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preliminary communication

Hot Air Drying of Green Table Olives

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Summary

The characteristics of hot air-drying of green table olives (Domat variety) by using a tray dryer were studied. Air temperature varied from 40 to 70 °C with an air velocity of 1 m/s. Drying rate curves were determined and quality of dried green olives was evaluated by instrumental analysis (bulk density, particle density, porosity, shrinkage, moisture content, water activity, colour value, protein content, oil content, peroxide value and acidity). Consumers' acceptance test and microbiological analysis were also applied.

Key words: table olives, drying, dehydration, water activity, tray drier, consumers' acceptibility

Introduction

The world production of table olives is around 1 million tons, with approximately 80 % coming from countries of the Mediterranean area. From the available data it can be estimated that approximately 45 % of the production is made up of green table olives. Table olives are consumed on a large scale all over the world, and their consumption is expanding owing to the increasing popularity of the Mediterranean diet (*1*). They can be used as flavouring, an ingredient or simply as a snack or appetiser. They are especially used in Mediterranean dishes including pizza, relishes, salads, sauces or antipasto platters.

The increasing interest of the consumers in natural products involves the use and diffusion of technologies which can offer a guarantee of preservation, hygiene and genuineness of food products (*1*). Especially in the developed world, there is now a great demand for a wide variety of high quality dried products, with emphasis on freshness and convenience (*2*). In this respect the development of new alternative products and tastes for table olives is under way. By introducing the drying techniques green table olives can be consumed as a snack food with a longer shelf-life. Water, being the main component of foods, has a direct and decisive influence on their quality and shelf life through its effect on several physicochemical and biological changes. Hot air drying is the conventional and most widely used technique for the production of dehydrated fruits and vegetables (*3*). The removal of moisture prevents the growth and reproduction of microorganisms that cause decay and minimizes many of the moisture-mediated deteriorative reactions. It brings about substantial reduction in mass and volume, minimising packaging, storage and transportation costs and makes possible storage of the product under ambient temperatures (*4*).

In this study, the characteristics of air-drying of green table olives were studied under different operating temperatures and the changes in physical and quality characteristics were determined. In addition, the con-

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sumers' acceptability of dried green table olives as a snack food was investigated.

Materials and Methods

Olive samples (Domat variety) were obtained locally. They were calibrated (140–180 particles/kg) and stored overnight at T=(10±2) °C before processing. The flow sheet of drying process is given in Fig. 1.

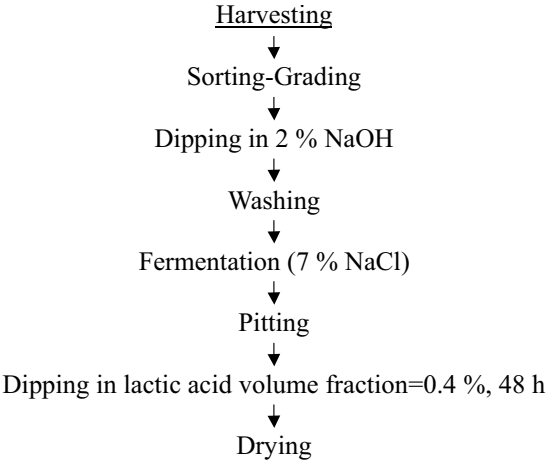

Fig. 1. Drying process of green table olives

Fermentation was carried out in 700-L tank, which contained 950 kg of green olives. During fermentation, the mass fraction of NaCl in brine was initially 5 % and it gradually increased to 7 %. Fermentation period was 45 days and acidity of fermentation medium was in the range of w(lactic acid)=0.75–0.90 %. When the fermentation was completed acidity and brine concentration were kept constant during storage. Before drying, fermented green table olives were pitted and dipped into 0.4 % of lactic acid to decrease salt concentration and acidity.

Hot air drying

Olive samples were dehydrated by using the tray dryer. The schematic diagram of the drying equipment is given in Fig. 2. In order to evaluate the effect of air temperature on the drying process, four temperatures (40, 50, 60 and 70 °C) were used. The air velocity was kept constant at 1 m/s and the relative humidity was maintained at 15 %. Every 30 min the samples were taken out, weighed and returned to the dryer. Drying was stopped when the mass of the samples reached a constant value.

Moisture content

Samples were dried at 70 °C and 400 mmHg in a vacuum oven overnight according to the AOAC method (*5*). Dry matter content was calculated on the basis of fresh mass.

Olive oil content

The oil content of samples was analysed by using Abencor system and calculated as mass fraction of oil in %.

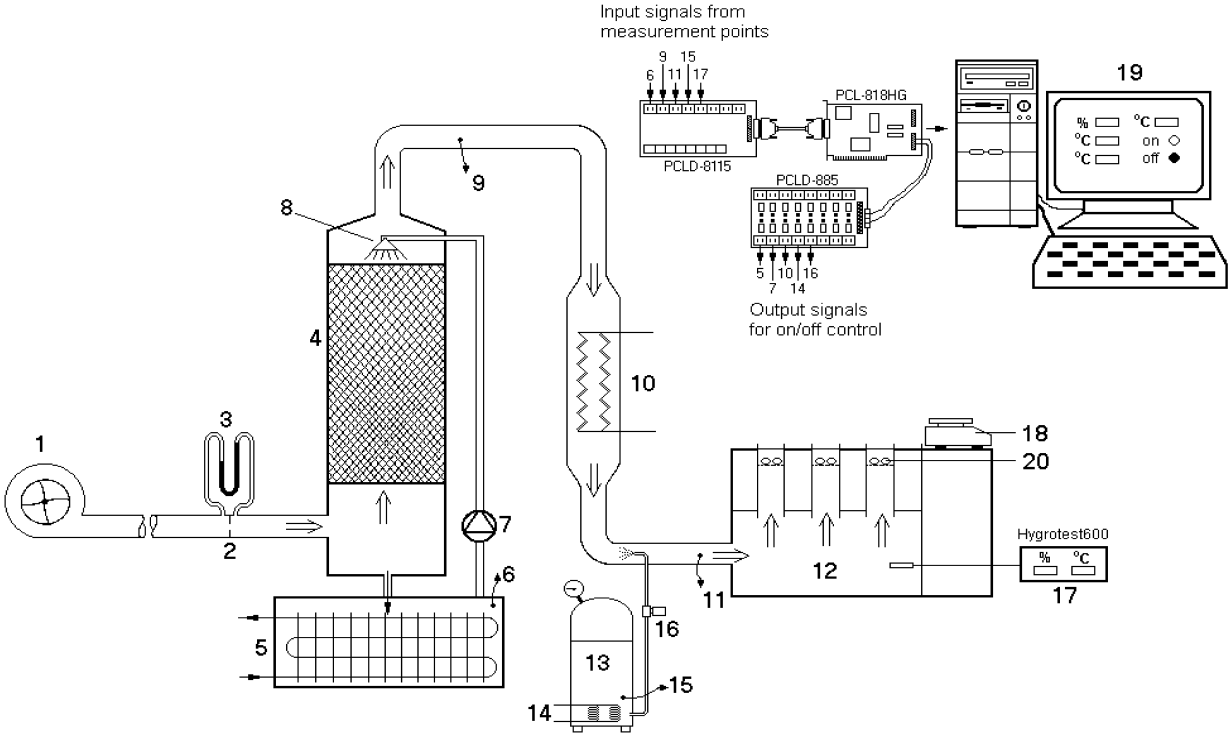

Fig. 2. Schematic diagram of the drying equipment. 1, centrifugal fan; 2, orifice plate; 3, differential manometer; 4, cooling and saturating tower; 5, cold water tank and evaporator; 6, 9, 11 and 15, thermocouples (T type); 7, circulation pump; 8, cold water shower; 10, electric heaters; 12, mixing chamber and air channels; 13, steam tank; 14, electric water heater; 16, injector and solenoid valve; 17, temperature and humidity sensor; 18, balance; 19, computer with data acquisition and control cards; 20, olives

Protein content

Protein (N×6.25) was determined as total nitrogen according to the Kjeldahl method with the addition of Kjeltabs ST as catalyst. Samples (1.5 g) were digested with sulphuric acid using the Kjeldatherm digestion and Vapodest 30 distillation systems (Gerhardt GmbH & Co. KG, Bonn, Germany) equipped with an end-point titrator (Gerchard, Vap. 5).

Salt content

The salt content of samples was analysed by using the Mohr method (*6*).

Caloric value

The caloric value of dried green table olives was determined according to procedure given by Balatsouras (*7*).

Water activity (a_w)

Water activity was measured using a Testo 610 relative humidity and temperature measurement device (*8*) and the results were calculated according to the Eq. /1/, where *ERH* is equilibrium relative humidity:

$$a_w = \frac{ERH}{100} \qquad /1/$$

Colour

L, *a* and *b* colour values of the samples were measured using a spectral photometer (Datacolor, Textflash, USA). After standardisation, *L*, *a* and *b* values were measured on fresh and dehydrated products. Colour values (ΔE), colour intensity (chroma, ΔC) and hue angle were calculated according to Eqs. /2–4/ (*9*); L_{ref}, a_{ref} and b_{ref} values belong to green table olive samples before dehydration:

$$\Delta E = \sqrt{[(L - L_{ref})^2 + (a - a_{ref})^2 + (b - b_{ref})^2]} \qquad /2/$$

$$\Delta C = \sqrt{[(a - a_{ref})^2 + (b - b_{ref})^2]} \qquad /3/$$

$$\text{hue angle} = 1/\tan\,(b/a) \qquad /4/$$

Peroxide value and acid value

Peroxide value (meq/kg oil) and acid value (% acidity in terms of oleic acid) were determined according to standard methods (*10*).

Bulk density and shrinkage

A glass cylinder (500 mL) was used for bulk density measurements. A known mass of sample (*m*) was poured into the cylinder and the volume was evaluated by reading the scale of cylinder (V_1) (*11,12*). Loose bulk density (ρ_{bl}) was found by Eq. /5/. The cylinder with the same sample was tapped 20 times on the smooth and soft surface from 10-cm height and the volume of the sample was evaluated by reading the scale (V_2) (*13,14*). Tapped bulk density (ρ_{bt}/(g/mL)) was calculated by Eq. /5/:

$$\rho_{bt} = \frac{m}{V^*} \qquad /5/$$

For loose and tapped bulk density calculation, V_1 or V_2 must be used instead of V^*.

The degree of shrinkage (s_b/%) can be calculated from Eq. /6/ where V_i is the final volume of the fermented green table olive samples immersed in distilled water and V_f is the final volume of the dried olive samples immersed in carosen solution. V_f was calculated by considering the ratio of carosen and distilled water densities:

$$s_b = \frac{V_i - V_f}{V_i} \cdot 100 \qquad /6/$$

Particle density

Known mass of sample (m_p) was immersed into a known volume of carosen solution (V_c) in a measuring cylinder and the final volume (V_f) was read by using the scale of the cylinder. Particle density (ρ_p/(g/mL)) of the sample was found by Eq. /7/ (*15*):

$$\rho_p = \frac{m_p}{V_f - V_c} \qquad /7/$$

Porosity

Porosity was calculated by using Eq. /8/ (*15*), in which for loose and tapped porosity calculation ρ_{bl} or ρ_{bt} must be used instead of ρ_b^*:

$$\text{Porosity} = 1 - \frac{\rho_b^*}{\rho_p} \qquad /8/$$

Sensory evaluation

Dehydrated samples were evaluated by a consumer acceptance test (*N*=110) (*16*). Panelists were scientists, research scholars of the department and undergraduate students within the age group of 18–55 years.

Microbiological analysis

To determine microbiological quality of dried green table olives (stored in plastic bags at 65 % relative humidity and 10 °C for 12 months), samples were taken under aseptic conditions, then transferred in 0.1 % peptone water and homogenised with blender. Appropriate 10-fold dilutions of the samples were prepared in peptone water and plated in duplicate on the selective growth media to estimate microbial burden. Aerobic mesophilic bacteria counts, mould counts, *Escherichia coli*, and *Salmonella* spp. analysis were done according to standard methods (*17–20*).

Statistical analysis

All treatments were done in triplicates and one way analysis of variance (ANOVA) and Duncan's post hoc tests were used. All hypotheses were tested at α=0.05 significance level. All data were analyzed using SPSS (10.0) for Windows.

Results and Discussion

The typical drying rate curves are shown in Fig 3. As expected, increasing drying temperature leads to

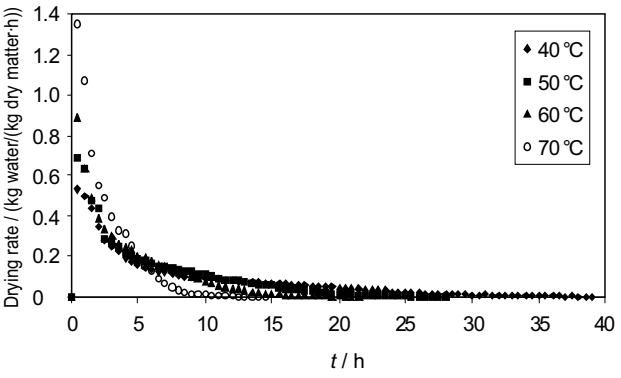

Fig. 3. Drying rate versus time curve of green table olive samples

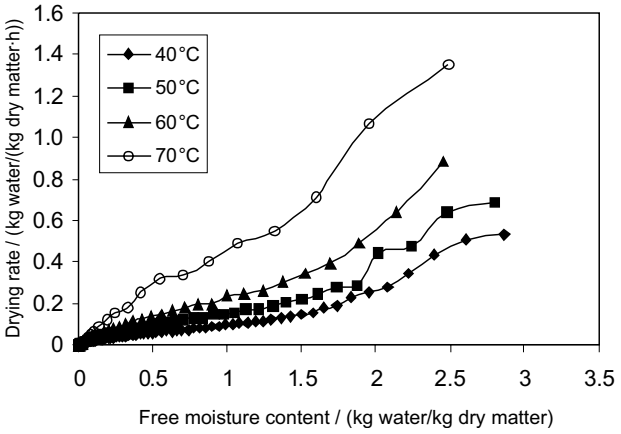

Fig. 4. Drying rate versus free moisture content of green table olive samples

lower drying time. Drying at 70 °C required 14 hours and 30 minutes, whereas 39 hours were needed to obtain the same moisture content at 40 °C. Dehydration process was stopped when the moisture content of samples reached 5.05–4.95 %, which is the equilibrium moisture content. Drying rate is defined as mass of water removed per mass of dry matter and time (kg/(kg·h)). Under the experimental conditions, the samples did not show any constant drying rate, suggesting that diffusion was the most dominant mechanism governing moisture movement in olive samples. For all drying conditions there was a fast falling rate period at the start of drying, followed by a more slowly falling rate region. This has also been reported in previous papers (*3,4,21,22*). The change in the drying rate as a result of the reduction of the free moisture content of the samples during drying is given in Fig. 4.

The effect of hot air drying on the quality characteristics of green table olives is shown in Table 1. Availability of water for growth of microorganisms, germination of spores, and participation in several types of chemical reactions is an important issue. This availability, which is defined as water activity (a_w), has a direct relationship with the equilibrium moisture content. As shown in Table 1, in all experimental sets the average water activities were not significantly different, with an average value of a_w=0.69, which is below the minimum a_w values for the growth of most bacteria, yeast and moulds (*23*).

No significant differences were found in terms of loose bulk density, tapped bulk density, particle density, shrinkage, loose porosity and tapped porosity of the dried green table olives in all applied drying temperatures (Table 2). This is because of the uniform particle size of the olive samples, which were calibrated before drying process. At the end of the drying period all the samples became spherical and their moisture contents had no significant differences (Table 1).

Table 1. The effects of hot air drying on the quality of green table olive samples

	Green table olives	Dried green table olives			
		40 °C	50 °C	60 °C	70 °C
w(moisture)/%	76.29±0.57	5.05±0.25^a	4.95±0.21^a	4.98±0.17^a	4.95±0.22^a
w(olive oil)/%	14.67±0.26	64.00±0.90^a	65.30±0.87^a	67.60±0.36^b	67.50±0.46^b
w(protein)/%	1.13±0.18	4.06±0.23^a	4.15±0.03^a	4.12±0.06^a	3.75±0.01^b
w(salt)/%	0.50±0.09	2.00±0.10^a	2.00±0.10^a	2.00±0.30^a	2.10±0.10^a
Caloric value	137.12±3.15	584.76±11.67^a	606.33±7.90^b	627.01±3.51^c	624.34±4.14^c
Water activity	0.99±0.00	0.69±0.01^a	0.69±0.01^a	0.69±0.01^a	0.69±0.01^a
Colour					
L	55.53±9.67	36.02±3.44^a	34.70±3.26^b	36.38±3.06^a	31.52±1.94^c
a	–0.98±0.98	2.41±1.22^a	3.14±0.94^b	3.94±1.05^c	3.29±0.76^b
b	35.48±6.80	19.62±2.52^a	18.87±3.12^a	19.85±3.13^a	13.67±2.64^b
hue angle	*	82.93±3.70^a	80.37±3.28^b	82.06±5.66^{a,b}	76.12±4.06^c
Δ*E*	*	27.11±5.24^a	28.76±5.18^a	27.32±4.32^a	34.82±5.99^b
Δ*C*	*	16.32±4.15^a	17.13±3.57^a	16.30±3.50^a	22.23±4.08^b
Peroxide value	8.61±0.03	45.00±0.02^a	29.00±0.04^b	35.00±0.05^c	62.00±0.01^d
Acidity/%	1.28±0.00	3.97±0.01^a	2.96±0.01^b	3.02±0.01^c	5.90±0.01^d

$^{a-d}$mean values with different supercript(s) in the same row are significantly different ($p<0.05$)
*used as a reference for related equations

Table 2. Physical properties of dehydrated samples

	Green table olives	Dried green table olives			
		40 °C	50 °C	60 °C	70 °C
ρ_{bl}/(g/mL)	0.47±0.01	0.38±0.02[a]	0.40±0.01[a]	0.40±0.02[a]	0.39±0.02[a]
ρ_{bt}/(g/mL)	0.55±0.01	0.41±0.01[a]	0.41±0.02[a]	0.44±0.01[a]	0.41±0.02[a]
ρ_p/(g/cm^3)	1.10±0.12	1.10±0.32[a]	1.08±0.03[a]	1.09±0.18[a]	1.06±0.04[a]
s_b/%	0.00±0.00	76.57±3.70[a]	76.51±2.73[a]	77.45±2.81[a]	74.18±2.72[a]
Loose porosity	0.52±0.10	0.64±0.09[a]	0.63±0.00[a]	0.63±0.05[a]	0.63±0.01[a]
Tapped porosity	0.49±0.08	0.61±0.11[a]	0.62±0.01[a]	0.59±0.06[a]	0.61±0.01[a]

[a]mean values with different supercript(s) in the same row are significantly different ($p<0.05$)

For the calculation of caloric value chemical analyses were performed to measure the protein and oil content of the olive samples. The carbohydrate and fiber content were omitted because all the sugars were fermented and the fiber content is not digestible for the humans. The differences in caloric values of samples dried at different temperatures were due to the oil and protein contents, which were found to be significantly different ($p<0.05$) (Table 1). The caloric value of the dried olive samples was found to be similar to those of snack foods such as peanut, hazelnut and pistachio (*24*). The salt content of the dried samples was not significantly different at the applied drying temperatures. Average final salt content was 2 % in all dried samples (Table 1). This salt content is preferable for dietetic table olive products.

The colour of products can be specified by three coordinates in the colour space, which can be obtained directly with a tristimulus colorimeter. The *L*, *a*, *b* system is the most frequently used scale for measuring the colour of food products (*25*). The *L*, *a*, and *b* values were found significantly different for each drying temperatures. However, these values do not represent the colour change on inhomogeneous materials (*9*). Thus, the different combinations of tristimulus *L*, *a* and *b* values are used to represent the colour change in foodstuffs (*26*). Browning was expressed as hue angles because this parameter showed a better correlation with visual estimation than did chroma and total colour difference (*9*). As shown in Table 1, hue angle, ΔE and ΔC values of the samples dried at 70 °C are significantly different ($p<0.05$), as compared to other temperature applications. This difference represents the increase in the degree of browning.

Since dried green olives contain more than 65 % of oil in dry basis, the quality characteristics of the oil after drying process are of importance. Peroxide value (*PV*, meq/kg oil) is a measure of oxidative rancidity and guide to olive oil quality. Along with the free fatty acid content (*AV*, acid value) it is a measure of hydrolytic rancidity (*27*). As shown in Table 1, the mean values of *PV* and *AV* were found significantly different for each drying air temperature ($p<0.05$). Both *PV* and *AV* of samples dried at 50 °C have the lowest values. The highest peroxide value was obtained at 70 °C because of the higher temperature as compared to other applications. At 40 °C the peroxide value and acidity were also found to be high due to longer drying period. Similar trend was observed at 60 °C, which had a higher peroxide value and acidity as compared to drying at 50 °C.

The acceptability of dried green table olives as a snack food was evaluated by sensory analysis. The results of the consumers' acceptability test showed that 82 % of the panelists prefer the samples dried at 50 °C in terms of overall acceptability (texture, taste, colour, chewiness). This result overlaps with the experimentally determined quality characteristics of the dried green olives at 50 °C, in which the peroxide and acid values are at the lowest level. After the evaluation of physical, chemical and sensory analyses performed on dried green table olives, the samples dried at 50 °C were analysed in terms of microbiological quality. For this purpose Turkish Food Codex microbiological criteria for snack foods were taken into consideration. The results of microbiological analysis performed on green table olives and dried green table olive samples are given in Table 3.

Table 3. Microbiological analysis of fresh and dried green table olive samples

Analysis	*N*	Green table olives		Dried green table olives*	
		Mean value	Range (min-max)	Mean value	Range (min-max)
Aerobic mesophilic bacteria at 25 °C/(CFU/g)	5	$2.9\cdot10^6$	$2.2\cdot10^6$– $3.8\cdot10^6$	$1.6\cdot10^4$	$1.0\cdot10^4$– $2.4\cdot10^4$
Aerobic mesophilic bacteria at 37 °C/(CFU/g)	5	$4.1\cdot10^6$	$3.4\cdot10^6$– $4.7\cdot10^6$	$1.5\cdot10^4$	$1.1\cdot10^4$– $2.2\cdot10^4$
E. coli	5	–	–	–	–
Salmonella spp.	10	–	–	–	–
Mould/ (CFU/g)	5	$1.4\cdot10^5$	$3.4\cdot10^4$– $4.5\cdot10^5$	–	–

* samples dried at 50 °C and stored for 12 months
N number of samples
– not detected

E. coli and *Salmonella* spp. were not detected neither in green table olive nor in dried green table olive samples. Mould population was eliminated by the effect of drying process and mould population at the end of 12 months of storage was not detected. Aerobic mesophilic bacteria count of dried samples after 12 months of storage was found to be in the acceptable range according to Turkish Food Codex for snack foods (*28*). Similarly, no rotting was reported after 1 year of storage of olive samples dried at 50 °C when different pretreatments for drying of green table olives were applied (*29*).

Conclusion

These results indicate that drying of green table olives at 50 °C for 22 h in a tray dryer gives the acceptable final product which is proven by sensory analysis. Besides, they can be stored for 1 year without the risk of microbial deterioration. That is why widespread consumption of this valuable food stuff as a snack food is possible.

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Sušenje zelenih stolnih maslina vrućim zrakom

Sažetak

Ispitana su svojstva zelenih stolnih maslina (vrsta Domat) sušenih vrućim zrakom u sušioniku s policama. Temperatura zraka mijenjala se od 40 do 70 °C uz protok zraka od 1 m/s. Utvrđene su krivulje brzine sušenja, a kakvoća sušenih zelenih maslina ispitana je instrumentalnom analizom (ukupna gustoća, gustoća čestica, poroznost, smežuranost, količina vlage, aktivitet vode, boja, udjel proteina i ulja, peroksidna vrijednost te kiselost), ocjenom potrošača o prihvatljivosti proizvoda i mikrobiološkom analizom.