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Drying of kanlıca mushroom by the hot air drying method and the investigations of Its effects on its quality

Kanlıca mantarının sıcak havalı kurutma yöntemiyle kurutulması ve kalitesi üzerine etkilerinin araştırılması

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Drying of Kanlıca Mushroom by the Hot Air Drying Method and the Investigations of Its Effects on Its Quality

Highlights

- *As the dried product, Kanlıca mushroom, the most consumed endemic plant spicy in terms of the vitamin and the mineral that it contains among the mushroom groups, has been used.*
- *By means of hot air drying, drying has been done at five different (30 °C, 40 °C, 50 °C, 60 °C and 70 °C) drying air temperatures. The best result in terms of water activity, colour changes, energy consumption and drying duration has been obtained in the experiments at 50°C.*
- *The colour analysis experiments result values were computed by drawing the drying value.*

Graphical Abstract

Experiments have been conducted at 30 °C, 40 °C, 50 °C, 60 °C and 70 °C drying air temperatures at different hour intervals of 7 hours 10 minutes, 4 hours 15 minutes, 2 hours 50 minutes, 2 hours 15 minutes and 1 hour 40 minutes respectively. After the experiments had been completed; by means of the data obtained, changing of moisture content according to the time has been calculated.

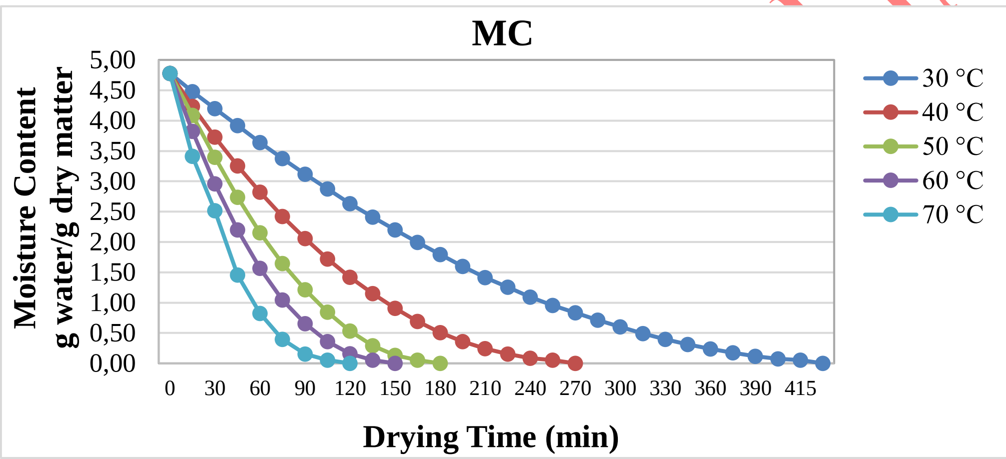

Figure 1. Changing of moisture content according to the time

Aim

Kanlıca mushroom, the most consumed endemic plant spicy in terms of the vitamin and the mineral that it contains among the mushroom groups, has been used. By means of hot air drying, drying process has been analysed at five different (30 °C, 40 °C, 50 °C, 60 °C and 70 °C) temperatures.

Design & Methodology

In our study, determination of the change of moisture content of Kanlıca mushroom dried at different temperatures, its water activity, its colour change, determination of its drying durations has been done.

Originality

Kanlıca mushroom collected from Karabük city; prevention of aflatoxin occurrence, shelf life extension, taking precaution against early putrefaction and decomposition, protection of the beneficent aromas in its content have been ensured.

Findings

The best result in terms of water activity, colour changes, energy consumption and drying duration has been obtained in the experiments at 50 °C. The water activity values of products (fresh mushroom water activity=0,983 aw) dried in hot air drying processes have been found in 0,429 and 0,173 interval (in literature lower than 0,6) and according to the colour analysis experiments result, L, a*, b*, C*, H_o, ΔE, BI values of Kanlıca mushroom dried at different temperatures have been calculated.*

Conclusion

According to the result of the analyses, it has been detected that the preservation of mushrooms by freezing and hot air drying is appropriate.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Drying of Kanlıca Mushroom by the Hot Air Drying Method and the Investigations of Its Effects on Its Quality

Araştırma Makalesi / Research Article

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ABSTRACT

In this study, by providing the hot air drying of Kanlıca mushroom collected from Karabük city; prevention of aflatoxin occurrence, shelf life extension, taking precaution against early putrefaction and decomposition, protection of the beneficent aromas in its content have been ensured. As the dried product, Kanlıca mushroom, the most consumed endemic plant spicy in terms of the vitamin and the mineral that it contains among the mushroom groups, has been used. By means of hot air drying, drying has been done at five different (30 ºC, 40 ºC, 50 ºC, 60 ºC and 70 ºC) temperatures. The best result in terms of water activity, colour changes, energy consumption and drying duration has been obtained in the experiments at 50 ºC. The water activity values of products (fresh mushroom water activity: 0,983 a_w) dried in hot air drying processes have been found in 0,429 and 0,173 interval (in literature lower than 0,6) and according to the colour analysis experiments result, L*, a*, b*, C*, H_o, ΔE, BI values of Kanlıca mushroom dried at different temperatures have been calculated. According to the result of the analyses, it has been detected that the preservation of mushrooms hot air drying is appropriate.

Keywords: Kanlıca Mushroom; drying; hot air drying; freeze drying; water activity.

Kanlıca Mantarının Sıcak Havalı Kurutma Yöntemiyle Kurutulması ve Kalitesi Üzerine Etkilerinin Araştırılması

ÖZ

Bu çalışmada, Karabük ilinden toplanan Kanlıca mantarının sıcak hava ile kurutulması sağlanarak; aflatoksin oluşumunun önlenmesi, raf ömrünün uzatılması, erken çürüme ve ayrışmaya karşı önlem alınması, içeriğindeki faydalı aromaların korunması sağlanmıştır. Kurutulmuş ürün olarak mantar grupları arasında içerdiği vitamin ve mineraller açısından en çok tüketilen baharatlı endemik bitki olan Kanlıca mantarı kullanılmıştır. Sıcak hava ile kurutma ile beş farklı sıcaklıkta (30 ºC, 40 ºC, 50 ºC, 60 ºC ve 70 ºC) kurutma yapılmıştır. Su aktivitesi, renk değişimi, enerji tüketimi ve kuruma süresi açısından en iyi sonuç 50 ºC'de yapılan deneylerde elde edilmiştir. Sıcak hava kurutma işlemlerinde kurutulan ürünlerin (taze mantar su aktivitesi: 0,983 a_w) su aktivite değerleri 0,429 ve 0,173 aralığında (literatürde 0,6 'dan düşük) bulunmuş ve renk analizi deneyleri sonucuna göre L*, Farklı sıcaklıklarda kurutulan Kanlıca mantarının a*, b*, C*, H_o, ΔE, BI değerleri hesaplanmıştır. Yapılan analizler sonucunda mantarların sıcak hava ile kurutularak muhafaza edilmesinin uygun olduğu tespit edilmiştir.

Anahtar Kelimeler: Kanlıca Mantarı; kurutma; sıcak havayla kurutma; dondurarak kurutma; su aktivitesi.

1. INTRODUCTION

Turkey is quite enriched in terms of natural eatable mushrooms that grow up at different environments, because of the geographic conditions and climate that it has. Mushrooms that have poisonous, uneatable, and eatable species; grow up at meadows, forests, on the parts of plants that had died and at the areas enriched in organic materials when the conditions such as temperature and moisture are appropriate [1]. In the drying study we had done, Kanlıca mushroom that is an endemic plant has been used. Turkey shows much diversity in terms of nature mushrooms that grow up at different environments. Kanlıca mushroom named as Lactorius has many species. The most expensive and most important of these are Lactarius delicious and Lactarius salmanicolor species. Mushroom species that belong to Lactarius genus; can be distinguished thanks to their milk. When any part of the

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mushroom is broken or cut; a liquid defined as milk that can be seen at different colors comes out. They are in shape of convex hat that consists of orange-yellowish rings [2]. This mushroom that can grow up on acidic and calcareous soil; is often encountered in forests, under coniferous plants, in pine and oak forests [3]. In our country, it often exists in regions where forest ecosystems are intensive such as Karabük, Bolu, Sinop, Bursa, Bartın, Kastamonu, Balıkesir. In public, it is named as pine breeze, sycamore, dirt, Melki, Tillice, scarlet red mushroom. It is the most desirable eatable wild mushroom speccy among the mushroom species in Turkey. It is mostly used for roasting, saute, pickle, roasting and pastry making, especially for grill [4]. The most extensively used one among the food preservation methods is the drying method. By means of drying method; free water inside the food is removed. The purpose in this method is making the product more resistant against microbiological, chemical, and enzymatic putrefactions by lowering the product's water activity (aw) under a certain value. Besides this, it is preferred for the purpose of providing that it is consumed outside its production season as well and that its shelf life increases for a long time. For the drying of fruits and vegetables, hot air drying method is applied the most. Dried food is exposed to hot air flow continuously. In these systems, heat is transferred from the drying environment to the food by convection. Hot air is passed above and through the food that will be dried. In order to provide heat for moisture evaporation from the product; energy is provided from the hot air (at certain velocity and relative humidity) flow and also, evaporated moisture, is removed from the product by means of air flow. The aim of this study is to investigate the drying behaviors of Kanlıca mushroom, that is the most consumed one among the mushroom species that can grow up at different areas in Turkey, at different temperatures. Since the time intervals in which they occur is limited; it has been aimed to provide that the product stands longer without putrefaction in storage by taking advantage of drying systems. In addition, by investigating the colour and water activity structures of dried products whose nutritive values are high, calculation of the quality parameters has been aimed. In literature, many studies related to drying, drying techniques, and drying of mushrooms have been investigated. Aktas; has designed, manufactured, and experimentally investigated a heat-pump aided PID-controlled dryer. He has analyzed the designed and manufactured dryer for the drying of hazelnut which is an important food product. He has tested the manufactured heat-pump aided dryer for the drying of hazelnuts and has done their energy analyses. In drying system; he has chosen the drying air temperature as 50 ºC, 45 ºC and 40 ºC. Inside the heat-pump aided dryer; at 50 ºC, 45 ºC and 40 ºC drying air temperature, hazelnuts have been dried in 24, 27 and 30 hours respectively. Drying air velocities have been observed as 0,25 m/s for 50 ºC; 0,32 m/s for 45 ºC and 0,38 m/s for 40 ºC [5]. Artnaseaw et al. has investigated the drying features of Shiitake mushroom and Jinda pepper which are species extensively grown up at the northeast of Thailand, under the varying conditions such as drying temperatures (50,55,60 and 65 ºC) and vacuum pressures (0,1; 0,2; 0,3 and 0,4 bar). Nine different thin layers mathematical drying model have been compared according to correlation coefficient, decreased khi-square and mean square root error in order to estimate vacuum heat-pump drying curves [6]. Cao et al. has analyzed the drying of Maitake mushroom (Grifola frondosa) whose first moisture content is high, by using the modified plate drying model. This model consists of three parameters as surface mass transfer coefficient H, dynamic balance moisture content M_E and drying constant K. They have dried Maitake mushroom at various air temperatures (35, 40, 45, 50 and 55 ºC) and relative humidities (% 30, 40, 50, 60 and 70) [7]. Engür has dried cultivated mushroom slices inside hot-air blow drying at different drying temperatures as 45, 55, 65 and 75ºC and 2 m/s air velocity. In addition, he has dried mushroom slices inside infrared dryers at different powers of 62, 74, 88 and 104 W. He has observed the effects of drying conditions on drying rate and on drying duration in both of the dryers [8]. İzli has determined the diffusion coefficients during the drying of mushrooms (Agoricus blazei) by means of hot air. They have applied experimental drying kinetics at different air temperatures (45, 60, 75 and 80 ºC) and air velocities (1; 1,2; 1,75; 2,3 and 2,5 m/s) to the sliced mushrooms. In dried mushrooms, they have detected diffusion coefficients as higher at high temperatures and high drying air velocities [9]. Öztürk has used Agoricus bisporus, Lentinus edodes, Pleurotus astreatus and Lactarius deliciosus mushroom species as material in his study. He has dried the mushrooms by freezing, by infrared and by using the drying methods in the oven after different pre-processing applications. He has investigated the changes of various nutrient elements such as reducing sugar, protein, mineral materials, and total phenolic material quantity besides the parameters that affect the quality features of the final product such as colour, rehydration capacity, antioxidant activity in investigated dried mushroom samples [10]. Kotwaliwale et al. has investigated the textural (hardness, stickiness, springiness, and chewing) and optical (spectral surface projection) features of the rice straw mushroom (Pleuratus spp) by hot air drying. Mushrooms have been dried at tray dryers at different air temperatures of 50, 55, 60 and 70 ºC. Texture Analyzer TM and Hunterlab TM calorimetry have been used in order to determine its textural and optical features respectively. They have calculated that the hardness and the chewing of the mushrooms during the drying is proportional to the temperature increase [11]. In our study, determination of the change of moisture content of Kanlıca mushroom dried at different temperatures, its water activity, its colour change, determination of its drying durations has been done.

2. MATERIAL AND METHOD

2.1. Theoretical Background

Drying system has primarily been preferred depending on the features of the product that will be dried and of the drying system. In the capacity calculation of the equipment necessary for this system, in the determination of the moisture content of the products and later in the analysis of the system, the equations represented in the form of items below have been used. In drying experiments, moisture content of Kanlıca mushrooms according to dry and wet basis are calculated by means of the formulas below respectively [12]:

$$MC_{KA} = \frac{YA - KA}{KA} \quad (1)$$

$$MC_{YA} = \frac{YA - KA}{YA} \quad (2)$$

Moisture Ratio (MR) is calculated by Equation 3; in the equation, MC_{KA} describes the moisture content, M_o the initial moisture content, MC_{YA} the moisture content at the balance situation on the other hand [12,13].

$$MR = \frac{M - M_e}{M_0 - M_e} \quad (3)$$

Because of the high moisture in the fresh product; the equation can be written as below by being simplified [5, 12, 27]:

$$MR = \frac{M}{M_0} \quad (4)$$

The changing of moisture content in the dried product per unit time is called the "drying rate". Drying rate has been calculated by taking the derivatives of moisture content versus drying time curves by the equation 5 below [13, 14]:

$$DR = \frac{M_{t+dt} - M_t}{dt} \quad (5)$$

Here, Mt being the moisture content at t instant and M_{t+dt} being that at (t+dt) instant [(kg water)/(kg dry matter)$^{-1}$], DR is the drying rate [(kg water)/(kg dry matter s)$^{-1}$] [15,16,27]. In order to determine the efficiency of the drying systems; drying efficiency, efficient diffusion effective coefficient and specific energy consumption criteria are benefitted. Energy efficiency of the dryers are usually determined by the moisture extraction rate. This value indicates the water mass removed from the product that will be dried, per unit kWh energy consumption (kg/kWh). Operating cost of a dryer is an important parameter for the energy efficiency [17, 18].

$$SMER = \frac{Moisture\ removed\ from\ the\ product}{Total\ Energy\ Input} \quad (6)$$

The mass of the moisture removed per unit time during the drying is moisture extraction rate (MER) and can be calculated by using the equation 7 below:

$$MER = \frac{Moisture\ removed\ from\ the\ product}{Drying\ time} \quad (7)$$

Specific energy consumption (SEC) has been described as the amount of energy necessary to remove the unit amount of water from the samples, during the drying of the samples. Its unit has been expressed as kJ/kg and it has been calculated by the equation 8 below [18]. Here,

$$SEC = \frac{\sum E}{m_w} \quad (8)$$

Drying efficiency, on the other hand; is expressed as the rate of energy consumed to remove the moisture from the product to the total amount of energy consumed [19,20].

$$DE = \frac{m_w x h_{fg}}{Q_t} \quad (9)$$

2.2. Experimental Study

In drying processes, the quality of the product depends on the appropriate adjustment of important variables such as drying temperature and relative moisture. In the situation in which these mentioned variables are not adjusted properly; the products can become dried without quality in a longer duration. Similarly, this causes high relative moisture and drying duration to become longer and due to that, more consumption of the energy.

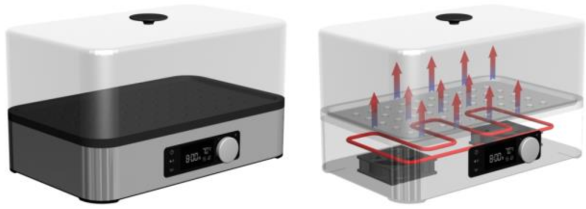

Figure 1. Hot air dryer

It is a natural preservation method that dries food with a hot air flow that can be adjusted between 30ºC and 70ºC. Vitamins, minerals, and nutritional values are preserved, and the flavor of food is enhanced. The dryer should always be used in accordance with the instructions given in the user manual. 5 drying racks are supplied with the device. Drying time also varies according to the drying air relative level of the room, the thickness of the slices and the level of drying required.

2.3. Determination of the Amount of Dry Matter of Dried Product

At the beginning of the drying, in order to determine the moisture content in the product, dry matter assignment must be done. Figure 2 shows what fresh kanlıca mushroom look like in general. Hot air dryer is a natural preservation method that dries food with hot air flow adjustable between 30°C and 70°C. Vitamins, minerals and nutritional values are preserved and the flavor of food is enhanced. The dryer should always be used in accordance with the instructions given in the user manual. 5 drying racks are supplied with the device. Drying time also varies according to the moisture level of the room, the thickness of the slices and the level of drying required.

Figure 2. General appearances of Fresh Kanlıca mushroom

Before beginning the experiment, in order to be able to determine the dry weight of Kanlıca mushroom, pre-preparation studies with wet Kanlıca mushrooms have been done. By throwing the stems of Kanlıca mushrooms that had been provided to be used in the experiment away, they has been sliced in 5 mm thickness. Pre-study is done by determining the moisture control according to the weight change of Kanlıca mushroom in the oven and by weighting Kanlıca mushrooms at certain intervals inside this oven that is kept at constant temperature (103±2 ºC) and by evaluating the measurement results. Measurement results obtained in the pre-study continues until the weight change of Kanlıca mushroom becomes less than 1 %. By continuing the weight measurements until the moisture amount of Kanlıca mushroom remains constant, in the situation in which weight between the last measurements is less than 1 %, Kanlıca mushrooms are assumed to be dry. By placing the sliced Kanlıca mushrooms whose initial moisture amounts had been determined, on the dryer grids; they have been made ready for the drying process. Weight changes have been measured by being tracked in every 15 minutes. Weight measurements obtained for five different temperatures have been recorded in digital environment. That way: the dry weight of the products has been determined. In Figure 3, the weight of sliced hookah mushrooms is measured.

Figure 3. Measurement of sliced Kanlıca mushroom weight

In the drying processes done, each experiment has been done for 30 ºC, 40 ºC, 50 ºC, 60 ºC and 70 ºC drying air temperatures and when the products had reached the final balance moisture amount, drying process has been ended. In the drying experiments, in Kanlıca mushrooms; operations have been done by considering the issues such as the final moisture amounts, water activities and color analyses.

2.4. Water Activity

Water activities of Kanlıca mushroom samples in fresh and dried form have been determined by using water activity measurement set (Testo-AG 650) with ±0,01 accuracy. For this purpose, approximately 3-4 g sliced Kanlıca mushroom samples have been placed inside the impermeable reservoir made of stainless-steel of the apparatus. In the water activity value, when there is a change less than 0,001 during 10 minutes, it has been assumed that the system reaches the balance and water activity value has been directly read from the gauge of the equipment. In general, water activity (a_w) of Kanlıca mushrooms most of which are dried, is low. For safe preservation, it is typically recommended that the water activity of the dried nutrient must be at a level less than 0,6. However; the nutrients of different types have different water activities. Low water activity prevents the growing up of various microorganisms, oxidation reactions and enzymatic reactions [21, 22]. When the water rate inside the nutrient reaches a balance with the relative moisture of the air of the ambience in which it takes place; by dividing the ambient air relative moisture by 100, water activity (a_w) at the present water rate that belongs to this nutrient becomes calculated and it is shown by Equation 10.

$$a_w = \frac{\varsigma_{bn}}{100} \quad (10)$$

2.5. Colour Analysis

In the study done in order to investigate the effect of drying process on the colour change of Kanlıca mushroom samples; colour values of the samples have been measured during the drying by a colour measurement device in the time intervals determined before. Colour measurements have been done from 3 different points and by taking the average of the obtained values, they have been evaluated [21]. Colour measurement is an important quality factor that indicates the quality and sensory attractiveness of the products dried by the drying process [23]. Colour parameters (L, a^*, b^*, c^* and h^0) and rehydration capacities have been determined. L^* value expresses the brightness, and it can take values between 0 and 100. L^* takes the value of 0 at black colour in the situation in which there is no reflection whereas takes the value of 100 at white colour in which there is full reflection. a^* value, on the other hand, is known as “redness value”. While positive “a” values represent the redness, negative “a” values represent the green colour. “b” value is known as yellowness value. While positive “b” values represent the yellowness, negative “b” values represent the blueness [24]. At zero intersection point ($a^*=0$ and $b^*=0$); colorlessness, namely, greyness occurs. Chroma value indicates the saturation of the colour. While the chroma values decrease in matt colors; they increase in vivid colors, on the other hand. Hue angle and chroma value have been calculated by the equations below [24]:

$$h^0 = Arctan\,\frac{b^*}{a^*} \quad (11)$$

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (12)$$

Another expression, on the other hand; is the browning index. Browning index represents the purity of the brown colour and is an important parameter in defining the changes that the browning reactions have made in product colour [25]. Browning index and the total colour change have been calculated by the equations 13 and 14 below [25]:

$$BI = \frac{[100(X - 0{,}31)]}{0{,}17} \quad (13)$$

$$\Delta E = \sqrt{((L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2)} \quad (14)$$

X value that takes place in the equation has been calculated from the equation below [25]:

$$X = \frac{a^* + 1{,}75L^*}{5{,}645L^* + a^* - 3{,}012b^*} \quad (15)$$

2.6. Uncertainty Analysis

The errors that can occur in the measurements done during the experiments, change according to the features of the equipment used. For the experimental data obtained; the most important factor that affects the correctness of the measured values, on the other hand, is the errors that can occur during the experiments [26]. In the measurement of a parameter in this experimental study done; by considering the errors that occur because of the constant errors, arbitrary errors and manufacturing errors, the total error can be calculated by Equation 16.

$$W_R = \left[\left(\frac{\partial R}{\partial x_1} w_1\right)^2 + \left(\frac{\partial R}{\partial x_2} w_2\right)^2 + \cdots + \left(\frac{\partial R}{\partial x_n} w_n\right)^2\right]^{1/2} \quad (16)$$

In Equation 16, R is the quantity must be measured; n independent variables that effect this quantity, on the other hand, is $x_1, x_2, x_3 \ldots x_n$. Error rates that belong to each of the independent variables are $w_1, w_2, w_3 \ldots w_R$ and the total uncertainty of R quantity is W_R. Technical features and error rates of the equipment used in this work have shown in Table 1.

Table 1. Technical properties of equipments.

The Equipments Used	***Technical Properties***	***Error Analysis***
Dijital Weight	KNMaster, CT-1000 The maximum measurable amount,1000g	±0,016g
Temperature and Moisture Measurement Device	Operation Temperature 30-70 °C WMF Dryer drying area 5 x 472,5 cm², 0-24 hours timer, ± 3 % measurement accuracy in relative humidity	± 2 °C
Water activity measurement device	Testo, 650 model a_w 0-1 interval	± 0.002a_w
Electricity Meter	1-Phase 2-Wired Electronic Electricity Meter, 230V-50Hz, Type:M600.2251, 0.25-5(100)A	±3-4 V
Thermostat	Temperature, Clock/Moisture HTC-2	±2°C
Colour Measurement Device	Hunter Calorimeter	±5.8

3. RESULT AND DISCUSSION

Since the formation and collection of Kanlıca mushroom occur at limited time durations in terms of climate conditions; in this study, by analyzing the drying mechanism, drying operation has been made at different temperatures. Figure 4 shows the dried mushroom slices dried at 50 °C. Experiments have been conducted at 30 °C, 40 °C, 50 °C, 60 °C, 70 °C drying air temperatures at different hour intervals of 7 hours 10 minutes, 4 hours 15 minutes, 2 hours 50 minutes, 2 hours 15 minutes and 1 hour 40 minutes respectively. After the experiments had been completed; by means of the data obtained, show Figure 5. Before beginning the drying experiment, moisture content of Kanlıca mushrooms have been decreased from 4,78 g water/g dry matter amount to the 0,05 g water/g dry matter amount according to the dry base by using Equation 1 content according to the time has been calculated.

Figure 4. Kanlıca mushroom slices dried at 50 °C

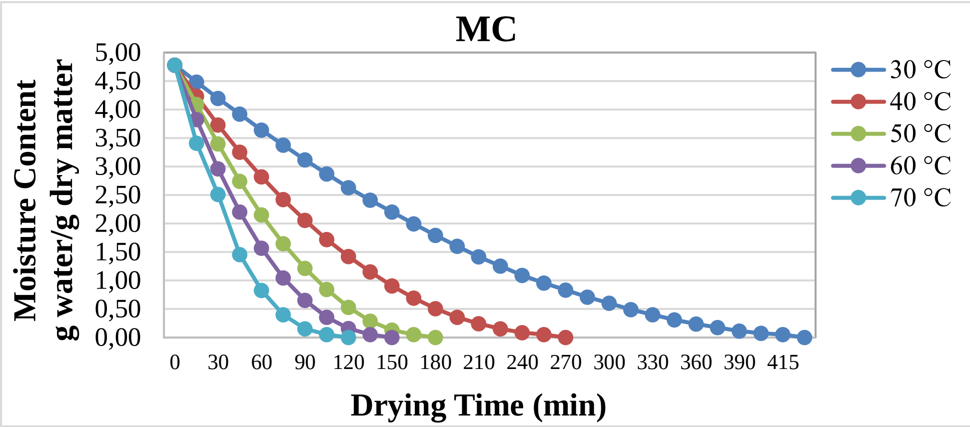

Figure 5. Changing of moisture content according to the time

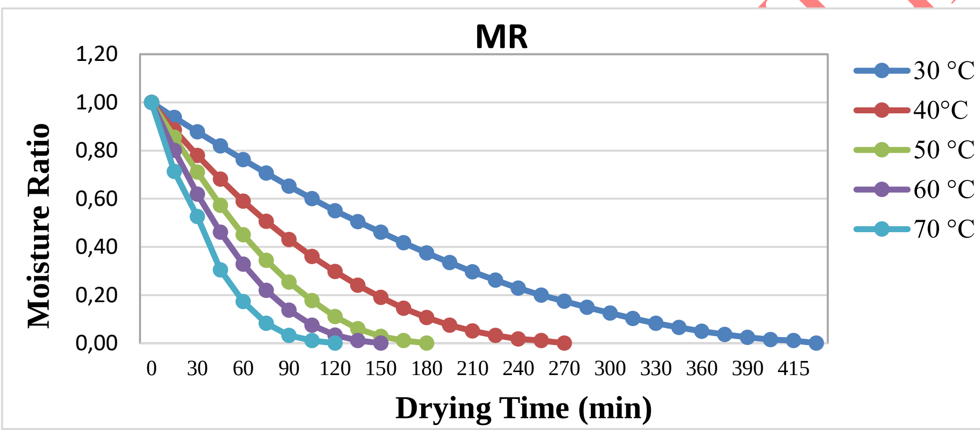

Figure 6. Moisture ratio -drying time

During the drying durations; changing of the moisture rates for Kanlıca mushrooms has been shown in Figure 6.In the experiments done, moisture rate has decreased from 1 to 0,01. As seen; according to the time, moisture rate has shown an inclination decreasing in a quite balanced way.

During the drying process, changing of drying rates according to the drying duration is shown in Figure 7. As the temperature increases, it has been observed that there is a rapid decrease in drying rate.

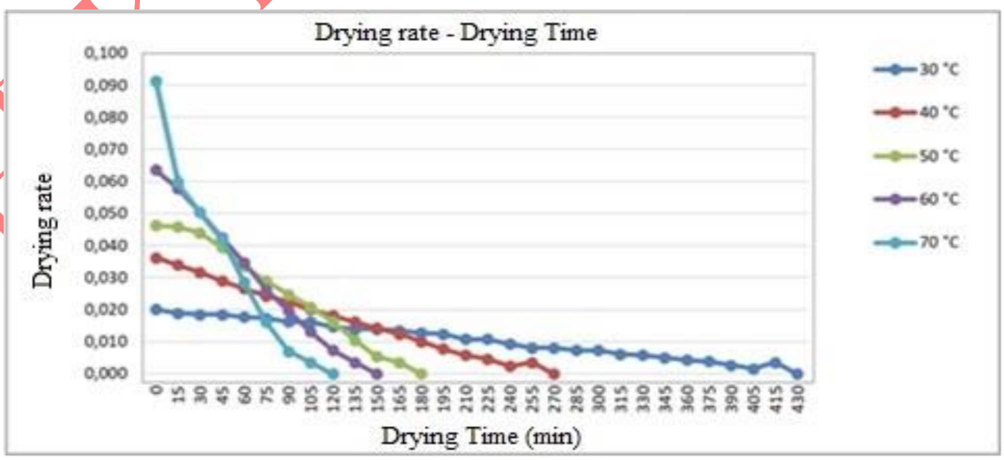

Figure 7. The changing of drying rate according to time

In addition to the weight measurements done in every 15 minutes; all the other data have been noted. All the experiments have been conducted under the same conditions. As seen in Figure 8; in the experiments done, differences in the energy consumption according to the time are observed. Amounts of energy consumed in the experiments have been calculated as 14600 kWh at 30ºC, 13680 kWh at 40 ºC, 9360 kWh at 50 ºC, 8800 kWh at 60 ºC, 7560 kWh at 70 ºC. Most of the total energy consumed is seen at 30 ºC and 40 ºC. As the temperature values had increased, decrease in the amounts of energy consumed has been observed. Increase of the drying durations has also caused the energy consumption to increase.

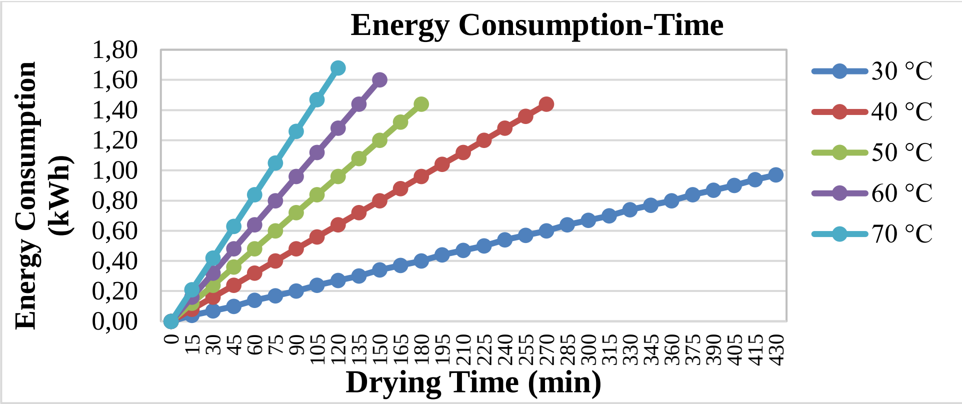

Figure 8. Energy consumption according to the time-time

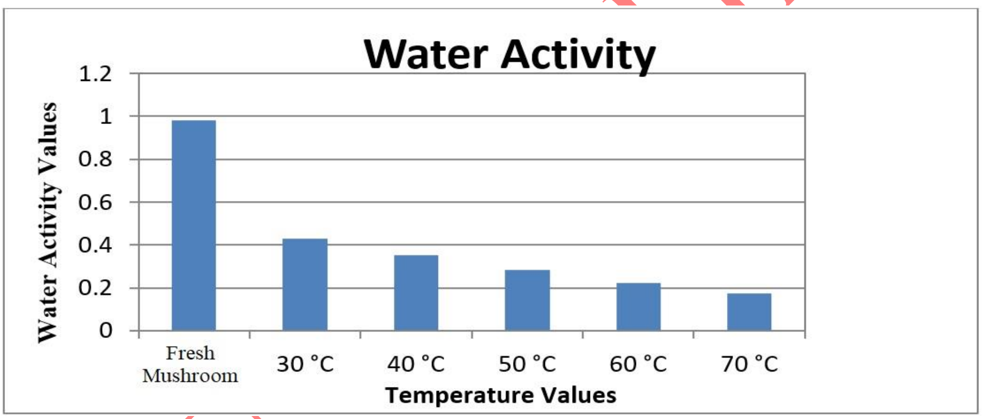

Figure 9. Water activity values according to the temperature

Water activity is a value considered in the preservation of the nutrients. The nutrients that have water activity value less than 0,6 are assumed to be safe in terms of no microbe proliferation. Figure 9 shows the water activity values depending on the temperature. After the drying operations had been completed in the experiments we had done; water activity and colour analysis experiments of the dried products have been done. As a result of the colour analysis experiments; L*, a*, b*, C*, H0, ΔE, BI values of Kanlıca mushrooms that are fresh and had been dried at different temperatures, have been reached. Table 2 shows the values measured in color analysis. The results obtained in the experiments done have been compared to the results of other studies that exist in the literature. As a result of the analyses, it has been seen that the system successfully enables the drying of Kanlıca mushroom.

Table 2. Measured values in colour analysis.

Drying Temperature	L *	a *	b *	C *	hº	BI	ΔE
Fresh Mushroom	47.93	14.20	20.82	25.20	55.70	587.46	1.45
30ºC	42.58	5.25	10.87	12.07	64.22	587.85	1.12
40ºC	36.00	5.07	8.57	9.95	59.39	587.86	1.02
50ºC	33.98	3.96	6.88	7.93	60.07	587.93	0.90
60ºC	34.05	3.01	5.98	6.69	63.28	587.99	0.56
70ºC	30.81	2.38	4.62	5.19	62.74	588.02	0.55

4. CONCLUSION

Within the scope of this study, the following results were reached.

- Moisture value known as the total water amount in nutrients; is very important to determine the shelf life, the microbial stability, the physical features, and the industrial processing processes of the nutrient. Before, during and after the hot air drying; measurements of the moisture amounts have been done. The initial amount of moisture of Kanlıca mushrooms whose dry matter amount had been determined, has been found as 4,78 g water/g dry matter. It has been dried until 0,05 g water/g dry material that is the last moisture amount.
- It has been detected that the drying time and the drying temperature are inversely proportional. In other words, it has been found that hot air drying lasts 7 hours 10 minutes at 30 oC, 4 hours 15 minutes at 40 oC, 2 hours 50 minutes at 50 oC, 2 hours 15 minutes at 60 oC, 1 hour 40 minutes at 70 oC. As the temperature increases, more energy transmission per unit time is provided.
- While the water activity value is 0,983 aw before hot air drying; this value has been measured between the values of 0,429 and 0,173 as a result of the experiments. By means of the hot air drying method; the product has been dried in shorter time and made ready to be storage compared to the other studies in the literature. The increase of the drying temperature and the decrease of the final moisture level according to that are important in water activity values.
- Storage, transportation, and usage of the dried Kanlıca mushroom slices are much easier than the fresh Kanlıca mushroom. In the system, Kanlıca mushroom can be dried at higher temperature; but, in this situation, while the drying duration decreases, some deteriorations in the dried product quality can occur.
- The best temperature value and the best drying performance obtained in drying of Kanlıca mushroom at different temperatures in the hot air drying have been found at 50 oC. Drying of Kanlıca mushroom at this temperature is recommended in terms of drying duration, energy, and quality parameters. In addition, it has also been observed that the physical and chemical properties are in the best results.
- Since the drying duration is long and the moisture content is high at 30 oC and 40 oC; these are not assumed as the ideal temperatures.
- The non-enzymatic browning reactions increased with the increase of the temperature as a result of the colour analyses have caused the decrease in L* value. L* had shown that its colour has darkened with the exchange product had been dried. When L* is investigated in terms of the colour parameter; the best colour has been seen to be at 40 oC-50 oC temperatures. The total colour change (ΔE) values; have been found in 1,42-0,55 interval for all the temperatures. The most colour change has been detected to occur at 60 oC and 70 oC temperatures. It has been seen that the differences in h0 values are small.
- Studies can be done for nutrient analysis and determination of vitamins and minerals in it. Increasing energy consumption in industry requires industrial enterprises to use energy in the most efficient way. With the improvements to be made in the drying mechanism, the instant determination of the moisture content of the food provides savings in the field of energy. In industrial drying, convective drying of cannabis can be done without deteriorating the food quality. In this study, sensory analysis studies for consumer acceptability were not carried out, and it is suggested that sensory evaluation and consumer acceptability studies of bloody mushroom samples dried with different drying methods are required for further studies. There is a need for reducing the large amount of energy required in drying processes and faster drying techniques, and innovative techniques that increase drying rate and quality are attracting increasing attention. Therefore, it is thought that combined drying systems, in which different drying methods are used together, will positively affect the product quality.

Directory of the Symbols and the Abbreviations
Symbols

a^*: Redness-Greenness Index in Colour Measurement
b^*: Blueness-Yellowness Index in Colour Measurement
L^*: Brightness-Darkness Index in Colour Measurement
C^*: Chroma value
X: Independent variable
d_t: Time (minute)
h^0: Hue angle
ΔE: Total colour change
h_{fg}: Latent heat (kJ/kg)
m_w: Evaporated water weight (kg)
$\sum E$: Total energy consumption of the system (J)
a_w: Water activity
M_0: First moisture content, g water/g dry matter
M_e: Balance moisture content, g water/g dry matter
T: Drying Temperature (°C)

The Abbreviations

MER: The moisture removed per unit time (kg water/h)
$Ç_{bn}$: Ambient air relative humidity (%)
MC_{KA}: Moisture content (dry)
MC_{YA}: Moisture content (wet)
MR: Moisture Rate
YA: Wet weight of the product (g)
KA: Dry weight of the product (g)
DR: Drying rate, g water/g dry matter minute
SEC: Specific energy consumption (kWh/kg water)
SMER: Specific Moisture Extraction Rate (kg water/kWh)
M: Moisture content, g water/g dry matter
M_t: Sample mass before the drying (g)
M_{t+dt}: Moisture content
BI: Browning Index
MR_{den}: Moisture rate
MR_{tah}: Estimated moisture rate

RMSE: Estimated standard error

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Göknur K. ONGUN: Wrote the manuscript.

Mustafa AKTAŞ: Analyse the results.

Bahadır ACAR: Performed the experiments and analyse the results.

Mehmet ÖZKAYMAK: Wrote the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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