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Colour Change of Chemically Pretreated Rosehips During Greenhouse and Open Sun Drying

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The effects of three different chemical solutions (Type I: 2% ethyl oleate, Type II: 2% ethyl oleate + 2% NaOH, Type III: 2% ethyl oleate +2% NaOH + 4% potassium carbonate, w/v) on the final colour of dehydrated rosehips in association with dipping temperature (23°C and 60°C) and drying method (greenhouse drying and open sun drying) were determined. The skin colour was measured by a reflection colorimeter. Secondary colour measures (hue angle, chroma, ratio of redness to yellowness, total colour change and browning index) were also calculated from the measured values of three primary chromatic scales (L, a, b).

Key Words: Rosehip, Drying method, Pretreatment solution, Colour.

INTRODUCTION

The market of agricultural products is influenced by their colour since abnormal colours, especially with deterioration in eating quality or with spoilage, cause the products to be rejected by the consumers at the point of sale[1, 2]. Surface colour of agricultural products can be directly measured by colorimetric reflection method[3–9]. This method gives numeric values of three chromatic scales (L, a, b) where, L is the brightness ranging from no reflection for black (L = 0) to perfect diffuse reflection for white (L = 100); a is the redness ranging from negative values for green to positive values for red; b is the yellowness ranging from negative values for blue and positive values for yellow. The colour at the grid origin (a = 0 and b = 0) is achromatic gray[9].

Drying process conditions are known to affect the final colour of dehydrated products since enzymatic and non-enzymatic browning reactions may occur at varying rates[6, 8, 10]. Enzymatic browning is the discolorization caused by the action of a group of enzymes called polyphenol oxidases (PPO) naturally existing in all plants while non-enzymatic browning includes the Maillard reaction, caramelization and ascorbic acid oxidation occurring because of heating at high temperatures[8, 11–13].

It is a common practice in agricultural industry that fresh fruit and vegetables are pretreated with some chemical solutions and bleached with hot water/water vapour to accelerate their dehydration by changing their skin permeability of moisture[14–16]. Chemical and thermal pretreatments can also affect the final colour of dried agricultural product by either accelerating or decelerating browning reactions. Drying of whole red peppers with 2% ethyl oleate and 5% K_2CO_3 solution yielded better colour quality than no pretreatment[16]. Potassium metabisulfite treatment and low drying temperature at 30°C resulted in better retention of β-carotene and ascorbic acid for drying leafy vegetables[17]. The use of ethyl oleate as pretreatment solution for the drying of grapes leads to brighter colour than that of the untreated grapes[18]. L values increased with higher drying temperature for both dehydrated grapes (60°C)[18] and rosehips (70°C)[19].

Rosehips (fruits of *Rose canina* L.) are in various colours (green, yellow, orange, orange red, red and finally dark red) based on the stage of ripening[20]. They contain significant amounts of vitamin C, β-carotene, flavonoids, tocopherol, tanning, amino acids, fruit-acids, fatty oils and minerals[20–24]. Rosehips are dried for future use as herbal tea, natural dietary supplement and natural food dye[25–27]. Drying rosehips with 70°C air temperature and 0.5 m s^{-1} air flow velocity in a parallel flow type air dryer was recommended to reduce drying energy consumption and to get better product colour quality[19]. However, drying at high temperatures as much as 70°C could result in significant nutritional loss such as ascorbic acid degradation[28]. Heat-sensitive materials such as food and bioproducts should be dried at low temperatures to retain their colour, taste, texture and nutrients[29].

Agricultural products are commonly dehydrated in solar dryers or by spreading them on the ground under open atmosphere (namely, open sun drying) in the most part of the world since both drying methods normally require low cost and technical information for manufacturing and operating[30, 31]. Based on the information in the literature presented above, it has considerable scientific and practical benefits to study the effects of chemical pretreatments on the colour properties of rosehips dried in a greenhouse dryer as selected model solar dryer and under open atmosphere (open sun drying). The objective of this research is to determine the effects of three commonly-used chemical pretreatment solutions on the colour change of rosehips dipped in these solutions at two pretreatment solution temperatures and then simultaneously dried in greenhouse drier and under open atmosphere.

EXPERIMENTAL

Fresh rosehips (the fruit of *Rosa canina* L.) were obtained from the local market in Tokat. Tokat is a city located in the Central Black Sea Region of Turkey. Its latitude, longitude and elevation (in m) are 40.18, 36.54 and 608, respectively. The average values of the length, width, weight and volume of a single rosehip are 21.92 (±2.96) mm, 13.01 (±1.53) mm, 1.95 (±0.12) g and 2.15 (±0.11) mL, respectively. The detailed pomological and chemical properties of rosehip varieties grown in Tokat area were reported earlier[21]. The moisture content of fresh rosehips was determined according to the vacuum oven method[32]. The average moisture content of fresh rosehips was determined to be 57.84 (±2.04)% in weight basis. Three different chemical solutions were prepared. Rosehips were poured into bags made of net and their weights were adjusted to 50 g. The bags were dipped into each solution for 1 min at room temperature. There were three replications of each pretreatment. Subsequently, the bags were immediately dipped into a fresh water container and shaken in it to rinse away the chemicals carried out by the bag and rosehips. After rinsing, the bags were placed over paper towels to remove water flowing over the bag and the rosehips. The same chemical solutions were placed in a hot water bath to do dipping process at 60°C. The untreated rosehips as control were just washed with clean water to take away dust and dirt. The treatments were coded for ease of data analysis and reporting as follows:

T1: 2% Ethyl oleate at room temperature; T2: 2% Ethyl oleate + 2% NaOH at room temperature; T3: 2% Ethyl oleate + 2% NaOH + 4% K_2CO_3 at room temperature; T4: 2% Ethyl oleate at 60°C; T5: 2% Ethyl oleate + 2% NaOH at 60°C; T6: 2% Ethyl oleate + 2% NaOH + 4% K_2CO_3 at 60°C and Tc: Control (no pretreatment).

Room temperature was measured to be 23°C. Rosehip samples were weighed by using an electronic balance with 0.01 g sensitivity. They were placed on drying trays in both greenhouse dryer and outdoor for open sun drying. The greenhouse dryer was a tunnel plastic dryer whose width, length and height were 6, 18 and 3 m, respectively. The thicknesses of rosehips in the bags were kept thin to accelerate free air flow. The drying trays were equipped with four 20 cm legs to let drying air pass through them from bottom to top by natural convection. The weights of drying bags were determined from the beginning to the end of the drying process at various time points. Then, the rosehips were collected and saved for colour measurement. The drying trials were conducted during 2–8 October 2003. The relative humidity and dry bulb temperature of greenhouse interior air were measured and stored by an electronic measurement device while the daily average temperature and relative humidity values of outdoor air were obtained from local meteorological stations.

The colours of both fresh and dehydrated rosehips were quantified by using a Minolta (CR-300) chromameter. Analysis of variance (ANOVA) was separately performed over the values of each chromatic scale (L, a and b) to determine the main and interactive effects of pretreatments (T1 ... T6 and Tc) and drying methods (greenhouse drying and open sun drying). Total effect of any pretreatment on colour values of dehydrated rosehips represents the sum of their main effects and interactions with drying methods. They were calculated as follows:

$$TEP_L = L_T - L_C \quad (1)$$

$$TEP_a = a_T - a_C \quad (2)$$

$$TEP_b = b_T - b_C \quad (3)$$

where TEP_L, TEP_a and TEP_b are total effects of any treatments on L (brightness), a (redness) and b (yellowness), respectively. Subscript T stands for treatment type (T1 . . . T6) while subscript C stands for control (no-pretreatment).

Total effect of greenhouse drying on colour of dehydrated rosehips was calculated as follows:

$$TEG_L = L_G - L_O \quad (4)$$

$$TEG_a = a_G - a_O \quad (5)$$

$$TEG_b = b_G - b_O \quad (6)$$

where TEG_L, TEG_a and TEG_b are total effects of greenhouse drying on L (brightness), a (redness), and b (yellowness), respectively. Subscript G stands for greenhouse drying while subscript O stands for open sun drying which is considered as the control treatment of drying method.

The equations of derived colour measures were as follows:

Total color change

$$\Delta E = \sqrt{(L_F - L)^2 + (a_F - a)^2 + (b_F - b)^2} \quad (7)$$

where subscript F stands for colour reading of fresh rosehip.

Ratio of redness over yellowness,

$$R = a/b \quad (8)$$

Hue angle, $$h^\circ = \tan^{-1}\left(\frac{b}{a}\right) \quad (9)$$

Chroma, $$C = (a^2 + b^2)^{1/2} \quad (10)$$

Browning index, $$BI = \frac{[100(x - 0.31)]}{0.17} \quad (11)$$

where $$x = \frac{(a + 1.75\,L)}{(5.645\,L + a - 3.012\,b)} \quad (12)$$

Weight loss percentage of rosehips during drying process was calculated as follows:

$$WLP\,(\%) = \frac{W_i - W_s}{W_i} \times 100 \quad (13)$$

where, W_i = initial weight of rosehip samples and W_s = weight of rosehip samples at sth weighing time point during drying process.

RESULTS AND DISCUSSION

The properties of outdoor and greenhouse drying air are presented in Table-1. During the drying trials, on the average, greenhouse provided drying air with 7.4°C higher temperature and 17.5% lower relative humidity than that of the outdoor. However, daytime greenhouse air temperature increased up to 51.8°C while daytime greenhouse air relative humidity decreased until 20.8%.

TABLE-1
PROPERTIES OF OUTDOOR AND GREENHOUSE DRYING AIR

Drying	Outdoor air properties		Greenhouse air properties					
	Temp (°C)	RH (%)	Temp (°C)			RH (%)		
	Ave	Ave	Ave	Max	Min	Ave	Max	Min
1	14.4	74.4	22.3	49.6	7.4	54.8	88.0	21.5
2	13.8	79.9	21.8	47.4	7.4	56.4	88.8	21.6
3	14.0	76.9	23.0	50.7	7.4	56.8	87.5	20.9
4	15.6	71.2	23.5	51.8	7.0	54.3	87.5	21.1
5	17.3	69.2	25.1	51.2	9.0	54.0	86.2	21.1
6	19.1	65.9	25.2	49.6	9.8	50.5	84.0	21.5
7	18.5	69.6	23.7	48.5	11.8	57.6	88.7	20.8

The weight loss percentage (WLP) values of rosehips against time were depicted in Fig. 1 for greenhouse drying and in Fig. 2 for open sun drying. The plots show that dipping fresh rosehips in any of two chemical solutions (T4 and T5) at room temperature provided faster weight loss of rosehips than those of untreated rosehips and rosehips dipped in the solution at 60°C. These results reveal that the active matter which accelerated rosehip weight loss was ethyl oleate and the action of ethyl oleate was held back by high chemical solution temperature. The rosehips in the greenhouse dryer lost *ca.* 55% weight while those under open atmosphere lost *ca.* 41% weight after 154 h drying. Hence, the type of drying methods and chemical pretreatments are important drying factors in the dehydration process of rosehips.

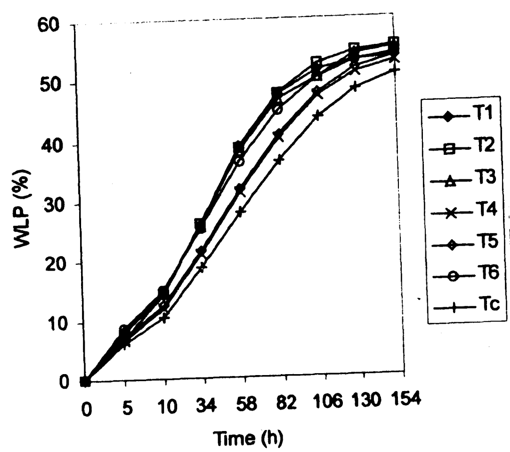

Fig. 1. Weight loss of rosehips dried in greenhouse dryer

The average values of three chromatic scales (L, a, b) measured on the skins of both fresh and dehydrated rosehips are given in Table-2. The brightness values of fresh rosehips are higher than those of dehydrated ones, which is analogous to

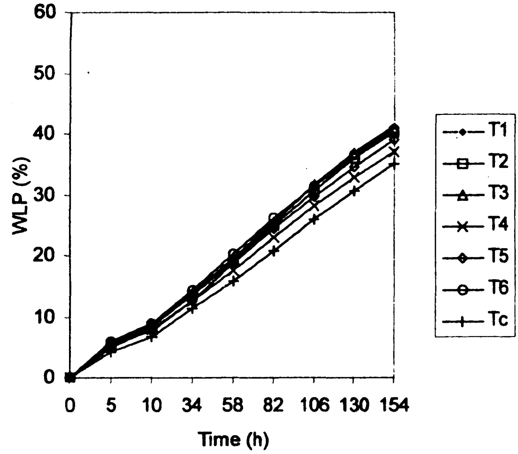

Fig. 2. Weight loss of rosehips dried under open atmposhere (open sun drying)

the information given in literature about the colour change during drying[6, 19]. It was reported that the decrease of brightness value could be taken as a measure of browning[33, 34]. The values of redness and yellowness scales also decreased at varying extents depending on the types of pretreatments and drying methods. The results of statistical analysis (analysis of variance) performed over the data belonging to each measured chromatic scale are given in Table-3. Both the main and interactive effects of pretreatments and drying methods on the final colour of rosehips are statistically significant ($P < 0.01$). The total effect, which is the sum of main and interactive effects, of pretreatments on the colours of dehydrated rosehips are shown in Fig. 3 for greenhouse drying and in Fig. 4 for open sun drying. In the case of greenhouse drying, the chemical pretreatments caused reductions in the values of colour scales, which were amplified by dipping temperature. Yellowness and redness seemed to be more sensitive to dipping temperature than brightness. T4 caused more dark color since, all of the three-colour scales had the lowest values. On the other hand, the total effects of chemical pretreatments on the colours of rosehips dehydrated under open atmosphere are much more different than the preceding explanations related to greenhouse drying. These differences were a result of interaction between the factors of pretreatment and drying method. Therefore, the effects of chemical pretreatments should be considered simultaneously with drying method. The total effects of pretreatments with open sun drying are less significant compared to the ones with greenhouse drying. As previously explained, the major difference of greenhouse drying from open sun drying is its much higher drying air temperature associated with lower relative humidity. Hence, it is plausible to state that the drying air temperature magnifies the effect of chemical pretreatments on the colour change of dehydrated rosehips in addition to dipping temperature. As a consequence of these relationships, T2 and T4 increased the values of yellowness compared to control treatments. The total effect of drying method is depicted in Fig. 5. The interactive effect between the factors of pretreatment and drying

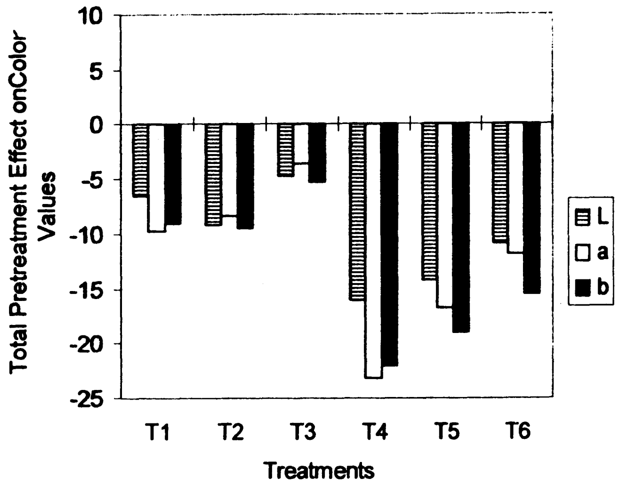

Fig. 3. Total effects of pretreatments on the final color of rosehips in greenhouse dryer

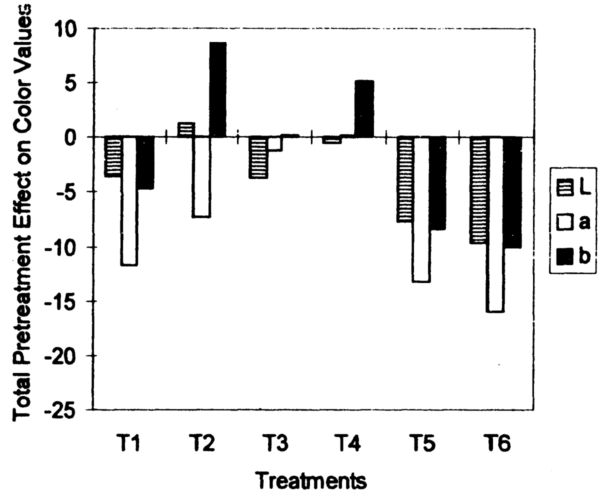

Fig. 4. Total effects of pretreatments on the final color of rosehips under open atmosphere

method are also seen in Fig. 5 since greenhouse drying does not show steady divergence. The greatest total effect of drying method was observed with T4 while the smallest total effect of drying method was associated with T1, T3 and T6. Pretreatments one and four have ethyl oleate as active chemical matter but their dipping temperatures are different. While their effects on weight loss progression of rosehips are considered, treatment one can be preferred because of its speeding up weight loss and its independence from drying method (namely drying air temperature) in terms of colour change of dehydrated rosehips. Drying untreated-rosehips in greenhouse resulted in more yellowish colour than drying under open atmosphere. In addition, greenhouse drying reduced the values of redness except T6. T3 and T6 in addition to T1 are independent of drying method in terms of their effects on colour changes of dehydrated rosehips.

TABLE-2
MEASURED COLOUR VALUES OF FRESH AND DEHYDRATED ROSEHIPS

Items	Greenhouse drying			Open sun drying		
	L	a	b	L	a	b
T1	36.98	36.61	22.32	39.51	35.93	21.48
T2	34.29	37.96	22.01	44.33	40.34	34.80
T3	38.76	42.69	26.12	39.39	46.38	26.41
T4	27.46	23.10	09.37	42.53	47.76	31.34
T5	29.28	29.53	12.42	35.41	34.35	17.82
T6	32.58	34.45	16.01	33.35	31.63	16.11
Tc	43.50	46.28	31.42	43.06	47.58	26.18
Fresh rosehip	46.19	53.32	34.61	46.19	53.32	34.61

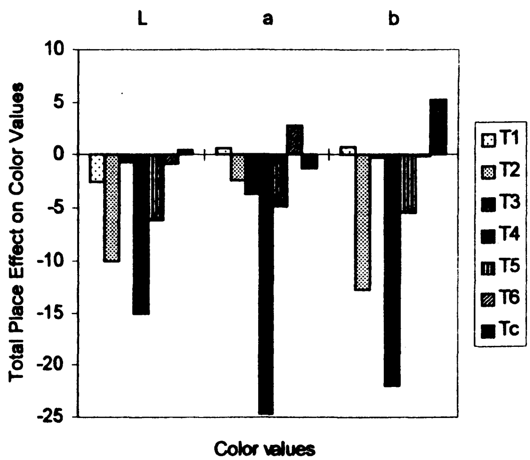

Fig. 5. Total effects of greenhouse drying on the final color of rosehips

TABLE-3
THE RESULTS OF ANALYSIS OF VARIANCE FOR COLOUR VALUES

Source	df	F-Values		
		L	a	b
Trt	6	7.5†	6.9†	9.8†
Place	1	21.1†	8.4†	7.3†
Trt* place	6	4.1†	4.4†	5.1†
Error	56			
Total	70			

† Statitically-significance at $P < 0.01$.

McGuire[9] stated that colour scales (L, a and b) do not provide an indication of hue and chroma-aspects of colour, which are intuitively understood by those in the marketing chain from producer to consumer. Furthermore, McGuire[9] recommended to use hue angle (h°) and chroma (C) as more practical measures of colour. Hue angle is defined as a colour wheel, with red-purple at an angle of 0°, yellow at 90°, bluish-green at 180° and blue at 270°. On the other hand, chroma (C) represents colour saturation, which varies from dull at low chroma values to vivid colour at high chroma values. There are three more derived colour measures used in literature. One of them is the total colour change parameter (ΔE)[6]. The ratio of redness over yellowness (a/b) is the second one of the last three derived parameters[5] while the third derived parameter is Browning index (BI). Browning index represents the purity of brown color and is considered as an important parameter associated with browning[35].

The values of derived colour measures are given in Table-4.

TABLE-4
VALUES OF DERIVED COLOUR MEASURES OF FRESH AND DRIED ROSEHIPS

Items	Greenhouse drying					Open sun drying				
	ΔE	a/b	h°	C	BI	ΔE	a/b	h°	C	BI
T1	22.69	1.64	31.37	42.88	152.26	22.79	1.67	30.88	41.86	135.82
T2	23.16	1.72	30.10	43.88	166.41	13.11	1.16	40.78	53.28	191.03
T3	15.49	1.63	31.46	50.05	173.29	12.71	1.76	29.66	53.37	176.18
T4	43.59	2.46	22.09	24.93	096.92	07.41	1.52	33.27	57.13	189.20
T5	36.66	2.38	22.81	32.03	119.48	27.53	1.93	27.41	38.70	131.42
T6	29.78	2.15	24.92	37.99	133.88	31.26	1.96	26.99	35.49	126.53
Control	08.17	1.47	34.17	55.94	182.77	10.66	1.82	28.82	54.31	159.07
Fresh rosehip	00.00	1.59	32.75	63.75	194.00	0.00	1.59	32.75	63.75	194.00

The values of total colour difference parameter changed from 7.41 for T4 with open-sun drying to 43.59 for the same pretreatment with greenhouse drying. In most cases, greenhouse drying and dipping temperature increased total colour difference while natural drying (no-pretreatment) and addition of K_2CO_3 to dipping solution decreased it. Dipping temperature provided more reddish colour over yellow since higher values of a/b were observed with dipping at 60°C except T4 with open sun drying. On the other hand, greenhouse drying of untreated rosehips decreased the value of a/b from 1.82 to 1.47. Addition of NaOH to dipping solution gave two different values of a/b depending on the type of drying method (Table-3). In terms of hue angles, the most reddish-purplish colour belongs to the rosehips treated with ethyl oleate solution at 60°C dipping temperature and dried in the greenhouse dryer while the most yellowish colour belongs to the rosehips dipped in ethyl oleate + NaOH solution at room temperature and dried under open atmosphere. More vivid rosehip colours were obtained with T4 with open sun drying, natural drying in greenhouse dryer and natural drying under open atmosphere. Duller rosehip colours are mostly associated with greenhouse drying and high dipping temperature. Fresh rosehips had the highest value of browning index, which practically means that they are more brownish than all the dehydrated rosehips. The effects of pretreatment and drying methods tended to change the brown colour of rosehips towards more reddish or yellowish colours.

The colour of dehydrated rosehips varied with the type of chemical solution, dipping temperature and the method of drying. Therefore, the desired colour of dehydrated rosehips and available drying methods should be determined to select appropriate pretreatment type. When the colour of dehydrated rosehips is desired to be closer to the colour of fresh rosehips and the available drying system is open sun drying, dipping fresh rosehips into ethyl oleate solution at room temperature is recommended based on the closeness of its hue angle to that of fresh rosehips and its positive effect on weight loss. However, if the rosehips are wanted to lose their moisture as fast as possible and their final colours are desired to be closer to their initial colours, the recommended method is to dip rosehips into the chemical solution containing ethyl oleate, NaOH and K_2CO_3 at room temperature and then to dry them in greenhouse dryer. In this case, the addition of NaOH into the chemical solution can be omitted based on the results associated with the application of T2 with greenhouse drying. As a conclusion, Table-4 can be used as a guide to select a drying strategy for rosehips based on the needs and availabilities.

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