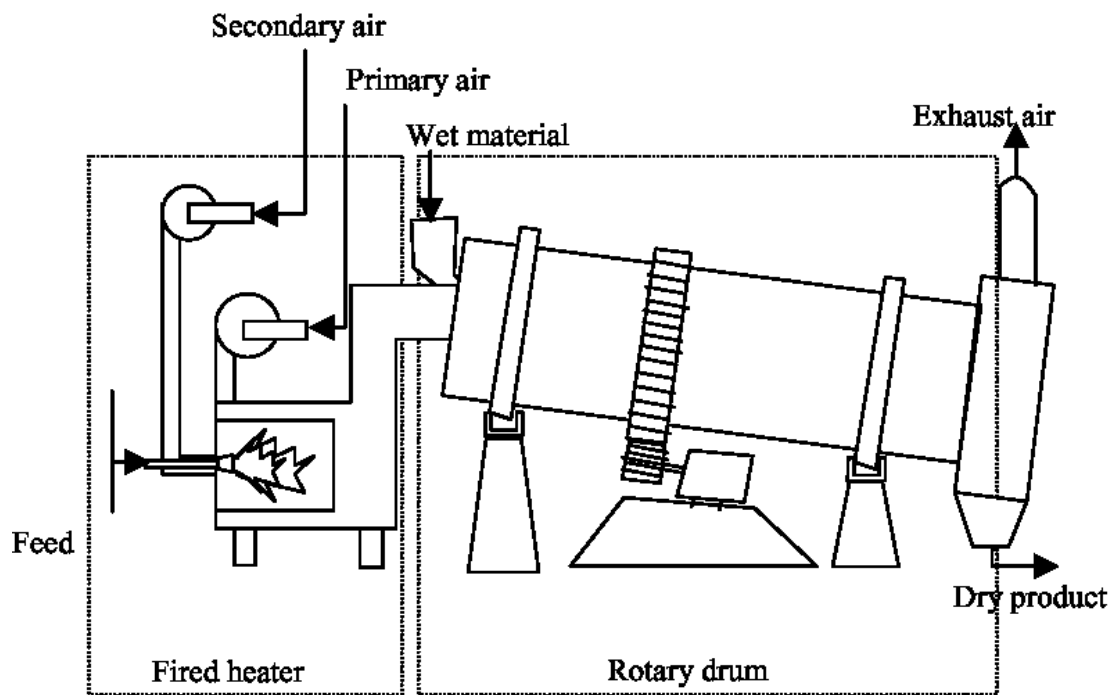
Figure 3.8. Rotary dryer.

3.2.2.12. Cabinet and Compartment Dryers

There are many models such as cabinet dryers, heated ceiling systems (these systems only provide natural convection and generally a weak and uneven drying), forced convection and more complex systems with specially designed compartments. In this type of dryers, the drying process is done by laying in trays to increase the surface

area of the material to be dried. In Figure 3.9, the cabinet dryer used in drying the products is given [99].
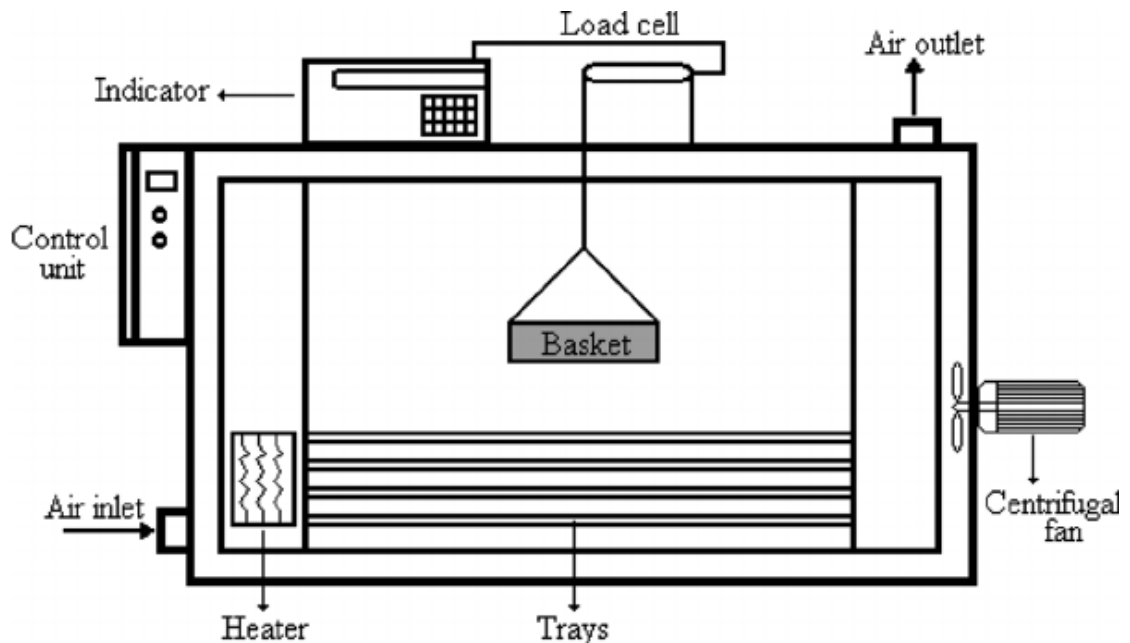
Figure 3. 9. Cabinet dryer.

3.2.2.13. Dielectric Drying

In this type of drying, thermal energy is generated inside the material placed in an electromagnetic field with a very high frequency in the radio frequency or microwave region. The heat generated as a result of molecular friction due to rapid changes in the direction of the electromagnetic field alters the polar flow. Since the dielectric constant of liquid water is much higher than that of many solid materials, heat is generated in the water-containing part of the material. This event is removed from the material by evaporating water [58].

3.2.2.14. Microwave Drying

A very high frequency (900 to 5000 Mhz) power supply is used in microwave drying. Since it is applied to heating non-conductive materials, it can be described as a dielectric heating form. Microwave drying is applied to thin materials in the form of strips. The protective measures required to be taken at the entrance and exit of the

system make it difficult to work continuously. The safety measures required to operate the system make microwave drying more expensive than dielectric drying [54].

3.2.2.15. Apphertization

Foodstuffs are sterilized for 10 to 15 minutes at 110 ° C to 115 ° C in hermetic containers and stored. This method is particularly used to process infant formula, dietetic food and fruit nectars [53].

3.2.2.16. Freeze Dry

Freeze drying is based on sublimation. Sublimation is the process of evaporation of water from the frozen product under the triple point, ie 0.6113 kPa pressure and 0.01 ° C, in a closed environment. Since the water does not become liquid during this process, the product does not deteriorate. The water crystals in the frozen product evaporate in the pores of the product and do not damage the cell wall in the product. This process does not spoil the color, structure and appearance of the product and also makes the product look fresh.

Freeze drying is used for drying very sensitive heat sensitive materials. Freeze drying is primarily used in the drying of serum, bacteria and virus cultures, in the pharmaceutical industry and in the drying of foods (coffee, milk powder, etc.). The material to be dried is first frozen between -20 and -40 ° C according to its properties. This freezing process can be carried out in any conventional freezing arrangement. It is then quickly taken to the drying cell. The drying cell is vacuumed with the help of a vacuum pump and the ice in the frozen material is sublimated and the drying process of the material takes place. The advantages of freeze drying are that when water is added to the dried material again, it reaches a structure that is very close to its pre-drying structure, the shelf life of the dried material is extended, its weight is reduced, storage space is saved and it is stored at room temperature.

PART 4

METHODOLOGY MATERIAL AND METHOD

4.1. MATERIEL

4.1.1. Carrots

A tentacle root plant., Utilizing its root found in the soil. It has several colors, purple, reddish-purple, yellow and close to white.Whenever the carrots are redder, this indicates an increase in the carotene content that the body needs by 1.5 mg per day.

Figure 4.1.. Carrots [62].

Plant the carrots in well-drained, crisp, clean soil free of stones in a sunny area for some time and canopy for each other in hot weather. Seed the seeds to a depth of at least 2 cm, with an ample amount of natural fertilizer and a little nitrogen.

Carrots have many benefits, and they can be used as food and medicine in treating kidney infections. Carrots also have antibiotic properties, as they destroy bacteria that appear in the intestine.

4.1.2. Measuring devices (SCANVAC COOLSAFE)

A freeze-drying device (SCANVAC COOLSAFE) in master thesis energysystemsendineering. for master thesis this device purchased within the scope of the project used. The thesis work done is done with this freeze drying device. has been carried out. The approximate price of the device is worth 100,000 $.

Figure 4.2. Scanvac coolsafe.

The CoolSafe range of Freeze Dryers CoolSafe 4-15 L is an outstanding and versatile range of advanced bench-top freeze dryers. They are the product of more than 40 years' experience and expertise, and are the ideal choice for research, process development and small-scale production. Available in 3 different capacities: 4 litres

and 9 litres and 15 litres. All come with a choice of condenser temperatures and a wide range of high-quality chambers and accessories. All models offer both simplicity of operation and the highest performance characteristics to meet the demands of today's research and development laboratories.

Device features

1. Material trays   4pcs
2. Material tray size   Dia.200mm
3. Condenser capacity   4L
4. Condenser Temp.   -55C/-80C
5. Vacuum degree   <5Pa
6. Defrosting   Natural
7. Control Type   Touch Screen
8. Power Install   1340W(-55C)/1520W(-80C)
9. Voltage   110V/60Hz/1P,220V/50-60Hz/1P
10. Machine Size(Without Drying chamber) 615*450*370(-55C),850*680*410(-80C)

4.1.2.2. Precision Balance

METTLER TOLEDO MS303S brand precision scales were used to measure the weights of the samples used in the experiment and the continuous weight change in the drying process. Technical features of this scale are presented below.

Figure 4.3. Precision balance^.

Device features

1. Max. capacity   320 g
2. Legibility   0.001 g
3. Repeatability (sd)   0.001 g
4. Linearity   0.002 g
5. Fixing time   1.5 s
6. IP Protection   IP54
7. Height storage area   165 mm
8. Weighing area dimensions 127x127 mm
9. Scale dimension   LxWxH 347x204x280 mm

4.1.2.3. Fridge

We frozen the carrots to take the moisture inside. Sublimation means going from solid to vapor phase, and in order to do this, we first freeze the moisture in the carrots and then pass that frozen moisture directly to the vapor phase. And the carrot has dried.

Figure 4.4. Fridge [62].

4.2. METHOD

4.2.1. Carrots and its Properties

In this study we will dry the carrots. Carrots are flexible and delicious. It has been used for medicinal purposes for thousands of years, as it contains high levels of beta-carotene, which in the human body converts to vitamin A, and gives carrots their distinctive orange color and forms a large part of its nutritional value. Besides positive effects on eyesight, it has a wonderful effect on the skin, benefiting those who are exposed to external radiation therapy. Besides being rich in vitamin A, it is also considered a good source of vitamin K and potassium. It also contains vitamins B12 and E. It is known to contain the antioxidant nucleus. It is useful for reducing free radical cell damage and boosting the immune system during chemotherapy.

Figure 4.5. carrots [62].

The carrots are washed and cut into two types of slides 5 mm and 7 mm with size 100 gm and are prepared in the laboratory to be ready for the experiment.

4.2.2. Preparing Carrots for Freezing Drying

We get the carrots to their laboratories in energy systems endineering. We prepare carrot models, then separate 5 mm from 7 mm. Then we record the weights using a sensitive balance, As in the Figure 4.6.   sliced of carrots.

Figure 4.6. Sliced of carrots [62].

4.2.3. Freeze Drying of Carrots

SCANVAC COOLSAFE   for freeze drying of carrotsthis device is used. carrots prepared in advance and laid on a trayThe cover was closed by sweating inside the device, the drying chamber temperature setting and the temperature change according to time, the machine is switched on.

Figure 4.7. Freeze drying of carrots by scanvac coolsafe

The settings made from the setup panel for the experiment are shown below.

Drying Room Pressure 0.1 kPa

Freeze Stage

-35 ° C........................ 24 hours

Drying Phase

-40 ° C........................ 120 min
-40 ° C........................ 240 min
-40 ° C........................ 360 min
-40 ° C........................ 480 min
-40 ° C........................ 600 min
-40 ° C........................ 720 min
-40 ° C........................ 840 min

4.2.4. Determination of Weight Loss During Drying of Carrots

In determining the weight loss, the sliced of carrots 5mm and 7mm with wight 100gr will be placed in a petri dish. It was weighed and then put into the device and the freezing process was performed (Figure 4.8.)

Figure 4.8. Cattots sliced in a petri dish.

In the first 120 minutes, the pressure is reduced to 0.1 kPa and the product is up to-40 ° C.kept frozen. During this period, the water content in the product is ice crystals. is provided to become. Actual drying i.e. sublimation event after 120 minutes is carried out. After this time, the temperature increase is applied and the evaporation of ice crystals from the product before they pass into the liquid phase provided. Weight losses in our experiments will be measured every two hours. has been set to. For this process, the first product was put into the device as 100 gr, 4 hours Then it was taken from the device and weighed and recorded. Same process with another productRe-applied as 100 gr and this time weight loss after 6 hourshas been recorded. These processes are applied as 2, 4, 6, 8, 10, 12 and 14 hours and the first 2 The graph of weight loss due to time after hours is given in Figure 4.9.
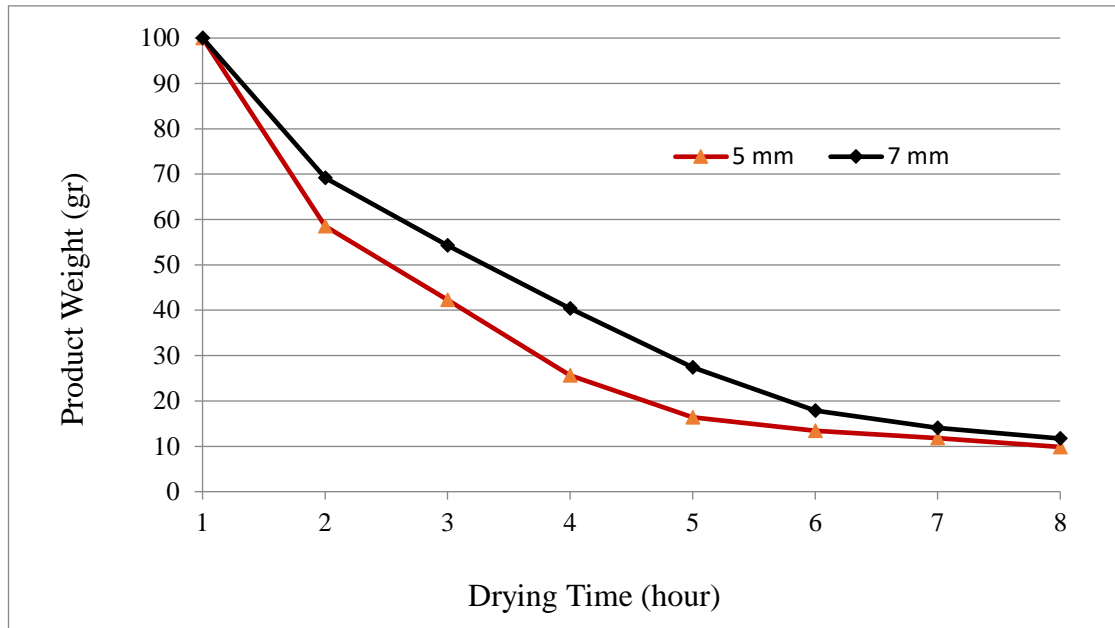
Figure 4.9. Time-dependent weight loss graph.

After each product is taken from the device and the weight losses are recorded, Figure 4.10. It was laid on papers as you can see.

Figure 4.10. Carrots Weight loss recorded products.

4.2.5. Determination of Drying Humidity and Drying Constants

Theoretical models can be applied for all kinds of items and conditions. But the solution The equations required for reduces the usefulness of the models. Semi-theoretical models are less complex Although the parameters they contain are only related to the products considered, restricts its use. In determining the drying rate based on the data obtained through experimental means, there are no complex mathematical equations. However, the equations obtained are It applies to sample and test conditions. Among the semi-theoretical models commonly used equation as "logarithmic drying" equationIt is known [60]. The change in moisture content (MR) over time (t), which is a dimensionless term, is given below can be determined equally.

$$MR = \frac{Mt - Md}{M0 - Mt} \qquad (4.1)$$

In the equation (M0) the initial humidity, (Mt) the humidity at the time t, (Md) the equilibrium humidity. The part on the left side of the equation gives the moisture content (MR) values at different times of drying. Some of the models used to explain the moisture content (MR) are given in equation4.1 [60].

Table 4.1. Mathematical Models used to explain drying curves.

Model No	Model Adı	Model
1	Newton	$MR = \exp(-kt)$
2	Page	$MR = \exp(-kt^n)$
3	Geliştirilmiş Page I	$MR = \exp\left[-(kt)^n\right]$
4	Henderson ve Pabis	$MR = a.\exp(-kt)$
5	Logaritmik	$MR = a.\exp(-kt) + c$
6	İki terimli- eksponansiyel	$MR = a\exp(-kt) + (1-a)\exp(-k\,a\,t)$
7	Wang ve Singh	$MR = 1 + at + bt^2$
8	Difüzyon Yaklaşım	$MR = a\exp(-kt) + (1-a)\exp(-k\,b\,t)$

The standard error of the estimation (RMSE), chi-square (x^2) values and the modeling adequacy (R^2) of the model can be found with the help of the following equations in order to statistically explain the harmony between the experimentally found models and the predicted humidity values.

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{tahmini} - MR_{deneysel}\right)^2\right]^{\frac{1}{2}} \tag{4.2}$$

$$X^2 = \frac{\sum_{i=1}^{n}\left(MR_{deneysel} - MR_{tahmini}\right)^2}{N-Z} \tag{4.3}$$

$$R^2 = 1 - \left[\frac{\sum\left(MR_{deneysel,ort} - MR_{tahmin,ort}\right)^2}{\sum\left(MR_{tahmin,ort}\right)^2}\right] \tag{4.4}$$

$MR_{deneysel}$	: Humidity rate determined by experimental data,
$MR_{deneysel,ort}$	: Average of experimental moisture content values,
$MR_{tahmini}$	: Estimated humidity,
$MR_{tahmini,ort}$	: Average of estimated moisture content values,
N	: Number of experimental data,
Z	: It is the coefficient number in the model used.

Estimated standard error (RMSE), experimental data with estimated values obtained with the model shows the deviation between values. Also, the decrease in the khi-square (x^2) value It is stated that compliance with Besides these, explaining the experimental data The model's adequacy (R^2) value is close to one. is an indicator of availability [61]. Statistical evaluation According to the results, the coefficients found in the most suitable model are calculated by multiple regression method. determines.

PART 5

EXPERIMENT RESULTS

In the post-harvest carrots, the best to be done to preserve fresh stigmas the important process is drying. Drying method, the quality of the carrots It has a significant effect on its parameters (color, aroma and taste). Depending on the availability of technical equipment, to reduce the moisture of the mound called different drying methods from region to region and country to country.is used. The drying method commonly used worldwide is natural sun drying. Drying in heated dark rooms as well as traditional method in Spain and Iran is also done. The traditional sun drying methods in Greece and Turkey is used. As a result of the experiments, the carrots grows in our country and the world In addition to freeze drying of carrots, in this freeze drying we are used SCANVAC COOLSAFE device in the laboratory. Before drying the carrots samples of the device, pressure and time dependent temperature change settings were made. According to these settings Drying chamber pressure is kept constant at 0.1 kPa, freezing at -40 ° C for the first 120 minutes phase, the drying phase was started at -35 ° C for the next 120 minutes and then the specified the desired temperatures were reached at times. During reaching these temperatures, the product the water, which crystallizes by freezing in it, evaporates from the product pores and gone away by sublimation.

In table 5.1. show Freeze dried weight loss of carrot slices, we are dried every two hours from 2 hours to 14 hours.

Table 5.1. Show freeze dried weight loss of carrot slices.

Freeze Dried Weight Loss of Carrot Slices		
Saat	5 mm	7 mm
0	100	100
2	58.554	69.178
4	42.268	54.276
6	25.619	40.398
8	16.372	27.421
10	13.428	17.847
12	11.776	14.061
14	9.856	11.717
Stable	9.042	10.11

From the data we got from the humidity calculations every two hours in the light of the data obtained, applications were made on a total of 10 models and the most suitable of these models was determined by regression analysis. These determination criteria depend on R^2, x^2 and RMSE obtained from the models. Here R^2 is close to one Khi-square (x^2) and the estimated standard error (RMSE) is close to zero is an indication that the model is the most suitable model for the experiment.

In the following (Figure 5.1.) it shows us the relationship between humidity and time in the hour during the drying process for carrots sliced 5mm and 7mm, which shows us the decrease in the humidity ratio to approximately 0.008949 for 5mm and 0.017877 for 7 mm
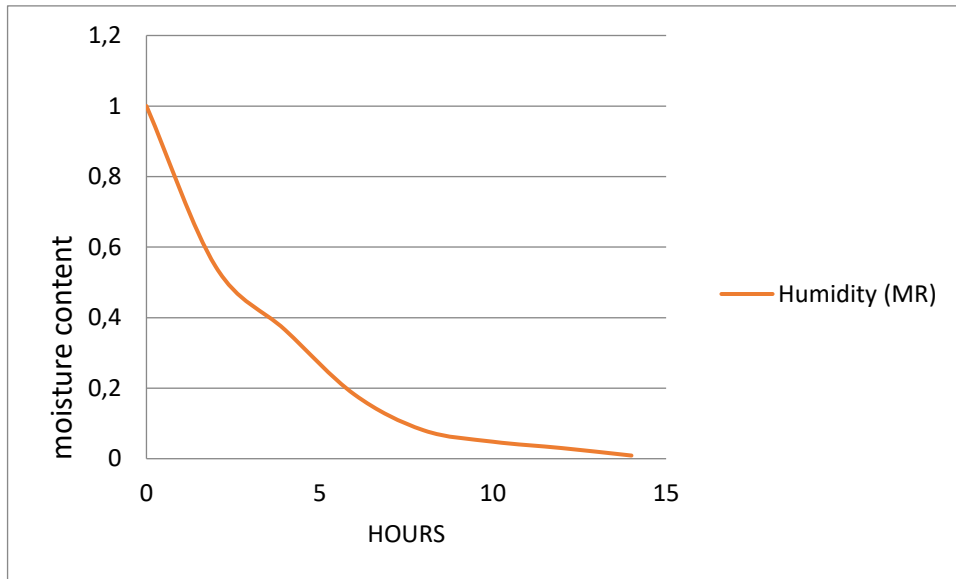
Figure 5.1. The relationship between humidity& time during the drying process 5mm.
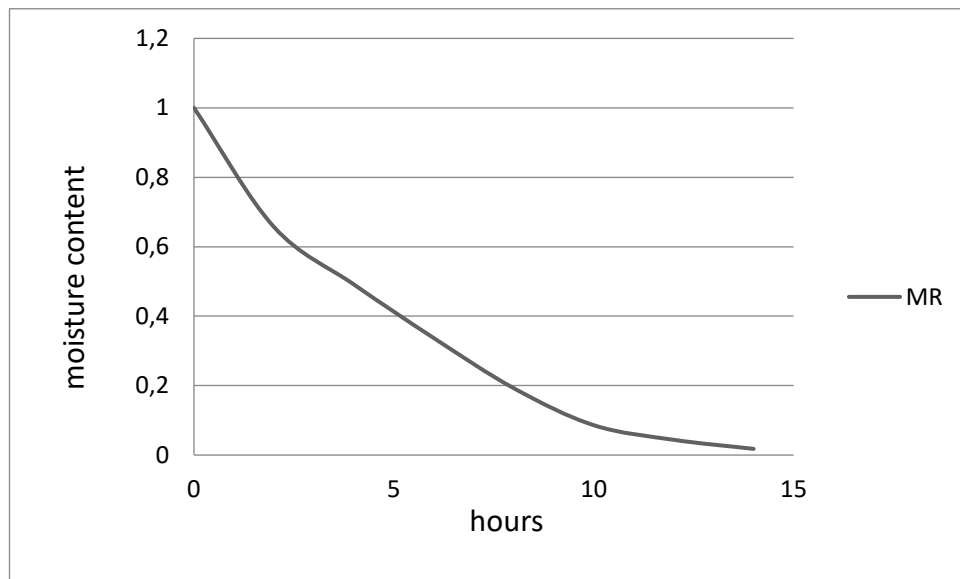

Figure 5.2. The relationship between humidity& time during the drying process 7mm.

carrots sliced As a result of freeze drying, 8 different regression analysis Constant numbers (a, k, n and b) and statistical error values (R^2, x^2 and RMSE) of mathematical models are given in Table 5.2.

Figure 5.3. Statistical error values (R^2, x^2 and RMSE) of mathematical models.

Model No	Samples (mm)	Model parameters	R^2	X^2	RMSE
1	5	k = 0,2834	0.9956	0.00048221	0.01989184
	7	k = 0,203	0.9885	0.00137433	0.034677683
2	5	k = 0,2782 n = 1,012	0.9962	0.00052435	0.019830898
	7	k = 0,1597 n = 1,133	0.9906	0.00111842	0.028962264
3	5	k = 0,3006 n = 0,9776	0.9982	0.00074693	0.023668484
	7	k = 0,1917 n = 1,286	0.9861	0.00166132	0.035298552
4	5	a = 0,9978 k = 0,2828	0.9962	0.00052666	0.019874495
	7	a = 1,011 k = 0,2052	0.9868	0.00157694	0.034390515
5	5	a = 1,01 c = -0,01652 k = 0,2696	0.9987	0.0004515	0.018565707
	7	a = 1,108 c = -0,1885 k = 0,1573	0.9949	0.00061046	0.019532936
6	5	a = 1,339 k = 0,3093	0.9963	0.0005089	0.019536411
	7	a = 0,001989 k = 101,9	0.9865	0.00161294	0.034780848
7	5	a = -0,1861 b = 0,008529	0.9726	0.00380867	0.053446242
	7	a = -0,1476 b = 0,005604	0.9918	0.00098255	0.027146104
8	5	a = 0,03202 b = 0,05582 k = 4,931	0.9962	0.00062677	0.019792268
	7	a = 6,564 b = 1,083 k = 0,2962	0.9897	0.00122402	0.027658831

PART 6

CONCLUSION AND SUGGESTIONS

6.1. CONCLUSION

In the summary of the experience of the freeze drying process, this process is one of the best ways to separate water from the product, which preserves the quality of foodstuffs in terms of their validity and on the other side, preserves their market value. In spite of this process, the investment costs and the operational value are high and it takes longer than the drying process by the usual methods.

In this experiment we carried out a freeze-drying process of the carrots, in which two slices with different thikness of carrots were frozen, the first 5 mm and the other 7 mm with a weight of 100 g, Where the operation was carried out using a device (SCANVAC COOLSAFE) for a period of 14 hours, and with several measurements that were made, it was noticed that the humidity level decreased by more than 30%. This means that the product does not deteriorate, increases the storage process of the product, and does not fade its color.

Weighing freeze-dried carrot slices during a total of 14 drying hours loss data were recorded. It was applied on 10 different mathematical models using the MATLAB program. The error analysis of the models at the result v was made using the estimated standard error (RMSE), chi-square (x^2) and regression coefficients (R^2) in the models used. According to the results, it was determined that the Page model was closer to the experimental results compared to the other models. Statistical error values found for samples; R^2, x^2, RMSE values respectively It was found to be 0.018565707 for 5 mm and 0.019532936 for 7 mm.

6.2. SUGGESTIONS

1. When weight loss is required during freeze-drying, the productHe is put into the device and weighed at the required time, and the same again the next day, A new product is placed by weight in the device and this time it differs from the previous product.It is taken at the appropriate time, weighed and this process is repeated for each period. this processIt is a big waste of time and requires a lot of product andIt also increases the operating time of the device. SensitiveBy weighing scale, on the digital display, during the drying period full weightLosses can be shown.

2. It is placed carrots slices inside the freeze drying deviceWhen the desired weight is reached with the weight loss measuring system, the device itself closing and internal pressure to suit the ambient conditions adjustment and automatic control is a necessary element for the device.

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RESUME

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